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

Data Acquisition & Processing Report

Type of Survey *Navigable Area Project:*

OPR-G329-TJ-16

Time Frame: *06 June 2016 – 01 October 2016*

LOCALITY

State *South Carolina*

General Locality *Approaches to Savannah*

2016

CHIEF OF PARTY

Chris van Westendorp, CDR/NOAA NOAA Ship Thomas Jefferson

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Data Acquisition and Processing Report

NOAA Ship Thomas Jefferson
Chief of Party: Christiaan Van Westendorp, NOAA
Year: 2016
Version: 1
Publish Date: 2017-02-21

A Equipment

A.1 Survey Vessels

A.1.1 NOAA Ship Thomas Jefferson (WTEA)

<table>
<tr><td>Name</td><td>NOAA Ship Thomas Jefferson (WTEA)</td></tr>
<tr><td>Hull Number</td><td>S-222</td></tr>
<tr><td>Description</td><td>NOAA Ship Thomas Jefferson is a steel hulled hydrographic survey ship built by Halter Marine, Inc, Moss Point, MS.</td></tr>
<tr><td>Utilization</td><td>The primary mission of “NOAA Ship Thomas Jefferson” is to acquire hydrographic survey data to update NOAA nautical charts. Based on current draft and sonar configuration, the ship can operate in waters between 30 feet and 8200 feet deep.</td></tr>
<tr><td>Dimensions</td><td><table>
<tr><td>LOA</td><td>208 feet</td></tr>
<tr><td>Beam</td><td>45 feet</td></tr>
<tr><td>Max Draft</td><td>17 feet</td></tr>
</table></td></tr>
<tr><td>Most Recent Full Static Survey</td><td><table>
<tr><td>Date</td><td>2016-09-01</td></tr>
<tr><td>Performed By</td><td>The IMTEC Group, Ltd.</td></tr>
<tr><td>Discussion</td><td>A full static survey was completed during the 2016 extended drydock of Thomas Jefferson. This was in conjunction with the installation of the Kongsberg EM710 and EM2040 MBES. The survey measured the following points: IMU, ORU, EM710 Transmitter and Receiver, EM2040 Transmitter and Recevier, Bubbler Orifice, Odom Echotrac Mk III transducer, Knudsen 320B Transducer, Port and Starboard POS MV GPS Antennae. The survey report is included as an appendix to this document.</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>Most Recent Partial Static Survey</td><td>Partial static survey was not performed.</td></tr>
<tr><td>Most Recent Full Offset Verification</td><td>Full offset verification was not performed.</td></tr>
<tr><td>Most Recent Partial Offset Verification</td><td>Partial offset verification was not performed.</td></tr>
<tr><td>Most Recent Static Draft Determination</td><td><table>
<tr><td>Date</td><td>2016-10-13</td></tr>
<tr><td>Method Used</td><td>Bubbler and Ellipsoid</td></tr>
<tr><td>Discussion</td><td>Static draft was performed by use of a Sutron bubbler gauge installed on the ship. An ellipsoidally-referenced static draft was also performed to confirm these values.</td></tr>
</table></td></tr>
<tr><td>Most Recent Dynamic Draft Determination</td><td><table>
<tr><td>Date</td><td>2016-10-13</td></tr>
<tr><td>Method Used</td><td>Ellipsoidally Referenced Dynamic Draft</td></tr>
<tr><td>Discussion</td><td>Dynamic draft was determined using the Ellipsoidally Referenced Dynamic Draft Model (ERDDM). Acquisition and processing was done in accordance with FPM Section 1.4.2.1.2.1 via the Pydro macro ProcSBETDynamicDraft.py. Ellipsoid heights were obtained via the 5P method, described in Section B.2.4.</td></tr>
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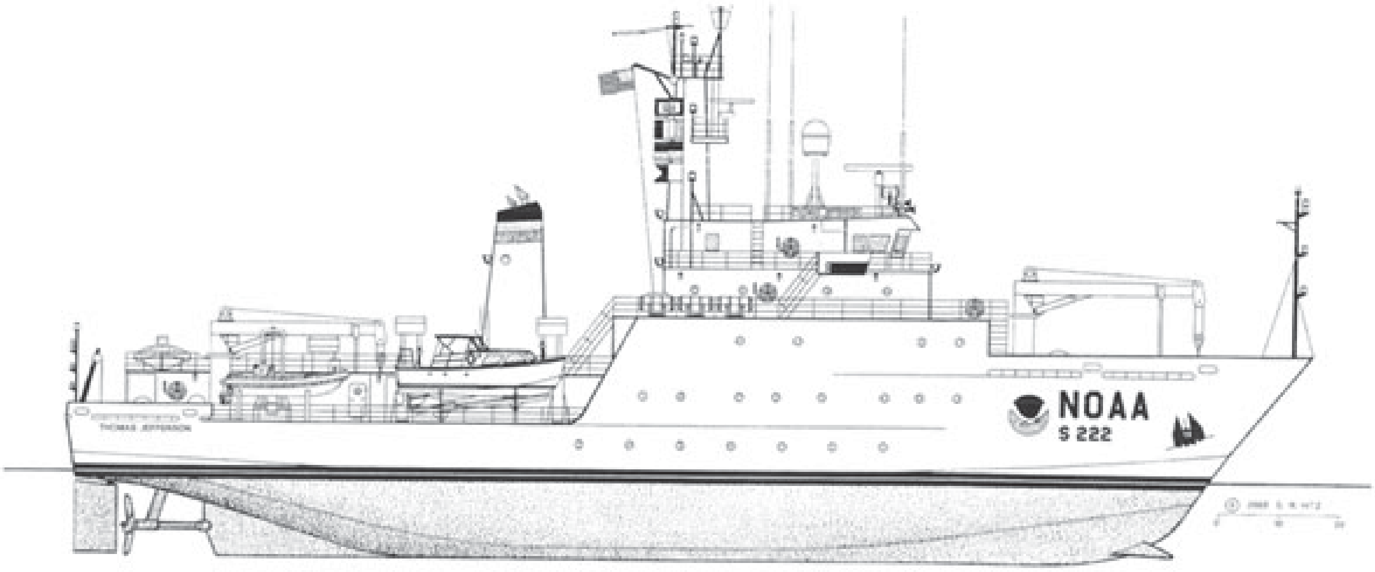
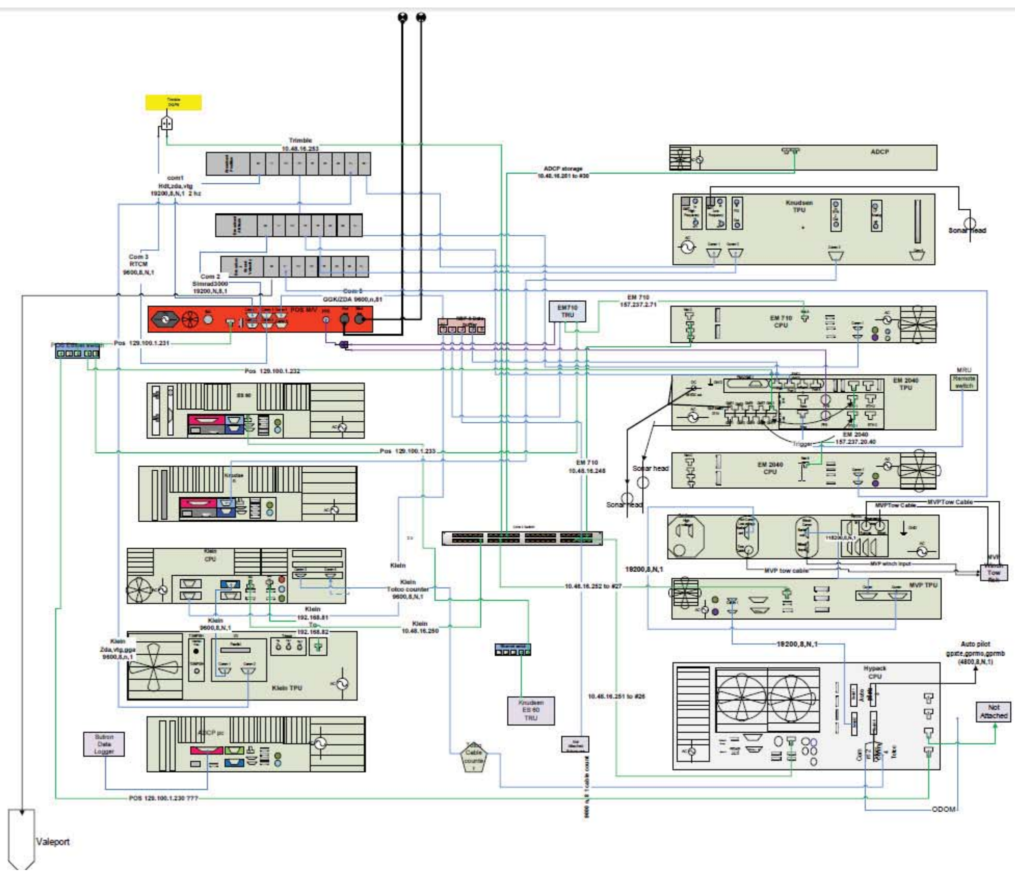


Figure 1: NOAA Ship Thomas Jefferson (WTEA)



A.2 Echo Sounding Equipment

A.2.1 Side Scan Sonars

A.2.1.1 Klein 5000 V2

Manufacturer	Klein
Model	5000 V2
Description	The Klein High Speed, High Resolution Multi-Beam 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 up to 250 meters, however “Thomas Jefferson” does not use the 150m or the 250m reconnaissance mode. In addition, the Klein 5000 V2 model can collect bathymetric information using phase differencing. Each side scan transducer stave contains 3 bathymetry staves. The bathymetry staves operate at 455kHz, with an along track resolution of 0.4°, and can resolve one discrete beam per side. “Thomas Jefferson” operates the Klein 5000 as a stern-towed unit, and does not process or use the collected bathymetric data. Positioning of the Towfish is calculated using Caris SIPS, and is derived from the amount of cable out, the towfish depth (from the towfish pressure gauge), the vessel's Course Made Good (CMG), and the vessel's heading. Towfish altitude is maintained between 8% and 20% of the range scale unless specifically noted in the Descriptive Report. Vessel speed is adjusted during SSS acquisition to ensure that object detection density is met. Confidence checks are performed by noting changes in linear bottom features extending to the outer edges of the digital side scan image, and by verifying aids to navigation or other known features on the side scan record.
Serial Numbers	*Vessel Installed On*: "Thomas Jefferson" *TPU s/n*: 778 *Towfish s/n*: 385

Specifications	*Frequency*	455 kilohertz			
	Along Track Resolution	*Resolution*	10 centimeters	20 centimeters	36 centimeters
		Min Range	0 meters	39 meters	76 meters
		Max Range	38 meters	75 meters	150 meters
	Across Track Resolution	3.75 centimeters			
	Max Range Scale	150 meters			
Manufacturer Calibrations	Manufacturer calibration was not performed.				

Figure 2: Klein 5000 V2

A.2.2 Multibeam Echosounders

A.2.2.1 Kongsberg EM2040

<table>
<tr><td>Manufacturer</td><td colspan="3">Kongsberg</td></tr>
<tr><td>Model</td><td colspan="3">EM2040</td></tr>
<tr><td>Description</td><td colspan="3">The Kongsberg EM2040 MBES is a high resolution shallow water MBES. It is capable of operating at 200, 300, and 400 kHz. Across-track swath width is up to 5.5 times water depth. Per HSTB recommendations, TJ operates the 2040 in a restricted fashion; namely, a 90 degree swath width and in Single Center Sector mode.</td></tr>
<tr><td rowspan="7">Serial Numbers</td><td>Vessel Installed On</td><td colspan="2">S222</td></tr>
<tr><td>Processor s/n</td><td colspan="2">CZC3410L1L</td></tr>
<tr><td>Transceiver s/n</td><td colspan="2">40072</td></tr>
<tr><td>Transducer s/n</td><td colspan="2">0</td></tr>
<tr><td>Receiver s/n</td><td colspan="2">334</td></tr>
<tr><td>Projector 1 s/n</td><td colspan="2">236</td></tr>
<tr><td>Projector 2 s/n</td><td colspan="2">None</td></tr>
<tr><td rowspan="11">Specifications</td><td>Frequency</td><td colspan="2">300 kilohertz</td></tr>
<tr><td rowspan="2">Beamwidth</td><td>Along Track</td><td>0.7 degrees</td></tr>
<tr><td>Across Track</td><td>0.7 degrees</td></tr>
<tr><td>Max Ping Rate</td><td colspan="2">50 hertz</td></tr>
<tr><td rowspan="2">Beam Spacing</td><td>Beam Spacing Mode</td><td>Equidistant</td></tr>
<tr><td>Number of Beams</td><td>200</td></tr>
<tr><td>Max Swath Width</td><td colspan="2">140 degrees</td></tr>
<tr><td>Depth Resolution</td><td colspan="2">26 millimeters</td></tr>
<tr><td rowspan="2">Depth Rating</td><td>Manufacturer Specified</td><td>635 meters</td></tr>
<tr><td>Ship Usage</td><td>600 meters</td></tr>
<tr><td rowspan="2">Manufacturer Calibrations</td><td>Vessel Installed On</td><td colspan="2">A Sea Acceptance Testing (SAT) cruise was conducted prior to starting this project. Personnel from HSTB, CSDL, Kongsberg USA, and UNH's CCOM were involved with the testing. A full report is attached.</td></tr>
<tr><td>Calibration Date</td><td colspan="2">2016-10-01</td></tr>
</table>

System Accuracy Tests	*Vessel Installed On*	"Thomas Jefferson"	"Thomas Jefferson"
	Methods	An accuracy test was conducted on DN321 (November 16th) by means of a reference surface run by the ship using the EM2040, and 3101 using a Reson 7125 SV2 MBES.	A self-reference test was conducted on DN293 by HSTB personnel as part of acceptance testing.
	Results	The resultant values, created by differencing two CUBE surfaces generated by the two datasets, showed a mean difference of 0.016m and a standard deviation value of 0.064m. Additional accuracy	The 300kHz mode showed a mean bias at nadir of 0.1% of water depth (in the 75m depth in which the testing was performed, this came out to 0.08m).
Snippets	Sonar does not have snippets logging capability.		

A.2.3 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

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.

Additional Discussion

The Klein 5000 V2 is a Phase Measuring Bathymetric Sonar, but it is not used in that capacity so it is documented above as a SSS, which is how it is used aboard "Thomas Jefferson."

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

<table>
<tr><td>Manufacturer</td><td colspan="4">Ship's Force</td></tr>
<tr><td>Model</td><td colspan="4">n/a</td></tr>
<tr><td>Description</td><td colspan="4">The lead lines aboard "Thomas Jefferson" are standard lead lines, constructed and calibrated in accordance with Appendix 1 of NOAA's Field Procedures Manual (2013 ed).</td></tr>
<tr><td rowspan="3">Serial Numbers</td><td colspan="4">TJ A 16m</td></tr>
<tr><td colspan="4">TJ S222 23m</td></tr>
<tr><td colspan="4">TJ 07 2012</td></tr>
<tr><td rowspan="3">Calibrations</td><td>Serial Number</td><td>TJ A 16m</td><td>TJ S222 23m</td><td>TJ 07 2012</td></tr>
<tr><td>Date</td><td>2015-04-15</td><td>2015-04-15</td><td>2015-04-15</td></tr>
<tr><td>Procedures</td><td>The lead line was calibrated against a steel measuring tape.</td><td>The lead line was calibrated against a steel measuring tape.</td><td>The lead line was calibrated against a steel measuring tape.</td></tr>
<tr><td>Accuracy Checks</td><td colspan="4">No accuracy checks were performed.</td></tr>
<tr><td>Correctors</td><td colspan="4">None of the lead lines required correctors.</td></tr>
<tr><td>Non-Standard Procedures</td><td colspan="4">Non-standard procedures were not utilized.</td></tr>
</table>

Figure 3: Lead line used aboard Thomas Jefferson and her survey launches

A.3.3 Sounding Poles

Manufacturer	Ship's Force
Model	n/a
Description	"Thomas Jefferson" has two non-traditional sounding poles. Both poles are round steel with a plastic covering, capped by a weighted metal shoe. Each pole is 4 meters in length, with graduations at 0.25m.
Serial Numbers	TJ-SP-1 TJ-SP-2

<table>
<tr><td rowspan="3">Calibrations</td><td>Serial Number</td><td>TJ-SP-1</td><td>TJ-SP-2</td></tr>
<tr><td>Date</td><td>2015-04-29</td><td>2015-04-29</td></tr>
<tr><td>Procedures</td><td>The sounding pole was calibrated using a steel tape.</td><td>The sounding pole was calibrated using a steel tape.</td></tr>
<tr><td>Accuracy Checks</td><td colspan="3">No accuracy checks were performed.</td></tr>
<tr><td>Correctors</td><td colspan="3">No correctors were required.</td></tr>
<tr><td>Non-Standard Procedures</td><td colspan="3">Non-standard procedures were not utilized.</td></tr>
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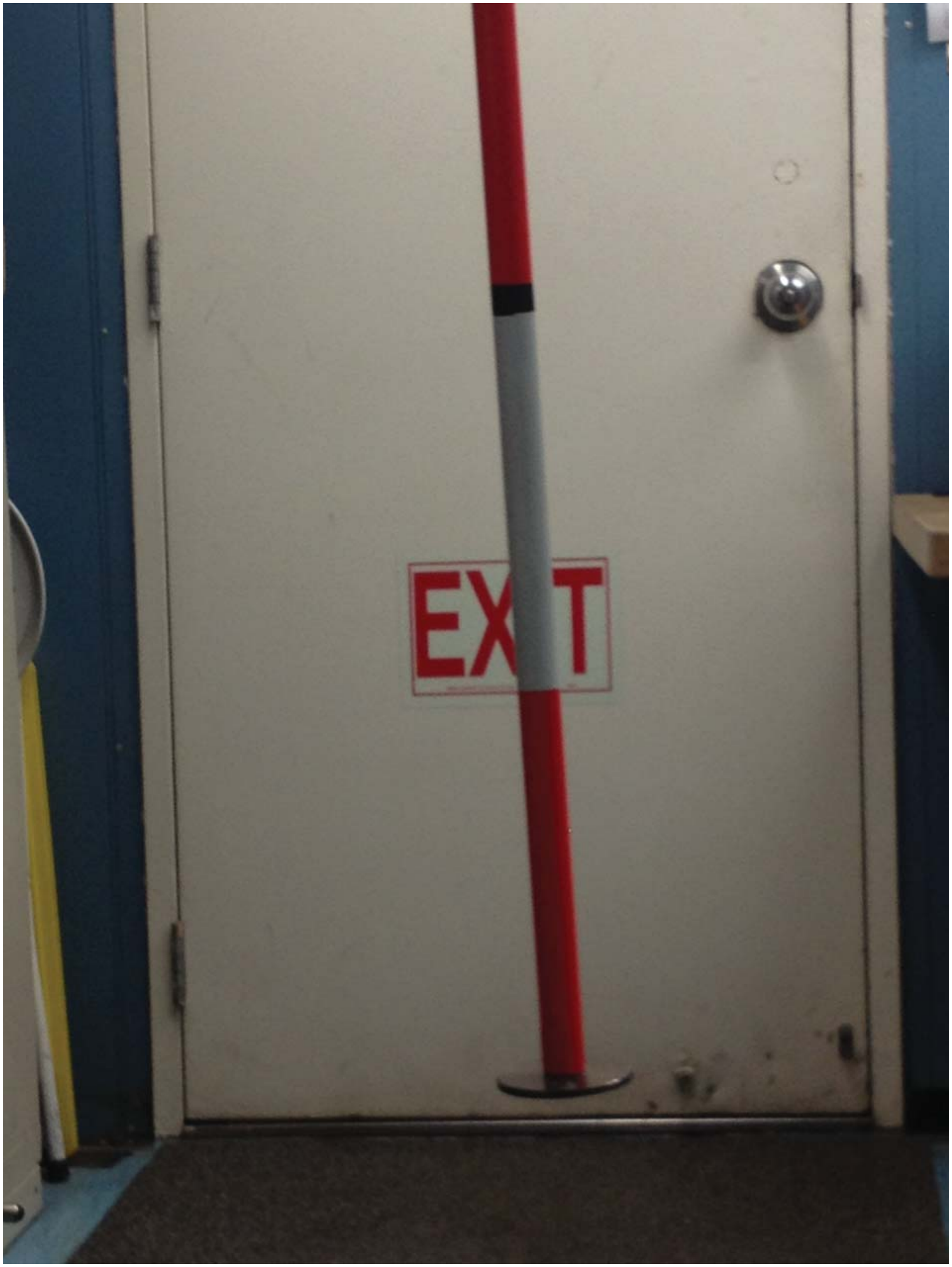

Figure 4: Sounding pole used aboard Thomas Jefferson and her survey launches.

A.3.4 Other Manual Sounding Equipment

No additional manual sounding equipment was utilized for data acquisition.

A.4 Positioning and Attitude Equipment

A.4.1 Applanix POS/MV

Manufacturer	Applanix (a Trimble company)
Model	320 v.4 & 320 v.5
Description	“Thomas Jefferson” is equipped with an Applanix POS MV 320 Position and Orientation Sensor version 5 to measure and calculate position and attitude. The POS MV is a GPS-aided inertial navigation system, which provides a blended position solution derived from both an Inertial Motion Unit (IMU) and an integrated GPS receiver. The IMU and GPS receiver are complementary sensors, and data from one are used to filter and constrain errors from the other. Position accuracy is displayed in real time by the POS MV software and was monitored to ensure that positioning accuracy requirements as outlined in the NOS Hydrographic Surveys Specifications and Deliverables (HSSD) were not exceeded. In addition, the POS MV software displays HDOP and the number of satellites used in position computation. Data acquisition was generally halted when an HDOP of 2.5 was exceeded or the number of satellites available dropped below four. However, because positional accuracy can be maintained by the POS/MV through short GPS outages with the help of the IMU, data acquisition was not halted during short periods of time when the HDOP and number of satellites used exceeded stated parameters. It has yet to be identified if this practice needs to be modified when using the MarineStar service or what the new operational constraints may be. In addition to position, the Applanix POS MV also provides accurate navigation and attitude data to correct for the effects of heave, pitch, roll and heading. The POS MV generates attitude data in three axes (roll, pitch and heading) to an accuracy of 0.02° or better. Heave measurements supplied by the POS MV maintain an accuracy of 5% of the measured vertical displacement for movements that have a period of up to 20 seconds. The Heave Bandwidth filter was configured with a damping coefficient of 0.707. The cutoff period of the high pass filter was determined by estimating the swell period encountered on the survey grounds. These values ranged from 8 seconds (flat water) to 20 seconds (long period ocean swell), with values of 8 or 12 seconds typically. Currently the ship system is set to 9 seconds and the launches are set to 8 seconds. Intermittent problems with the heading accuracy climbing above the ideal cutoff of 0.05° are observed. Heading accuracy is monitored by the launch

<table>
<tr><td></td><td>crew and survey operations are temporarily suspended in the event that the error exceeds 0.08°. Applanix “TrueHeave” values are also recorded. The TrueHeave algorithm uses a delayed filtering technique to eliminate many of the artifacts present in real time heave data. The TrueHeave data were applied to Kongsberg bathymetry in Caris HIPS post processing. Full POSPac data are also recorded on “Thomas Jefferson” and both of her survey launches. These data are used in real-time to correct for vessel motion. Additionally , in the event of real-time data falling outside of acceptable quality bounds, these files are post processed to produce superior position and attitude data in the form of a Smoothed Best Estimate of Trajectory (SBET) which is then applied in Caris.</td></tr>
<tr><td>PCS</td><td>
<table>
<tr><td>Manufacturer</td><td>Applanix</td></tr>
<tr><td>Model</td><td>320 v.5</td></tr>
<tr><td>Description</td><td>The PCS blends raw acceleration measurements from the IMU, with position information from the GPS antennas and RTCM beacon, creating a tightly-coupled position and orientation solution. The PCS outputs a one Pulse Per Second (PPS) signal to integrated systems to accurately time-stamp data.</td></tr>
<tr><td>Firmware Version</td><td>8.23</td></tr>
<tr><td>Software Version</td><td>7.92</td></tr>
<tr><td>Serial Numbers</td><td>
<table>
<tr><td>Vessel Installed On</td><td>S222</td></tr>
<tr><td>PCS s/n</td><td>6497</td></tr>
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</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td>IMU</td><td>
<table>
<tr><td>Manufacturer</td><td>Applanix</td></tr>
<tr><td>Model</td><td>LN 200</td></tr>
<tr><td>Description</td><td>The POS MV Inertial Measurement Unit (IMU) is used to record the amount of heave, pitch, and roll experienced by the vessel. The IMU is located at the vessel's central reference point, and is strapped down to the vessel. Since the IMU is fixed to the vessel, the motion experienced by the IMU is, by definition, the same motion experienced by the vessel. The IMU housing contains three orthogonally placed accelerometers, which sense acceleration in the x, y, and z directions. It also contains three orthogonally placed gyros, which sense angular rate of motion around the three axes. The measured amount of acceleration and rate of rotation is then used to find the degree of pitch, roll, and heave experienced by the vessel. Data from the IMU is also combined with data from the GNSS antennas to calculate vessel heading.</td></tr>
<tr><td>Serial Numbers</td><td>
<table>
<tr><td>Vessel Installed On</td><td>S222</td></tr>
<tr><td>IMU s/n</td><td>1074</td></tr>
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<tr><td>Certification</td><td>
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<tr><td>IMU s/n</td><td>1074</td></tr>
<tr><td>Certification Date</td><td>2014-09-25</td></tr>
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<tr><td>Antennas</td><td>
<table>
<tr><td>Manufacturer</td><td>Trimble</td></tr>
<tr><td>Model</td><td>GA830</td></tr>
<tr><td>Description</td><td>A high gain GNSS antenna.</td></tr>
<tr><td>Serial Numbers</td><td>
<table>
<tr><td>Vessel Installed On</td><td>Antenna s/n</td><td>Port or Starboard</td><td>Primary or Secondary</td></tr>
<tr><td>S222</td><td>7238</td><td>Port</td><td>Primary</td></tr>
<tr><td>S222</td><td>7239</td><td>Starboard</td><td>Secondary</td></tr>
</table>
</td></tr>
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</td></tr>
<tr><td>GAMS Calibration</td><td>
<table>
<tr><td>Vessel</td><td>S222</td></tr>
<tr><td>Calibration Date</td><td>2015-06-16</td></tr>
</table>
</td></tr>
<tr><td>Configuration Reports</td><td>
<table>
<tr><td>Vessel</td><td>S222</td></tr>
<tr><td>Report Date</td><td>2016-10-13</td></tr>
</table>
</td></tr>
</table>

A.4.2 DGPS

Description	The Trimble SPS361 receiver uses RTCM DGPS corrections either broadcast free by IALA Beacon stations, from SBAS (Satellite Based Augmentation Systems) or via an external radio or Internet connection from a DGPS reference station. GPS correctors are fed to the Applanix POS MV to produce real time differentially corrected positions.
Antennas	No DGPS antennas were installed.
Receivers	No DGPS receivers were installed.
Description	Fugro Marinestar is a commercial service that provides real-time GPS correctors via satellite. The correctors are derived using a Precise Point Positioning (PPP) approach and are based on a state estimation of the GPS system rather than a differential correction. The state estimation includes real-time estimate of satellite orbits, clock errors, and atmospheric delays. The specified accuracy advertised by MarineStar are generally less than 10cm in the horizontal and 15cm in the vertical at 95% confidence interval. The Marinestar corrector signal is received on the L1 channel of the primary POS MV antenna and is logged directly into the POS MV PCS. As such, no additional antenna or receiver equipment is necessary.
Antennas	No DGPS antennas were installed.
Receivers	No DGPS receivers were installed.

A.4.3 Trimble Backpacks

Trimble backpack equipment was not utilized for data acquisition.

A.4.4 Laser Rangefinders

Manufacturer	Laser Technology Inc.
Model	TruPulse 360 R
Description	LTI TruPluse 360 R is a hand held laser range finder. The device can be operated in 5 modes: horizontal distance, vertical distance, slope distance and inclination (or percent slope), 3-point flexible height routine with auto sequencing, and 2-shot missing line routine. There are also 5 target modes which are standard, closest, farthest, continuous, and filter. The Measurement range is 0 to 3280ft typical and 6560ft max to reflective target, inclination range of +/- 90 degrees and an azimuth range 0 to 359.9 degrees. The range finder is accurate in distance +/- 0.30 meters to high quality targets and +/-1

	meter to low quality targets, inclination accuracy of +/-0.25 degrees and azimuth accuracy of +/- 1 degree.
Serial Numbers	000172
DQA Tests	DQA test was not performed.

Figure 5: TruPulse 360 R

A.4.5 Other Positioning and Attitude Equipment

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

A.5 Sound Speed Equipment

A.5.1 Sound Speed Profiles

A.5.1.1 CTD Profilers

A.5.1.1.1 Sea-Bird Electronics SBE19

<table>
<tr><td>Manufacturer</td><td>Sea-Bird Electronics</td></tr>
<tr><td>Model</td><td>SBE19</td></tr>
<tr><td>Description</td><td>“Thomas Jefferson” uses a Sea-Bird Electronics SeaCat SBE19 Conductivity, Temperature, and Depth (CTD) Profiler to collect vertical sound speed profiles. The speed of sound is calculated from temperature, salinity, and pressure measurements. Temperature is measured directly. Salinity is calculated from measured electrical conductivity. Depth is calculated from strain gauge pressure. The system is configured for a sampling rate of 0.5 seconds. Depending on the depth of water, the profiler is either deployed by hand, or using a winch.</td></tr>
<tr><td>Serial Numbers</td><td><table><tr><td>Vessel Installed On</td><td>S222</td></tr><tr><td>CTD s/n</td><td>192472-0285</td></tr></table></td></tr>
<tr><td>Calibrations</td><td><table><tr><td>CTD s/n</td><td>192472-0285</td></tr><tr><td>Date</td><td>2016-01-13</td></tr><tr><td>Procedures</td><td>Calibrations performed by Sea-Bird Electronics</td></tr></table></td></tr>
</table>

Figure 6: Sea-Bird 19 CTD used aboard Thomas Jefferson S222

A.5.1.2 Sound Speed Profilers

A.5.1.2.1 AML Oceanographic AML Smart/Micro SV&P Probe

Manufacturer	AML Oceanographic
Model	AML Smart/Micro SV&P Probe
Description	“Thomas Jefferson” uses an AML Micro SV&P Probe to collect speed of sound profiles via the Brooks Ocean Technology MVP. The speed of sound is measured directly using a 'time-of-flight' sensor. Depth is calculated via strain gauge pressure. The currently installed probe is the Micro SV&P, serial number 7591. Any changes to the installed probe will be noted in the Descriptive Report of the effected survey. Calibration files are included in Appendix IV of this report.

Serial Numbers

Vessel Installed On	S222	S222	S222
Sound Speed Profiler s/n	Smart SV&P 4988	Smart SV&P 5340	Smart SV&P 7591

Calibrations

Sound Speed Profiler s/n	4988	5340	7591
Date	2016-07-01	2016-06-01	2016-06-01
Procedures	Calibrations performed by AML Oceanographic.	Calibrations performed by AML Oceanographic.	Calibrations performed by AML Oceanographic.

Figure 7: AML Smart SV&P Probe used in the MVP free-fall fish.

A.5.1.2.2 AML Micro CTD

Manufacturer	AML
Model	Micro CTD
Description	The MicroCTD is a sensor package used to measure conductivity and temperature in the water column while attached to a Moving Vessel Profiler towfish. This sensor provides a much broader range of data than the singaround sensors traditionally used, and is principally used to provide temperature data for backscatter correction on the Kongsberg EM2040.

Serial Numbers	*Vessel Installed On*	S222
	Sound Speed Profiler s/n	007761
Calibrations	*Sound Speed Profiler s/n*	007761
	Date	2016-11-04
	Procedures	Calibration was performed by AML

Figure 8: AML MicroCTD

A.5.2 Surface Sound Speed

A.5.2.1 Valeport MODUS SVS Thruhull

Manufacturer	Valeport
Model	MODUS SVS Thruhull

Description	The Valeport MODUS SVS Thruhull is a digital time-of-flight sound speed sensor used to measure the speed of sound at the transducer faces of the EM710 and EM2040. The system has a manufacturer-stated accuracy of 0.02m/s. The sensor is fully removable, and is deployed and recovered prior to and at the completion of acquisition via a Valeport-made valve flange.	
Serial Numbers	*Vessel Installed On*	S222
	Sound Speed Sensor s/n	33711
Calibrations	*Sound Speed Sensor s/n*	33711
	Date	2015-10-17
	Procedures	Calibration was performed by Valeport, Ltd in 2014; however, the sensor was not put into service until 2016.

Figure 9: Valeport MODUS SVS

Additional Discussion

“Thomas Jefferson” primarily uses a Brooke Ocean Moving Vessel Profiler (MVP) installed on the port quarter to collect sound speed profiles. The integrated system consists of a computer controlled high-speed winch with cable metering, a conductor cable, and a free-fall fish (FFF). Housed in the FFF is an Applied Microsystems SV&P Smart Sensor or a (see above). The profiler is deployed at survey speed via the winch. A traditional winch on the port side can collect stationary casts with the SeaBird SBE19 or SBE19+ as a backup to the MVP system. The MVP has 162m of cable on its drum as of November 2016.

Figure 10: MVP winch aboard NOAA Ship Thomas Jefferson

A.6 Horizontal and Vertical Control Equipment

A.6.1 Horizontal Control Equipment

A.6.1.1 Base Station Equipment

No base station equipment was utilized for data acquisition.

A.6.1.2 Rover Equipment

No rover equipment was utilized for data acquisition.

Additional Discussion

The Horizontal Datum for all projects is the World Geodetic System of 1984 (WGS84). During data acquisition and initial processing, horizontal control for all survey data is derived from either differentially corrected GPS using USCG differential beacons or from the Marinestar realtime satellite corrector service. If DGPS is used, differential beacons are chosen based on their proximity to the survey grounds and the signal-to-noise ratio of the beacons if more than one beacon is near the survey grounds.

The primary means of horizontal and vertical control is the Real-Time Precise Point Positioning (RT3P) method, described in section B.2.4.

As needed owing to issues with the real-time solution, horizontal and vertical control for MBES data is replaced in post-processing with a Smooth Best Estimate Trajectory (SBET). In the case of DGPS, the SBET process overwrites the position solution with an improved IAPPK solution. In the case of MarineStar, SBETs are used to transform the reference frame from ITRF00 to WGS84. A more detailed discussion of the processing pipeline is included in Section C.4.

A.6.2 Vertical Control Equipment

A.6.2.1 Water Level Gauges

No water level gauges were utilized for data acquisition.

A.6.2.2 Leveling Equipment

No water level gauges were utilized for data acquisition.

Additional Discussion

Vertical Datum for all projects is Mean Lower Low Water (MLLW), unless otherwise stated in the specific Descriptive Report. See Section C.5 for more details on the different methods used to reduce data to tidal datum. "Thomas Jefferson" typically does not install additional tide gauges on projects.

The form of Vertical Control used for each survey will be listed in section C.1 of the Descriptive Report.

A.7 Computer Hardware and Software

A.7.1 Computer Hardware

<table>
<tr><td>Manufacturer</td><td colspan="3">Individual computers utilized are not discussed in this report.</td></tr>
<tr><td>Model</td><td colspan="3">See Additional Discussion for more information.</td></tr>
<tr><td>Description</td><td colspan="3">N/A</td></tr>
<tr><td rowspan="2">Serial Numbers</td><td>Computer s/n</td><td>Operating System</td><td>Use</td></tr>
<tr><td>N/A</td><td>N/A</td><td>Acquisition and Processing</td></tr>
</table>

A.7.2 Computer Software

Manufacturer	Caris
Software Name	HIPS/SIPS
Version	9.1.9
Service Pack	N/A
Hotfix	N/A
Installation Date	2016-12-01
Use	Processing
Description	Caris HIPS (Hydrographic Information Processing System) is used for all initial processing of multibeam echo sounder bathymetry data. The program applies vessel offsets to the raw sonar data, corrects for tide and sound velocity, and calculates a Total Propagated Uncertainty (TPU) for each sounding. Individual soundings are then processed into a CUBE (Combined Uncertainty and Bathymetry Estimator) surface. These surfaces are then reviewed in HIPS or BDB (see below) for depth fliers, systematic errors, and agreement with adjoining and prior surveys. Caris SIPS (Side Scan Information Processing System) is used for all processing of side scan sonar imagery, including cable layback correction, slant range correction, contact selection, towpoint entry, and mosaic generation.

Manufacturer	Caris
Software Name	BASE Editor
Version	4.2
Service Pack	N/A
Hotfix	N/A
Installation Date	2016-03-03
Use	Processing
Description	Caris BASE Editor (FKA/AKA BDB) is used for quality control of multibeam and vertical beam surfaces, and for management of survey features. CUBE and Uncertainty grids are imported, and then reviewed for depth fliers and systematic errors, and agreement with adjoining surveys. Multibeam contacts (designated soundings), side scan sonar contacts, and detached position contacts are analyzed, grouped, and assigned S-57 classification.

Manufacturer	NOAA OCS HSTP
Software Name	Pydro
Version	16.9
Service Pack	r6326

Hotfix	N/A
Installation Date	2017-02-04
Use	Processing
Description	HSTB Pydro is a suite of programs used to process survey data, and to generate reports. FetchTides is used to create a .tid file from NWLON tide station data. Pydro can be used to classify side scan sonar and multibeam bathymetry contacts and manage survey features, however this functionality has largely been replaced by Caris BASE Editor. Pydro is still used for the generation of chartlets, the generation of Danger to Navigation reports, and to process TCARI tides. Velocipy is a program used for processing sound velocity casts. This program converts the hexadecimal SeaCat data to ASCII, and converts the ASCII data into a depth-binned sound velocity file. MVP data is recorded in a .txt format, and can be binned via Velocipy without conversion to ASCII. The resulting .svp files are applied to MBES and VBES data during post processing to correct for sound velocity variation within the water column. XmlDR is used to generate Descriptive Reports for each survey and the Data Acquisition Processing Report for each project. QC Tools is used to assess the quality of surfaces output by HIPS and SIPS.

Manufacturer	HYPACK, Inc
Software Name	Hypack 2016
Version	N/A
Service Pack	N/A
Hotfix	N/A
Installation Date	2016-03-19
Use	Acquisition
Description	Hypack is used to support ship navigation via position (from the POS MV) and autopilot interfacing.

Manufacturer	Applanix
Software Name	POSPac MMS
Version	7.2
Service Pack	N/A
Hotfix	N/A
Installation Date	2015-04-20
Use	Processing
Description	Applanix POSPac MMS is used to create SBETs, which provide horizontal and vertical control to bathymetric data.

Manufacturer	Applanix

Software Name	MV-POSView
Version	7.92
Service Pack	N/A
Hotfix	N/A
Installation Date	2015-04-08
Use	Acquisition
Description	The MV-POSView controller program is used on the ship to configure and operate the POS MV attitude and positioning system. This program is also used to record the POS MV .000 files used to produce the SBET files applied in Caris to improve attitude and navigation.

Manufacturer	Brooke Ocean
Software Name	MVP
Version	2.450
Service Pack	N/A
Hotfix	N/A
Installation Date	2007-02-01
Use	Acquisition and Processing
Description	The MVP program is used to control the MVP winch and fish.

Manufacturer	QPS, Inc
Software Name	Fledermaus Geocoder Tool (FMGT)
Version	7.4.0d
Service Pack	N/A
Hotfix	N/A
Installation Date	2015-04-10
Use	Processing
Description	Fledermaus Geocoder Tool (FMGT) is used to process backscatter mosaics.

Manufacturer	ESRI, Inc
Software Name	ArcGIS
Version	10.3
Service Pack	N/A
Hotfix	N/A
Installation Date	2015-04-08
Use	Acquisition and Processing

Description	ArcGIS is used for initial survey planning, such as the creation of line plans for export into Hypack to guide the survey acquisition. ArcGIS is also used for data analysis, where a variety of tools and a high level of customization allow for detailed analysis of surfaces and data products.

Manufacturer	Kongsberg
Software Name	Seafloor Information System
Version	N/A
Service Pack	N/A
Hotfix	N/A
Installation Date	2016-09-01
Use	Acquisition
Description	Seafloor Information System (SIS) is produced by Kongsberg Maritime and is supplied as part of the EM2040 multi-beam sonar system. This real time software is designed to be the user interface and real time data processing system for the EM2040. All necessary sensor interfaces, data displays for quality control and sensor calibration, seabed visualization, data logging, and integrated seabed acoustical imaging capability (sidescan) are standard parts of the software. Sound speed, vessel motion, and positional data are all logged into the .all files created by the program. It operates under the Windows operating system in a rack mounted computer dedicated to control of the EM2040.

Additional Discussion

Computer hardware that was a core component of a sensor is listed under the Echo Sounding section, referred to as the "Processor" for MBES systems or the "TPU" for the SSS systems. Computers used for processing of the data or controlling acquisition were completely interchangeable and the serial numbers used were not tracked.

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Ponar Wildco #1728

Manufacturer	Ponar Wildco
Model	#1728
Description	The Ponar Wildco is a winch-deployed bottom sampler used aboard "Thomas Jefferson."

Figure 11: Ponar style grab sampler used aboard NOAA Ship Thomas Jefferson.

A.8.1.2 Kahlsico Mud Snapper 214WA100

Manufacturer	Kahlsico Mud Snapper
Model	214WA100
Description	The Kahlsico Mud Snapper is a hand held bottom sampler that is used aboard TJ3101 and TJ3102.

Figure 12: Snapper type grab sampler used aboard TJ3101 & TJ3102.

B Quality Control

B.1 Data Acquisition

B.1.1 Bathymetry

B.1.1.1 Multibeam Echosounder

All multibeam data is logged using Kongsberg Seafloor Information System (SIS) in the .all format. During acquisition, 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;
- Monitors the vessel speed and requests the bridge to adjust as necessary to ensure density and coverage specifications are met.

B.1.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

B.1.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

B.1.2 Imagery

B.1.2.1 Side Scan Sonar

All side scan sonar data are logged using Klein SonarPro, in the .SDF format. During acquisition the hydrographer:
- Monitors range, towfish height, heading, pitch, roll, latitude, longitude, speed, pressure, and temperature;
- Adjusts towfish height, in accordance with Field Procedures Manual.

B.1.2.2 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

B.1.3 Sound Speed

B.1.3.1 Sound Speed Profiles

"Thomas Jefferson" uses an AML Micro SV&P Probe or an AML MicroCTD installed inside an MVP free-fall fish to acquire sound speed profiles. Profiles aboard the ship are acquired at 30 - 90 minute intervals. The interval between casts is monitored real-time using NOAA's CastTime program. CastTime compares successive casts using a ray-tracing uncertainty analysis that estimates the effect of the sound speed variability towards multibeam echo sounding. When the profile comparisons show redundancy, meaning that the effect of the sound speed variability towards echo sounding is negligible, then this provides justification to relax the sampling intervals towards the 90 minute bound. Conversely, when the comparisons show variability with a significant effect towards echo sounding, the MVP usage is increased accordingly. Additionally, the Kongsberg SIS interface provides guidance on the need for a cast (typically at 1-2 m/s change at the surface). At any time, sampling intervals are adjusted as needed at the discretion of the surveyor, to ensure spatial variability accounted for, or if there is suspicion of sudden changes or anomalies in the water-column.

TJ also uses a Sea-Bird SBE19+ CTD to collect sound speed profiles, generally 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 Valeport sound velocity probe for changes greater than 2 m/s in the surface sound velocity indicative of the need for a new cast.

Velocipy software is used for both data processing and setting up Sea-Bird SEACAT instruments. Prior to deployment the SEACAT voltage is checked. The SBE 19plus should have a minimum of 9.5 volts and the SBE 19 should have a minimum of 7 volts. In the event of lower voltage readings, the instrument batteries were changed.

The site selected should be in the deepest portion of the project area expected to be surveyed.

When conducting SEACAT casts with the SBE 19, the 3-2-1 rule of thumb is followed. The instrument should be turned on and allowed to sit on deck for 3 minutes while the sensors settle and form baseline. The instrument is then set to soak just below the surface for 2 minutes. Finally the instrument is lowered at a rate of 1 meter/second.

When conducting SEACAT casts with the SBE 19+, the instrument should be lowered and held just below the water's surface for about 1 minute to allow air to escape the salinity cell. After soaking the instrument, it should be lowered at a rate of 1 meter/second through the water column. In areas with lenses of fresh water or other complex sound speed variation near the surface, the instrument should be lowered slowly (in some cases, much less than 1 meter/second) through the first 5-10 meters of water in order to accurately sample the sound speed. After this initial descent, the instrument should proceed to drop at a rate of 1 meter/second.

The Moving Vessel Profiler (MVP) is an automated winch system that deploys a fish containing a sound speed sensor by free fall. The fish is towed behind the survey vessel in a ready position that is marked by messengers attached to the tow cable. Ideally, at survey speeds the fish is "flying" just above the depth of the sonar transducers. The specified depth deployed is selected by specifying a distance off the bottom. Once at the depth limit, the winch freefall is automatically stopped 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 towing position.

Aboard all platforms, the hydrographer processes each cast immediately, then reviews it for erroneous data.

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Figure 13: This image intentionally left blank

B.1.3.2 Surface Sound Speed

"Thomas Jefferson" uses a Valeport probe to find the speed of sound at the Kongsberg transducer face. These 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.

B.1.4 Horizontal and Vertical Control

B.1.4.1 Horizontal Control

Depending on Project Instructions and availability, "Thomas Jefferson" used one of the two following methods for horizontal control:

Marinestar Realtime PPP Corrector Service:
“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. The data are then put out in real time to the EM2040, and positional and motion data are applied to the acquired bathymetry.

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.

Inertially Aided Post-Processed Kinematic:
During post-processing horizontal positioning can be shifted to an Inertially Aided Post-Processed Kinematic (IAPPK) solution. The 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 is 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 a Smoothed Best Estimate of Trajectory (SBET). The resulting position can be used to apply higher quality navigation information to the processed data.

B.1.4.2 Vertical Control

Vertical Control methods for each project are specified in the project instructions, and utilize one of three possible methods:

-Zoned Tides: when using zoned tides vertical control is based on one or more NWLON stations operated by CO-OPS. 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 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 is 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.

-GPS Tide: The IAPPK, 5P, or RT3P solution described in the Horizontal Control section can also be used to provide vertical control. Using this method the bathymetric data is initially referenced to the ellipsoid using the high accuracy position data. It is later reduced to MLLW using a separation model called VDatum, which is provided to the field unit by NOAA's Hydrographic Services Division.

B.1.5 Feature Verification

The following work flow is used to develop and verify features:
- The location of all potentially significant features are opened in Caris BASE Editor (BDB). Any indication of shoaling found in VBES data is also noted, and the area outlined in BDB;
- A development area polygon is exported from BDB and a line plan is created using ArcMap, creating line spacing that will ensonify all features with near nadir beams;
- Object Detection level MBES data is collected over all SSS contacts, VBES designated soundings, and all possible shoals.

Quality of data is controlled through:
- Real time monitoring during acquisition to ensure that all features are covered by near nadir beams;
- Post processing inspection of the 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.

B.1.6 Bottom Sampling

Bottom samples are collected in accordance with the recommended bottom sample plan provided in each survey's Project Reference File (PRF). The potential sample sites are examined by the Command and potentially culled based on the actual depths found during survey operations. Additional sample sites may also be added.

"Thomas Jefferson" uses a winch-deployed Ponar Wildco. Once obtained, samples are analyzed for sediment type and classified with S-57 attribution using Caris BASE Editor. In the event that no sample is obtained after three attempts, the nature of the surface is characterized as "unknown". Samples are discarded after field analysis is complete.

B.1.7 Backscatter

"Thomas Jefferson" processes all acquired backscatter into a mosaic using Fledermaus.

All backscatter data are logged using the SIS .all format.

B.1.8 Other

No additional data were acquired.

B.2 Data Processing

B.2.1 Bathymetry

B.2.1.1 Multibeam Echosounder

Five workflows exist depending on whether a survey uses zoned tides, TCARI tides, Marinestar service and the Real-Time Precise Point Positioning (RT3P) method, the Post-Processed Precise Point Positioning (5P) method, or Inertially Aided Post Processed Kinematic (IAPPK) method. A more detailed description of 5P and IAPPK SBET creation is covered below in Section B.2.4.

These workflows are shown in descending order of preferred use.

-RT3P
1) Convert .all file into Caris project
2) Load Delayed Heave via Auxiliary Data Import
3) Sound Velocity Correction (note: no file is loaded in this step. This is purely to apply Delayed Heave.)
4) Compute GPS Tide
5) Merge
6) Compute Total Propagated Uncertainty (TPU) using fixed uncertainty values (11cm for Marinestar, and the uncertainty value provided as part of the vDatum model)

-5P

1) Create SBET and RMS files in POSPac MMS.
2) Convert raw .HSX data to Caris HDCS format
3) Load Delayed Heave
4) Import ancillary data: SBET and RMS
5) Apply tide correctors. While unused, if available these are useful for a QC check in Subset Editor.
6) Compute GPS Tides using the provided VDatum SEP model.
7) Apply sound speed correctors
8) Merge; use GPS Tides.
9) Compute Total Propagated Uncertainty (TPU)

-IAPPK
IAPPK requires a delay of around 48 hours to produce the SBET and RMS files, due to reliance on updates of CORS station and ephemeris data. The need for fast QC of the data ("night processing") to allow planning of the next day's survey operations necessitates that initial processing must happen before the IAPPK solution is available. As a result, it initially follows the tidal scheme appropriate to that project area (Zoned Tides or TCARI). Once sufficient time has passed, SBETs and RMS files are produced and the data is reprocessed using the same work flow as 5P, skipping the conversion and Delayed Heave steps.

-Zoned Tides:
1) Convert raw .HSX data to Caris HDCS format
2) Load Delayed Heave
3) Apply tide correctors
4) Apply sound speed correctors
5) Merge
6) Compute

-TCARI Tides:
The TCARI Tides work flow is the same as Zoned Tides except that Step 3 applies the TCARI correctors via Pydro, and Step 6 applies "realtime" tidal uncertainty values instead of project specific static values.

At this stage, all of the work flows merge into a common process.

1) Create CUBE surfaces. Surface resolution is dictated by the type of coverage required (Complete Coverage vs. Object Detection), and the depth of water. Disambiguation method is NOAA CUBE Parameters.
Compliance with HSSD gridding requirements is strictly observed.
2) Review the CUBE surface for holidays.
3) Create a holiday line plan.
4) Review the uncertainty and standard deviation layers and address areas where the standards set by the HSSD are exceeded.
5) Examine all surfaces for erroneous surface designation and evidence of systematic errors. Also identify features and look for evidence of shoaling.
6) Significant features are flagged 'designated', forcing the CUBE algorithm to honor the depth of the sounding. Designated soundings are reviewed to ensure compliance with guidance in the HSSD.

7) Create finalized grids. In finalization, the standard deviation for each node in the surface is multiplied by 1.96 to provide the 95% (2-sigma) confidence level. Standard deviation is then compared to the computed Total Vertical Uncertainty (TVU) for each node. The larger of the two values is retained as the finalized Uncertainty for each node. Finalization is also when the surface is forced to honor designated soundings.

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Figure 14: This image intentionally left blank

B.2.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not processed.

B.2.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not processed.

B.2.1.4 Specific Data Processing Methods

B.2.1.4.1 Methods Used to Maintain Data Integrity

All bathymetric data is moved through the Caris HIPS processing pipeline using a step-by-step method. Data integrity is maintained through the use of acquisition and processing logs, which track: acquisition of each line of data; conversion of the data; examination of ancillary sensor (navigation and attitude); and the application of heave, tides, SVP, and TPU. When processing an ERS survey using the 5P or IAPPK method, an additional log tracking the quality of SBETs is used.

B.2.1.4.2 Methods Used to Generate Bathymetric Grids

After initial processing the bathymetric data is gridded into BASE surfaces using the CUBE algorithm. This type of surface calculates a horizontal and vertical uncertainty for each sounding, derived from the combined uncertainty from each of the sensors that contributes data to the sounding (e.g water levels, tide zoning, attitude sensor error, navigation sensor horizontal position error, and sound velocity profile error). Individual soundings are then propagated to grid nodes, which takes on a depth value as well as an uncertainty value based on all the soundings that contribute to the node. The influence of a sounding on a grid node is limited to 0.707 times the grid resolution.

MBES data is gridded using the CUBE algorithm. Resolution is dictated by the Project Instructions, as well as section 5.2.2 of the HSSD. The disambiguation method used is always Density and Local. The settings used for Capture Distance Scale, Horizontal Error Scale, and Capture Distance Minimum are those listed in section 4.2.1.1.1.1 of the FPM. After creation, Uncertainty and CUBE surfaces go through a quality control process. During this process, the Depth, Uncertainty, Standard Deviation, and Density child layers are examined for compliance with NOAA specifications. After the surfaces pass quality control, they are finalized. Uncertainty values for finalized surface come from the greater of either Uncertainty, or Standard Deviation.

B.2.1.4.3 Methods Used to Derive Final Depths

Methods Used	Cleaning Filters Gridding Parameters Surface Computation Algorithms
Description	Filters are used on a case-by-case basis as determined by the hydrographer. Refer to the Descriptive Report for more information. Gridding parameters and surface computation algorithms comply with the HSSD and are described above.

B.2.2 Imagery

B.2.2.1 Side Scan Sonar

1) Convert raw .sdf data using Caris SIPS;
2) Scan Navigation and Attitude data, flagging erroneous data as rejected;
3) Re-compute towfish navigation. This is when tow point offsets and horizontal layback is applied to the data;
4) Slant range correct each line of data;
5) A primary reviewer scans each line for significant contacts;
6) A secondary reviewer makes an independent check-scan of all lines, verifying contacts and checking for missed contacts;
7) If the Project Instructions call for 200% Side Scan coverage, the scanners check correlation of contacts between 100% and 200% coverage;
8) Correlation is also used to reveal systematic errors, particularly if a contact shows up on lines collected in opposite or orthogonal directions;
9) Create individual mosaics for 100% and 200% coverage. Examine for coverage;
10) If necessary, create a holiday line plan.

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Figure 15: This image intentionally left blank

B.2.2.2 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not processed.

B.2.2.3 Specific Data Processing Methods

B.2.2.3.1 Methods Used to Maintain Data Integrity

Periodic confidence checks were completed to ensure integrity of data. These checks were completed by ensonifing a target in the outer limits of the range scale on either side of towfish. When this target was seen on the trace within ten meters of the target's actual position (the positional accuracy of a towed system), it was understood that data integrity was maintained. Additionally, integrity is controlled through the use of acquisition and processing logs.

B.2.2.3.2 Methods Used to Achieve Object Detection and Accuracy Requirements

Object detection from side scan imagery is obtained by acquiring the entire survey area two times, with survey lines in the second coverage offset halfway between the lines from the first coverage. This results in 200% Side-Scan Coverage with line spacing based on 80% of the range scale. To ensure positional accuracy, a side scan certification test is performed. Multiple passes are made on a discrete feature (1m cube when possible) that ensonifies the feature with each transducer at a distance approximately 15%, 50%, and 80% of the range scale in use. A total of 12 passes are made and the feature must be detected in at least 10 of the 12 pass. All survey lines are then processed and a contact created for the feature. Contact positions are plotted and compared to the actual position of the feature. The contacts must be within 5m of the actual position for hull-mounted systems and 10m for towed systems.

B.2.2.3.3 Methods Used to Verify Swath Coverage

Side scan sonar coverage is determined by creating mosaics using Mosaic Editor in Caris SIPS. Each 100% of coverage is evaluated independently for gaps in coverage. Any holidays noted in the mosaics must be re-acquired in a manner that will ensonify the area from the same incidence angle as originally intended.

B.2.2.3.4 Criteria Used for Contact Selection

For water depths less than 20m, contact heights of 1m or greater are considered significant. For water depths 20m or greater, contact heights of 10% of the water depth are considered significant. A feature is created for each significant contact.

B.2.2.3.5 Compression Methods Used for Reviewing Imagery

No compression methods were used for reviewing imagery.

B.2.3 Sound Speed

B.2.3.1 Sound Speed Profiles

Sound speed profiles are acquired by two types of devices: CTD and MVP. Downloading and processing of all sound speed data is performed using Velocipy, a part of the HSTP supplied Pydro program suite. Sound speed profiles are also loaded directly into SIS and applied in real time, with an option to re-apply later in HIPS in the event of problems.

B.2.3.1.1 Specific Data Processing Methods

B.2.3.1.1.1 Caris SVP File Concatenation Methods

All sound speed profiles are concatenated into master files using Velocipy.

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Figure 16: This image intentionally left blank

B.2.3.2 Surface Sound Speed

Surface sound speed data were not processed.

B.2.4 Horizontal and Vertical Control

B.2.4.1 Horizontal Control

Realtime horizontal correctors are applied during acquisition from either USCG DGPS stations, or from the Marinestar satellite service. In all cases, the necessary data for post processing of the position is recorded by the POS PCS into .000 files (when automatically split for file size, the file suffix increments to .001, .002, etc). The post processing workflow varies based on using 5P (with the Marinestar service) or IAPPK (with DGPS).

Marinestar workflow:
1) Create a new project in POSPac MMS.
2) Drag all of the POS files into the new project window.
3) Wait for extraction and download of rapid ephemeris.
4) Run the GNSS-Inertial Processor.
5) Export SBET files.

IAPPK workflow:
1) Create a new project in POSPac MMS.
2) Drag all of the POS files into the new project window.
3) Wait for extraction and download of ephemeris and CORS data.
4) Run the GNSS-Inertial Processor.
5) Export SBET files.

While very similar, the two are very different in practice. The primary requirement for running MarineStar through POSPac is to change the reference system of the data to WGS84, with the added benefit of reducing the uncertainty of the solution by running the processing both forward and backward. For IAPPK, there is a time delay of around two days waiting on upload of the CORS data and availability of ephemeris. Slow satellite internet download rates can make the download of CORS data prohibitively slow and prone to failure. The reprocessing of the solution using the CORS data and recorded raw observables takes around two hours per 8 hour platform survey day, as compared to 10-15 minutes for the same processing via 5P. For “Thomas Jefferson,” with 24 hours of ship acquisition per day and two launch acquisition periods of 9 hours, the IAPPK processing typically takes 10 hours per day compared to about one hour for 5P processing.

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Figure 17: This image intentionally left blank.

B.2.4.2 Vertical Control

Methods vary based on project assigned vertical control.

If Zoned Tides or TCARI are assigned, all tidal data processing is done by CO-OPS. Tides are then loaded in Caris or Pydro, respectively.

For ERS projects, a VDatum separation model (SEP) is provided with the Project Instructions. This SEP and the GPS heights in either the processed HDCS data (RT3P) or the SBET) exported from POSPac (5P/ IAPPK are combined in Caris using the Compute GPS Tides command. Reduction to tidal datum is then completed by checking the "GPS Tides" option during the Merge step in Caris.

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Figure 18: This image intentionally left blank.

B.2.5 Feature Verification

Feature verification begins during initial data processing. When conducting Side Scan surveys the data is converted and scanned for contacts using 2 independent reviewers. 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. 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.

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Figure 19: This image intentionally left blank.

B.2.6 Backscatter

All backscatter data are logged in the SIS .all format. All acquired backscatter data are processed into a mosaic and delivered to AHB. All processing of backscatter is done using the FMGT module of the QPS Fledermaus software package.

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Figure 20: This image intentionally left blank.

B.2.7 Other

No additional data were processed.

B.3 Quality Management

Prior to each field season, “Thomas Jefferson” and her survey launches perform an annual Hydrographic Survey Readiness Review, during which all multibeam echo sounders, vertical beam echo sounders, side scan sonars, positioning systems, sound speed measuring devices, lead lines, and leveling equipment are calibrated.

Prior to acquisition, the hydrographer ensures that all charted features are in the Composite Source File (CSF), and reviews the coverage requirements. During daily acquisition, a hydrographer monitors the cumulative uncertainties in position and attitude data, watches incoming data for errors, and compares the surface sound speed against full water column data for each CTD cast. During post-processing, navigation and attitude data is scanned using Caris HIPS and SIPS. Side Scan data is then examined for significant features by two separate individuals. Multibeam data is binned into a BASE surface using the CUBE algorithm, then undergoes directed editing using the Standard Deviation, Depth, Uncertainty, and

Hypothesis Count child layers. The HSSD allowed uncertainty is also calculated for each surface node, and compared against the actual uncertainty. Any systematic errors, problems in density, or areas of high uncertainty are addressed in the Descriptive Report.

Before any data is to be submitted, it is reviewed by at least three experienced hydrographers who are signatories to the Descriptive Report.

B.4 Uncertainty and Error Management

Caris computes TPU based on both the static and dynamic measurements of the vessel and survey-specific information including tidal zoning uncertainty estimates and sound speed measurement uncertainties. Static offset values are entered into the Caris .hvf file. Dynamic (realtime) and sound speed uncertainties are entered using the Caris Compute TPU tool. Where TCARI tides are used, uncertainty is calculated and applied during application of TCARI tidal correctors to HDCS data.

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.4.1 Total Propagated Uncertainty (TPU)

B.4.1.1 TPU Calculation Methods

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: Realtime, Static, or Vessel. Realtime values are provided from the sensor or processing package, such as POSPac RMS files. Static values are those entered manually into the Compute TPU dialog, such as tidal zoning uncertainty and sound speed measurement uncertainties. These Static values are documented in each sheet's Descriptive Report. Vessel values are taken from the HVF if no realtime or static values are available.

B.4.1.2 Source of TPU Values

Uncertainty values entered into the HVF for the multibeam and positioning systems were compiled 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. Tidal uncertainty values are realtime if using TCARI, or static and provided with the Project Instructions for Zoned Tides or VDatum. Realtime values for the sonar are provided by the sonar. Realtime values for motion and navigation are output from POSPac via the RMS file.

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.4.1.3 TPU Values

Vessel	n/a			
Echosounder	n/a n/a 0 kilohertz			
TPU Standard Deviation Values	*Motion*	*Gyro*	0 degrees	
		Heave	0 % Amplitude	
			0 meters	
		Pitch	0 degrees	
		Roll	0 degrees	
	Navigation Position	0 meters		
	Timing	*Transducer*	0 seconds	
		Navigation	0 seconds	
		Gyro	0 seconds	
		Heave	0 seconds	
		Pitch	0 seconds	
		Roll	0 seconds	
	Offsets	*x*	0 meters	
		y	0 meters	
		z	0 meters	
	MRU Alignment	*Gyro*	0 degrees	
		Pitch	0 degrees	
		Roll	0 degrees	
	Vessel	*Speed*	0 meters/second	
		Loading	0 meters	
		Draft	0 meters	
		Delta Draft	0 meters	

B.4.2 Deviations

There were no deviations from the requirement to compute total propagated uncertainty.

C Corrections To Echo Soundings

C.1 Vessel Offsets and Layback

C.1.1 Vessel Offsets

C.1.1.1 Description of Correctors

See included HVFs for information on applied correctors.

C.1.1.2 Methods and Procedures

See included HVFs for information on applied correctors.

C.1.1.3 Vessel Offset Correctors

Vessel	See included HVFs for information on applied correctors.		
Echosounder	See included HVFs for information on applied correctors. See included HVFs for information on applied correctors. 0 hertz		
Date	2015-11-13		
Offsets	*MRU to Transducer*	*x*	0 meters
		y	0 meters
		z	0 meters
		x2	0 meters
		y2	0 meters
		z2	0 meters
	Nav to Transducer	*x*	0 meters
		y	0 meters
		z	0 meters
		x2	0 meters
		y2	0 meters
		z2	0 meters
	Transducer Roll	*Roll*	0 degrees
		Roll2	0 radians

C.1.2 Layback

Layback correctors were not applied.

Additional Discussion

All offsets for “Thomas Jefferson” were derived from full surveys performed by Kongsberg USA-contracted personnel and verified by HSTB. All offsets are tracked and updated as needed.

All sensor offsets for “Thomas Jefferson” were measured with respect to the vessel's reference point, then translated to the IMU. Offset values for the EM2040 are entered into SIS and the ship's Caris HIPS Hydrographic Vessel File (HVF), with the exception of the x,y,z offsets between the primary GPS antenna and the IMU. The distance between primary antenna and IMU is entered into POSView, which then feeds position relative to the IMU to all integrated sonars. All other offsets are applied to data during the SVP or Merge steps in processing of bathymetric data. Offsets are applied to side scan sonar data during the Recompute Towfish Navigation step.

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.

Additional Discussion

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.

C.2 Static and Dynamic Draft

C.2.1 Static Draft

C.2.1.1 Description of Correctors

See Additional Discussion for information on static draft application.

C.2.1.2 Methods and Procedures

See Additional Discussion for information on static draft application.

C.2.2 Dynamic Draft

C.2.2.1 Description of Correctors

See Additional Discussion for information on dynamic draft application.

C.2.2.2 Methods and Procedures

See Additional Discussion for information on dynamic draft application.

C.2.2.3 Dynamic Draft Correctors

<table>
<tr><td>Vessel</td><td>S222</td></tr>
<tr><td>Date</td><td>2015-11-07</td></tr>
<tr><td>Dynamic Draft Table</td><td><table><tr><td>Speed</td><td>Draft</td></tr><tr><td>0</td><td>0</td></tr></table></td></tr>
</table>

Additional Discussion

Dynamic draft for “Thomas Jefferson” 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).

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.

Additional Discussion

Static draft is measured , a Sutron Bubbler system. The orifice was surveyed into the IMU reference frame, and a waterline height was calculated. A common waterline for the ship when fully loaded with fuel and ballasted normally is approximately 35cm below the reference point of the ship, but the waterline may change by as much as +/- 30cm over the course of a field season.

In ERS surveys, the Static Draft is not applied to the soundings.

The waterline for "Thomas Jefferson" is measured at least weekly. When feasible, waterline measurements are taken before and after fueling or ballasting of the ship. 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.

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.

C.3 System Alignment

System alignment correctors were not applied.

C.4 Positioning and Attitude

C.4.1 Description of Correctors

No description was provided.

C.4.2 Methods and Procedures

Vessel navigation and attitude is measured by the POS MV and recorded in the .all file created by SIS, supporting the RT3P pipeline. Navigation and attitude measurements not applied in real time (typically, only heave data) are applied during post processing in Caris HIPS using the attitude data recorded in the .all file. The POS MV TrueHeave data are logged within the POS MV .000 files and applied in Caris HIPS during post processing using the Import Ancillary Data command. TrueHeave is a forward-backward filtered heave corrector as opposed to the real time heave corrector, and is fully described in section 6 of the POS MV V5 User Guide 2009. In the event of issues with the real time positional solution applied by SIS, SBET files are applied to soundings to increase the accuracy of the kinematic vessel corrections and to allow the ability to reference soundings to the ellipsoid. Standard daily data processing procedures include post processing of POS MV kinematic .000 files using Applanix POSPac MMS and POSGNSS software using either IN-Fusion SmartBase, IN-Fusion SingleBase or Omnistar Precise Point Positioning (a reference to the previous commercial name of Marinestar) processing modes. After processing and quality control analysis of the post-processed SBET files is complete, the SBET and RMS files are applied to the HDCS data in Caris HIPS using the Import Ancillary Data command.

Additional Discussion

As part of an HSTB-led Sonar Acceptance Trial, the EM2040 was calibrated in all frequencies and operational modes.

As part of the annual HSRR, “Thomas Jefferson” conducted MBES calibration tests for each individual multibeam system on the ship and her launches. Multibeam systems with two frequencies required an individual test for each frequency. The procedure used follows that outlined in section 1.5.5.1 of the Field Procedures Manual dated April 2014. Timing bias was determined using the method of running the same line at different speeds. Pitch and yaw bias was determined using a target on the seafloor. Finally, roll bias was determined using the standard flat bottom method. Offset values were derived using SIS' built-in patch testing tools

All calibration reports can be found in the Appendix Folder, Patch Test Reports.

C.5 Tides and Water Levels

C.5.1 Description of Correctors

Unless otherwise noted in the survey Descriptive Report (DR) or project Horizontal and Vertical Control Report (HVCR), the vertical datum for all soundings and heights is Mean Lower Low Water (MLLW).

C.5.2 Methods and Procedures

Reduction to MLLW is accomplished by a variety of means depending on the project.

Predicted, preliminary, and verified water level correctors from the primary tide station(s) listed in the Project Instructions may be downloaded from the CO-OPS website and used for water level corrections during the course of the project. These tide station files are collated to include the appropriate days of acquisition and then converted to Caris .tid file format using FetchTides. Water level data in the .tid files are applied to HDCS data in Caris HIPS using the zone definition file (.zdf) or, for TCARI, in Pydro using a TCARI model provided by CO-OPS. Upon receiving final approved water level data, all data are reduced to MLLW using the final approved water levels as noted in the individual survey's Descriptive Report.

ERS surveys are reduced to MLLW via the application of the CO-OPS provided VDatum SEP model using the Compute GPS Tides tool in Caris.

In the event that shore-based vertical control is established via either base stations or tide gauges, a complete description of vertical control utilized for a given project can be found in the project specific HVCR, submitted for each project under separate cover when necessary as outlined in section 5.2.3.2.3 of the FPM.

C.6 Sound Speed

C.6.1 Sound Speed Profiles

C.6.1.1 Description of Correctors

Aboard “Thomas Jefferson,” the MVP free-fall fish is used to collect sound speed profiles.

C.6.1.2 Methods and Procedures

Seabird .cnv and MVP .bot files are collected when necessary and converted to .svp files using NOAA's Pydro/Velocipy program. Additionally, .S12 files are created by the MVP software, and sent directly to the EM2040 computer via the SendToSIS utility. .svp files are concatenated into one vessel specific master file per project. This method of applying sound speed to data is listed in the sheets processing log included in the Separates submitted with the individual survey.

C.6.2 Surface Sound Speed

C.6.2.1 Description of Correctors

Aboard “Thomas Jefferson,” surface sound speed is measured using a Valeport Thru-Hull sensor.

C.6.2.2 Methods and Procedures

The speed of sound at the transducer face is fed directly to the Kongsberg EM2040 and is used in real-time by the MBES for beamforming.

Appendix I
Vessel Files

Vessel Name: S222_EM2040_HSTB.hvf
Vessel created: February 27, 2017

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2016-278 00:00

Comments:
Time Correction(s) 0.000

Transduer #1:

Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset: 0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer:
Model: em2040_300N
Serial Number:

Transducer #2:

Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset: 0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Navigation Sensor:

Time Stamp: 2016-278 00:00

Comments:
Time Correction(s) 0.000
DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

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

Gyro Sensor:

Time Stamp: 2016-278 00:00

Comments:
Time Correction(s) 0.000

Heave Sensor:

Time Stamp: 2016-278 00:00

Comments: (null)
Apply No
Time Correction(s) 0.000
DeltaX: -2.146
DeltaY: 2.923
DeltaZ: -5.022
Offset: 0.000

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

Pitch Sensor:

Time Stamp: 2016-278 00:00

Comments:
Apply No
Time Correction(s) 0.000
Pitch offset: 0.000

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

Roll Sensor:

Time Stamp: 2016-278 00:00

Comments:
Apply No
Time Correction(s) 0.000
Roll offset: 0.000

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

Draft Sensor:

Time Stamp: 2016-278 00:00

Apply Yes
Comments:
Time Correction(s) 0.000

Entry 1) Draft: 0.000 Speed: 0.000
Entry 2) Draft: -0.012 Speed: 0.972
Entry 3) Draft: -0.012 Speed: 1.944
Entry 4) Draft: -0.004 Speed: 2.916
Entry 5) Draft: 0.018 Speed: 3.888
Entry 6) Draft: 0.040 Speed: 4.860
Entry 7) Draft: 0.068 Speed: 5.832
Entry 8) Draft: 0.104 Speed: 6.803
Entry 9) Draft: 0.140 Speed: 7.775
Entry 10) Draft: 0.186 Speed: 8.747
Entry 11) Draft: 0.232 Speed: 9.719
Entry 12) Draft: 0.284 Speed: 10.691
Entry 13) Draft: 0.350 Speed: 11.663

TPU

Time Stamp: 2015-001 00:00

Comments:
Offsets

Motion sensing unit to the transducer 1
X Head 1 2.146
Y Head 1 -2.923
Z Head 1 5.022
Motion sensing unit to the transducer 2
X Head 2 2.450
Y Head 2 -2.818
Z Head 2 5.005
Navigation antenna to the transducer 1
X Head 1 0.757
Y Head 1 7.014
Z Head 1 27.360
Navigation antenna to the transducer 2
X Head 2 1.061
Y Head 2 7.119
Z Head 2 27.343

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

Heave Error: 0.000 or 0.000" of heave amplitude.
Measurement errors: 0.002
Motion sensing unit alignment errors
Gyro:0.030 Pitch:0.010 Roll:0.010
Gyro measurement error: 0.015
Roll measurement error: 0.003
Pitch measurement error: 0.003

Navigation measurement error: 0.100
Transducer timing error: 0.001
Navigation timing error: 0.001
Gyro timing error: 0.001
Heave timing error: 0.001
PitchTimingStdDev: 0.001
Roll timing error: 0.001
Sound Velocity speed measurement error: 0.000
Surface sound speed measurement error: 0.000
Tide measurement error: 0.000
Tide zoning error: 0.000
Speed over ground measurement error: 0.000
Dynamic loading measurement error: 0.000
Static draft measurement error: 0.000
Delta draft measurement error: 0.000
StDev Comment: (null)

Svp Sensor:

Time Stamp: 2016-278 00:00

Comments:
Time Correction(s) 0.000

Svp #1:

Pitch Offset: -0.266
Roll Offset: 0.327
Azimuth Offset: 179.504

DeltaX: 2.146
DeltaY: -2.923
DeltaZ: 5.022

SVP #2:

Pitch Offset: -0.277
Roll Offset: 0.419
Azimuth Offset: 179.498

DeltaX: 2.450
DeltaY: -2.818
DeltaZ: 5.005

WaterLine:

Time Stamp: 2016-278 00:00

Comments: (null)
Apply No
WaterLine 0.371

Vessel Name: TJ_S222_Klein5000_SSS100_2015.hvf
Vessel created: June 23, 2015

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2015-001 00:00

Comments:
Time Correction(s) 0.000

Transduer #1:

Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset: 0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer:
Model: Unknown
Serial Number:

Navigation Sensor:

Time Stamp: 2015-001 00:00

Comments: (null)
Time Correction(s) 0.000
DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer: Applanix
Model: v4
Serial Number: (null)

Heave Sensor:

Time Stamp: 2015-001 00:00

Comments: (null)
Apply No
Time Correction(s) 0.000
DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000
Offset: 0.000

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

Pitch Sensor:

Time Stamp: 2015-001 00:00

Comments: (null)
Apply No
Time Correction(s) 0.000
Pitch offset: 0.000

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

Roll Sensor:

Time Stamp: 2015-001 00:00

Comments: (null)
Apply No
Time Correction(s) 0.000
Roll offset: 0.000

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

Tow Point:

Time Stamp: 2015-001 00:00

Comments: HSRR 2015
Time Correction(s) 0.000
DeltaX: 6.370
DeltaY: -42.550
DeltaZ: -4.800

Manufacturer: Klein
Model: 5000 V2
Serial Number:

Time Stamp: 2015-117 00:00

Comments: HSRR 2015 SSS Cert Results
Time Correction(s) 0.000
DeltaX: 6.370

DeltaY: -42.550
DeltaZ: -4.800

Manufacturer: Klein
Model: 5000 V2
Serial Number:

WaterLine:

Time Stamp: 2015-001 00:00

Comments: HSRR 2015
Apply Yes
WaterLine 0.380

Time Stamp: 2015-166 00:00

Comments: With HSL's, after ballasting during Charleston port call.
Apply Yes
WaterLine 0.441

Vessel Name: TJ_S222_Klein5000_SSS200_2015.hvf
Vessel created: June 23, 2015

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2015-001 00:00

Comments:
Time Correction(s) 0.000

Transduer #1:

Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset: 0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer:
Model: Unknown
Serial Number:

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2015-117 00:00

Comments:
Time Correction(s) 0.000

Transduer #1:

Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset: 0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer:
Model: Unknown
Serial Number:

Navigation Sensor:

Time Stamp: 2015-001 00:00

Comments: (null)
Time Correction(s) 0.000
DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer: Applanix
Model: v4
Serial Number: (null)

Heave Sensor:

Time Stamp: 2015-001 00:00

Comments: (null)
Apply No
Time Correction(s) 0.000
DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000
Offset: 0.000

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

Pitch Sensor:

Time Stamp: 2015-001 00:00

Comments: (null)
Apply No
Time Correction(s) 0.000
Pitch offset: 0.000

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

Roll Sensor:

Time Stamp: 2015-001 00:00

Comments: (null)
Apply No
Time Correction(s) 0.000
Roll offset: 0.000

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

Tow Point:

Time Stamp: 2015-001 00:00

Comments: HSRR 2015
Time Correction(s) 0.000
DeltaX: 6.370
DeltaY: -42.550
DeltaZ: -4.800

Manufacturer: Klein
Model: 5000 V2
Serial Number:

Time Stamp: 2015-117 00:00

Comments: HSRR 2015 SSS Cert Results
Time Correction(s) 0.000
DeltaX: 6.370
DeltaY: -42.550
DeltaZ: -4.800

Manufacturer: Klein
Model: 5000 V2
Serial Number:

WaterLine:

Time Stamp: 2015-001 00:00

Comments: HSRR 2015
Apply Yes
WaterLine 0.380

Time Stamp: 2015-166 00:00

Comments: With HSL's, after ballasting during Charleston port call.
Apply Yes
WaterLine 0.441

D. APPROVAL SHEET

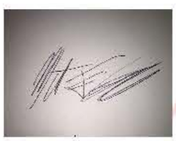
This Data Acquisition and Processing Report is respectfully submitted for the following projects:

OPR-G329-TJ-17

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 (2016 ed), and the Field Procedures Manual for Hydrographic Surveying (2014 ed).

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

Approved and Forwarded:



Digitally signed by FORREST.MATTHEW.ROBERT.1362733100
DN: c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=NOAA, cn=FORREST.MATTHEW.ROBERT.1362733100
Date: 2017.02.27 19:59:47 Z

LT Matthew R. Forrest, NOAA

Operations Officer

VAN WESTENDORP.CHRISTIAAN.HENRY.1012828175
c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=NOAA, cn=VAN WESTENDORP.CHRISTIAAN.HENRY.1012828175
2017.02.27 14:40:00 -05'00'

CDR Chris Van Westendorp, NOAA

Commanding Officer

Appendix II
Echo Sounder Reports

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.

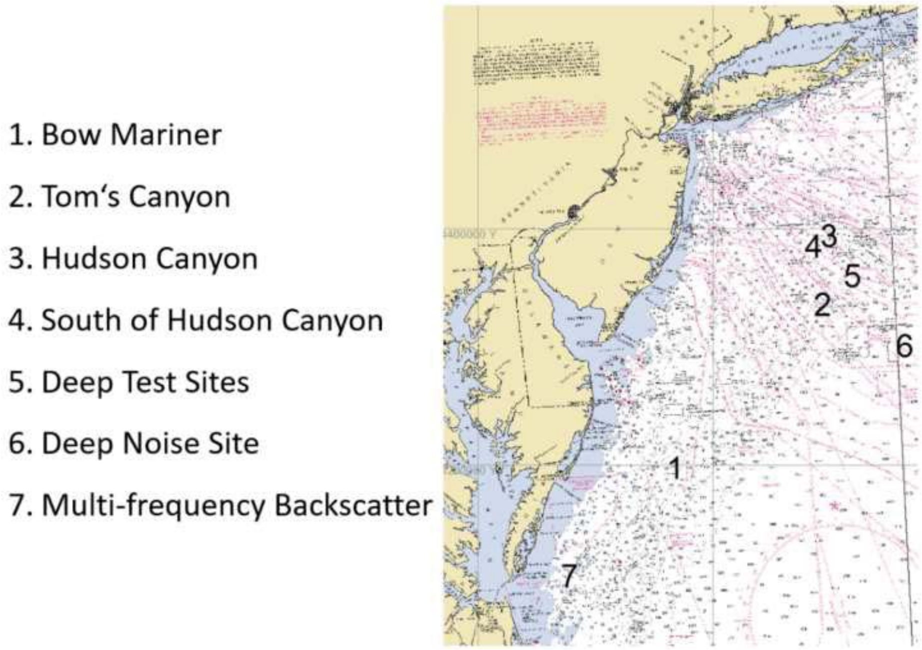


Figure 3 - Acceptance testing planned locations as displayed on chart 13003.

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.

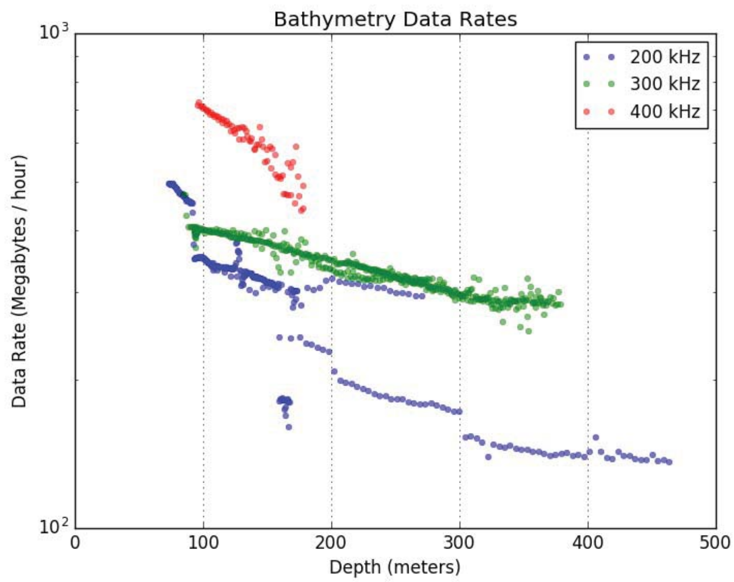


Figure 4 - Data collection rates for the EM2040 without water column data.

The EM2040 data collection rates with water column are shown in Figure 5.

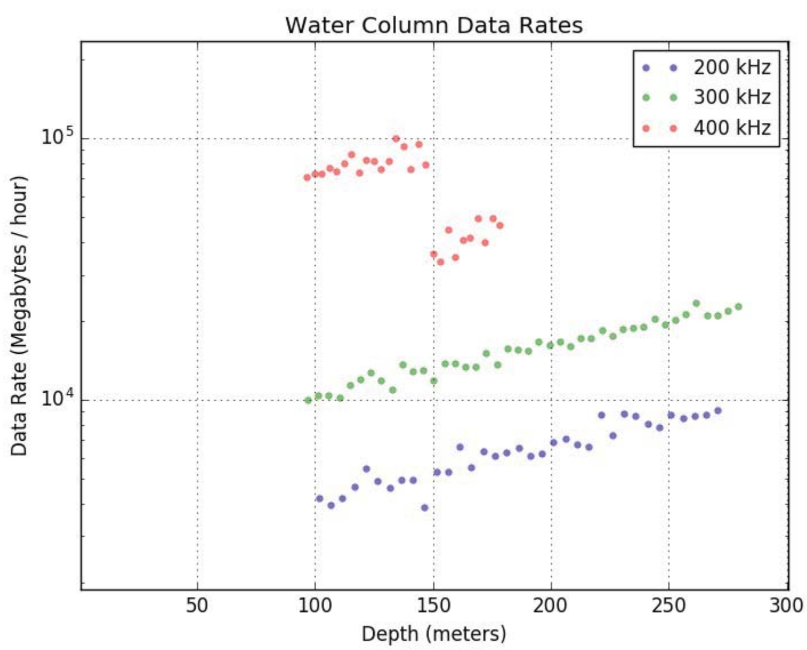


Figure 5 - Data collection rates for the EM2040 with water column data.

The EM710 data collection rates without water column are shown in Figure 6.

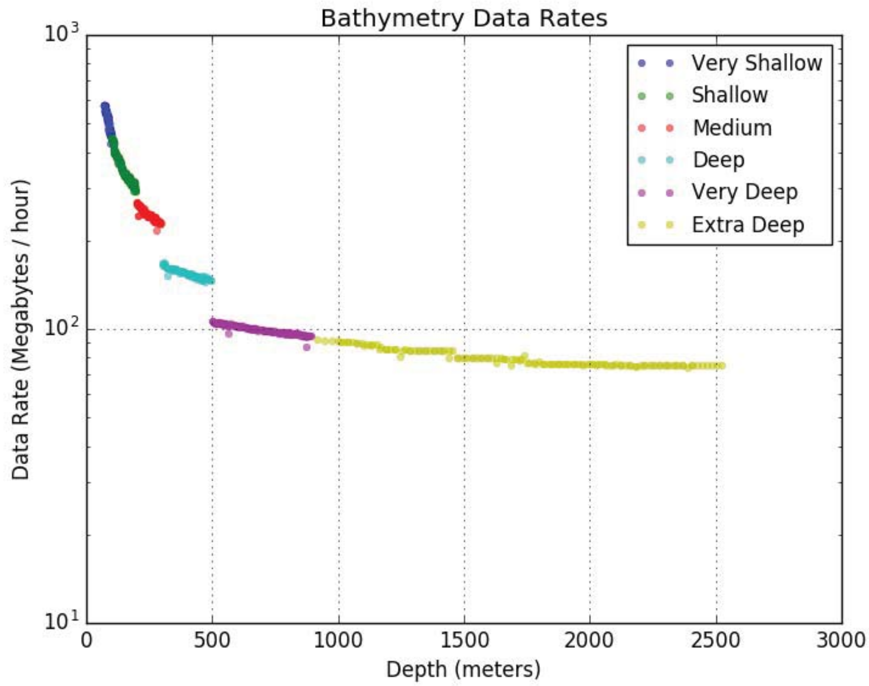


Figure 6 - Data collection rates for the EM710 without water column data.

The EM710 data collection rates with water column are show in Figure 7.

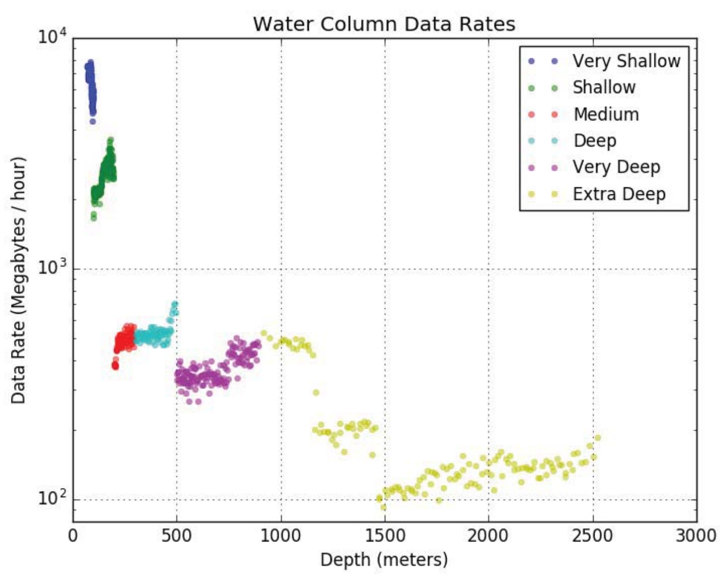


Figure 7 - Data collection rates for the EM710 with water column data.

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.

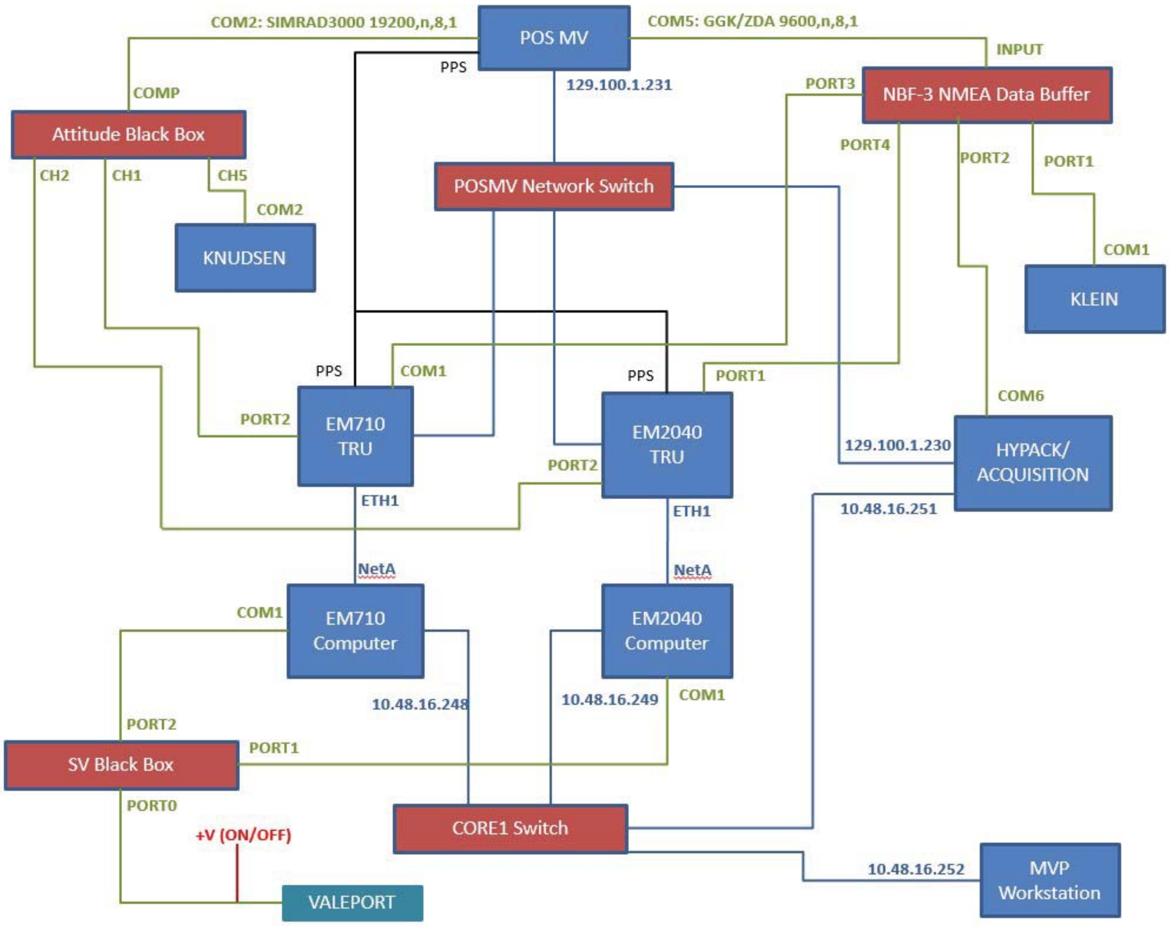


Figure 8 - The Thomas Jefferson survey system configuration as of the acceptance cruise.

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

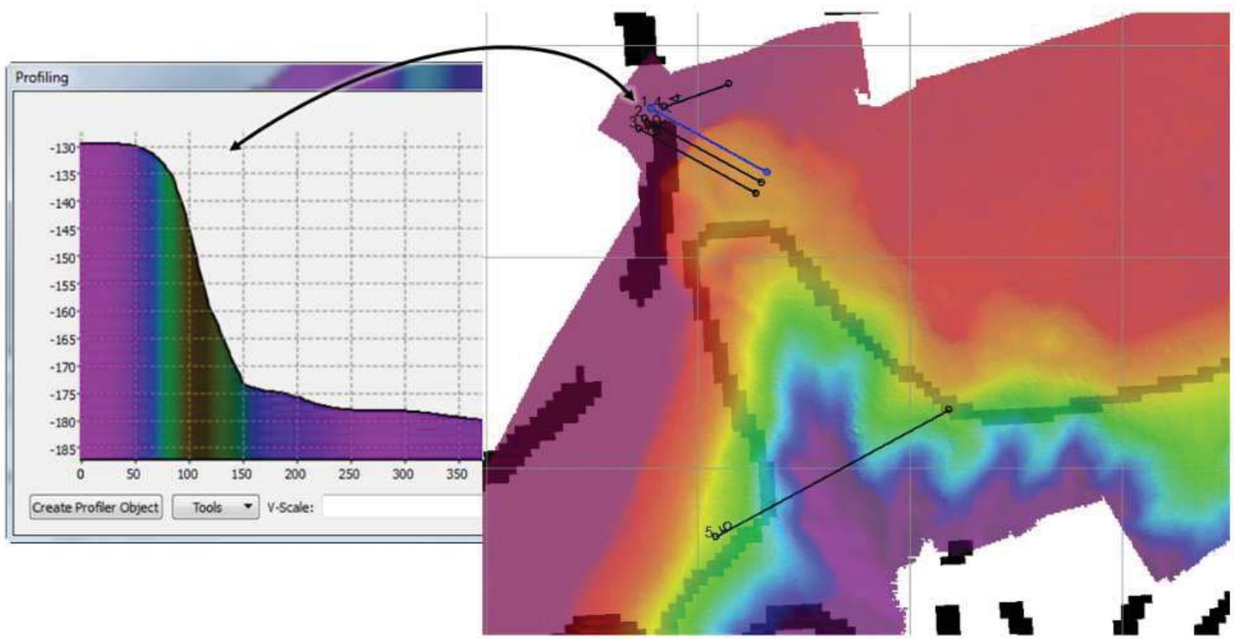


Figure 10 - The patch test lines at Tom Canyon. On the left is a profile of the pitch line. On the right is an overhead view of the relief and patch test lines. Line 2 is pitch, 1 and 3 were for yaw, and 4 was for roll. Line 5 is the confirmation line, with the maximum depth being at 450 meters.

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.

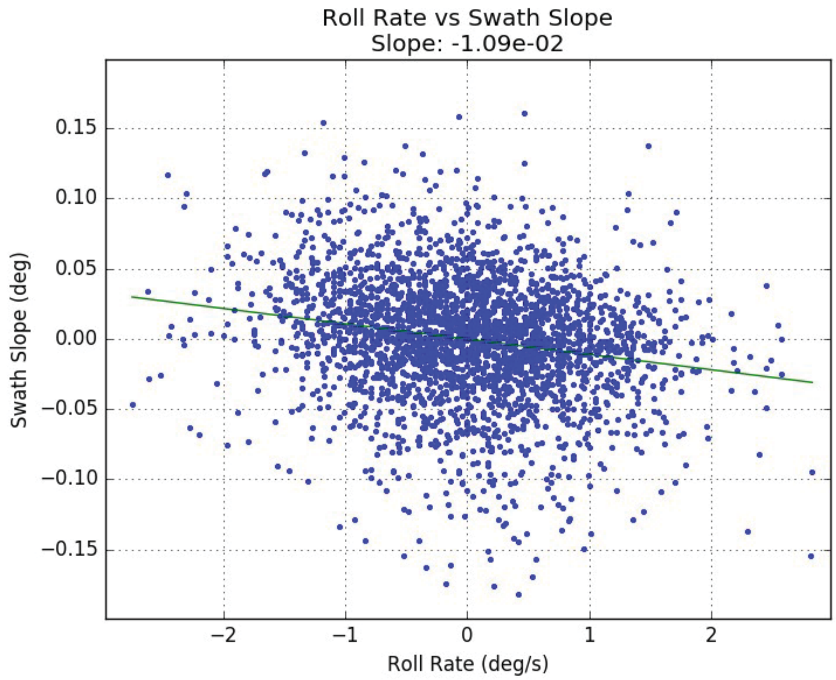


Figure 11 - Roll Rate to Swath Slope Correlation for the EM2040. Green line is a linear fit.

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.

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.

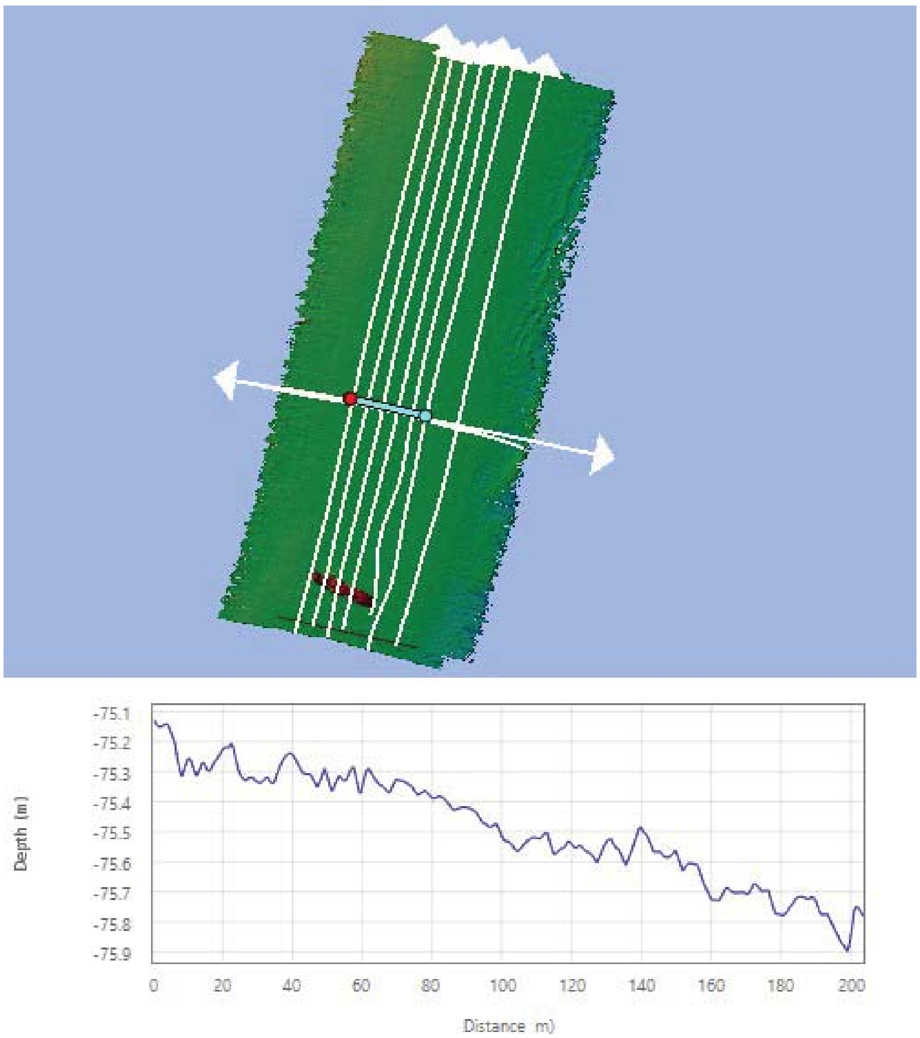


Figure 12 - The accuracy test site at the Bow Mariner. Accuracy data were extracted along the profile (blue line in top, plot in bottom). The wreck can be seen as red in the bottom of the surface. Depths are relative to mean lower low water.

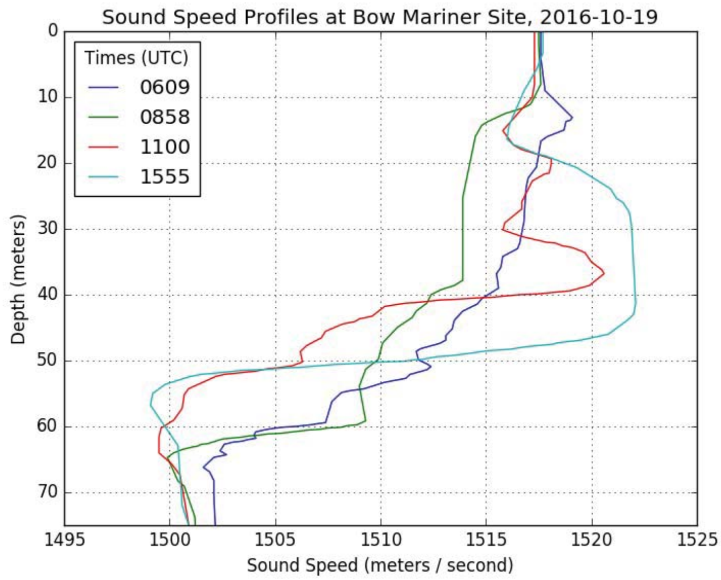


Figure 13 – Sound Speed Profiles at the Bow Mariner site during object detection and accuracy testing. There are significant changes in these casts between 10 meters and 60 meters of water depth.

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.

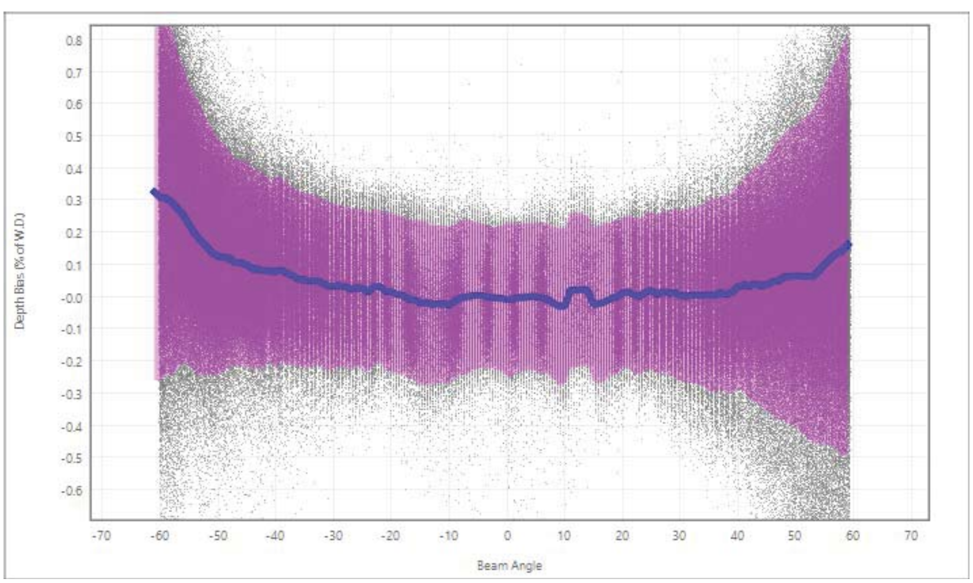


Figure 14 – EM2040 400 kHz accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and these data. The pink region is 2 standard deviations from the mean. IHO Order 1 is 1.3% for this location.

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.

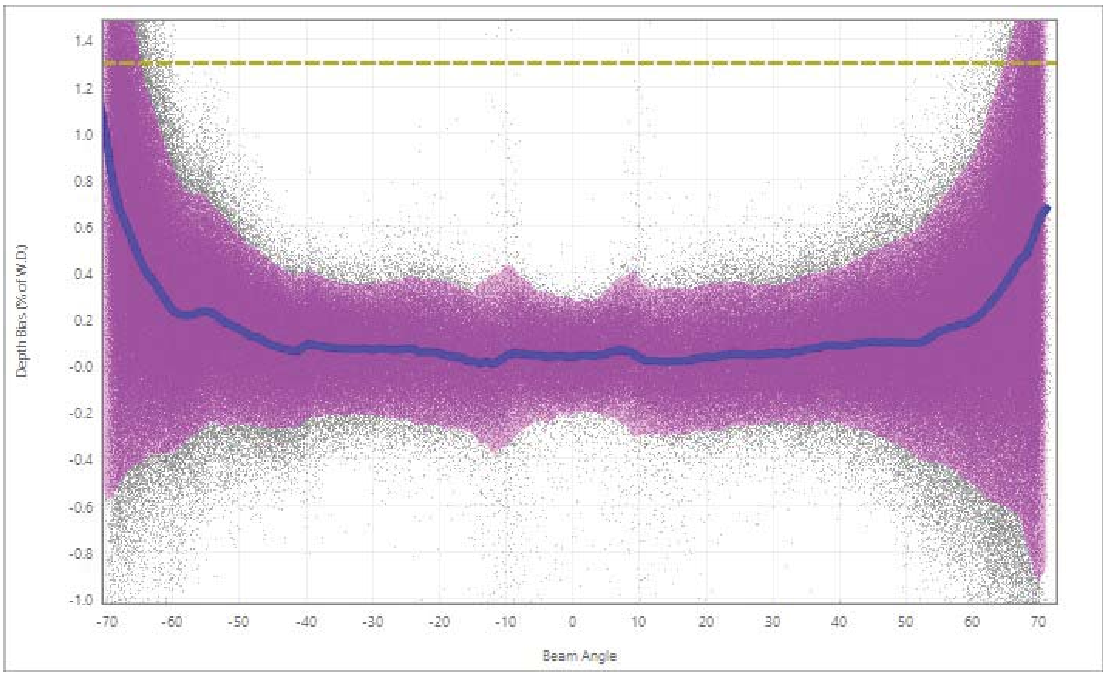


Figure 15 – EM2040 300 kHz accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean. IHO Order 1 is 1.3% for this location.

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.

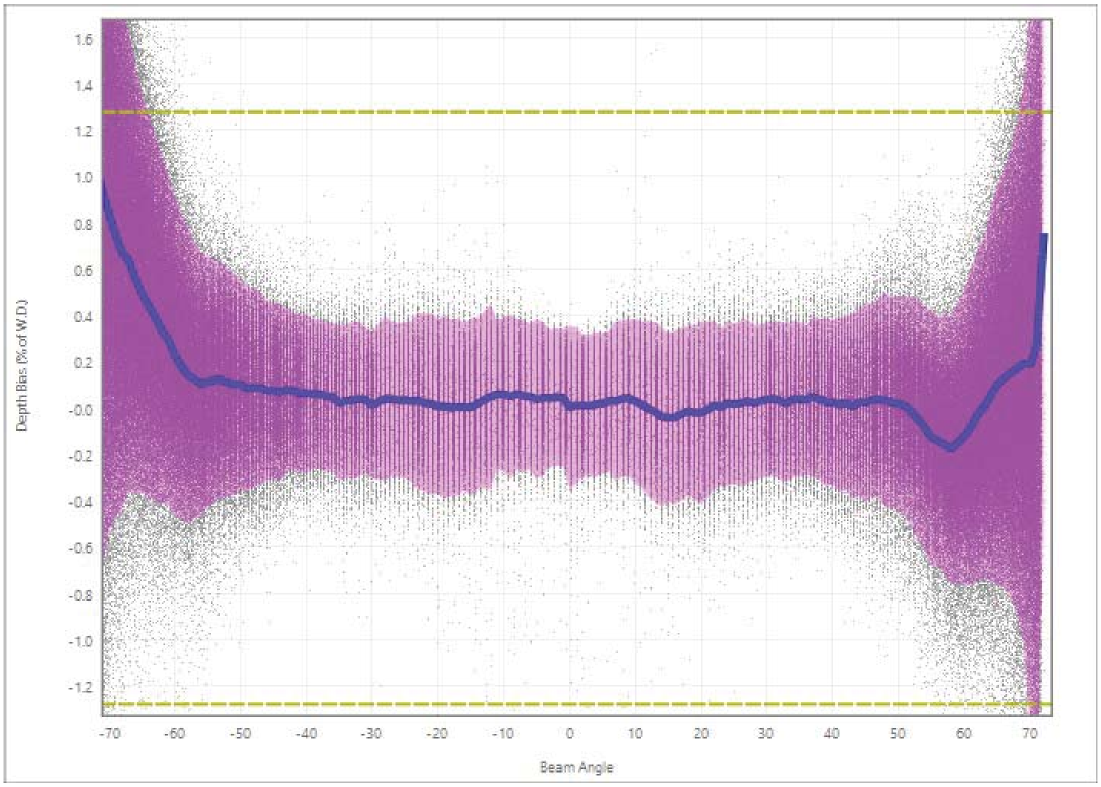


Figure 16 – EM2040 200 kHz accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean. IHO Order 1 is 1.3% for this location.

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.

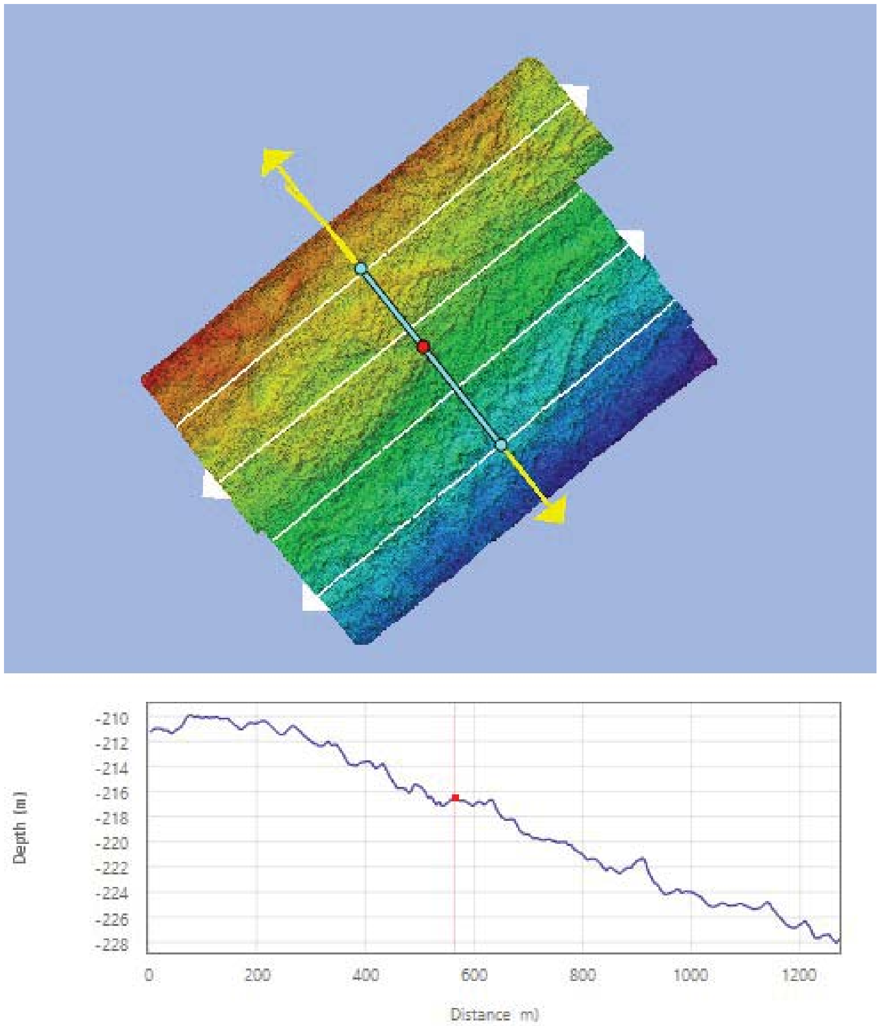


Figure 17 – The EM710 medium depth accuracy test site. Accuracy data were extracted along the profile (blue line in top, plot in bottom). Depths are to the ellipsoid.

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.

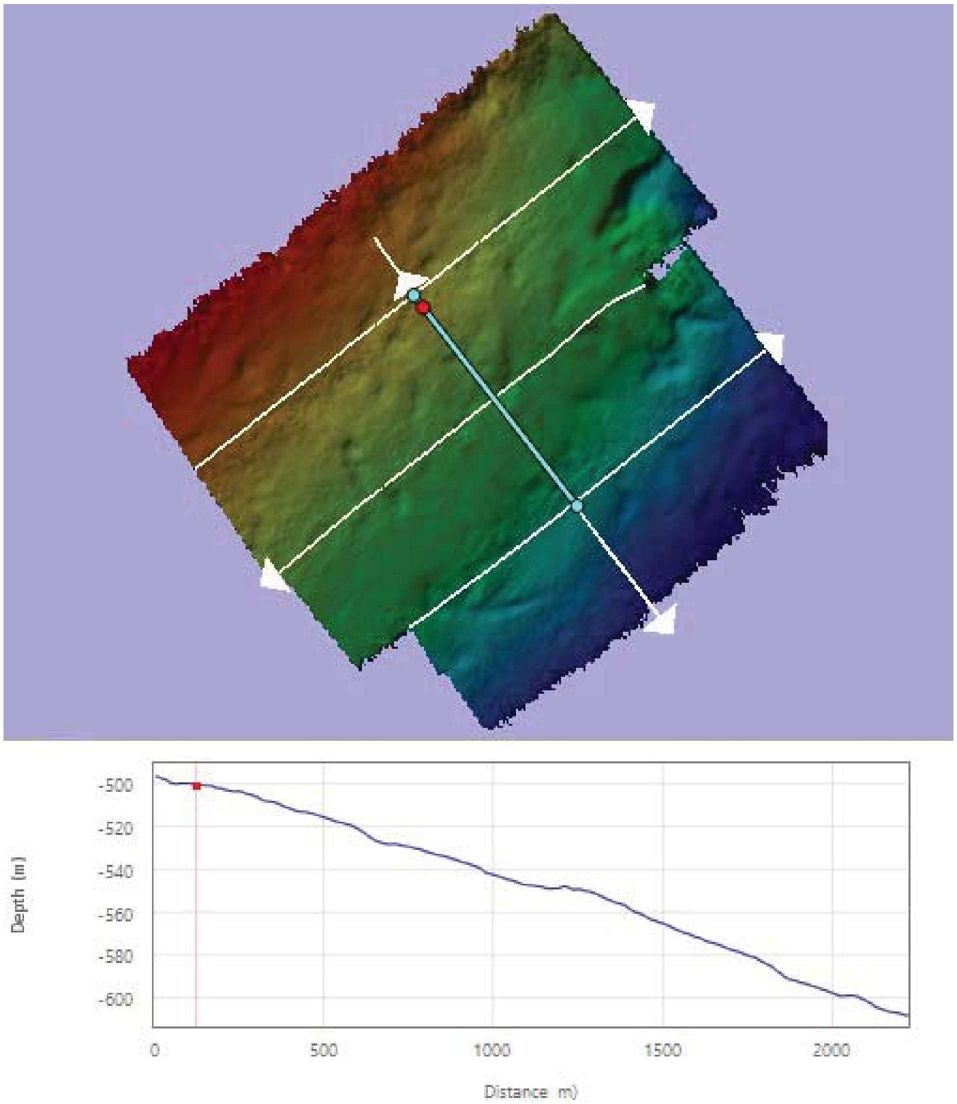


Figure 18 - The EM710 deep accuracy test site. Accuracy data were extracted along the profile (blue line in top, plot in bottom). Depths are to the ellipsoid.

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.

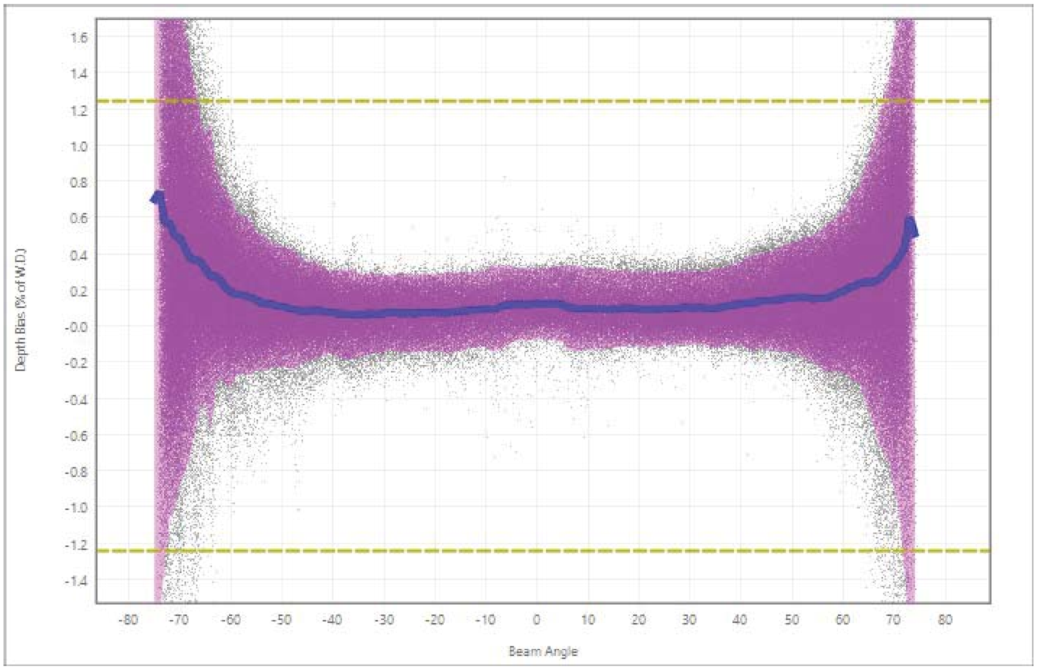


Figure 19 - EM710 Very Shallow Dual Swath mode accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean.

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).

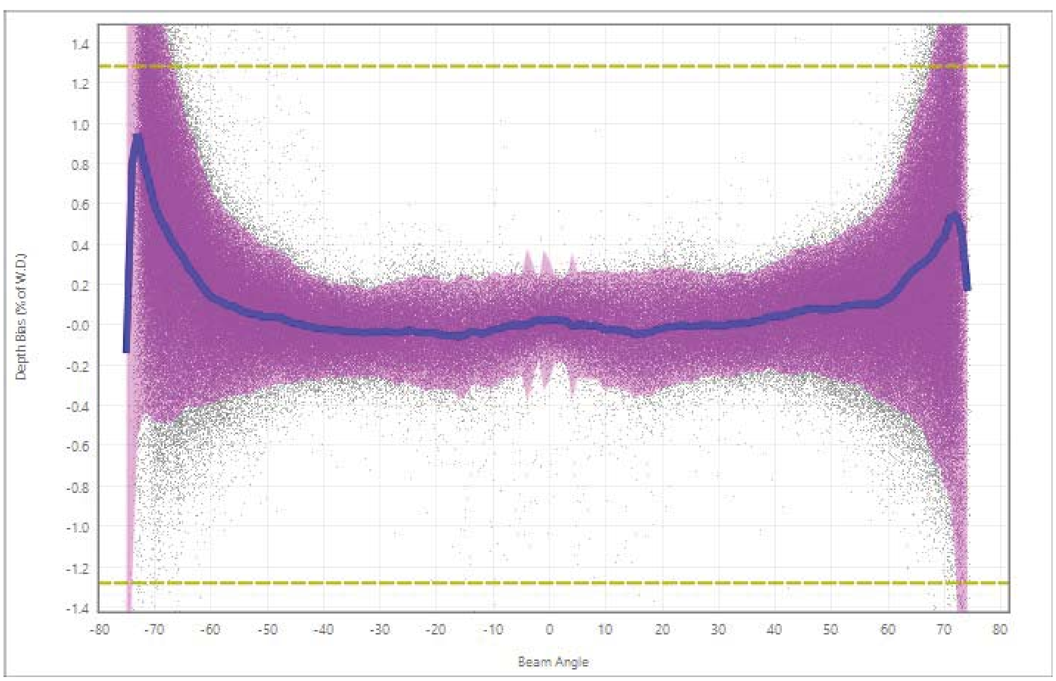


Figure 20 - EM710 Shallow Dual Swath mode accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean.

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.

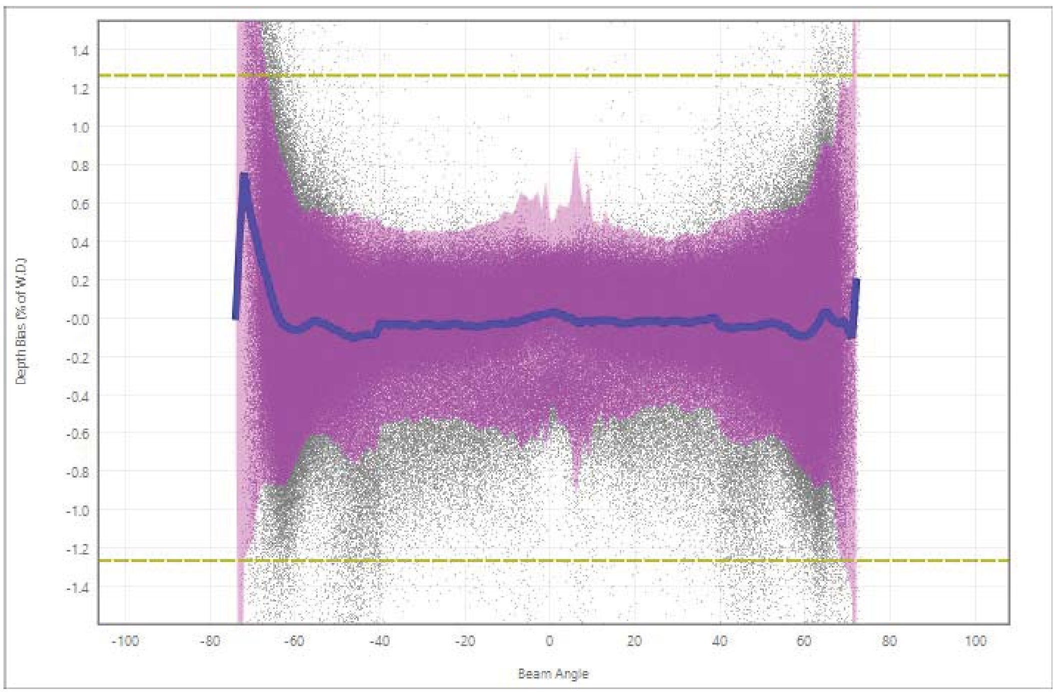


Figure 21 - EM710 Medium Dual Swath mode accuracy results as a percent of depth at the Bow Mariner site (75 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean.

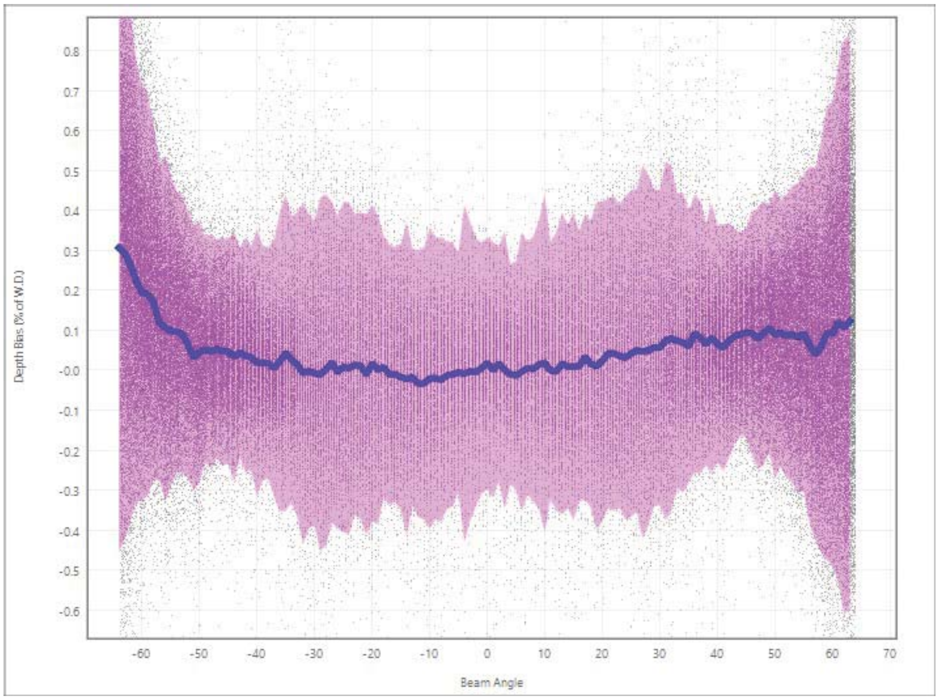


Figure 22 - EM710 Medium Dual Swath mode accuracy results as a percent of depth from the medium depth site (200 meters). The crosslines have been used to make a small nadir-only surface and compared to the main scheme lines. The blue line is the mean difference between the reference surface and this 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).

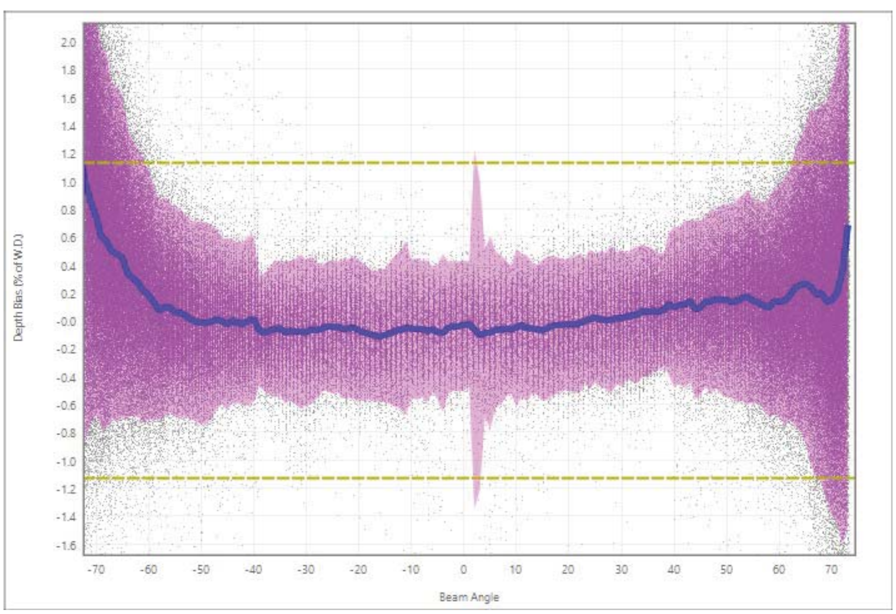


Figure 23 - EM710 Deep Dual Swath mode accuracy results as a percent of depth from the medium depth site (200 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean.

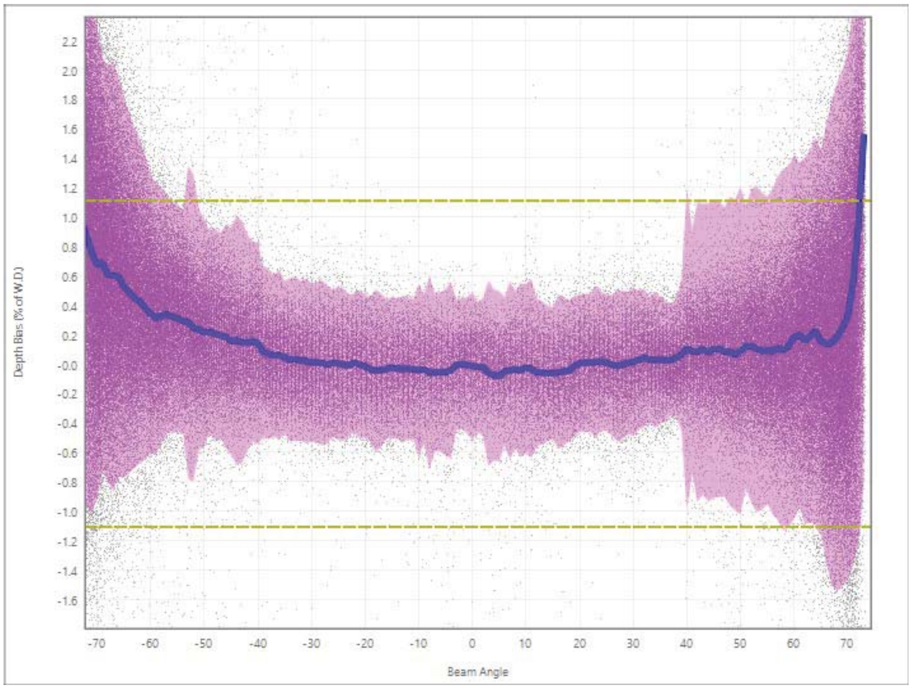


Figure 24 - EM710 Deep Single Swath mode accuracy results as a percent of depth from the medium depth site (200 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean. The rapid change at +40 degrees is the port 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.

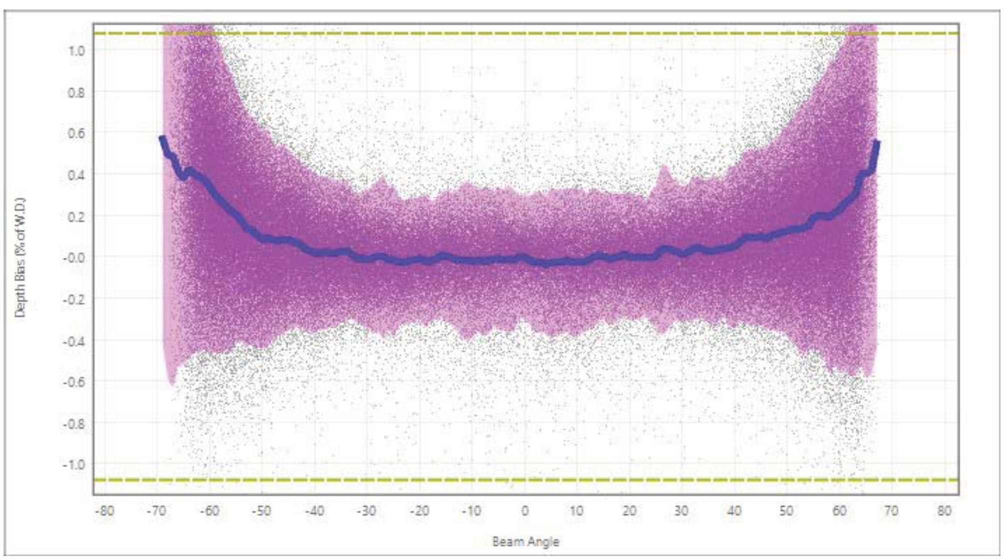


Figure 25 - EM710 Very Deep mode accuracy results as a percent of depth from the deep site (~550 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations.

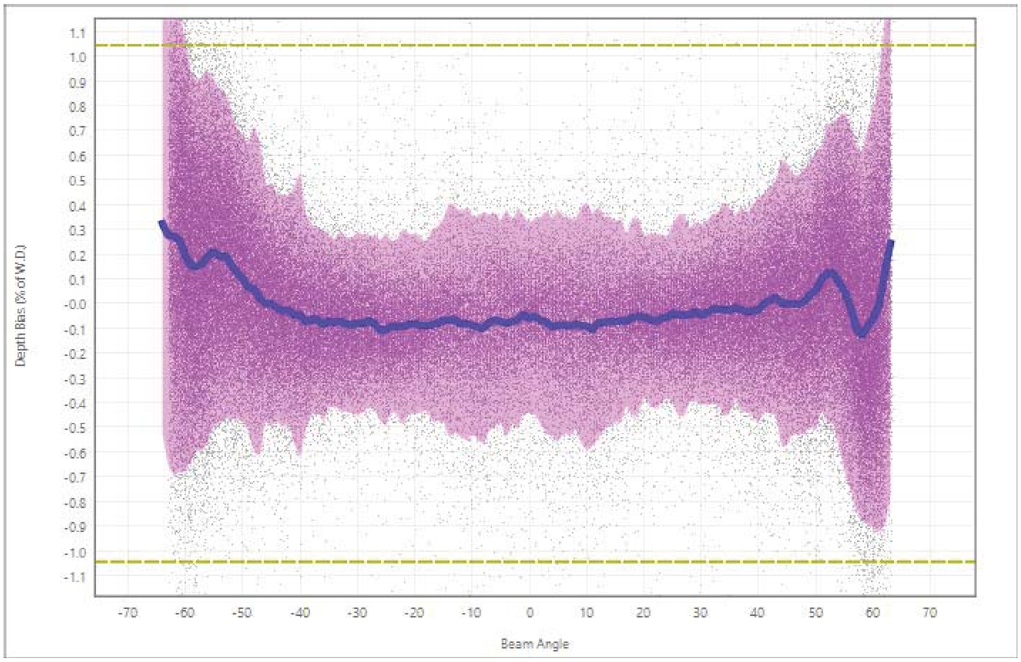


Figure 26 - EM710 Extra Deep mode accuracy results as a percent of depth from the deep site (~550 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations.

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.

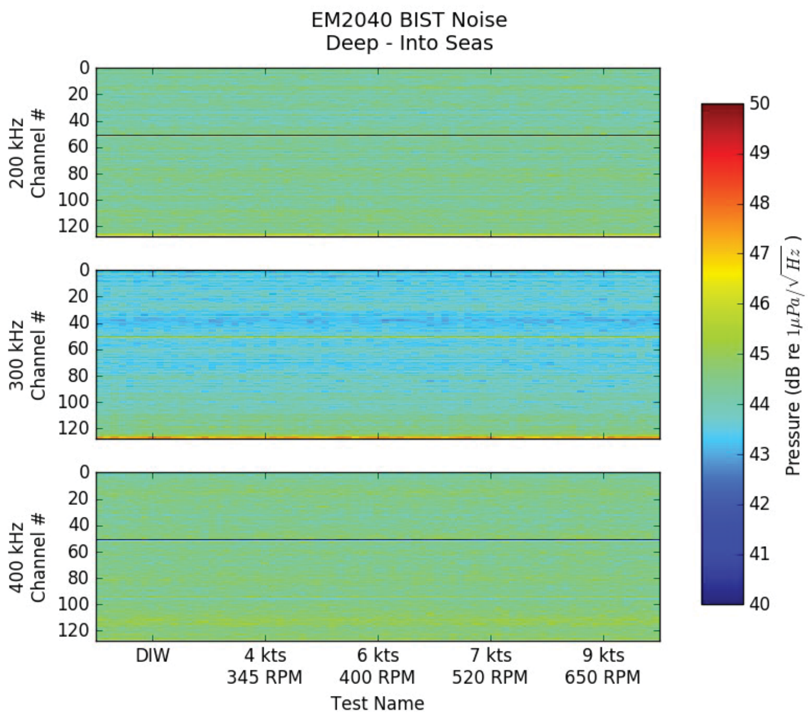


Figure 27 - Deep water BIST Noise tests heading into the seas.

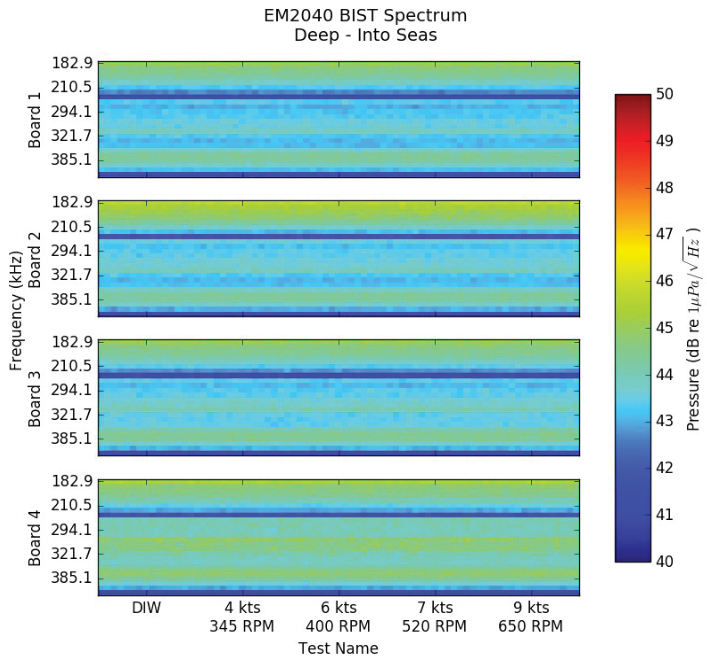


Figure 28 - Deep water noise spectrum tests heading into the seas.

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.

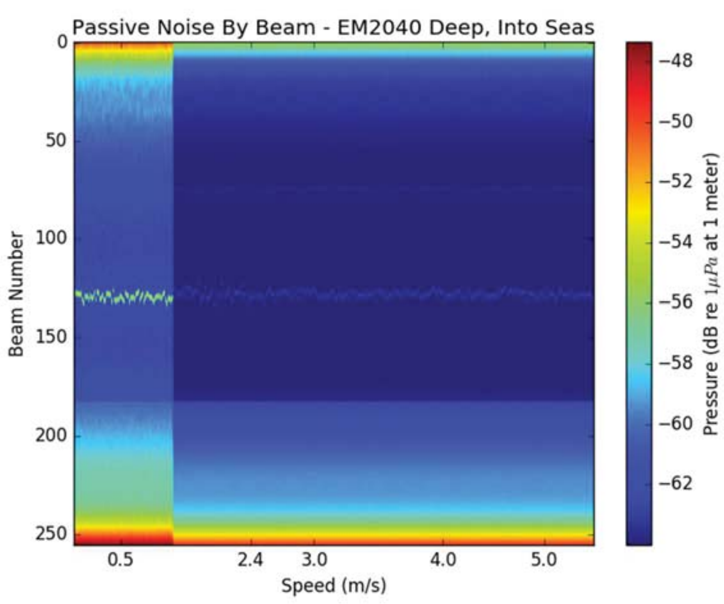


Figure 29 - Deep water noise from passive water column heading into the seas. The EM2040 was in 200 kHz mode.

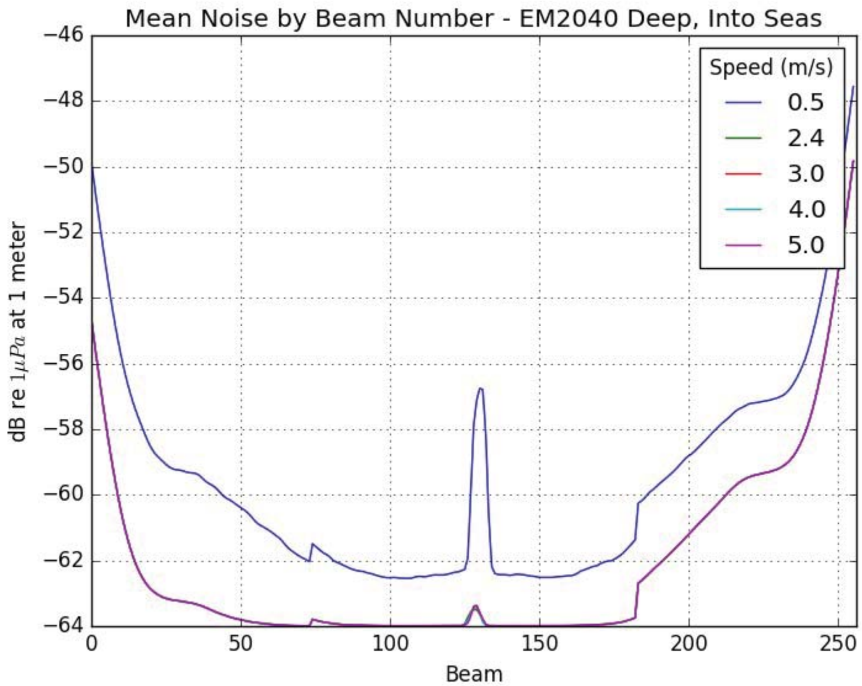


Figure 30 - EM2040 deep water passive water column noise averaged by beam and for each speed heading into the seas. EM2040 frequency setting was 200 kHz.

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.

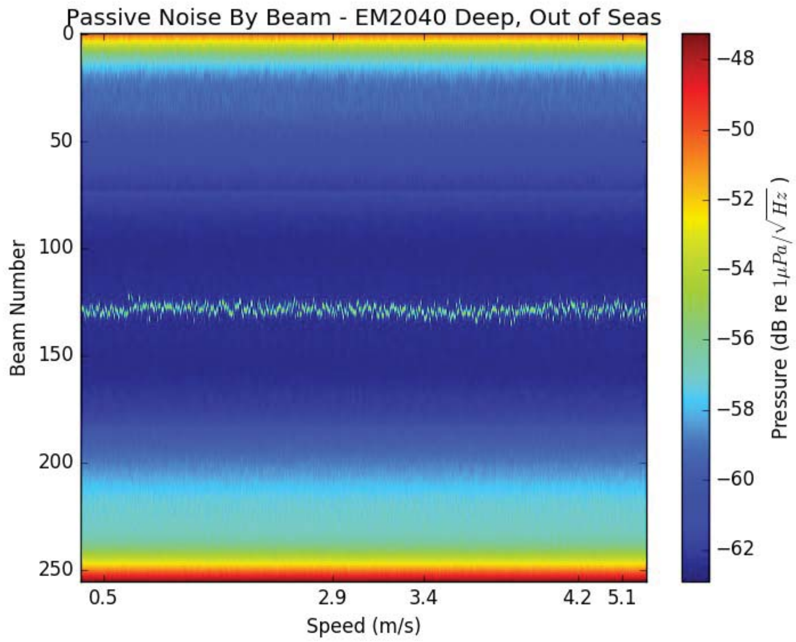


Figure 31 - Deep water passive water column noise averaged by beam heading out of the seas.

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.

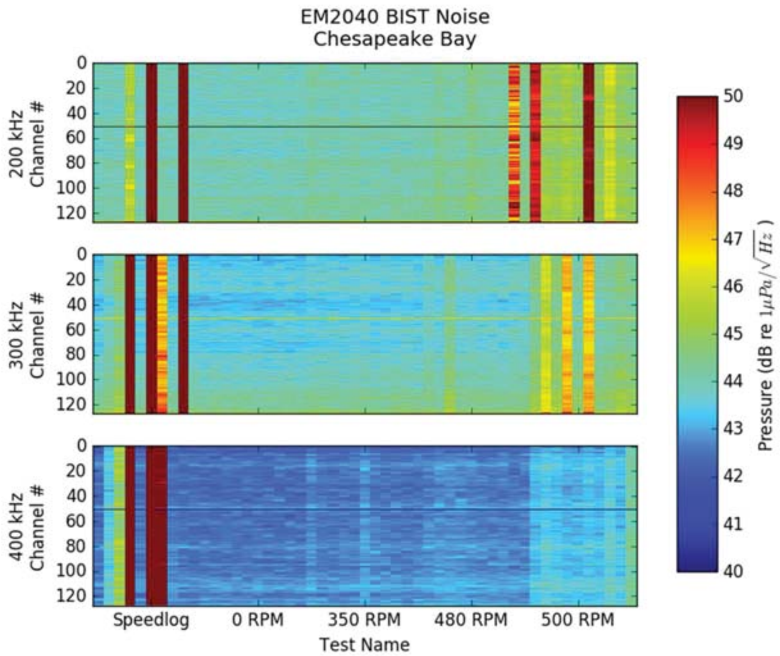


Figure 32 – EM2040 RX Noise BIST Tests from 14 meters of water in Chesapeake Bay. High, intermittent levels are interference from the Doppler speed log.

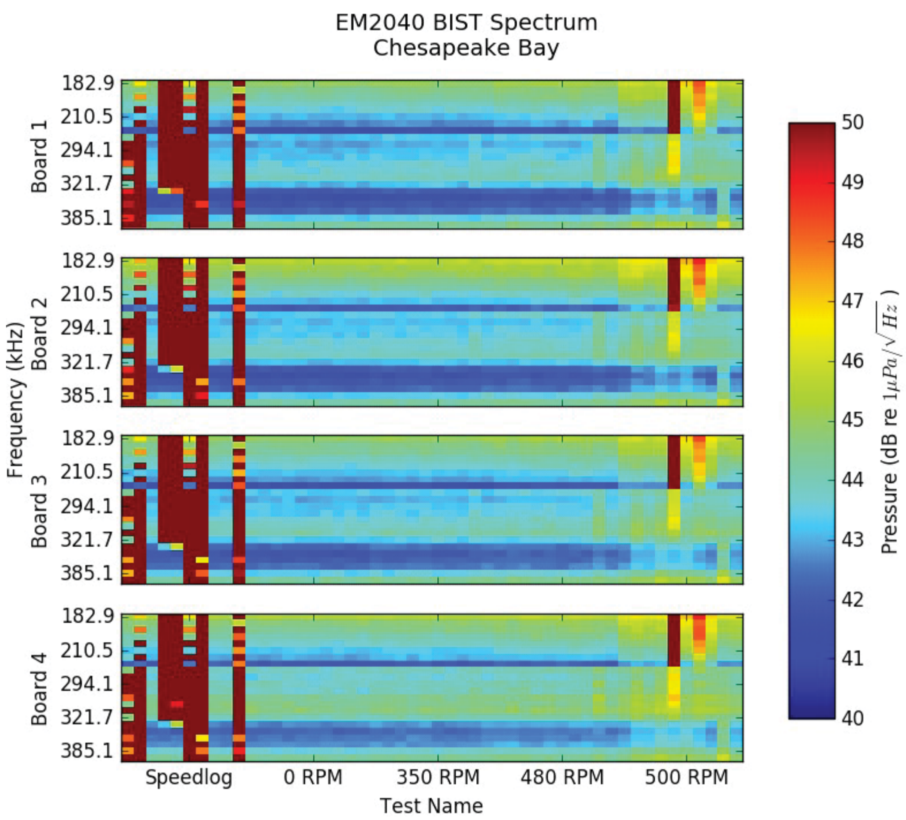


Figure 33 - EM2040 RX Noise Spectrum test from 14 meters of water in Chesapeake Bay. High, intermittent levels are interference from the Doppler speed log.

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.

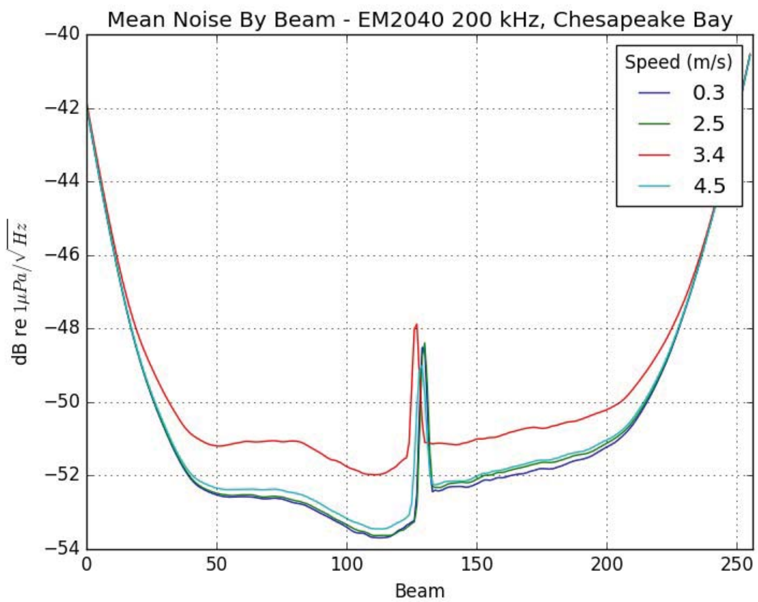


Figure 34 – EM2040 passive water column noise for the 200 kHz mode as averaged by beam and for each speed in 14 meters of water.

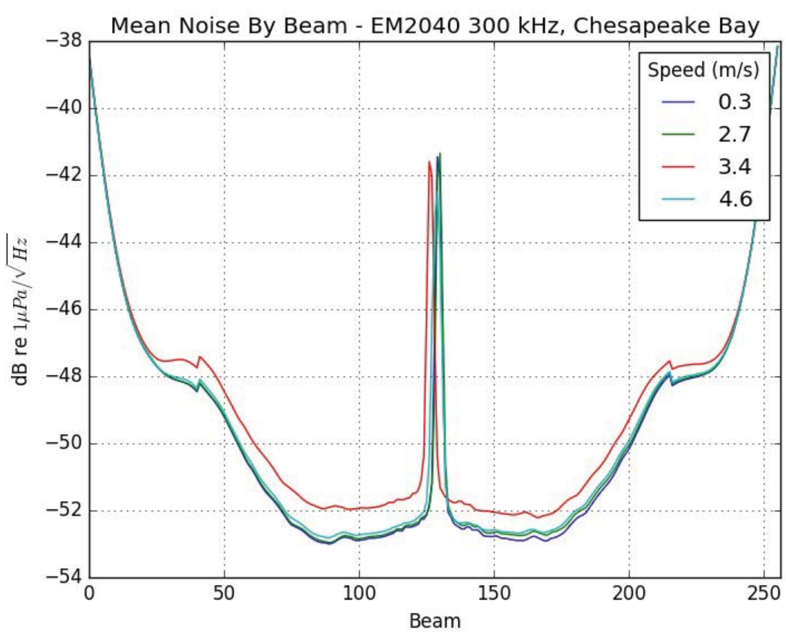


Figure 35 - EM2040 passive water column noise for the 300 kHz mode as averaged by beam and for each speed in 14 meters of water.

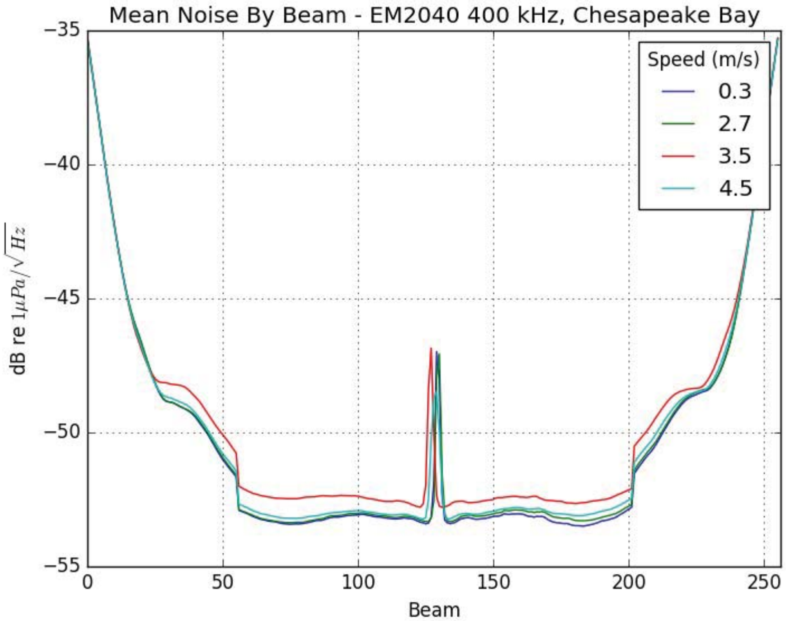


Figure 36 - EM2040 passive water column noise for the 400 kHz mode as averaged by beam and for each speed in 14 meters of water.

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.

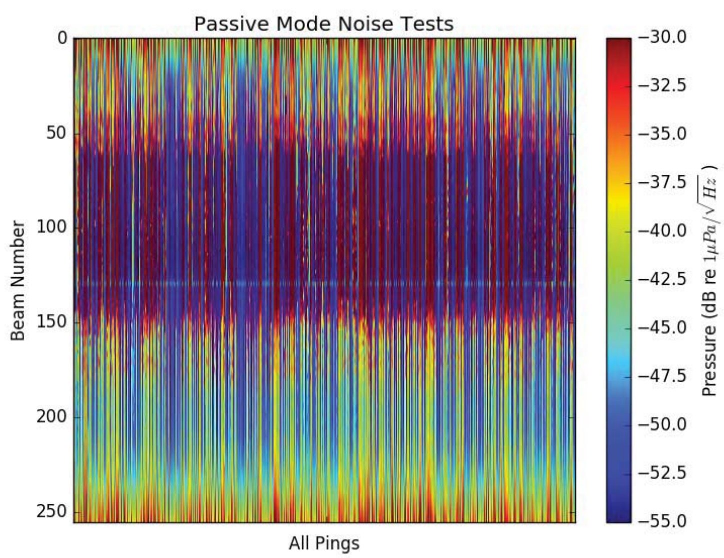


Figure 37 - EM2040 passive water column noise for the 200 kHz mode as averaged with each beam in 14 meters of water. The speed log was active during this test.

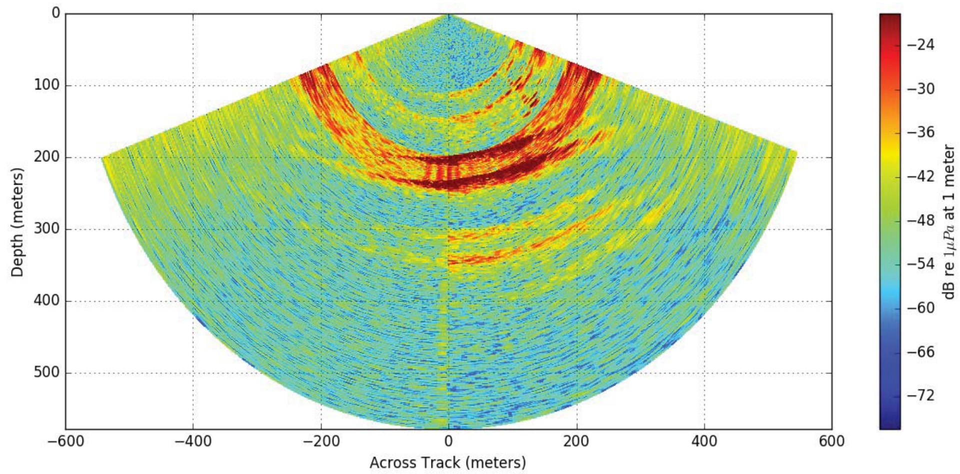


Figure 38 – EM2040 passive water column from a single "ping" for 200 kHz mode. Speed log interference is evident.

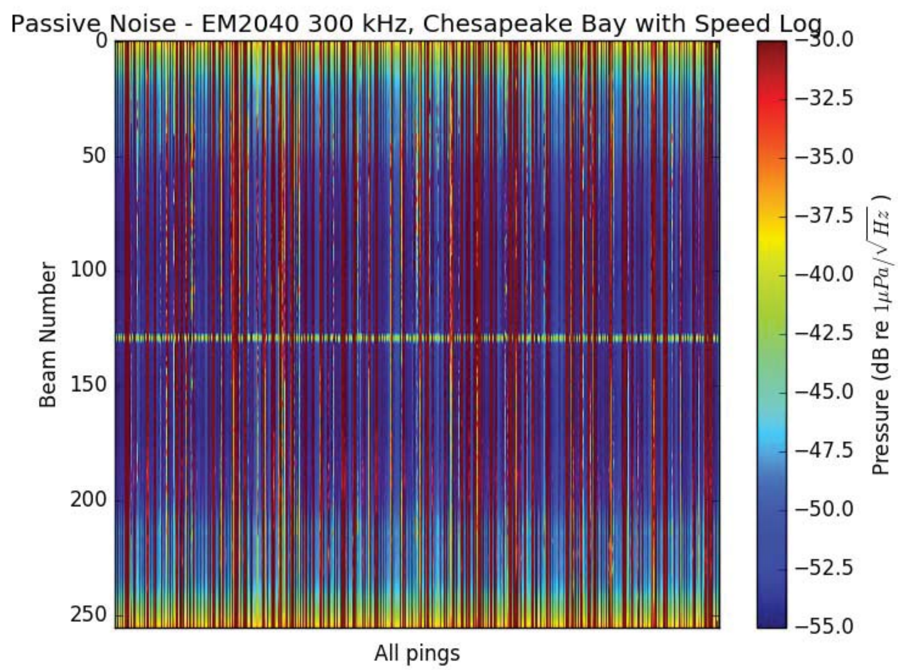


Figure 39 - EM2040 passive water column noise for the 300 kHz mode as averaged with each beam in 14 meters of water. The speed log was active during this test.

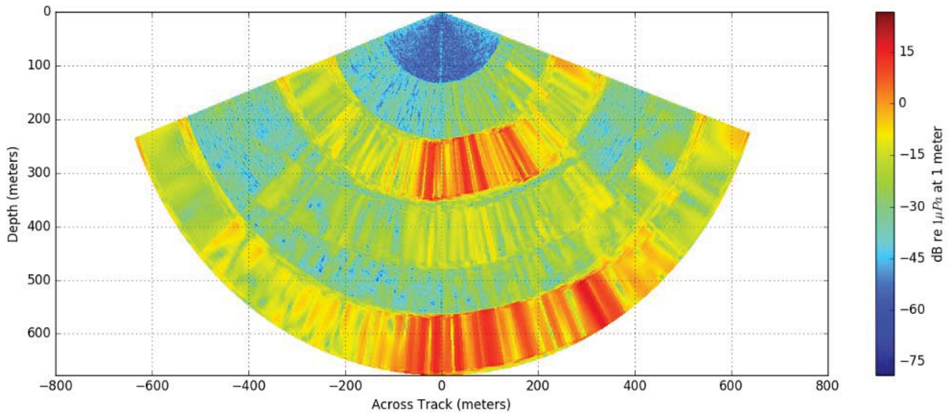


Figure 40 - EM2040 passive water column from a single "ping" for 300 kHz mode. Speed log interference is evident.

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.

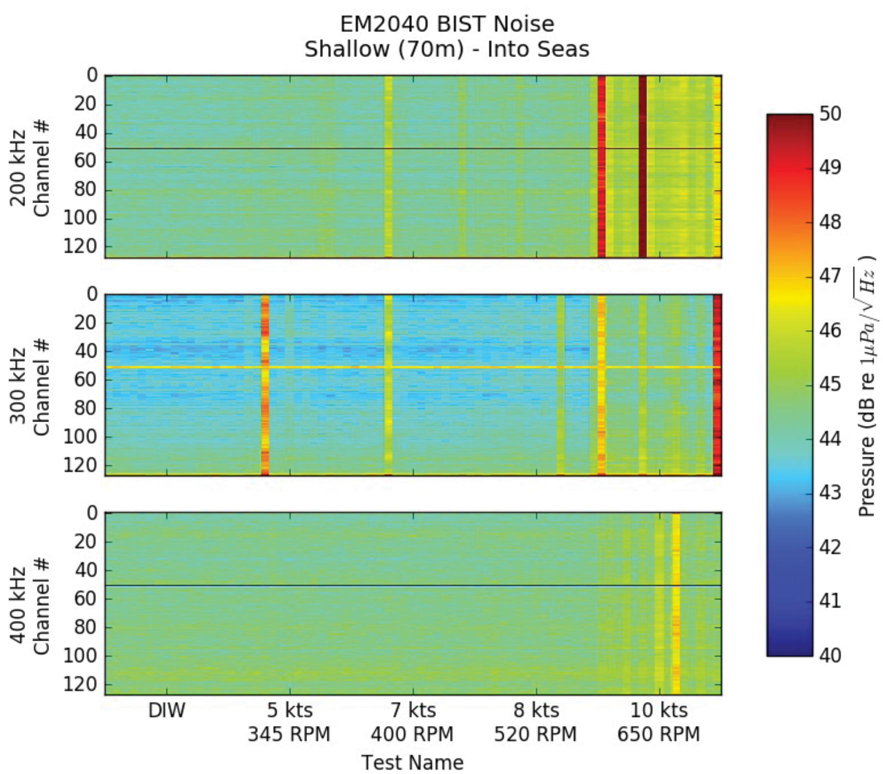


Figure 41 - EM2040 RX Noise BIST Tests from 70 meters of water and into seas.

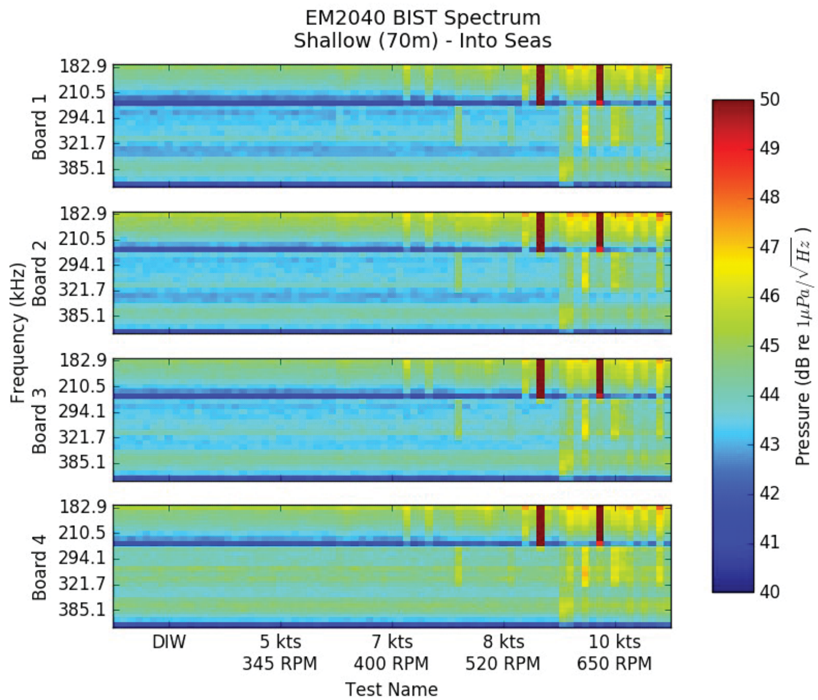


Figure 42 - EM2040 RX Noise Spectrum test from 70 meters of water and heading into seas.

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.

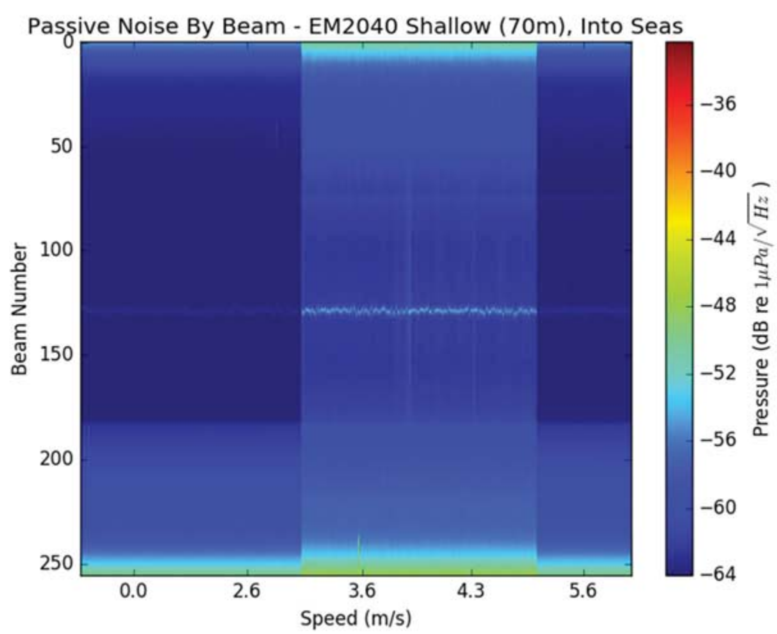


Figure 43 – EM2040 300 kHz passive water column averaged by beam, heading into seas in 70 meters of water.

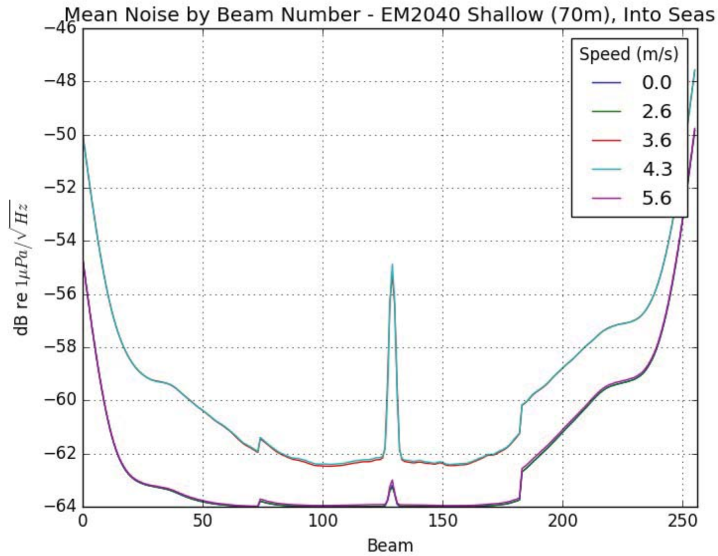


Figure 44 – EM2040 passive water column in 70 meters of water averaged by beam and by speed while heading is into seas.

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.

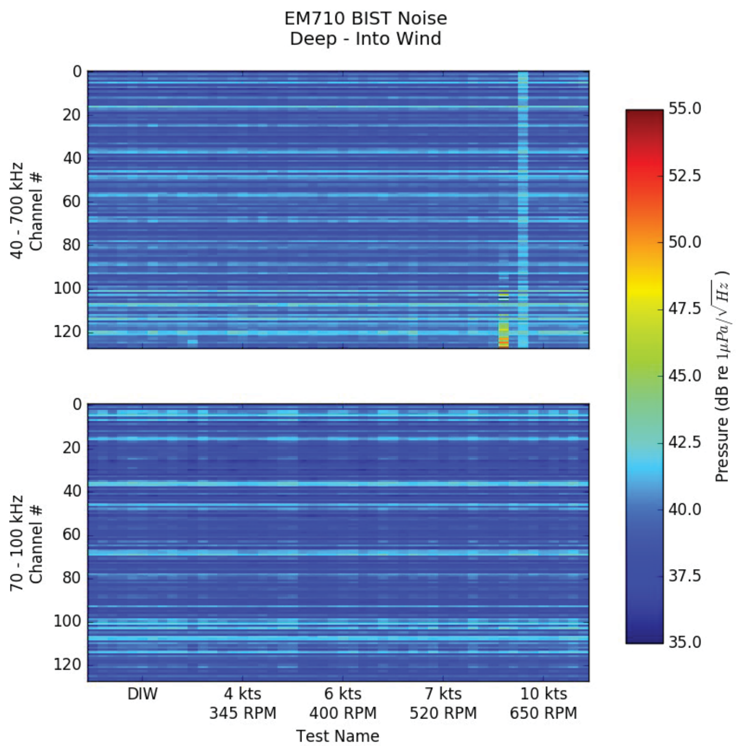


Figure 45 - EM710 RX BIST Noise by speed and heading into seas in 2500 meters of water.

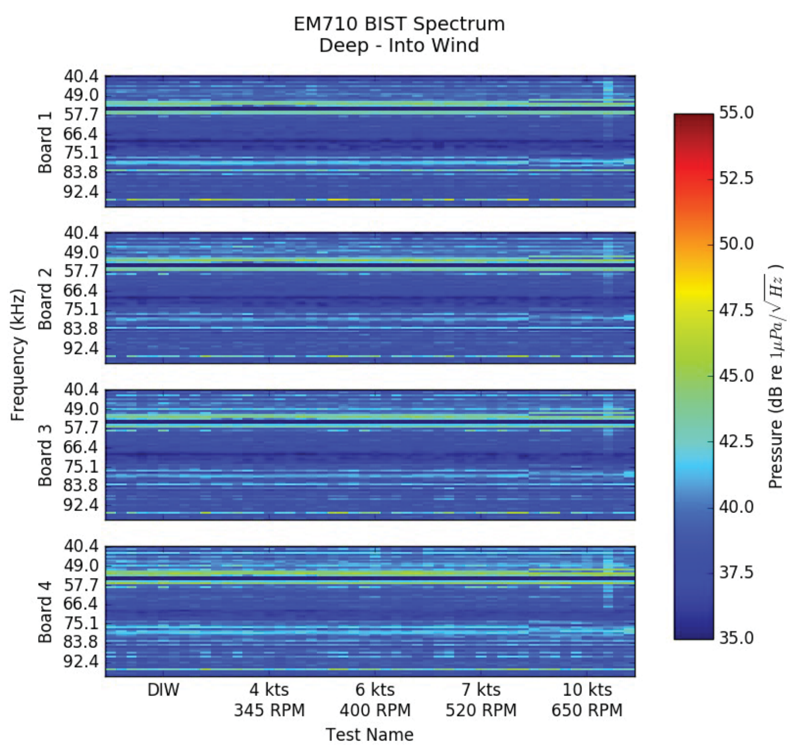


Figure 46 – EM710 RX BIST Noise Spectrum by speed and heading into seas in 2500 meters of water.

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).

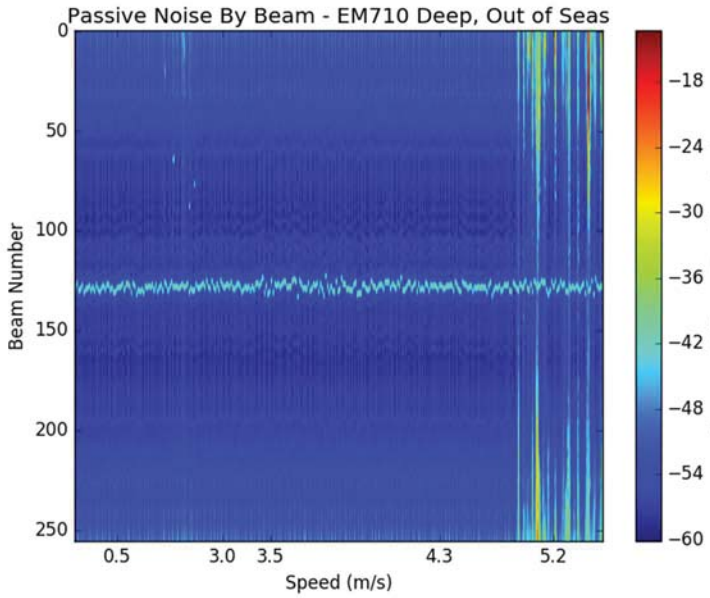


Figure 47 - EM710 passive water column averaged by beam, heading into seas in 2500 meters of water.

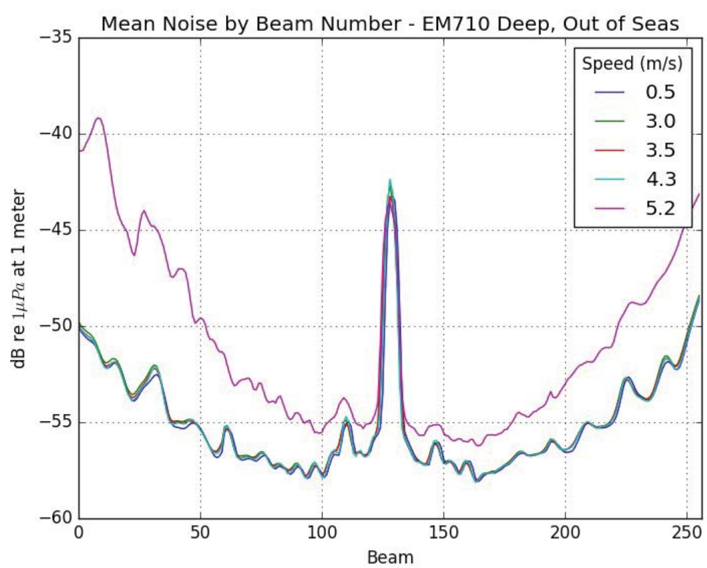


Figure 48 - EM710 passive water column averaged by beam and by speed, heading into the seas in 2500 meters of water.

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.).

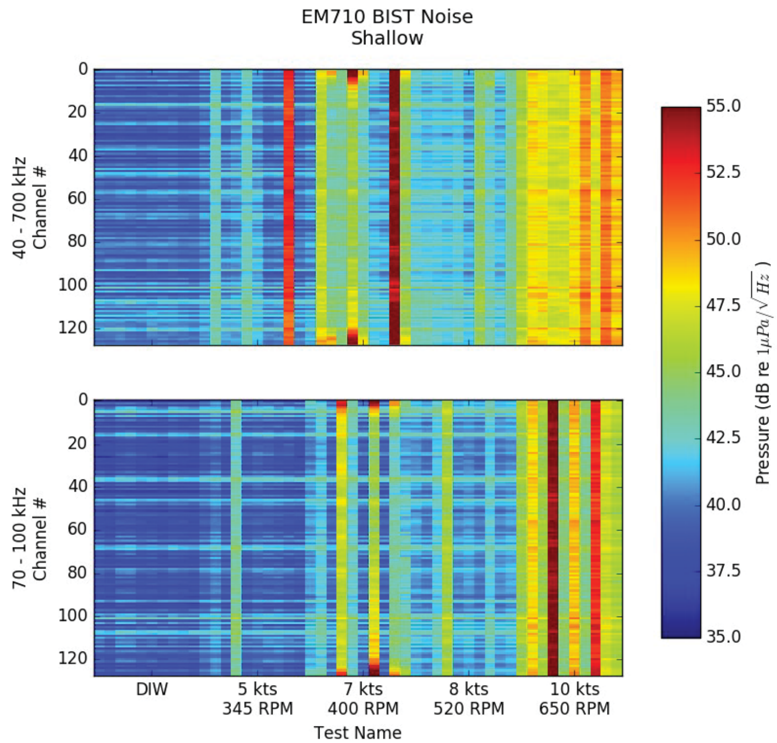


Figure 49 – EM710 RX BIST Noise by speed and heading into seas in 70 meters of water.

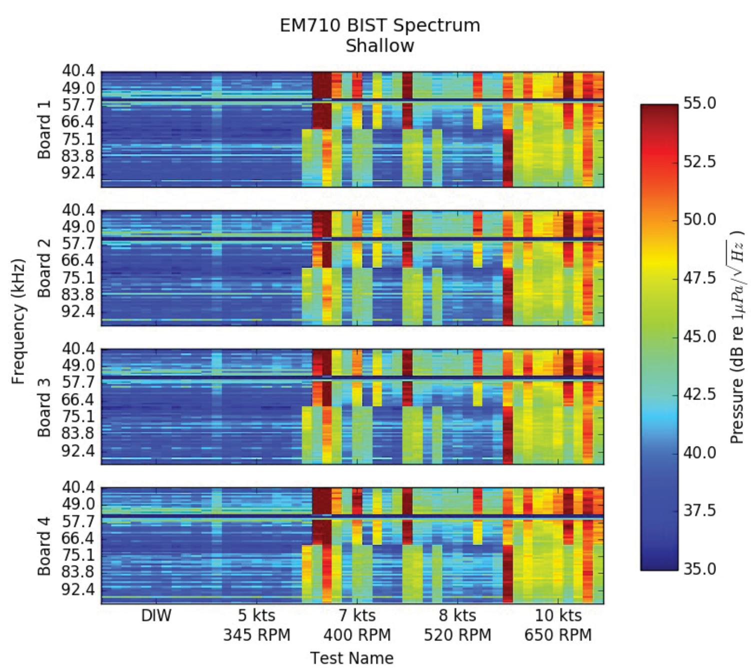


Figure 50 – EM710 RX BIST Noise Spectrum by speed and heading into seas in 70 meters of water.

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.

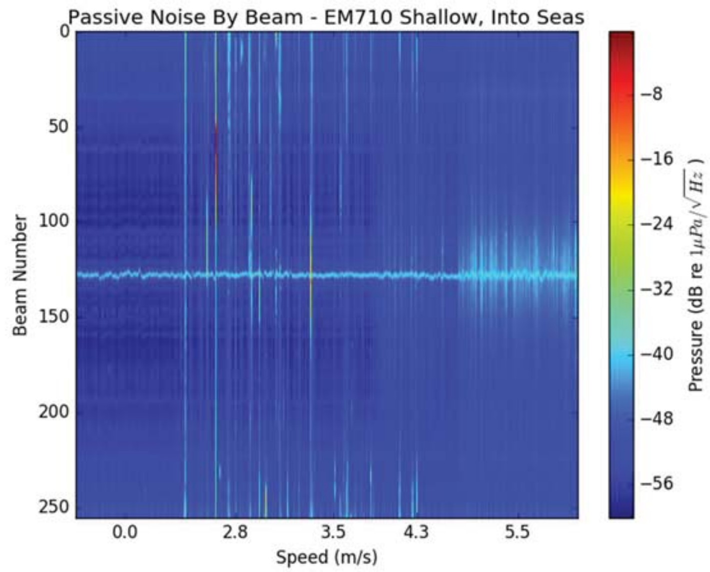


Figure *51* - EM710 passive water column averaged by beam, heading into seas in 70 meters of water.

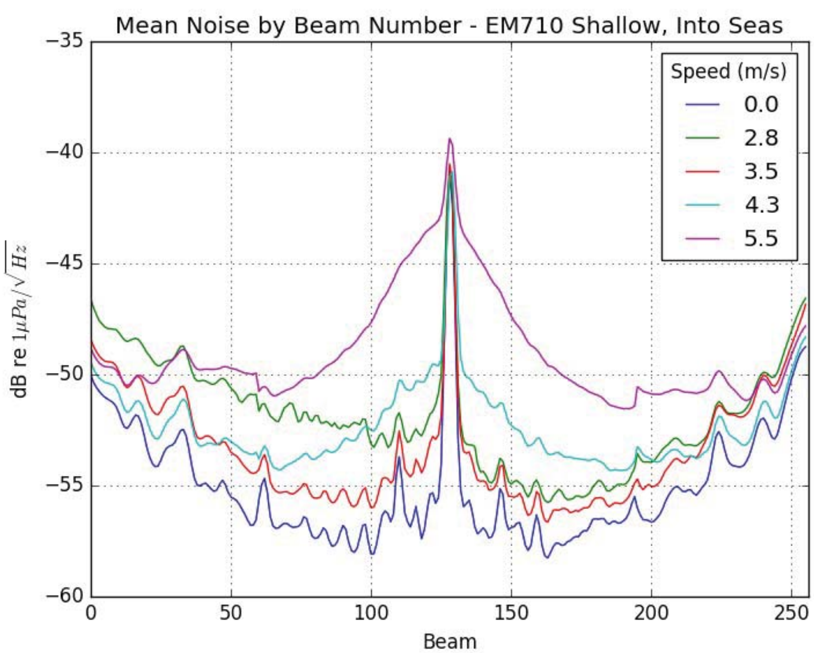


Figure 52 – EM710 passive water column averaged by beam and by speed, heading into the seas in 70 meters of water.

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.

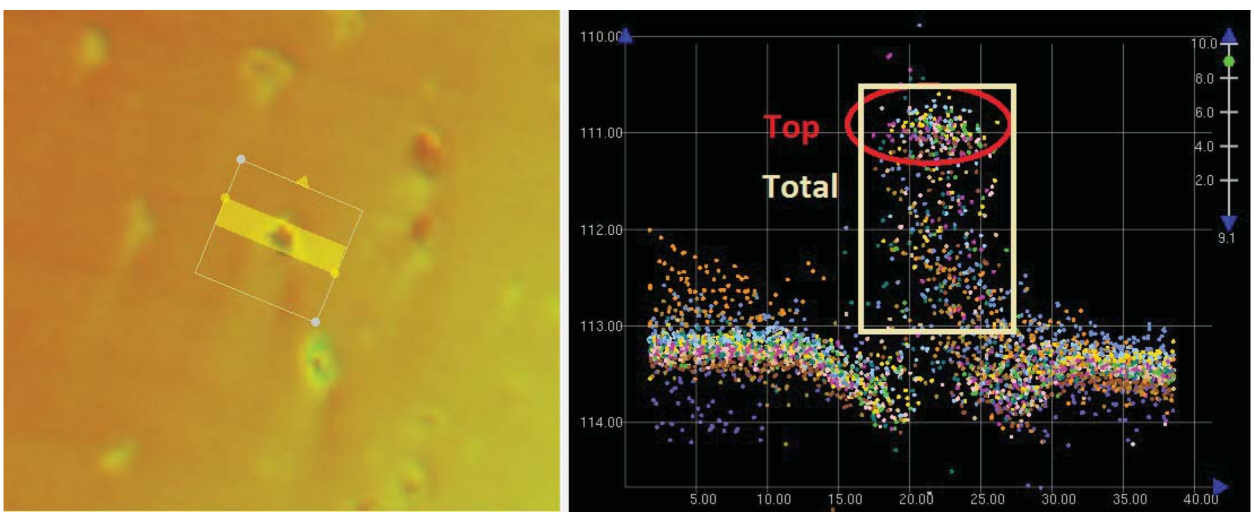


Figure 53 – The seafloor object 1100 meters north of the Bow Mariner wreck used for object detection work. Depths are in meters from the ellipsoid.

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.

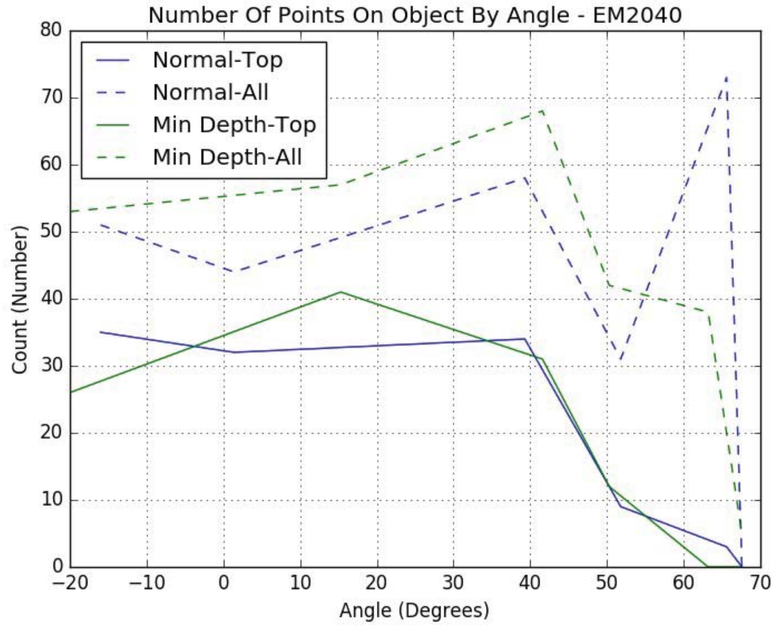


Figure 54 – The number of detections on the object by the EM2040 by angle and for the Normal detection mode and Min Depth detection mode. "Top" is the number of detection on the top of the object, while "All" is for all points perceived to be anywhere on the object.

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.

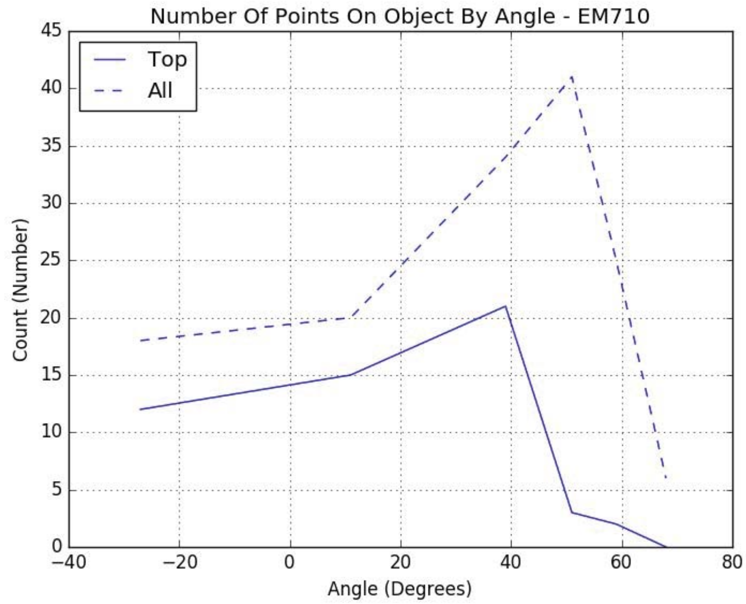


Figure 55 - The number of detections on the object by the EM710 and by angle. "Top" is the number of detection on the top of the object, while "All" is for all points on the object.

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).

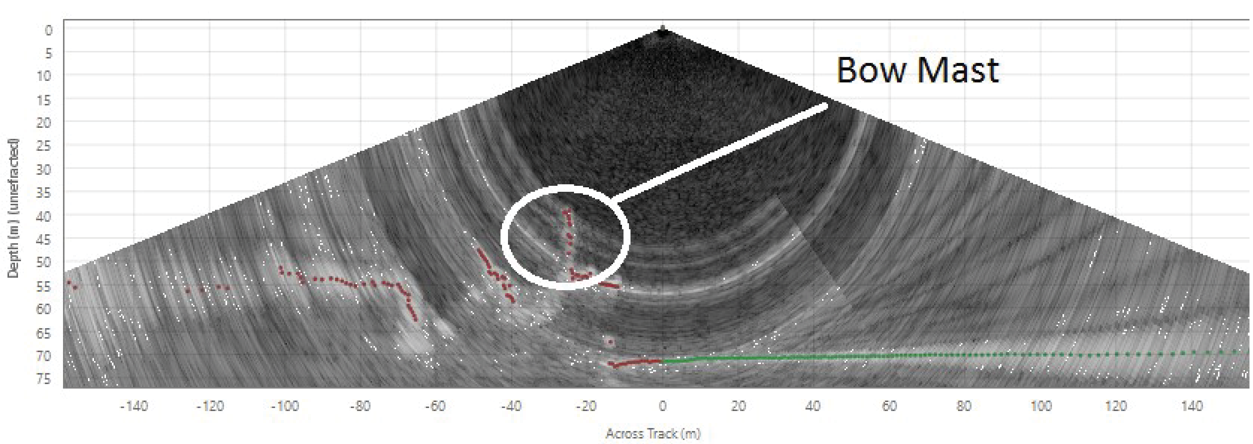


Figure 56 – The bow mast feature as observed with the EM2040.

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).

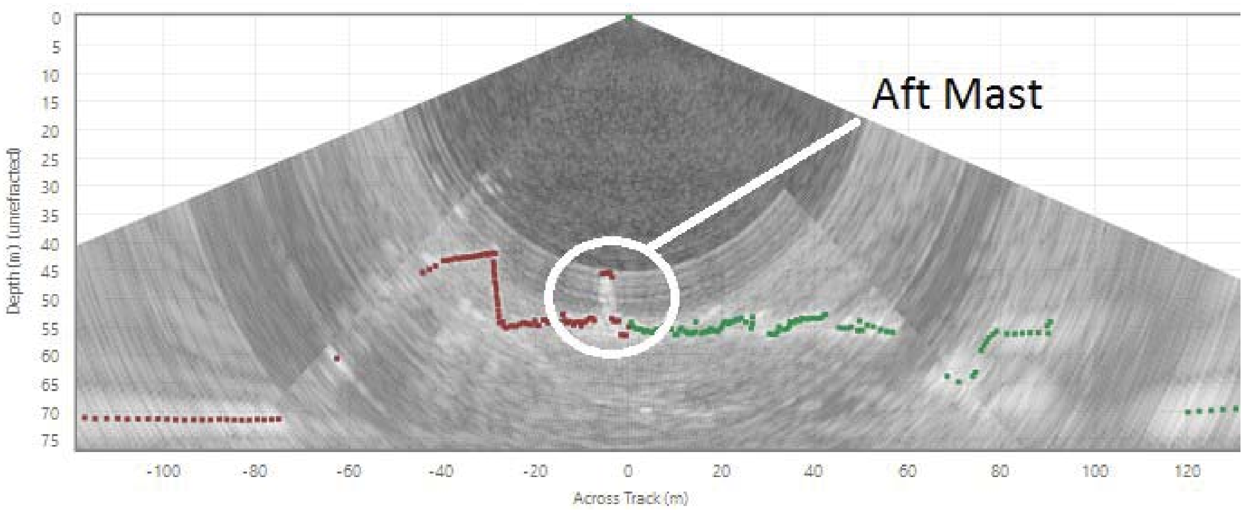


Figure 57 – The aft mast feature as observed in a single line with the EM2040.

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.

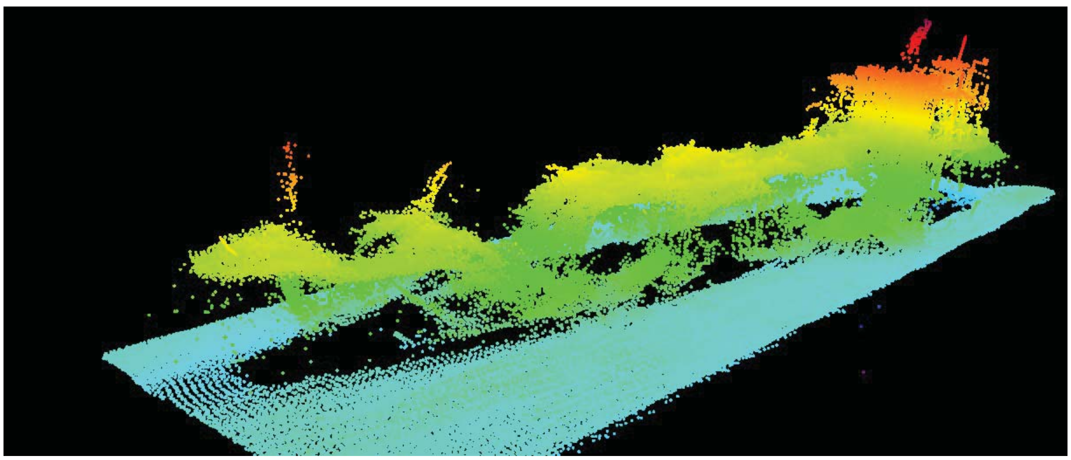


Figure 58 – EM2040 data from the wreck without cleaning.

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.

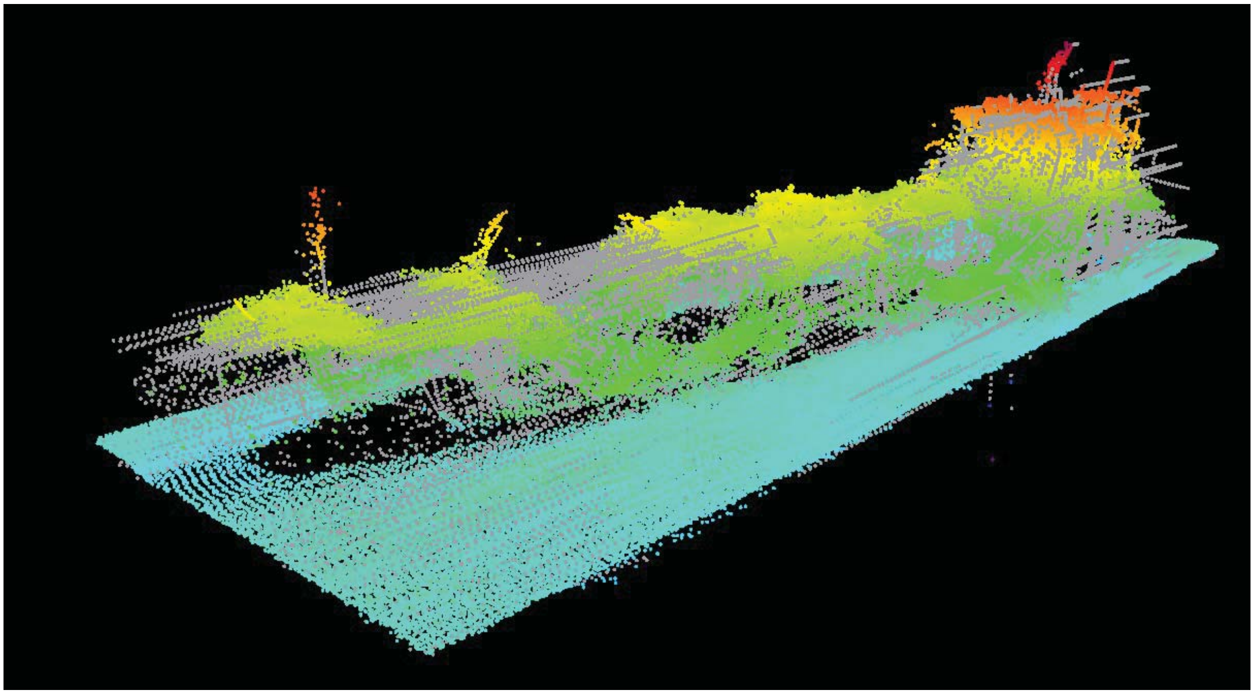


Figure 59 – EM2040 data from the wreck, showing data rejected, interpolated, or extrapolated by the MBES as grey.

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.

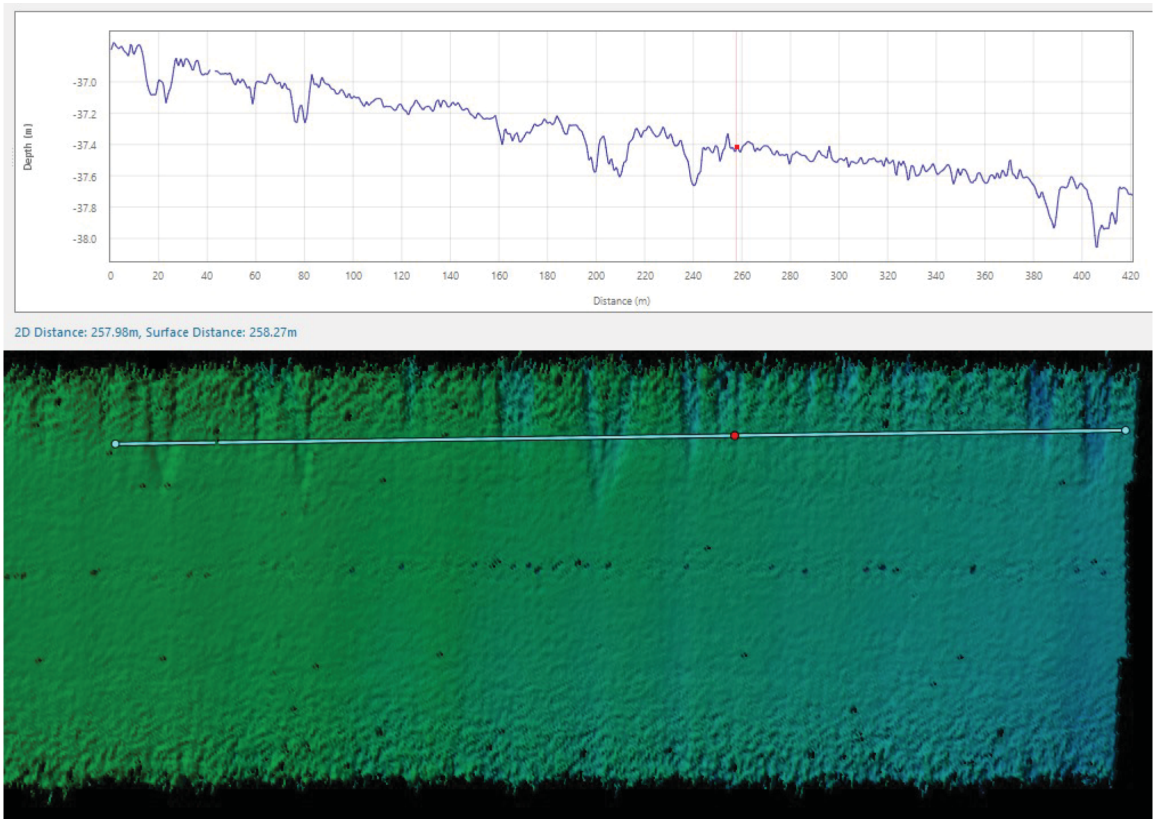


Figure 60 – The leeward artifact as observed in a single line of EM2040 data. The top plot is a profile view of the swath, while the bottom is an overhead view of the line along which the profile was taken. Heading was toward the left.

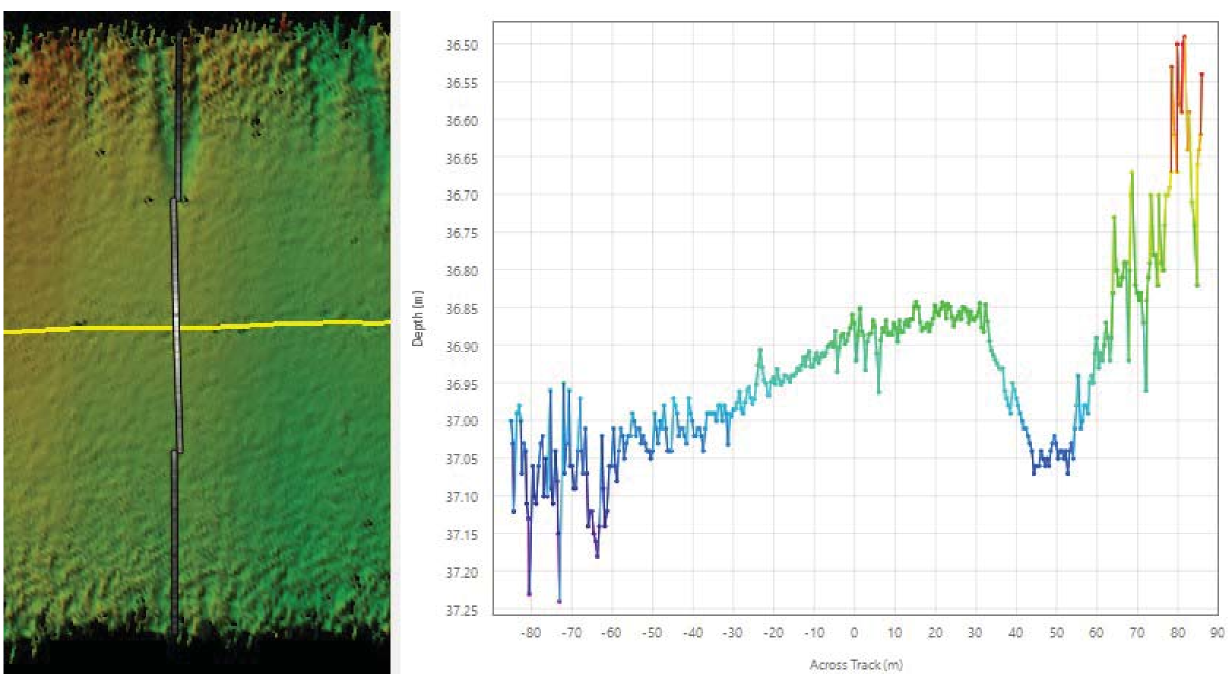


Figure 61 – The leeward artifact as observed in a single ping of EM2040 data. Left is the swath cross section, right is the single swath profile colored by depth.

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).

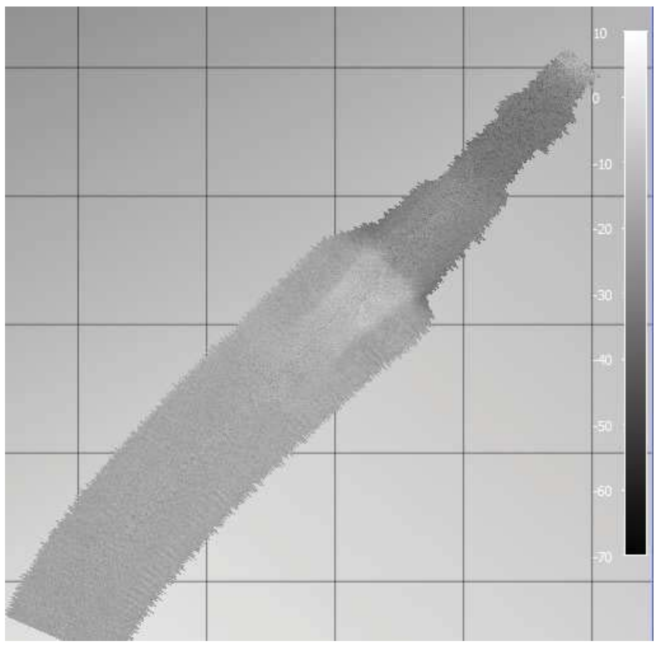


Figure 62 - A line in 300 kHz mode from the first extinction site demonstrating the change in backscatter as seen in QPS FMGT.

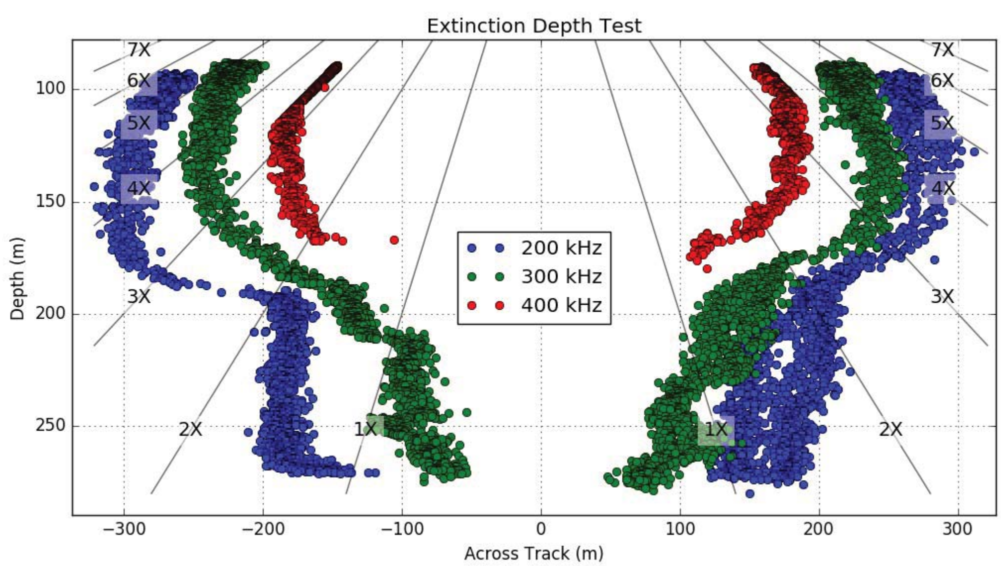


Figure 63 – EM2040 extinction data at the improvised location. The pulse length was selected by the system automatically. Shown are the outermost good detections on each side of the swath.

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.

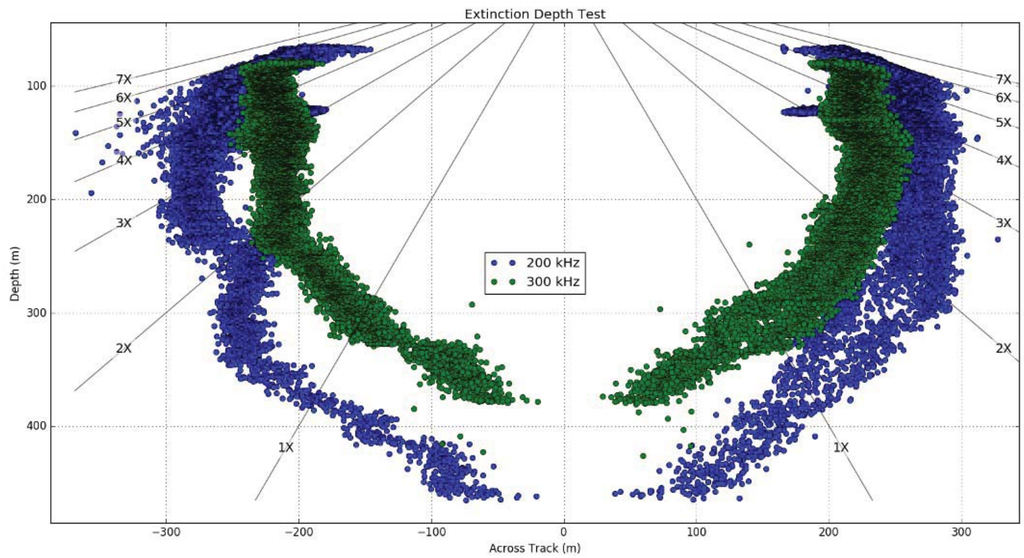


Figure 64 – EM2040 extinction testing on the EM710 extinction test line. The pulse length was selected by the system automatically. Shown are the outermost good detections on each side of the swath.

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.

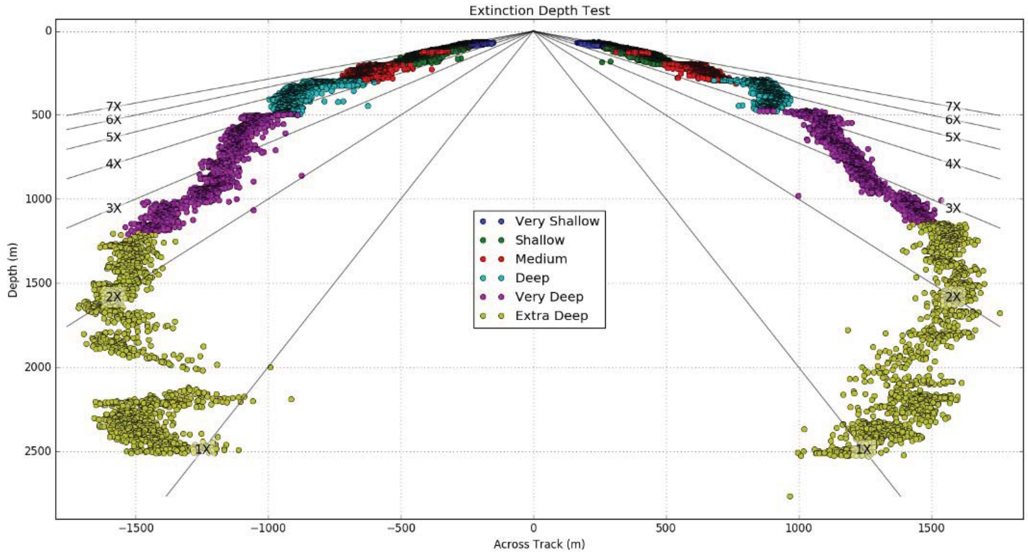


Figure 65 – EM710 extinction test results. The mode setting was selected automatically. Shown are the outermost good detections on each side of the swath.

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.

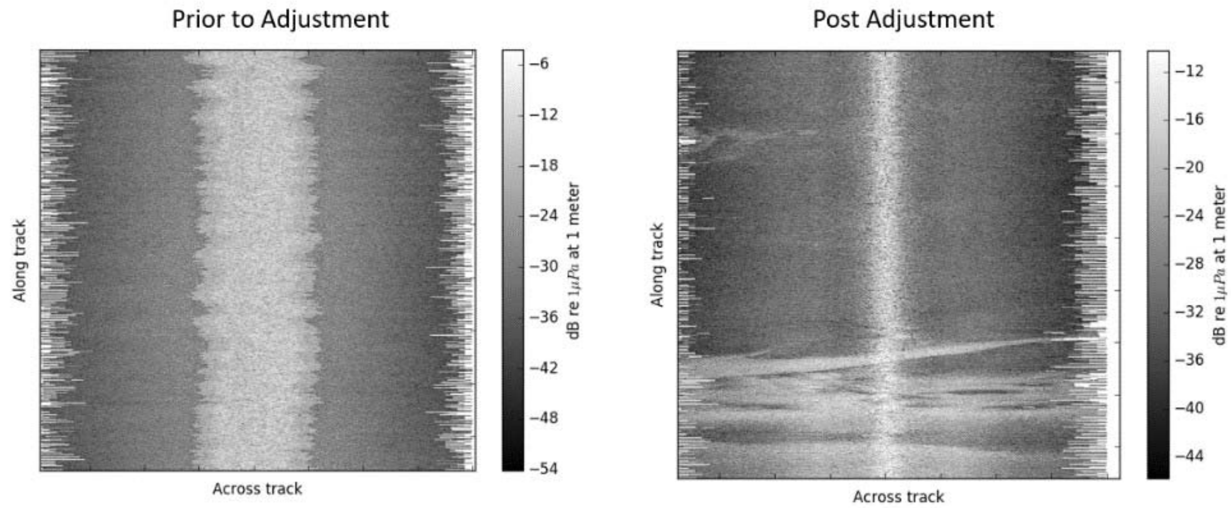


Figure 66 – Seafloor backscatter with the EM710 before the BSCorr.txt file was adjusted (left) and after adjustment (right).

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.

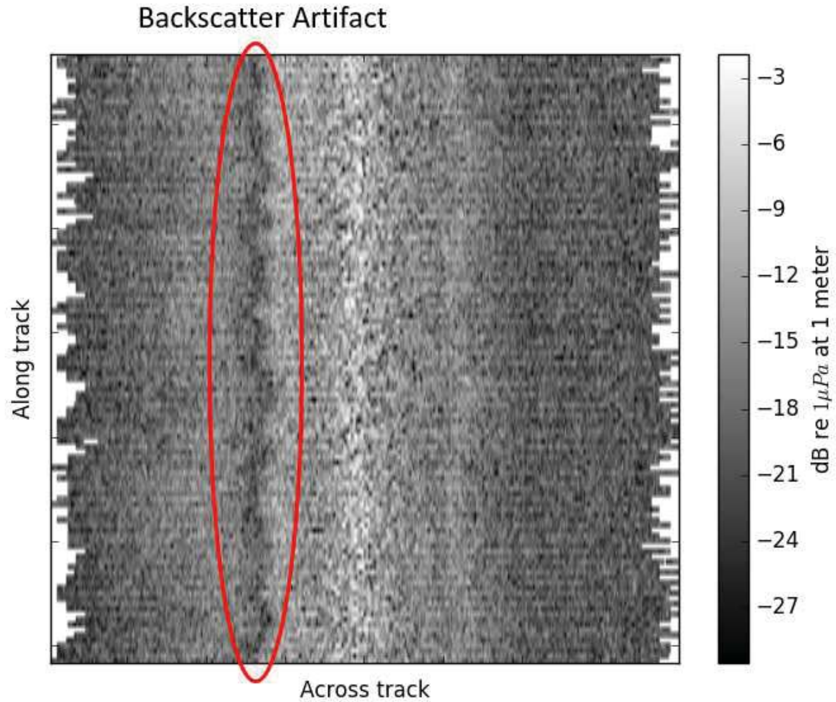


Figure 67 – The EM2040 200 kHz mode backscatter artifact.

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.

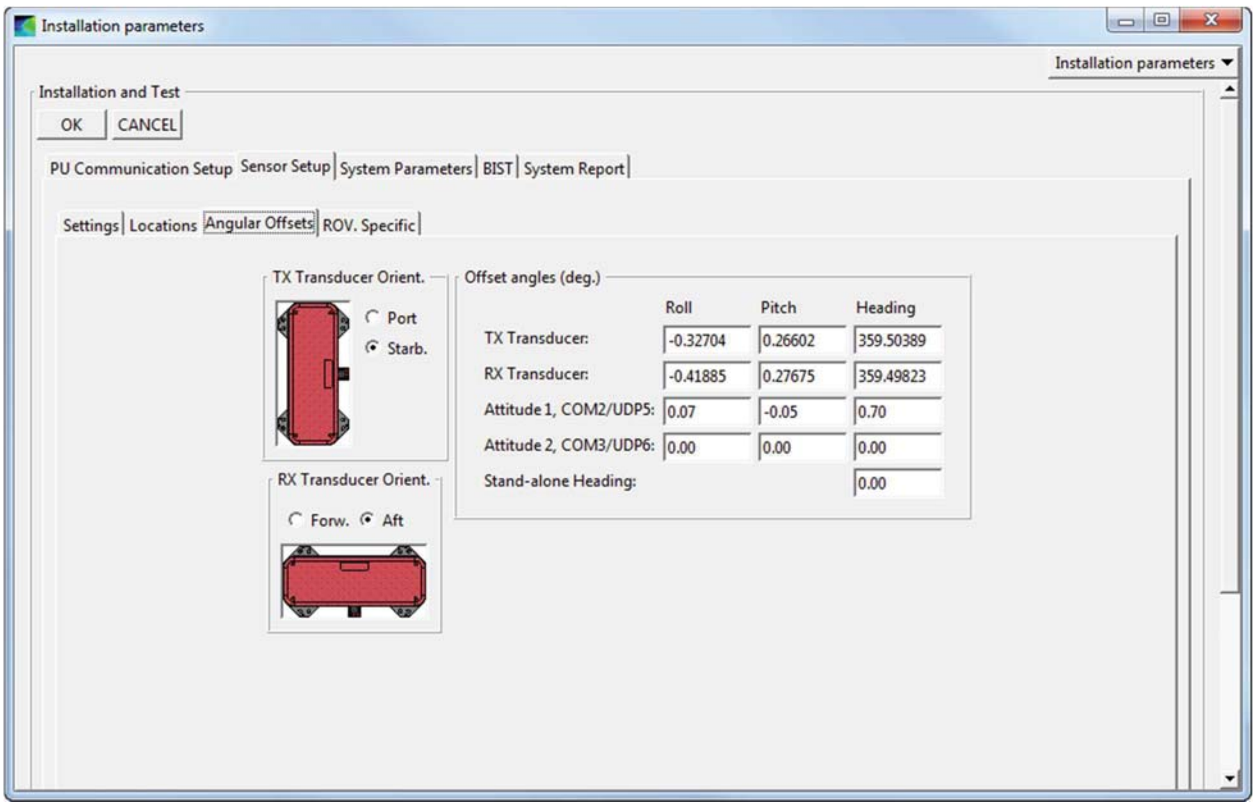


Figure 68 - The Installation and Test Parameters, Sensor Setup, Angular Offsets for the NOAA Ship Thomas Jefferson EM2040.

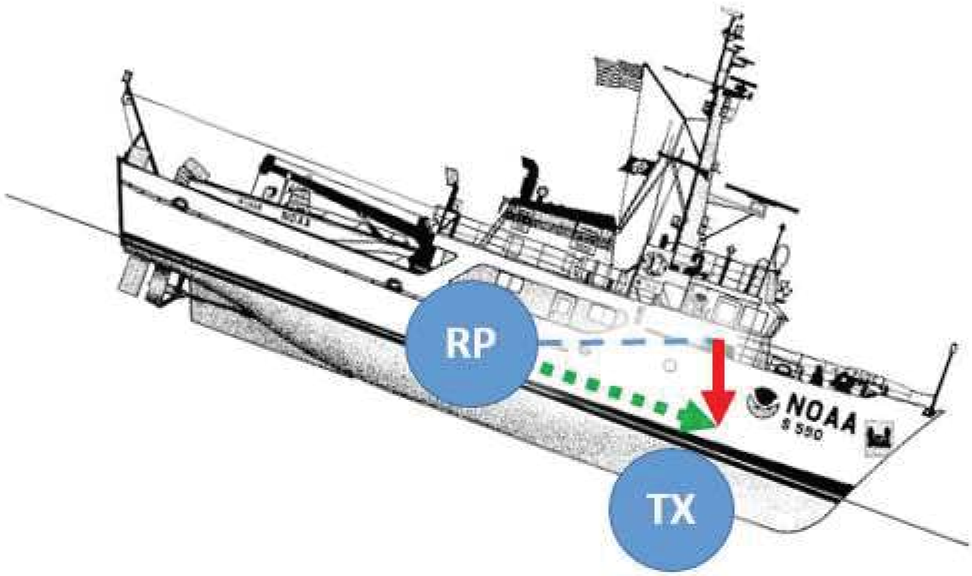


Figure 69 - Pitched induced heave (red arrow) is a result of the along track lever arm between the reference point (RP) and transducers (TX).

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.

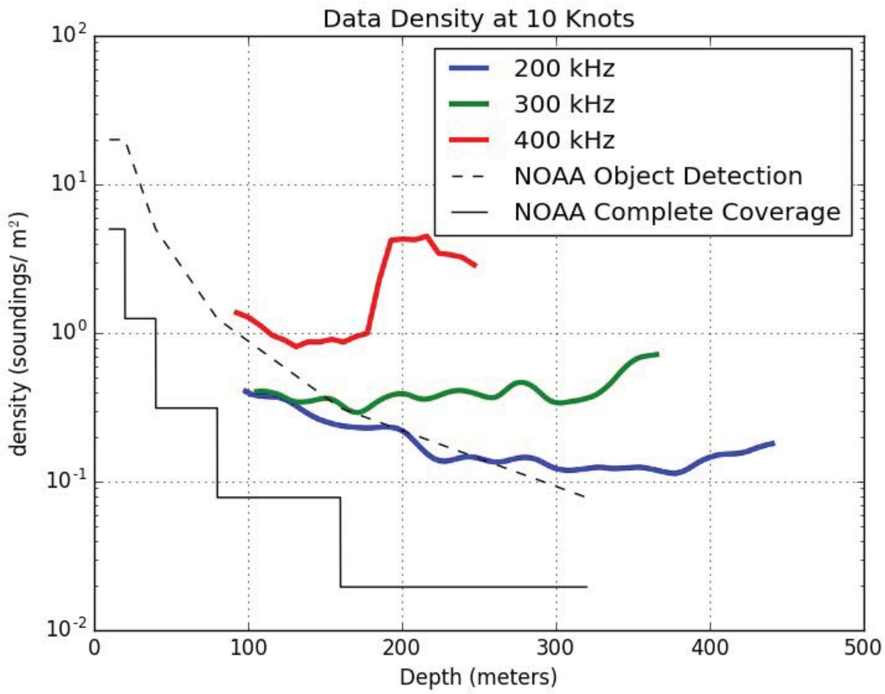


Figure 70 – Sounding density for the EM2040 estimated from the extinction lines.

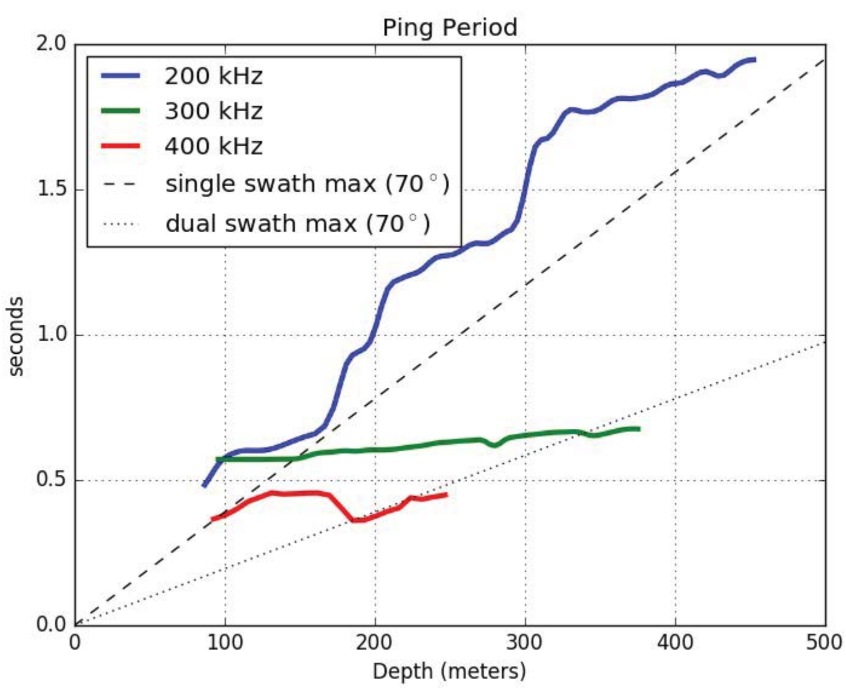


Figure 71 – Ping periods for the EM2040 during the extinction lines.

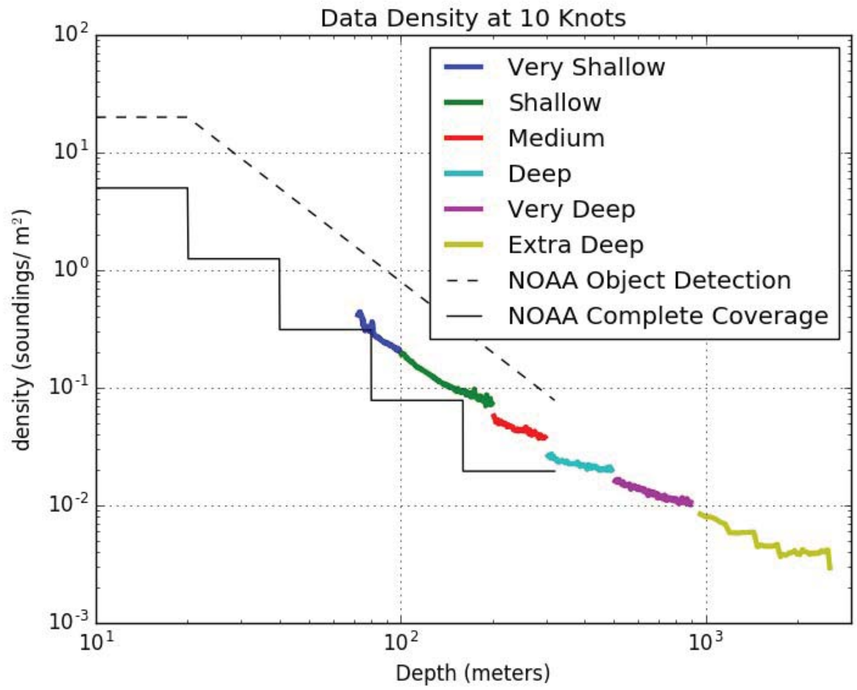


Figure 72 – Sounding density for the EM710 estimated from the extinction lines.

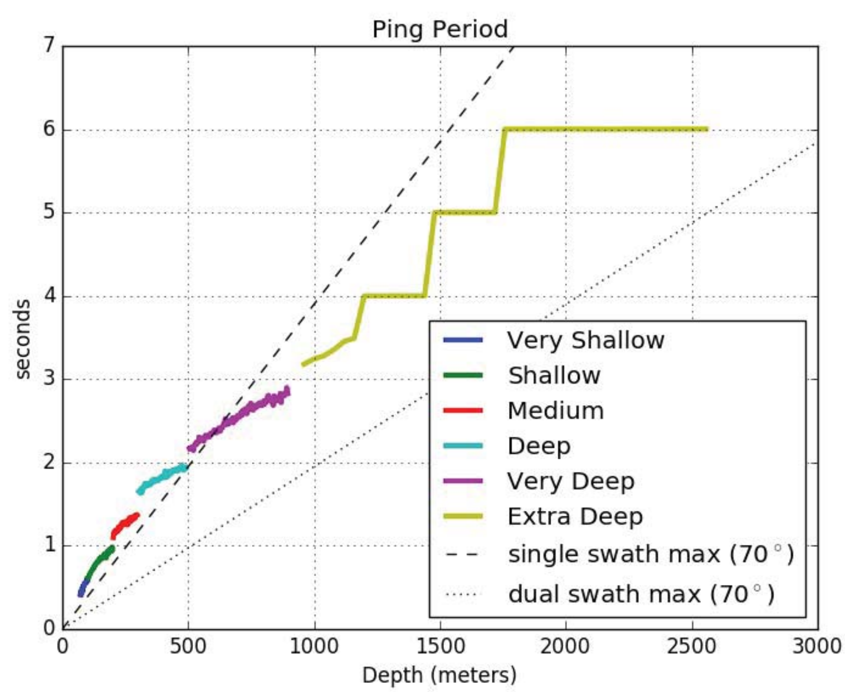


Figure 73 – Ping period for the EM710 during the extinction lines.

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.

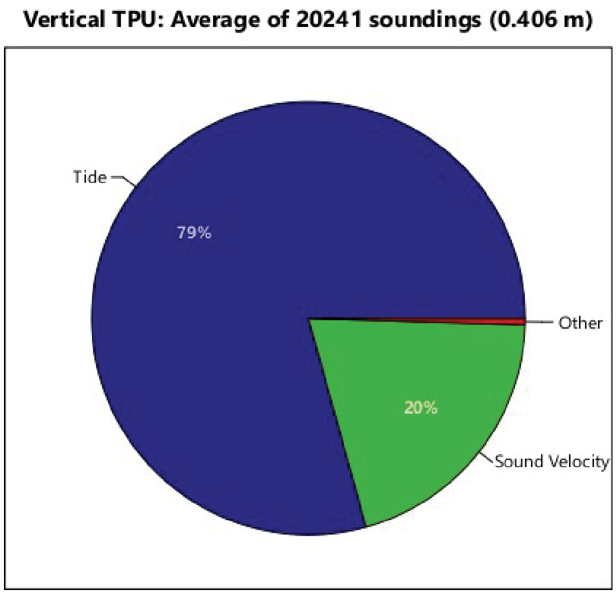


Figure 74 - Nadir Total Vertical Uncertainty breakdown by contribution source for the EM2040. The real time uncertainty from the echo sounder is small and included in the "Other" portion of the plot.

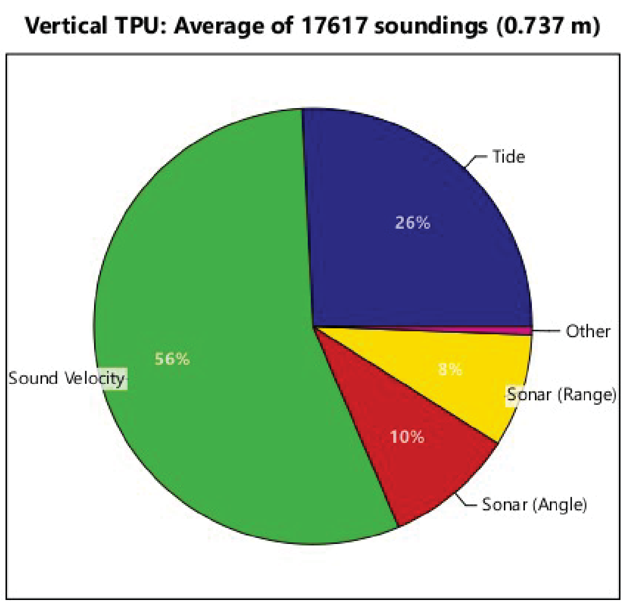


Figure 75 – Outer beam Total Vertical Uncertainty breakdown by contribution source for the EM2040. The contribution from the echo sounder real time uncertainty is small relative to other factors.

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

[1] G. Rice and S.F. Greenaway, "NOAA Ship *Rainier* 2014 Ice Hardened Transducer Testing and Acceptance," NOAA Office of Coast Survey, Silver Spring, MD, Tech Rep. 2014.

[2] S.F. Greenaway and G. Rice, "NOAA Ship *Fairweather* Kongsberg EM710 Multibeam Echosounder Acceptance Trials," NOAA Office of Coast Survey, Silver Spring, MD, Tech Rep. 2015.

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[7] G. Rice and M. Malik, "NOAA Ship *Nancy Foster* EM710 Acceptance Testing," NOAA Office of Coast Survey, Silver Spring, MD, Tech Rep. 2015.

[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.

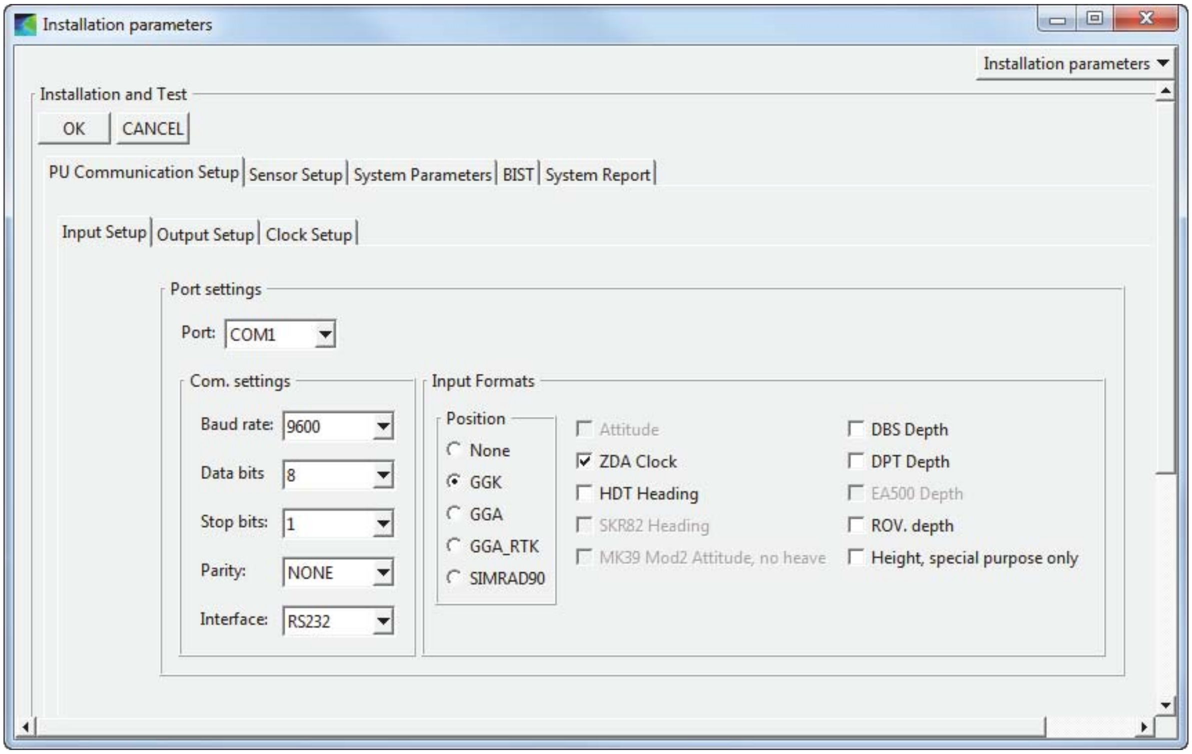
[10] G. Rice, "Bay Hydrographer II EM2040 Testing of Acceptance Testing," NOAA Office of Coast Survey, Silver Spring, MD, Tech Rep, 2016.

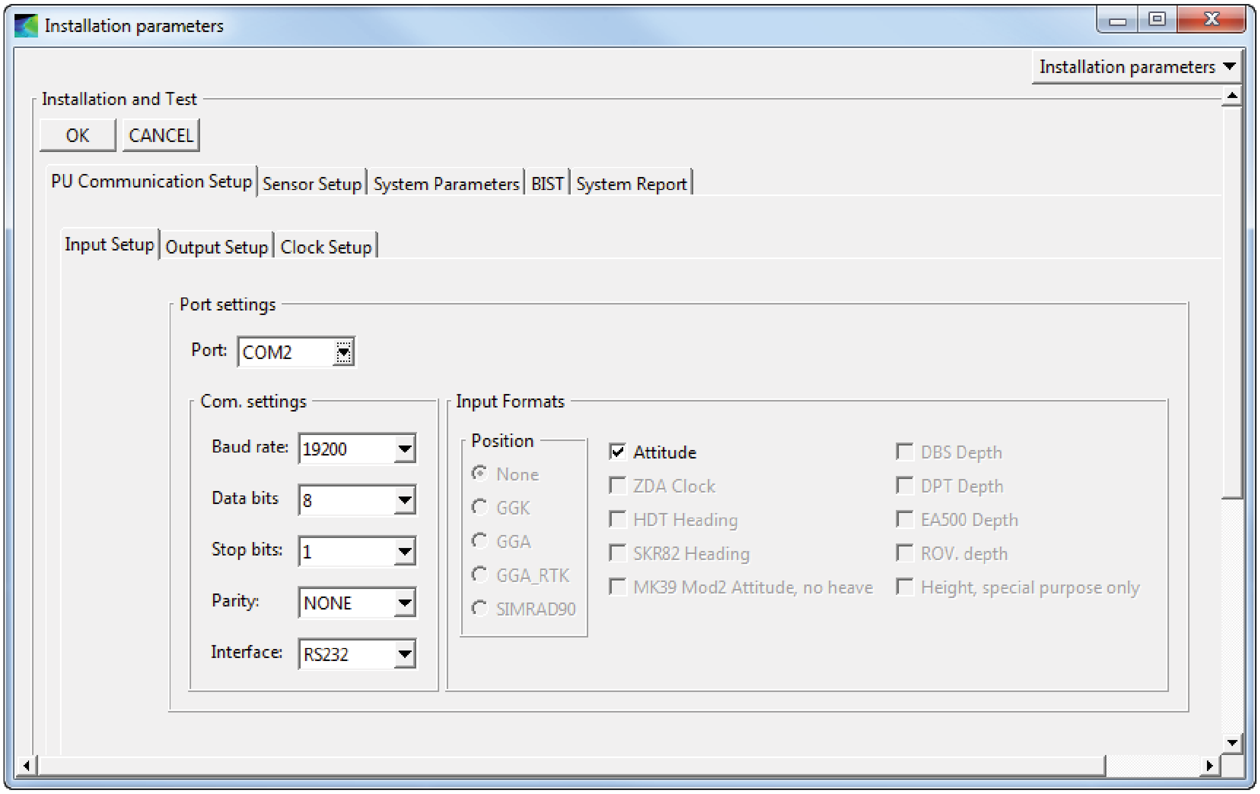
10 Appendices

10.1 Configuration Screen Grabs

10.1.1 SIS

10.1.1.1 EM2040

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Installation and Test
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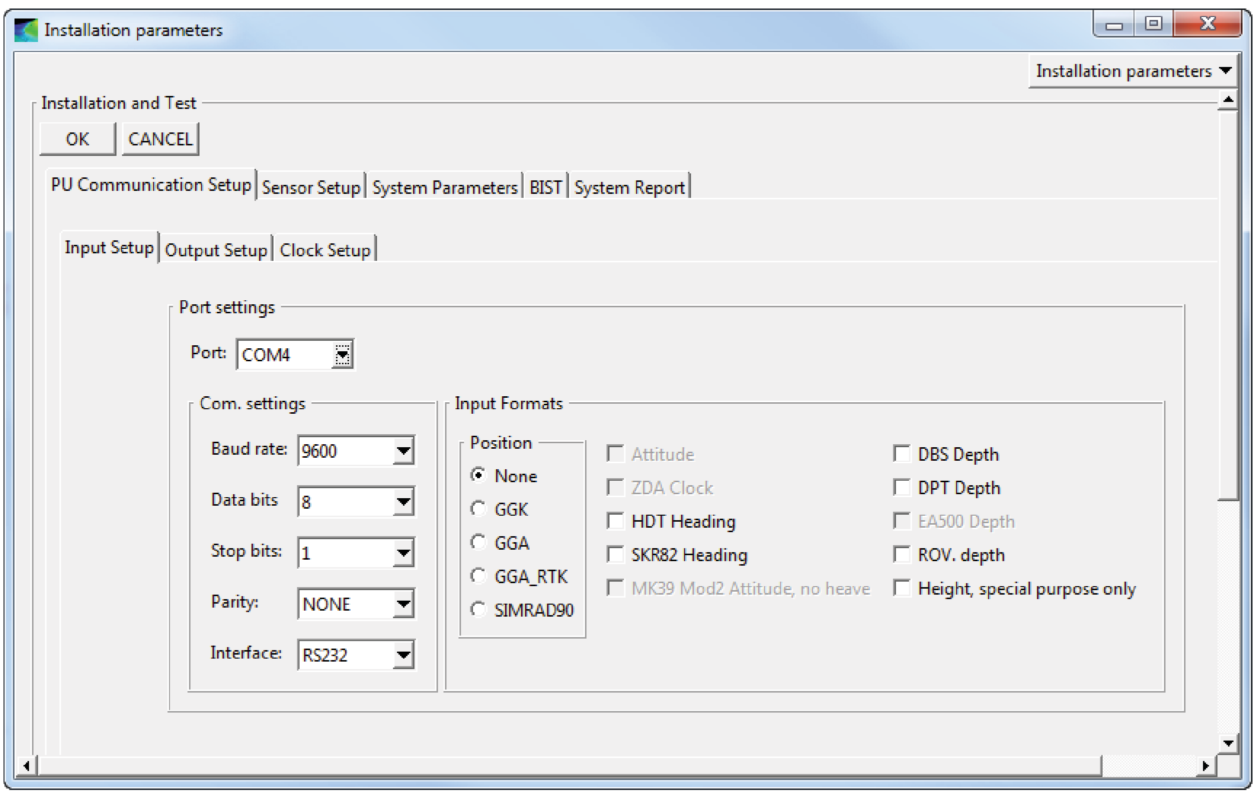
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: COM2
Com. settings
Baud rate: 19200
Data bits 8
Stop bits: 1
Parity: NONE
Interface: RS232
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only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Installation parameters
Installation and Test
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PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
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Com. settings
Baud rate: 9600
Data bits 8
Stop bits: 1
Parity: NONE
Interface: RS232
Input Formats
Position
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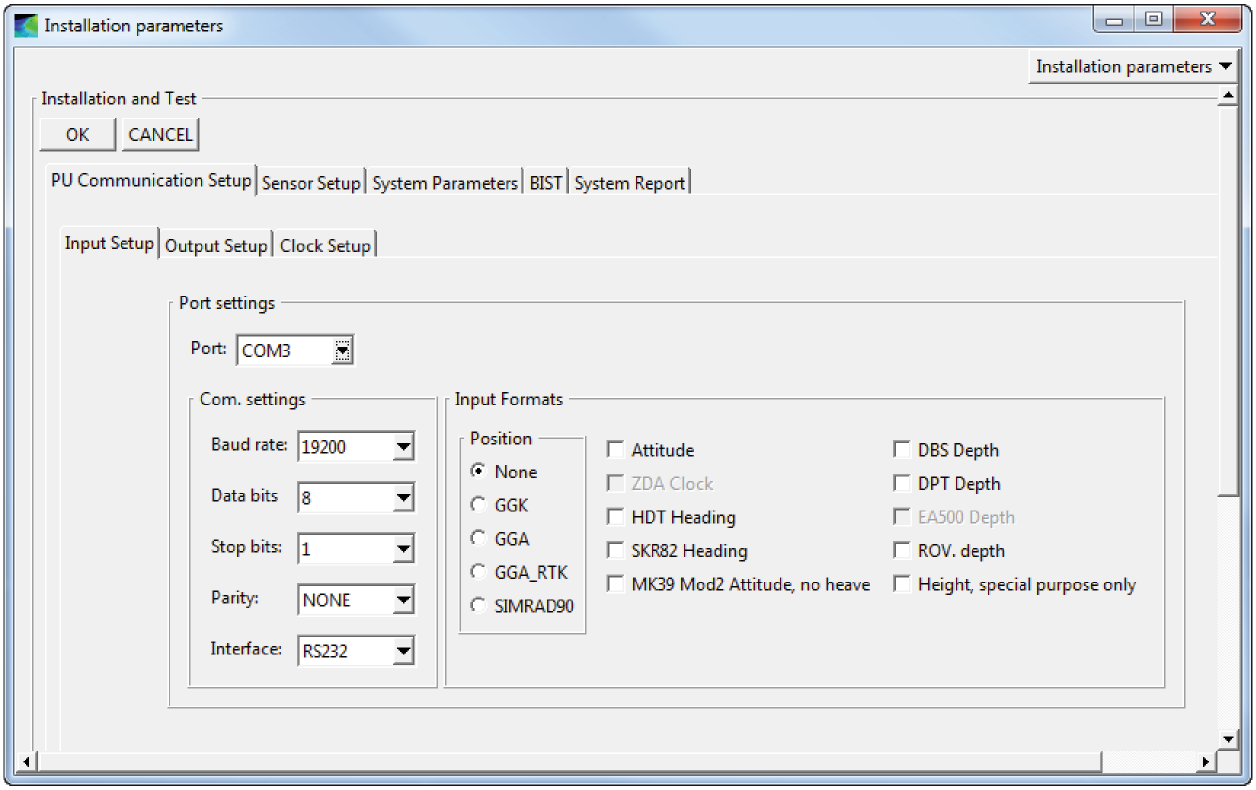
GGK
GGA
GGA_RTK
SIMRAD90
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only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Sensor Setup
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System Report
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Output Setup
Clock Setup
Port settings
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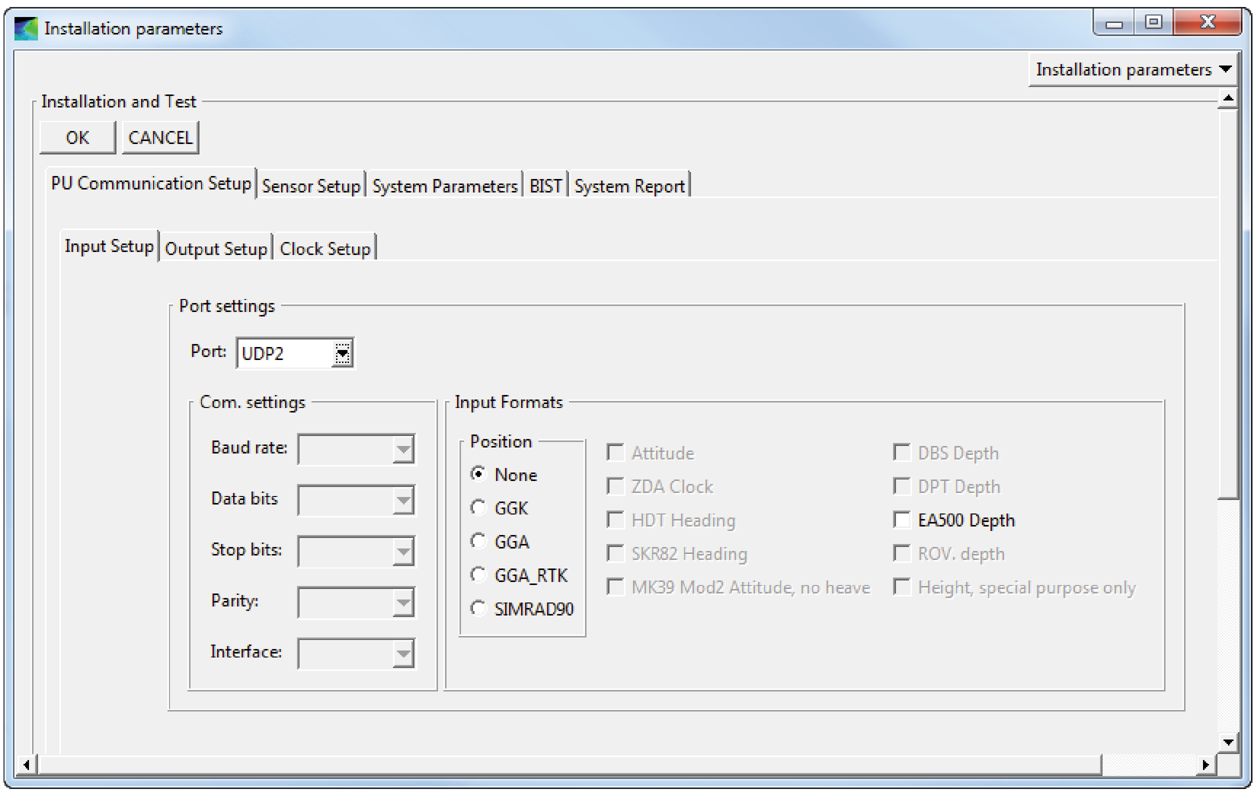
Com. settings
Baud rate: 19200
Data bits 8
Stop bits: 1
Parity: NONE
Interface: RS232
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only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Sensor Setup
System Parameters
BIST
System Report
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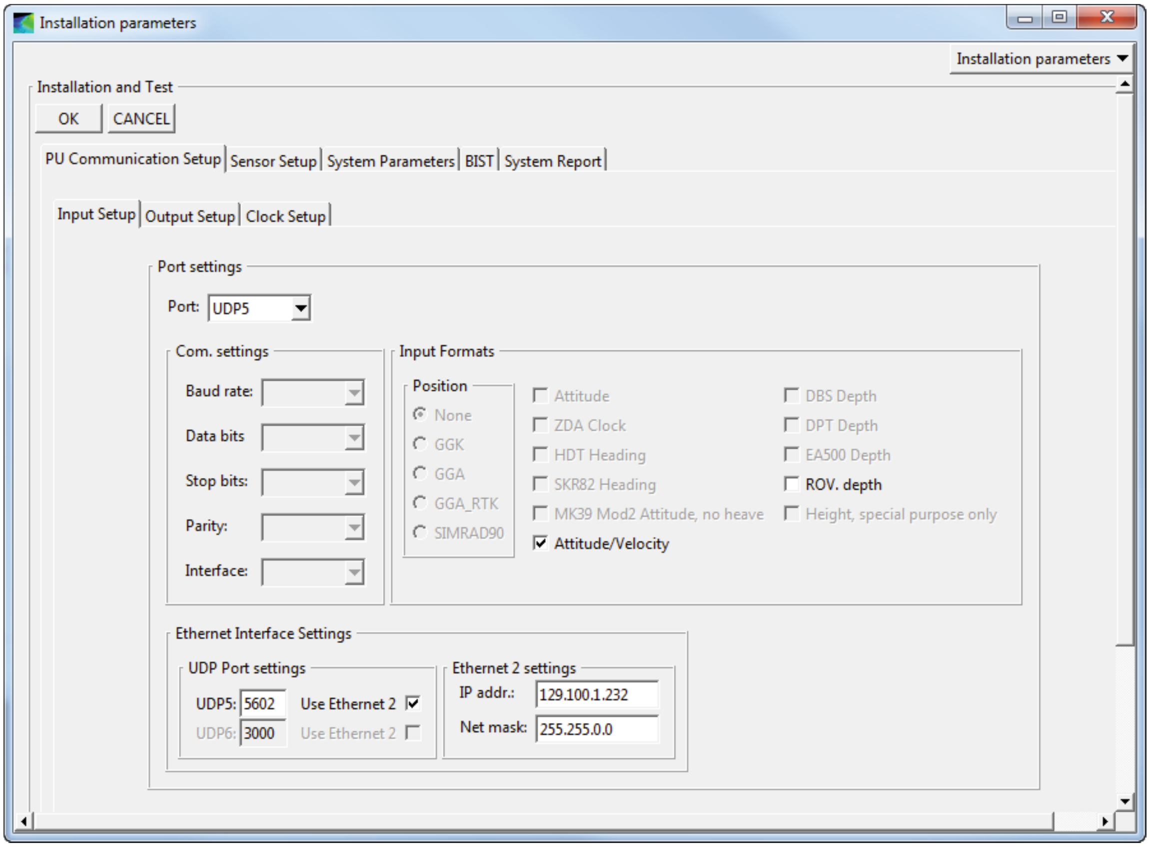
Output Setup
Clock Setup
Port settings
Port: UDP2
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only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Installation and Test
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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
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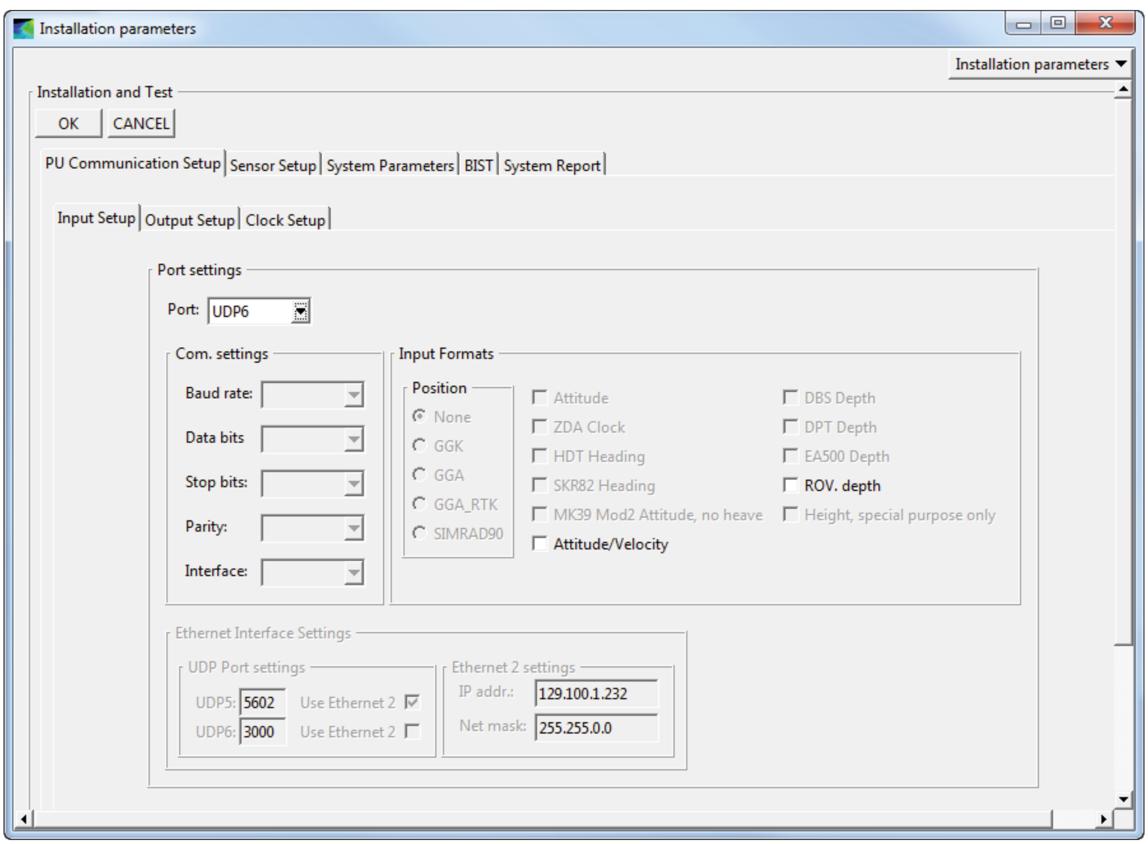
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Installation parameters
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Sensor Setup
System Parameters
BIST
System Report
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Output Setup
Clock Setup
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Com. 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
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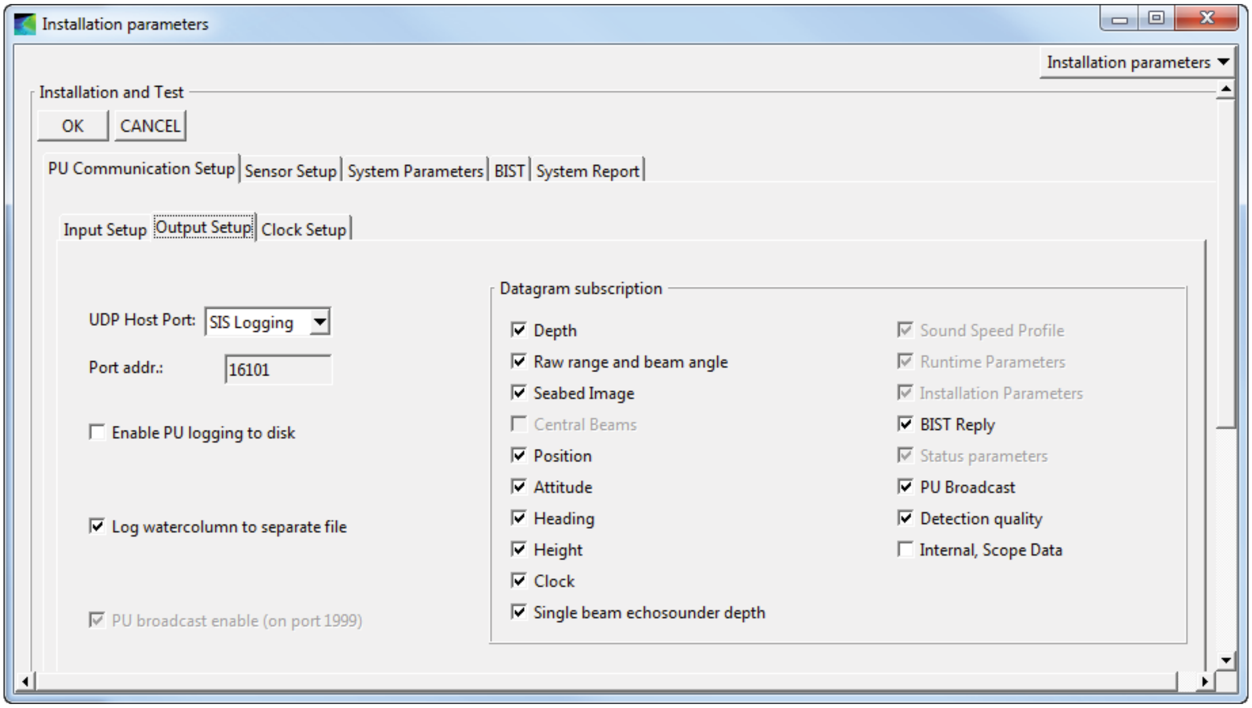
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Sensor Setup
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System Report
Input Setup
Output Setup
Clock Setup
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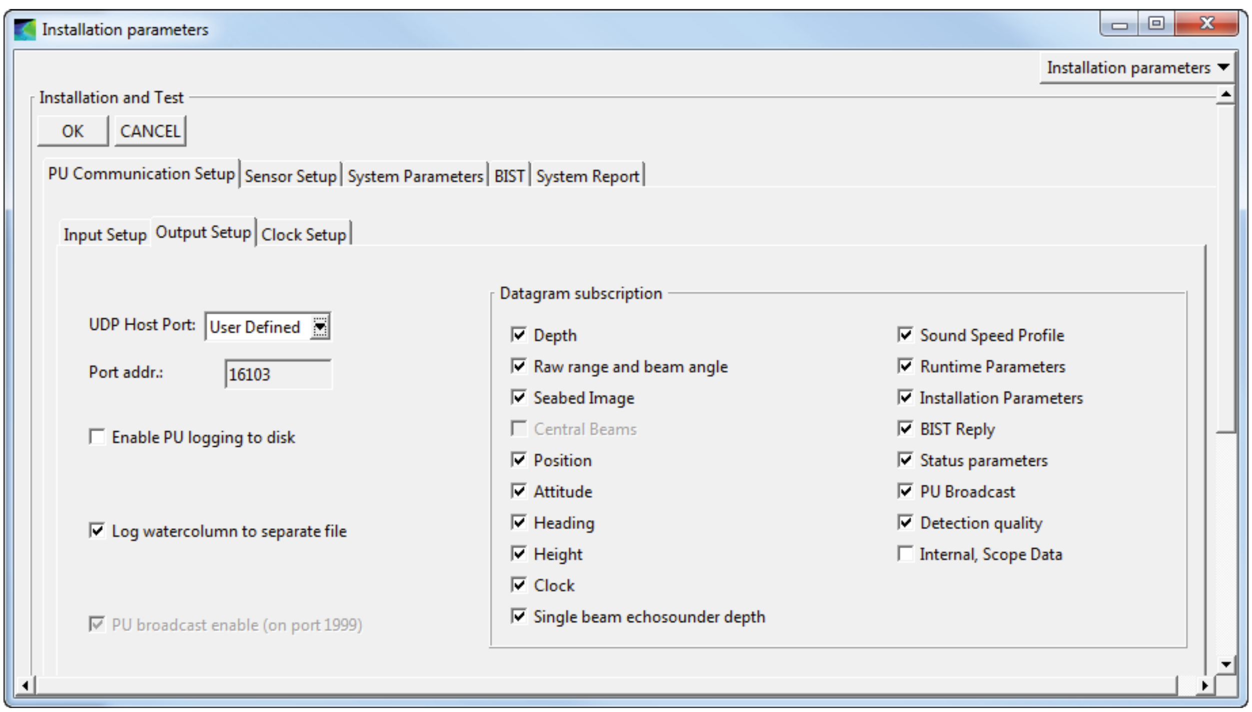
SIS Logging
Port addr.:
16101
Enable PU logging to disk
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram subscription
Depth
Raw range and beam angle
Seabed Image
Central Beams
Position
Attitude
Heading
Height
Clock
Single beam echosounder depth
Sound Speed Profile
Runtime Parameters
Installation Parameters
BIST Reply
Status parameters
PU Broadcast
Detection quality
Internal, Scope Data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CANCEL
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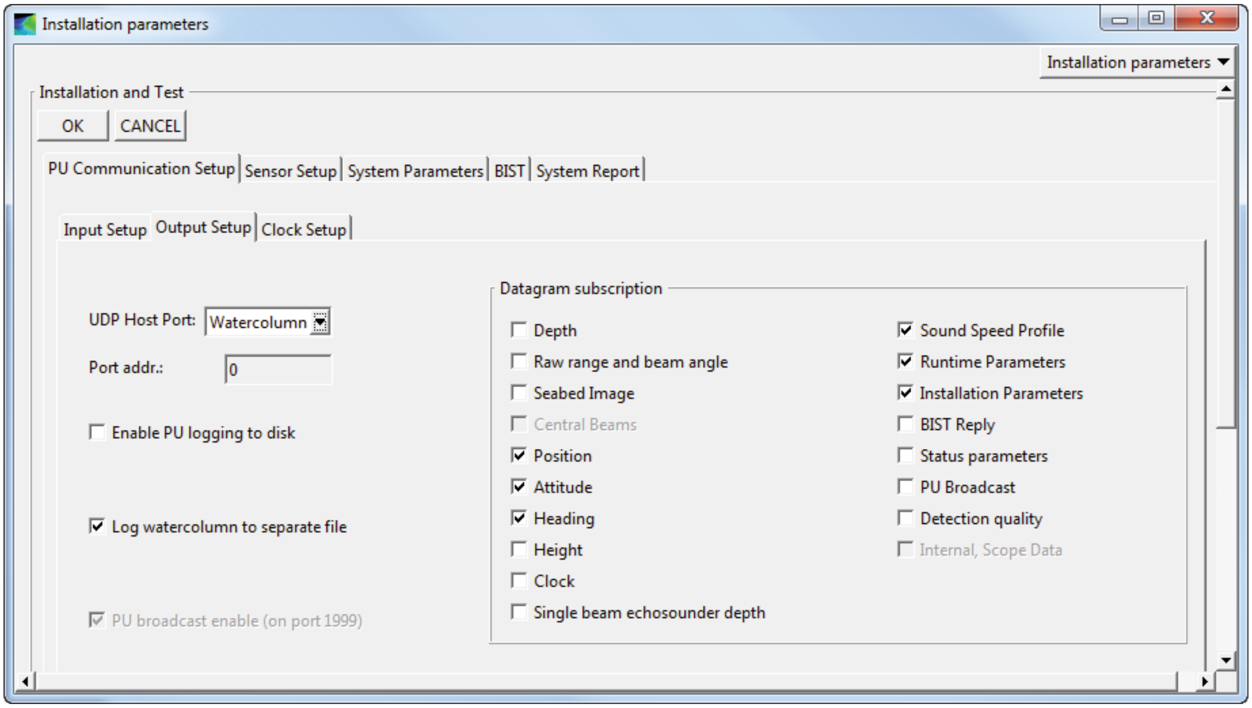
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port:
User Defined
Port addr.:
16103
Enable PU logging to disk
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram subscription
Depth
Raw range and beam angle
Seabed Image
Central Beams
Position
Attitude
Heading
Height
Clock
Single beam echosounder depth
Sound Speed Profile
Runtime Parameters
Installation Parameters
BIST Reply
Status parameters
PU Broadcast
Detection quality
Internal, Scope Data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Installation and Test
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Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
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Watercolumn
Port addr.:
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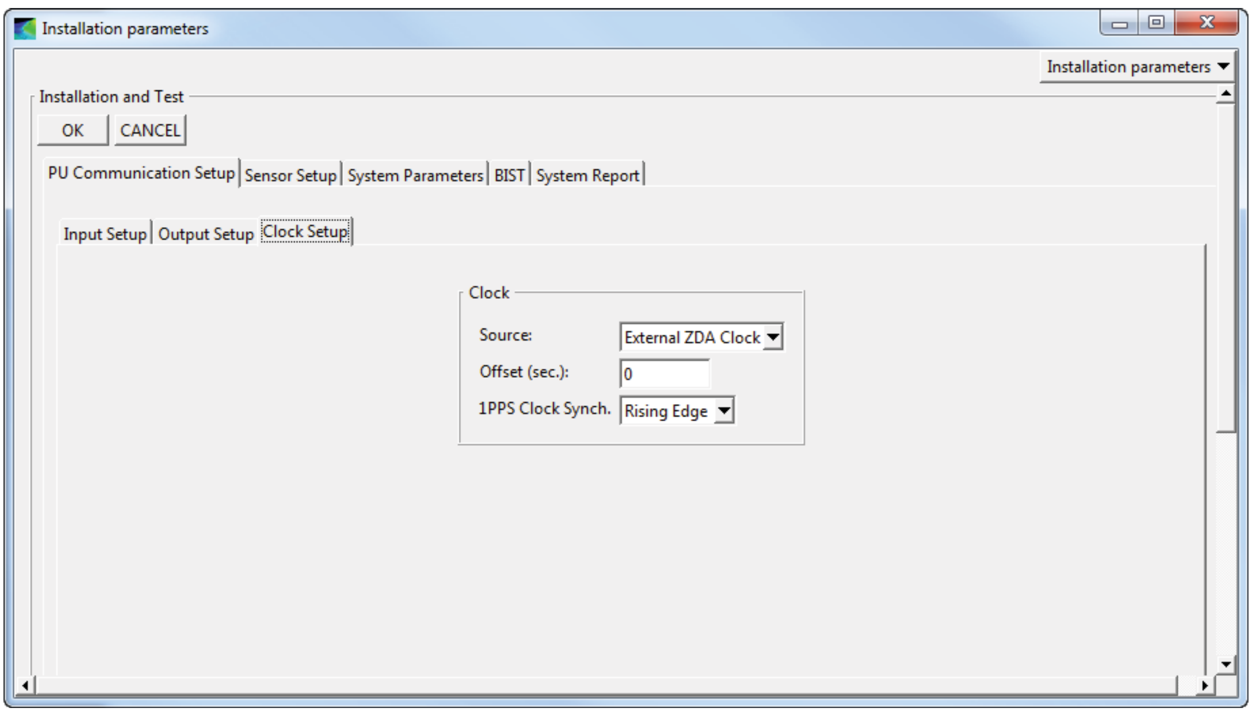
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram subscription
Depth
Raw range and beam angle
Seabed Image
Central Beams
Position
Attitude
Heading
Height
Clock
Single beam echosounder depth
Sound Speed Profile
Runtime Parameters
Installation Parameters
BIST Reply
Status parameters
PU Broadcast
Detection quality
Internal, Scope Data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BIST
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Output Setup
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External ZDA Clock
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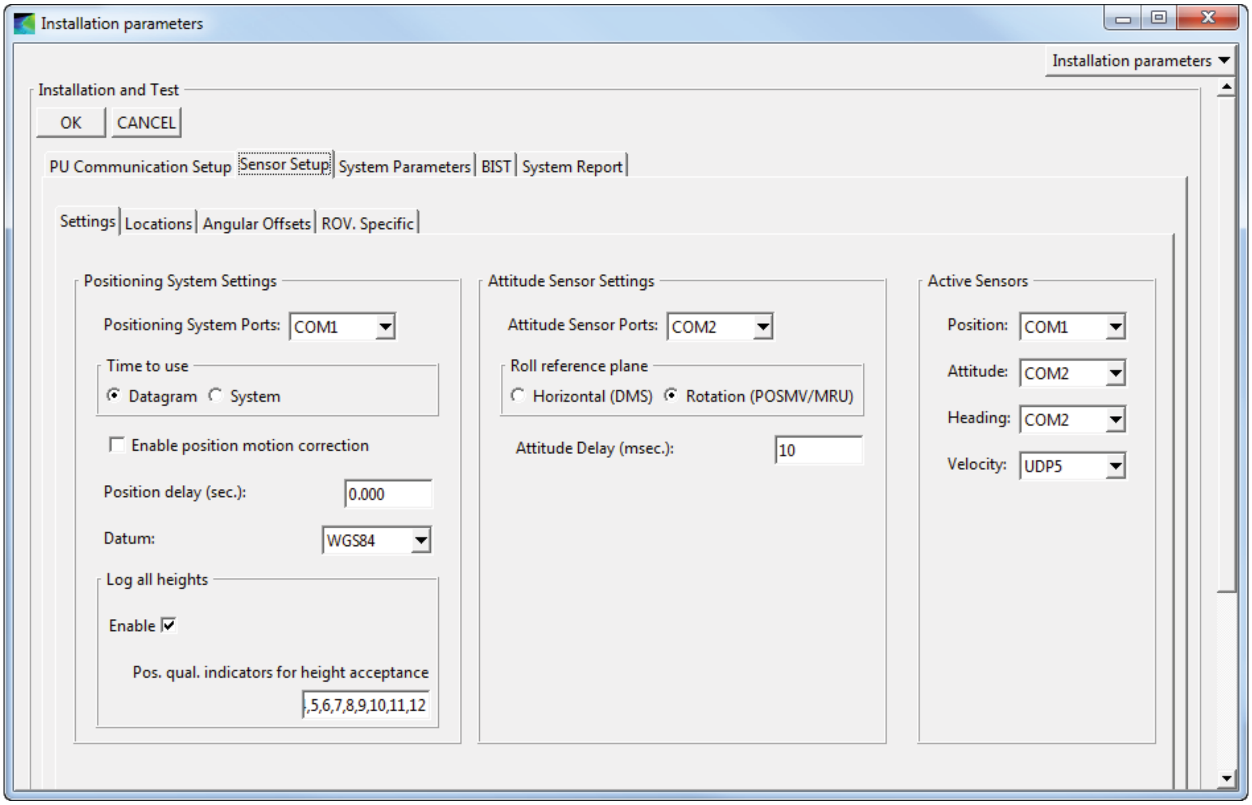
1PPS Clock Synch.
Rising Edge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Installation parameters
Installation and Test
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CANCEL
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Sensor Setup
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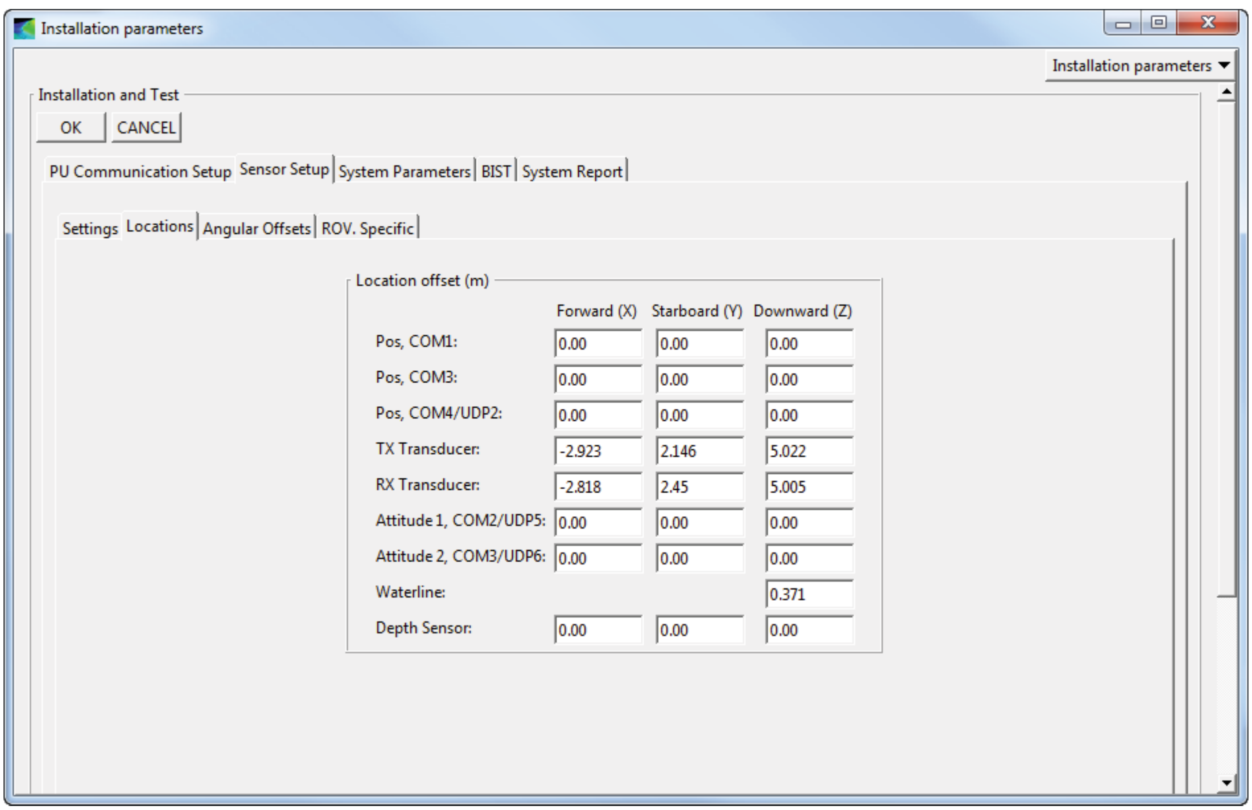
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
Positioning System Settings
Positioning System Ports: COM1
Time to use
Datagram
System
Enable position motion correction
Position delay (sec.): 0.000
Datum: WGS84
Log all heights
Enable
Pos. qual. indicators for height acceptance
,5,6,7,8,9,10,11,12
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
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CANCEL
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Sensor Setup
System Parameters
BIST
System Report
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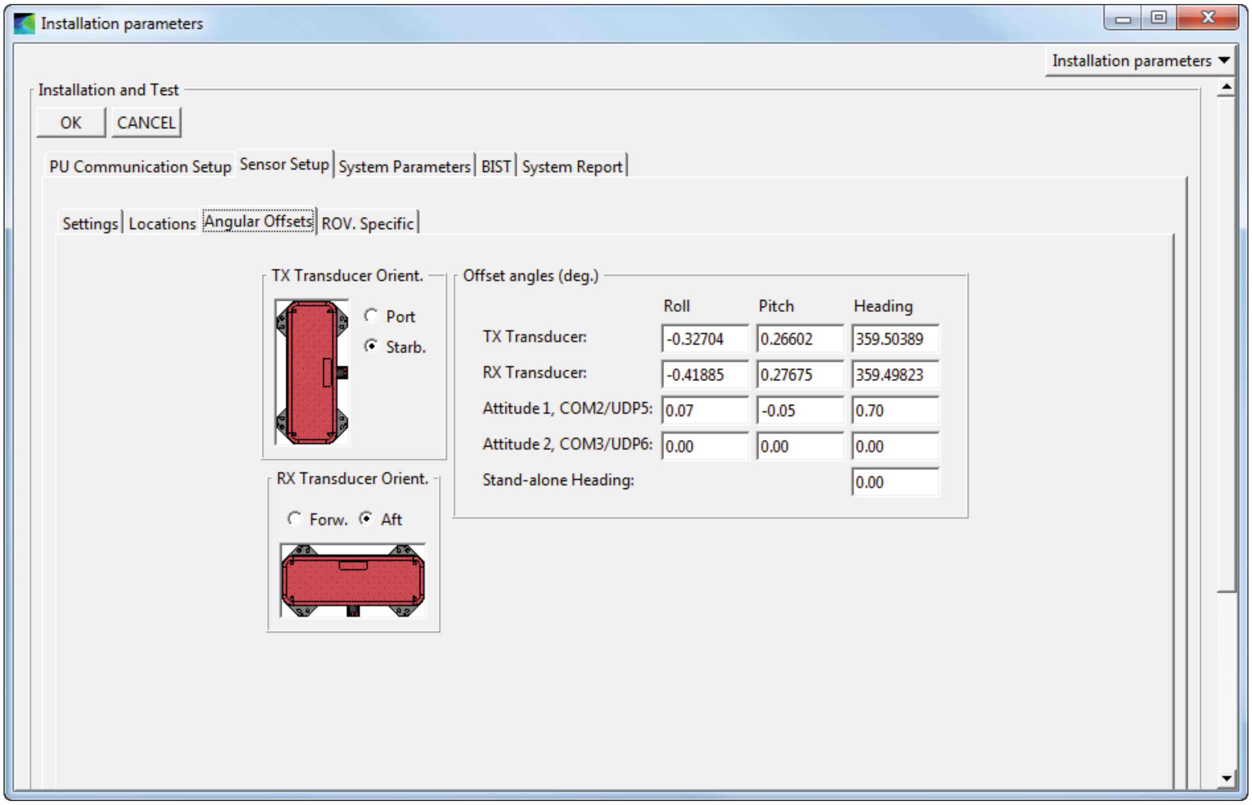
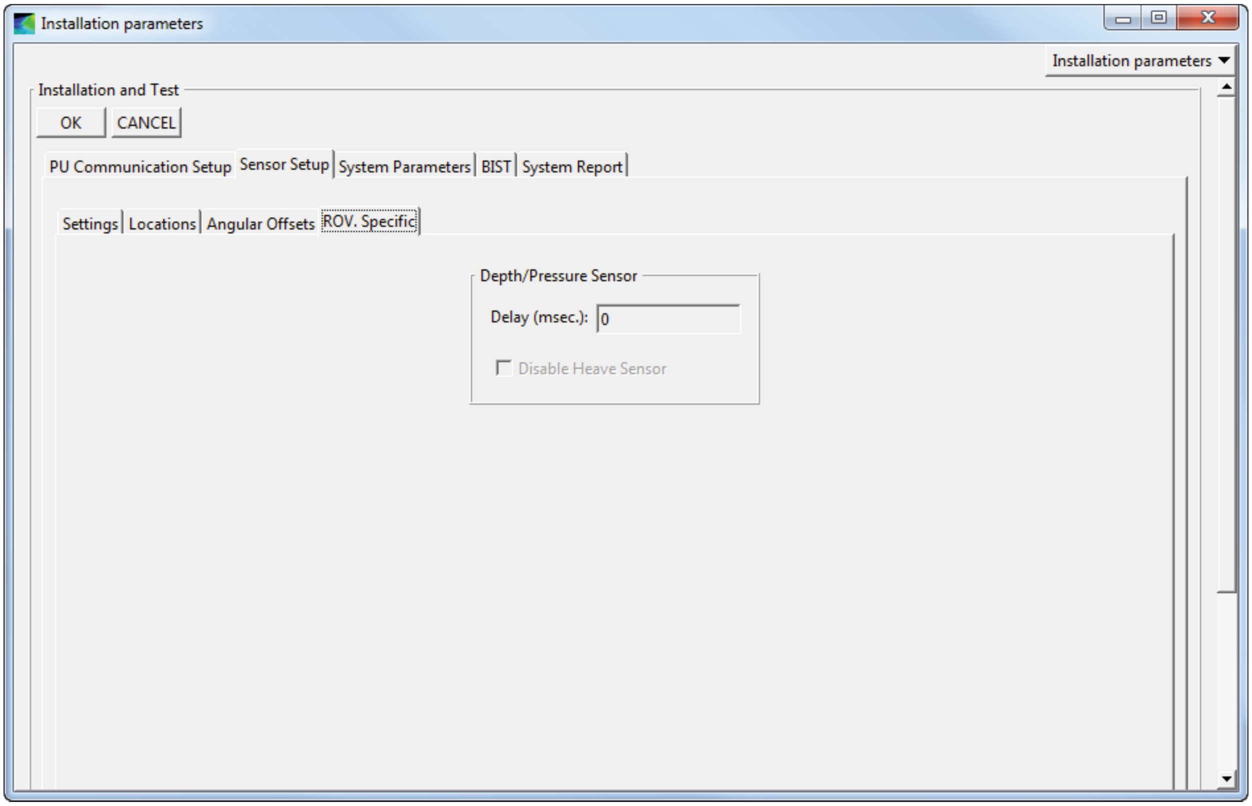
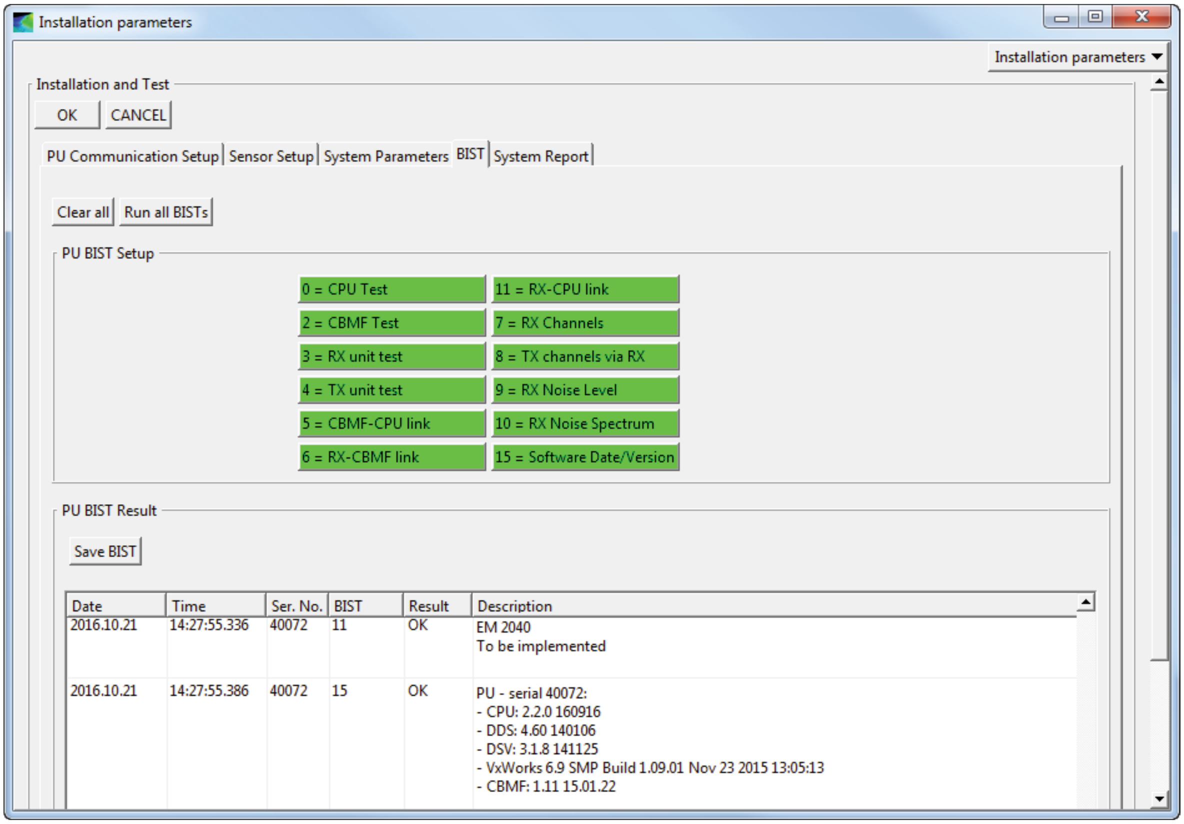
Locations
Angular Offsets
ROV. Specific
Location offset (m)
Forward (X)
Starboard (Y)
Downward (Z)
Pos, COM1: 0.00 0.00 0.00
Pos, COM3: 0.00 0.00 0.00
Pos, COM4/UDP2: 0.00 0.00 0.00
TX Transducer: -2.923 2.146 5.022
RX Transducer: -2.818 2.45 5.005
Attitude 1, COM2/UDP5: 0.00 0.00 0.00
Attitude 2, COM3/UDP6: 0.00 0.00 0.00
Waterline: 0.371
Depth Sensor: 0.00 0.00 0.00

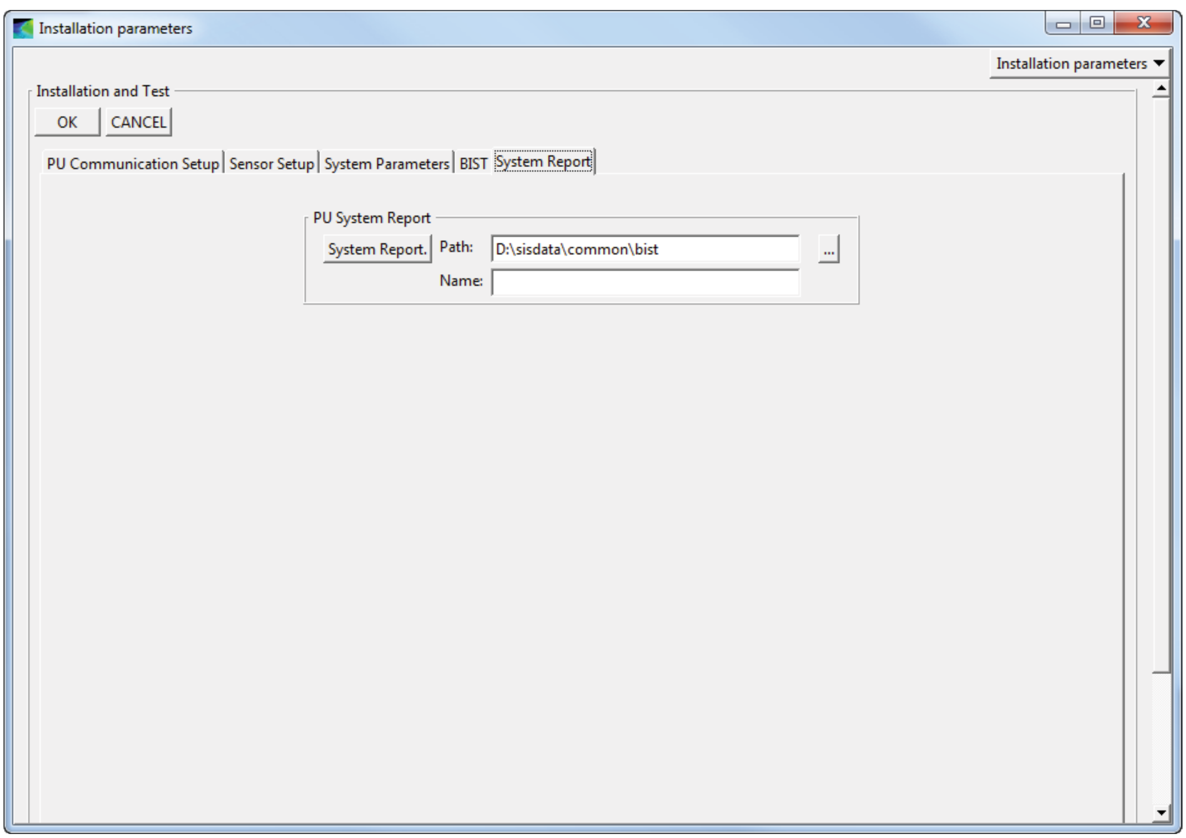


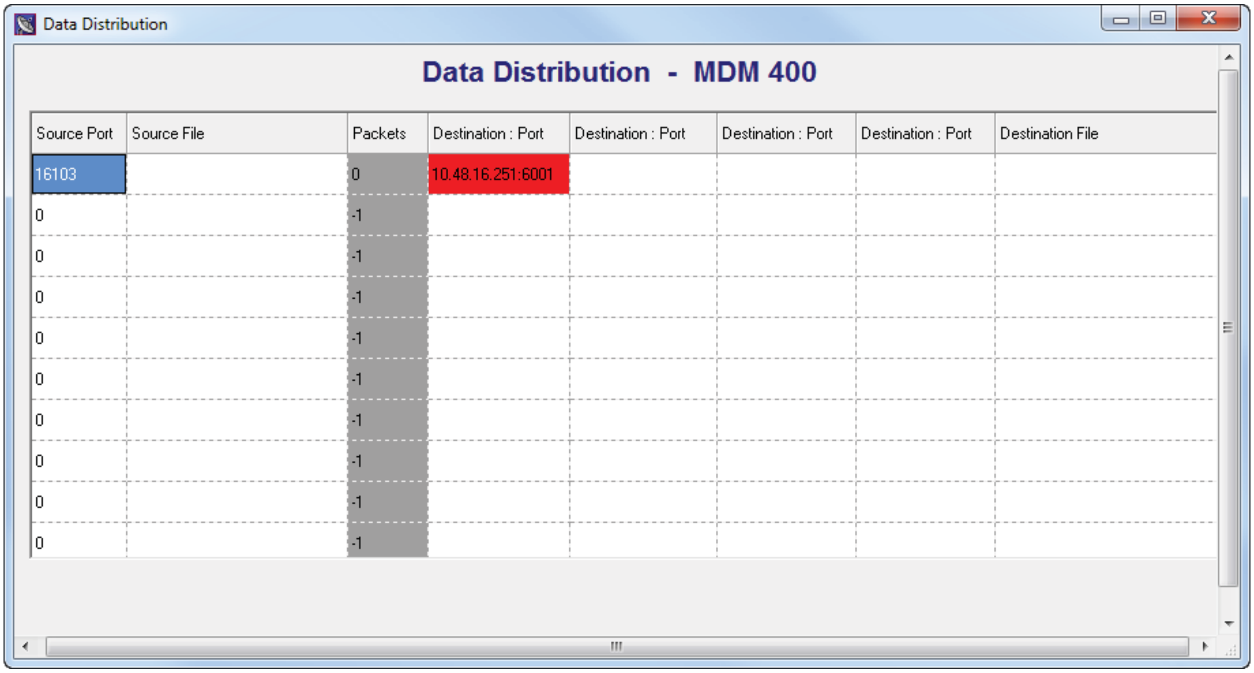
Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
TX Transducer Orient.
Port
Starb.
RX Transducer Orient.
Forw.
Aft
Offset angles (deg.)
Roll
Pitch
Heading
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
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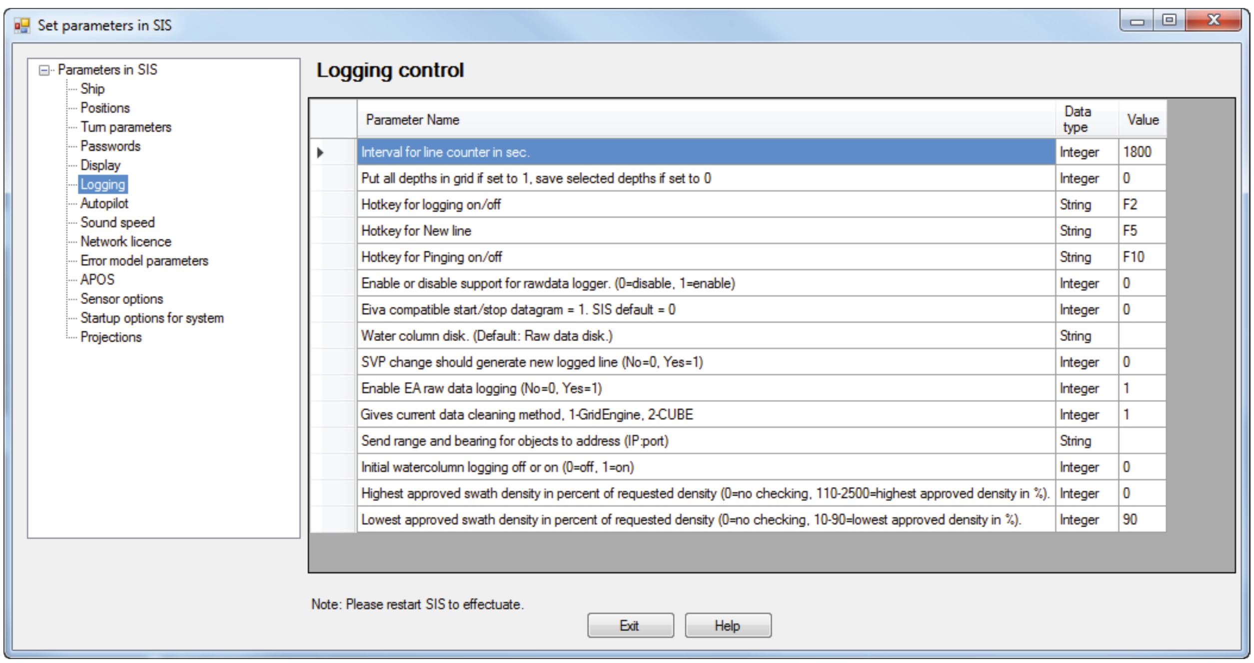
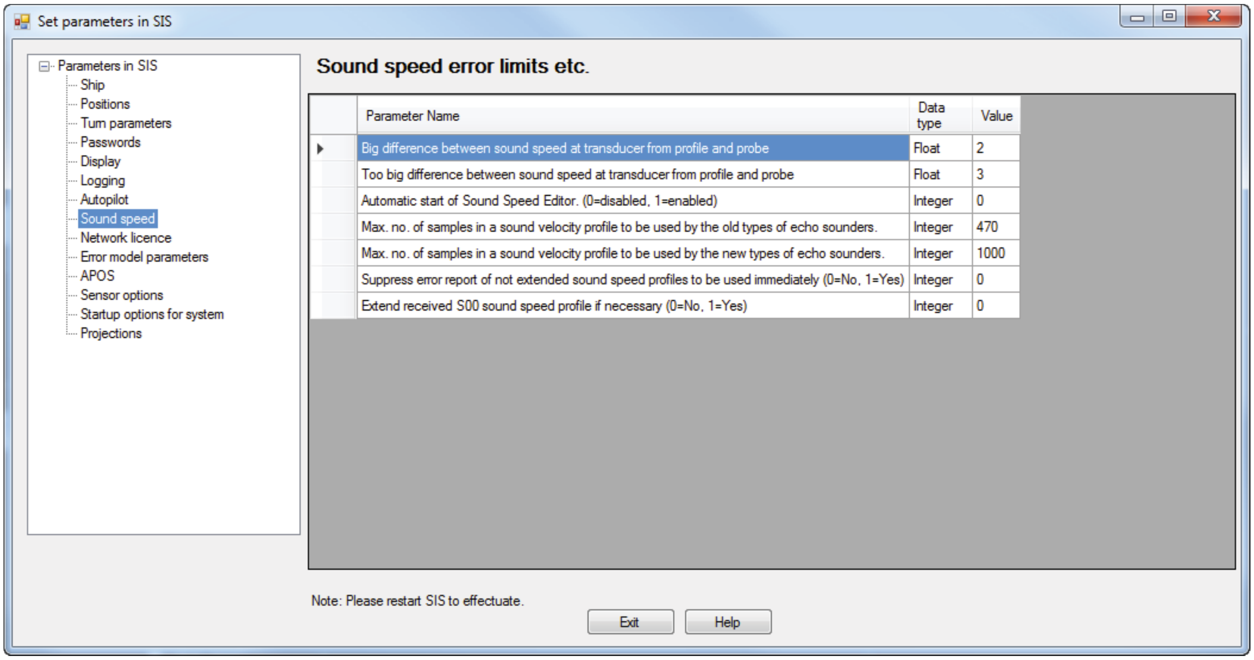
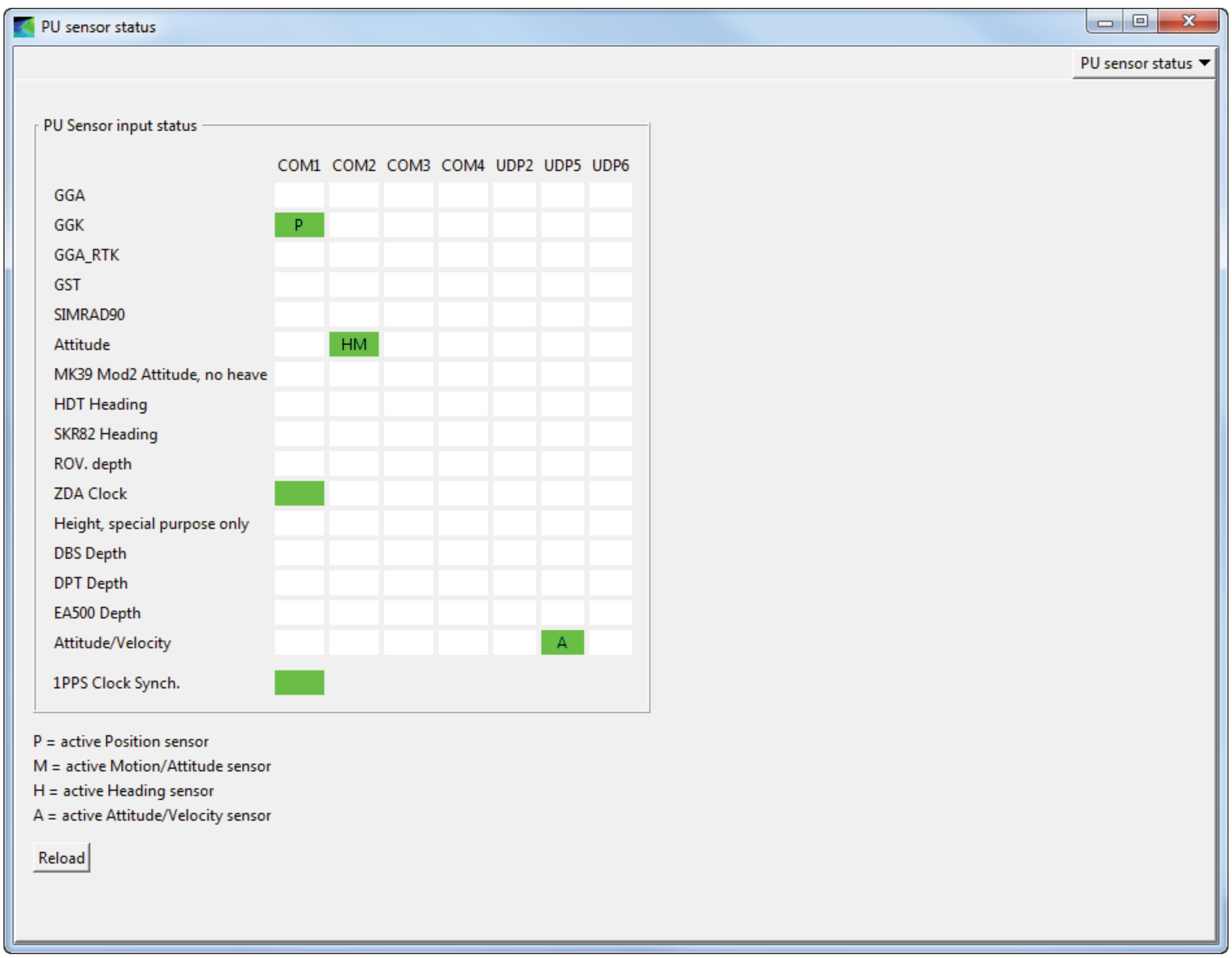
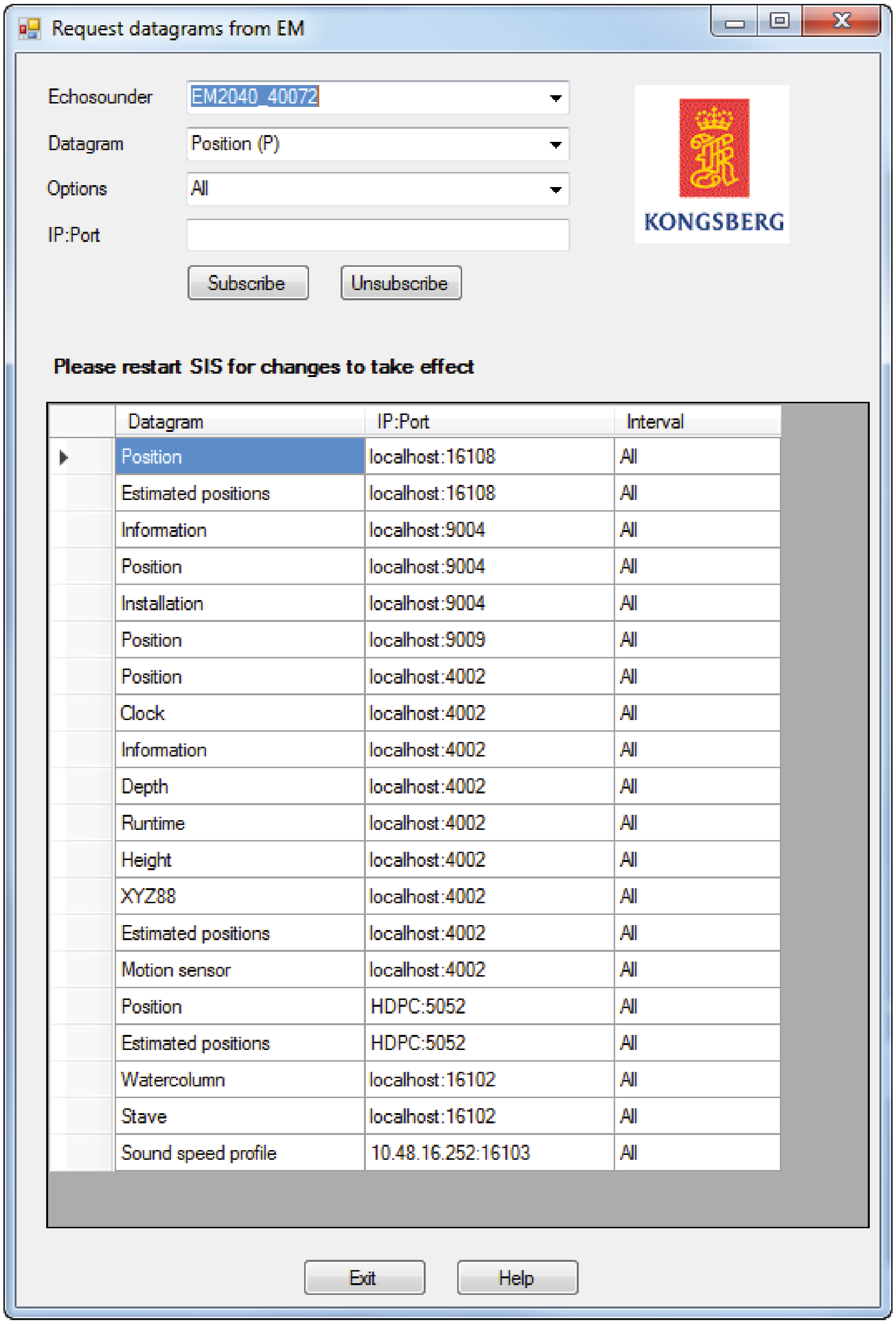
10.48.16.251:6001
-1

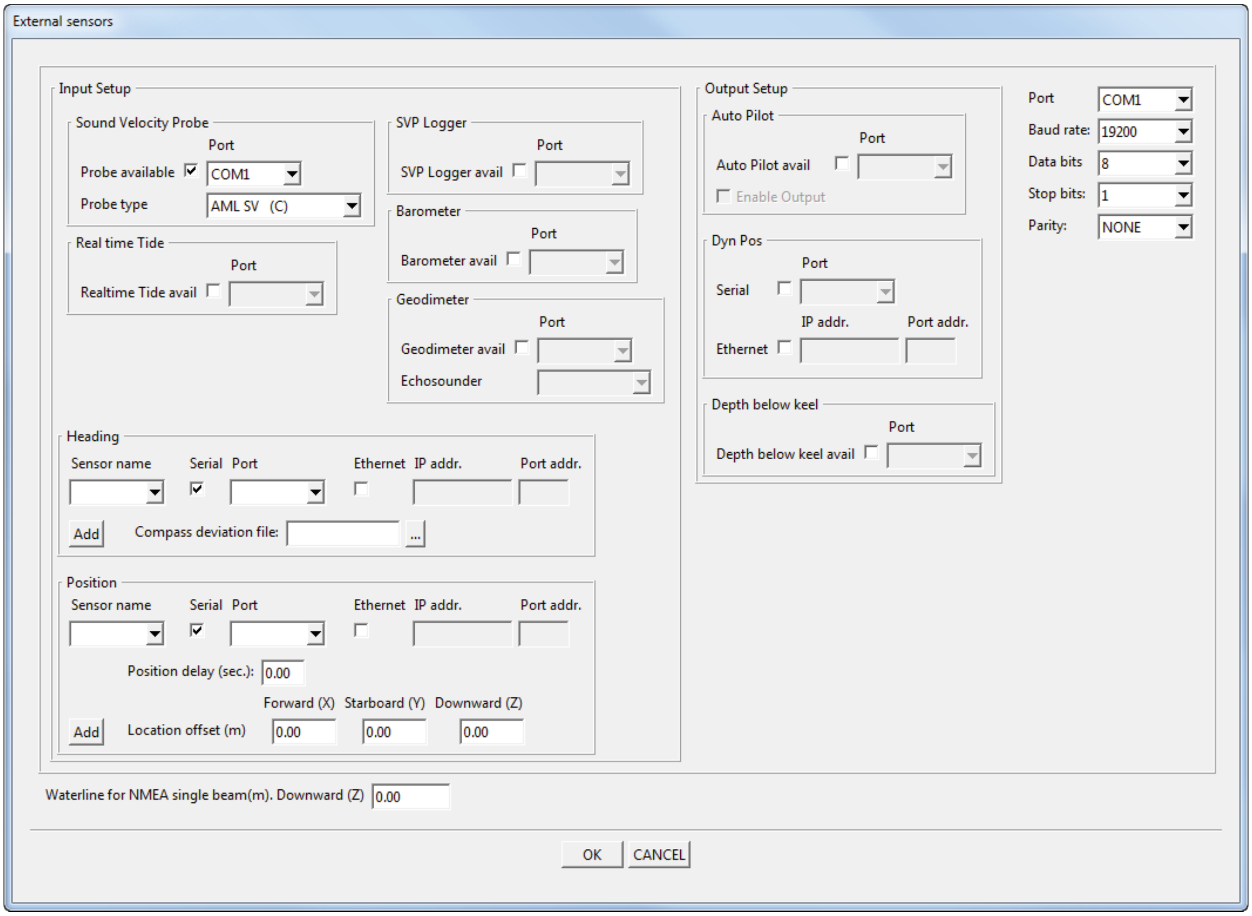

Set parameters in SIS
Parameters in SIS
Ship
Positions
Turn parameters
Passwords
Display
Logging
Autopilot
Sound speed
Network licence
Error model parameters
APOS
Sensor options
Startup options for system
Projections
Logging control
Parameter Name
Data type
Value
Interval for line counter in sec. Integer 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

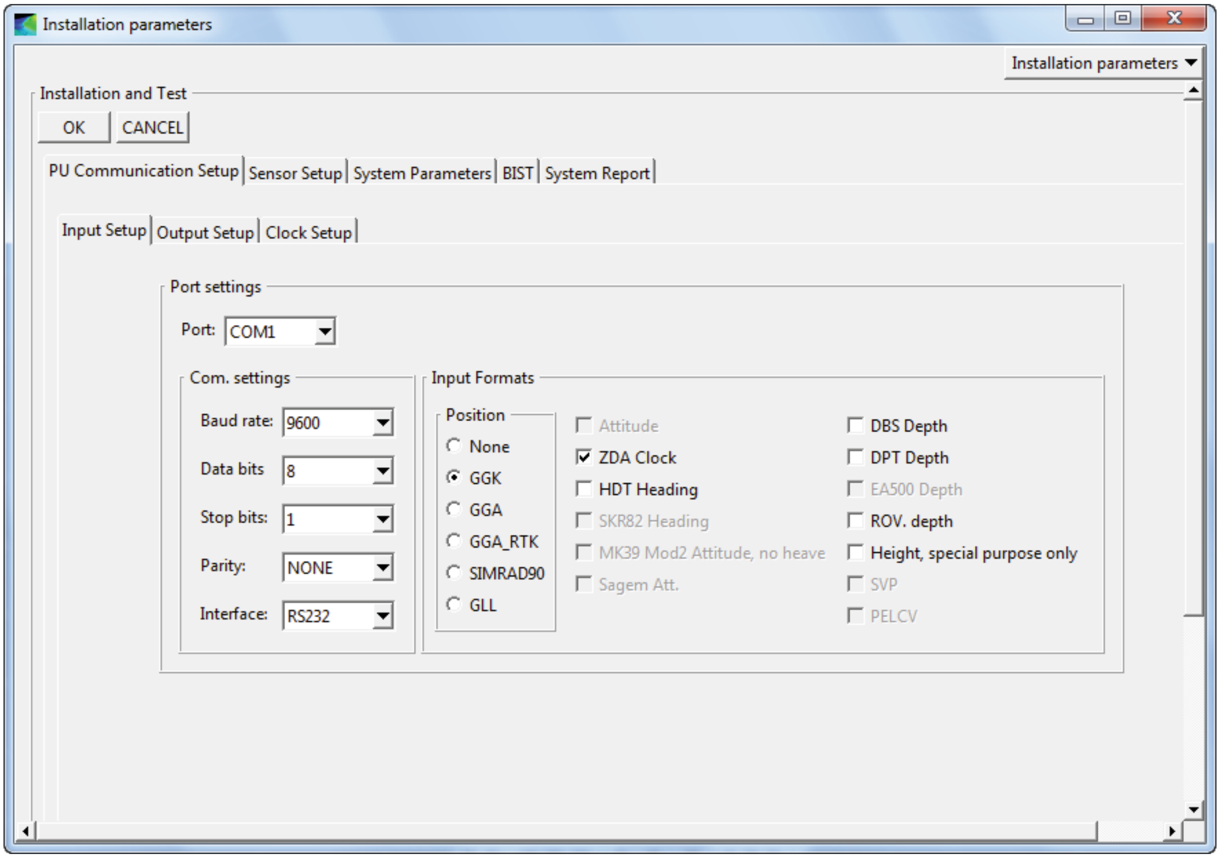

PU sensor status
PU sensor status
PU Sensor input status
COM1 COM2 COM3 COM4 UDP2 UDP5 UDP6
GGA
GGK
P
GGA_RTK
GST
SIMRAD90
Attitude
HM
MK39 Mod2 Attitude, no heave
HDT Heading
SKR82 Heading
ROV. depth
ZDA Clock
Height, special purpose only
DBS Depth
DPT Depth
EA500 Depth
Attitude/Velocity
A
1PPS Clock Synch.
P = active Position sensor
M = active Motion/Attitude sensor
H = active Heading sensor
A = active Attitude/Velocity sensor
Reload

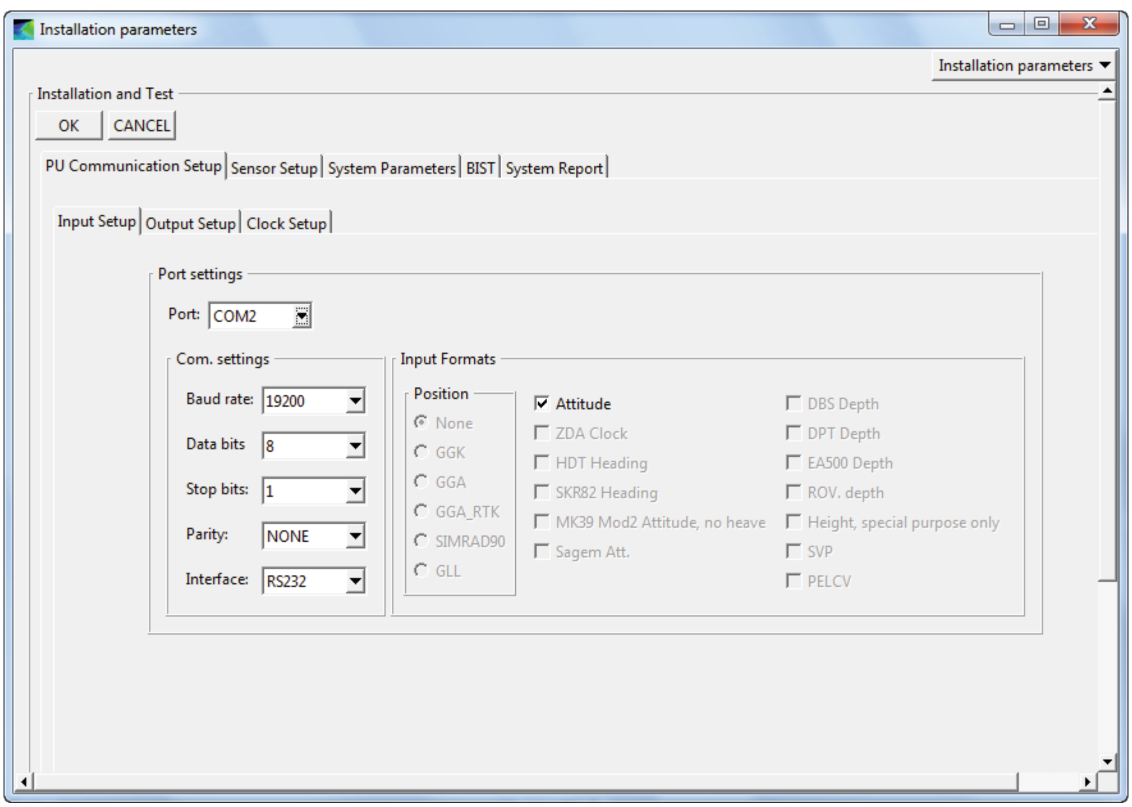


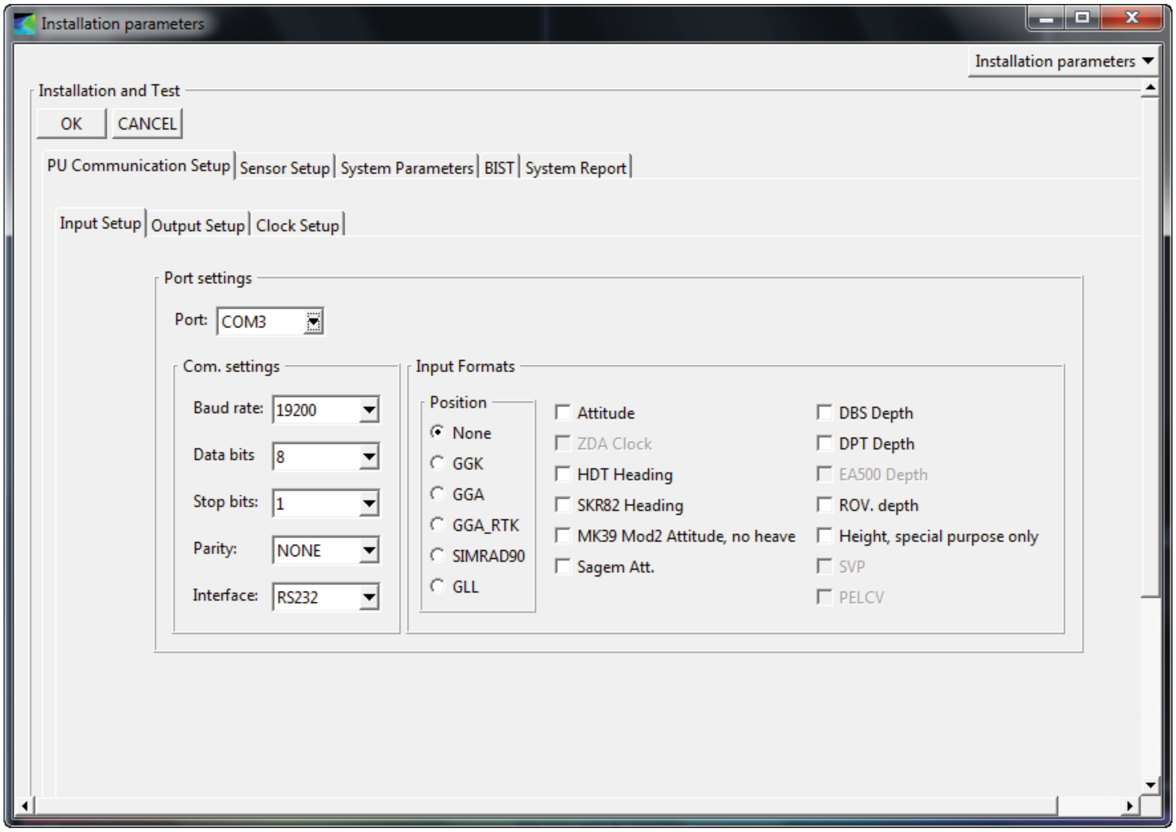
Datagram	IP:Port	Interval
Position	localhost:16108	All
Estimated positions	localhost:16108	All
Information	localhost:9004	All
Position	localhost:9004	All
Installation	localhost:9004	All
Position	localhost:9009	All
Position	localhost:4002	All
Clock	localhost:4002	All
Information	localhost:4002	All
Depth	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

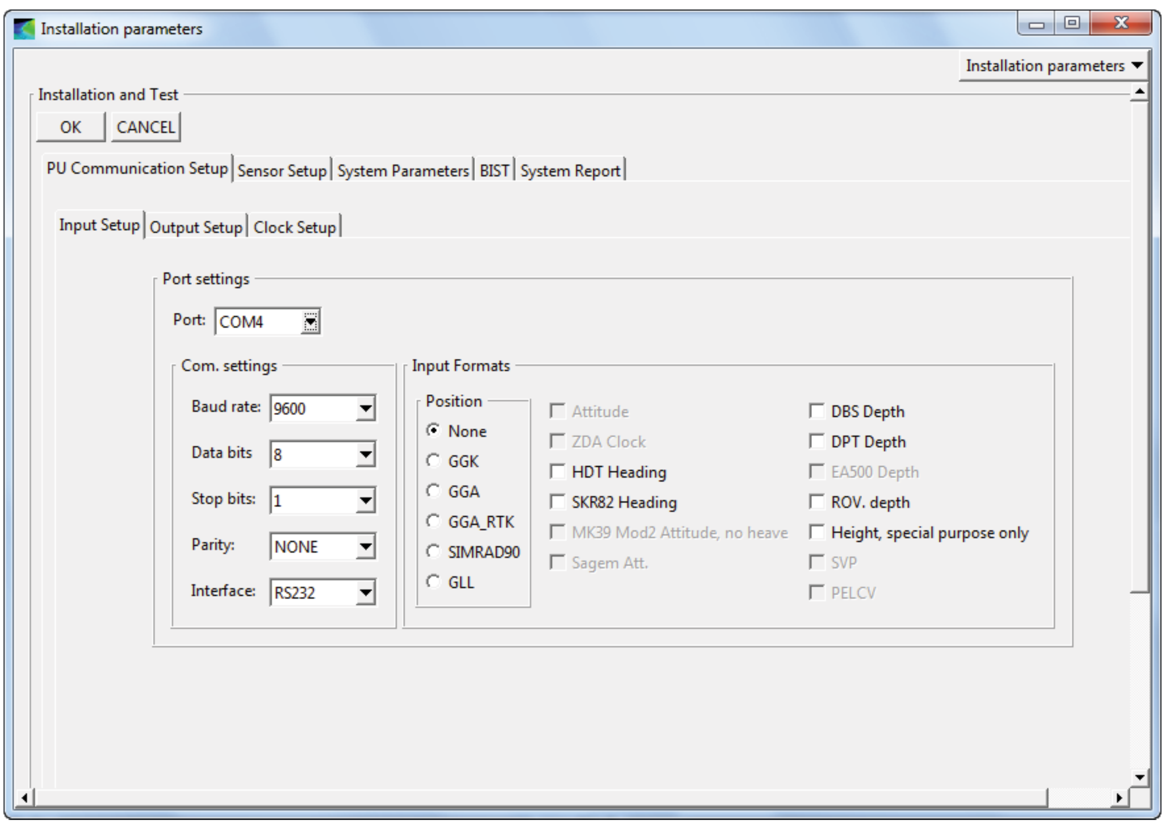

External sensors
Input Setup
Sound Velocity Probe
Port
Probe available
COM1
Probe type
AML SV (C)
SVP Logger
Port
SVP Logger avail
Barometer
Port
Barometer avail
Real time Tide
Port
Realtime Tide avail
Geodimeter
Port
Geodimeter avail
Echosounder
Heading
Sensor name
Serial
Port
Ethernet
IP addr.
Port 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

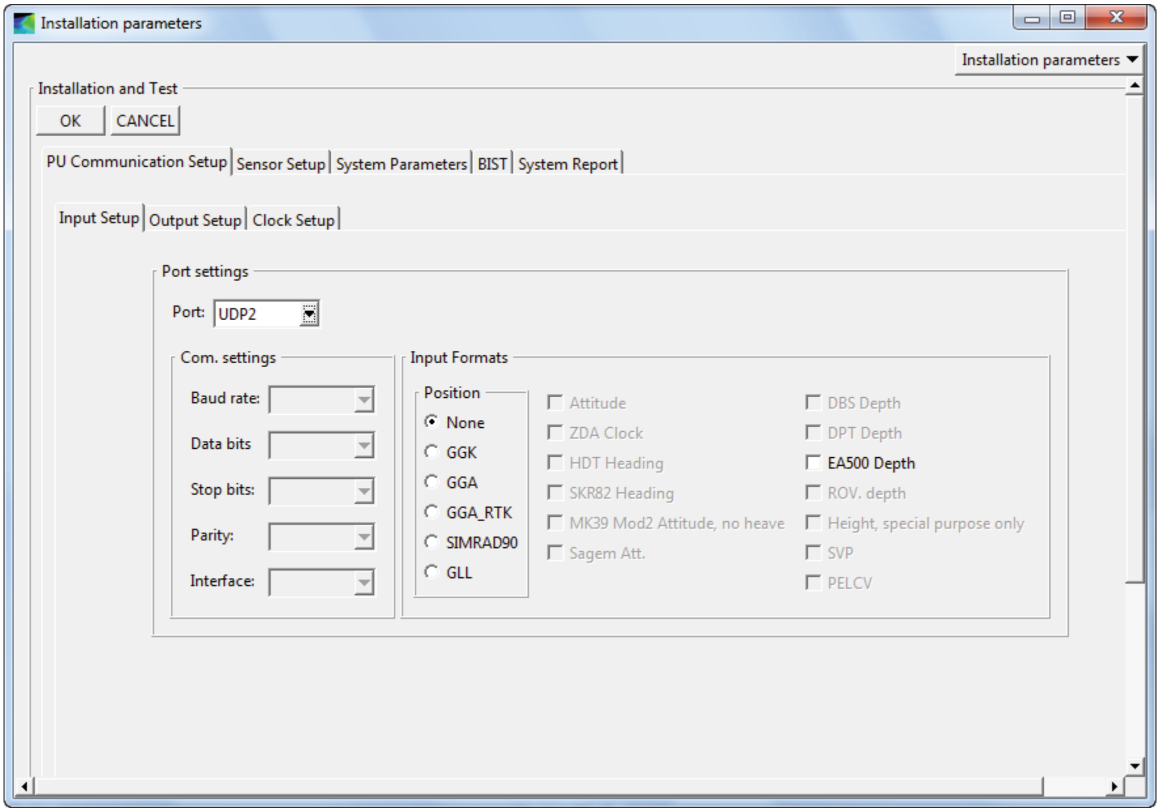
10.1.1.2 EM710

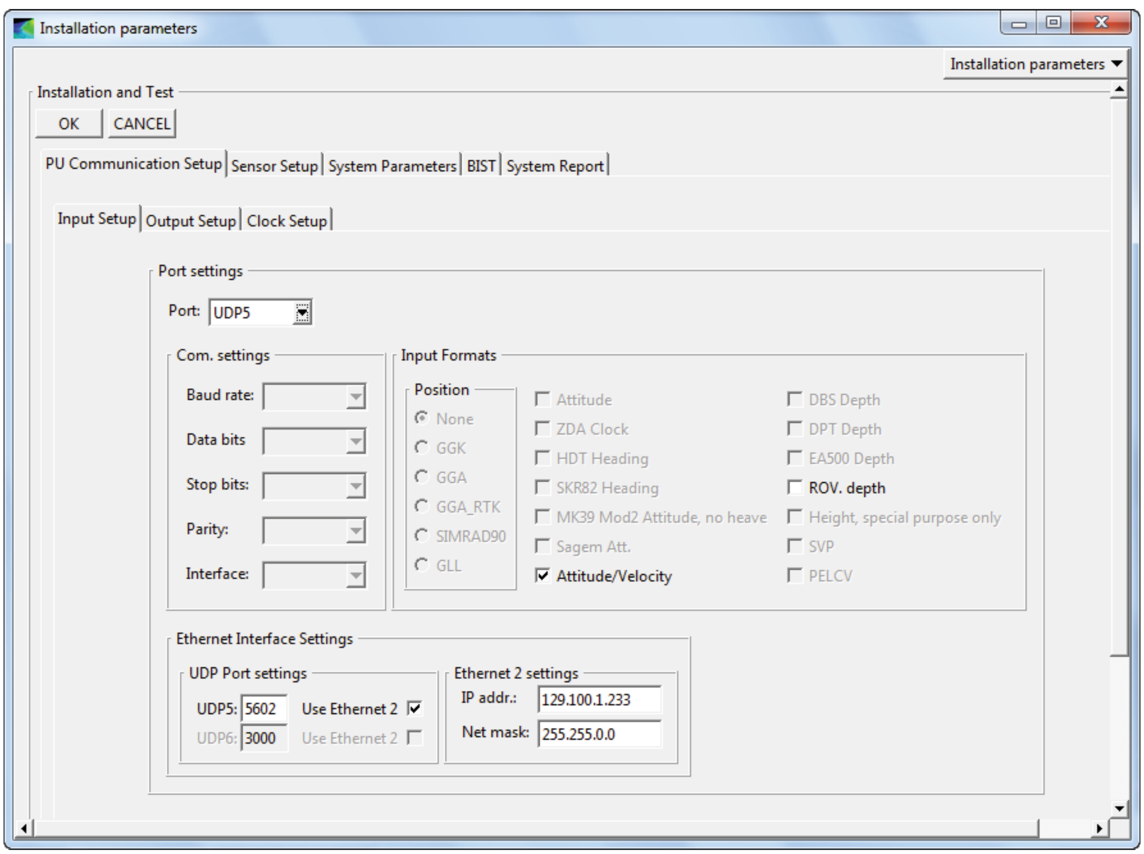

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: COM1
Com. settings
Baud rate: 9600
Data bits 8
Stop bits: 1
Parity: NONE
Interface: RS232
Input 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

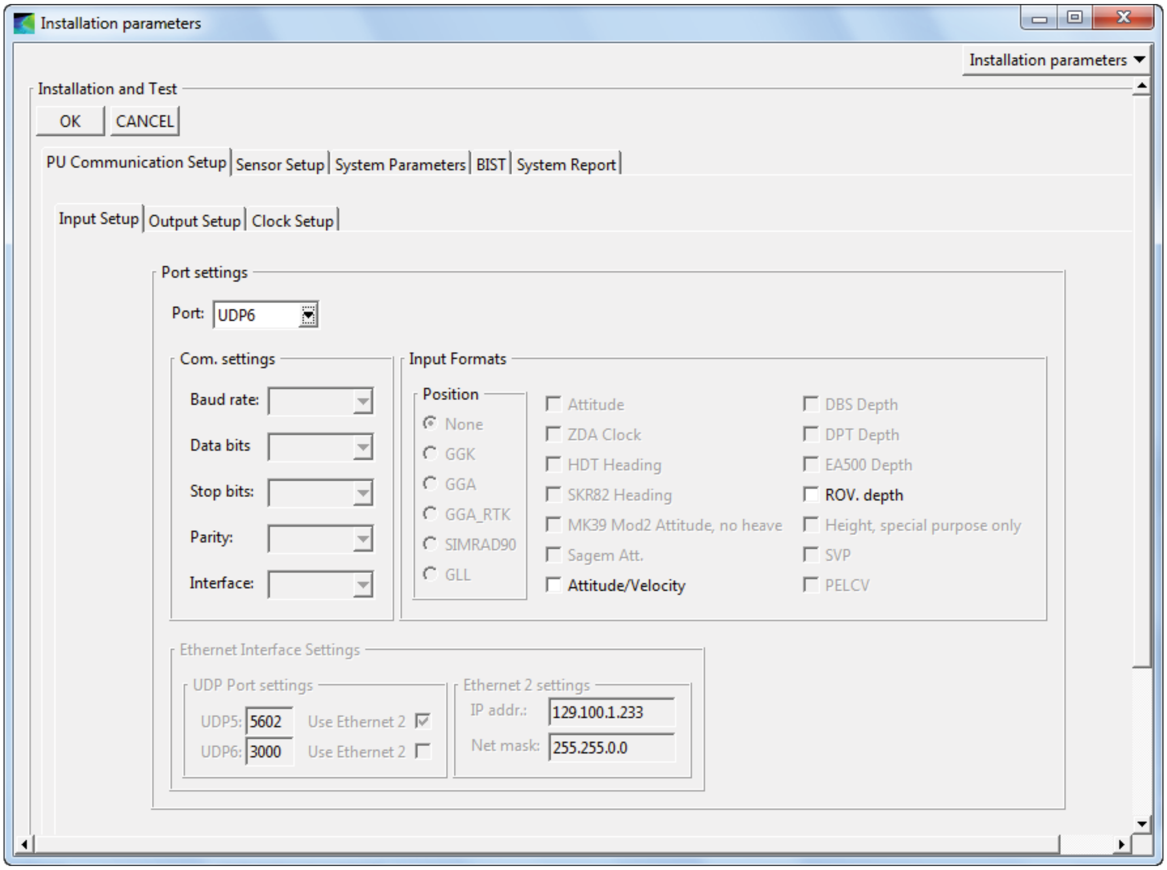

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: COM2
Com. settings
Baud rate: 19200
Data bits 8
Stop bits: 1
Parity: NONE
Interface: RS232
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

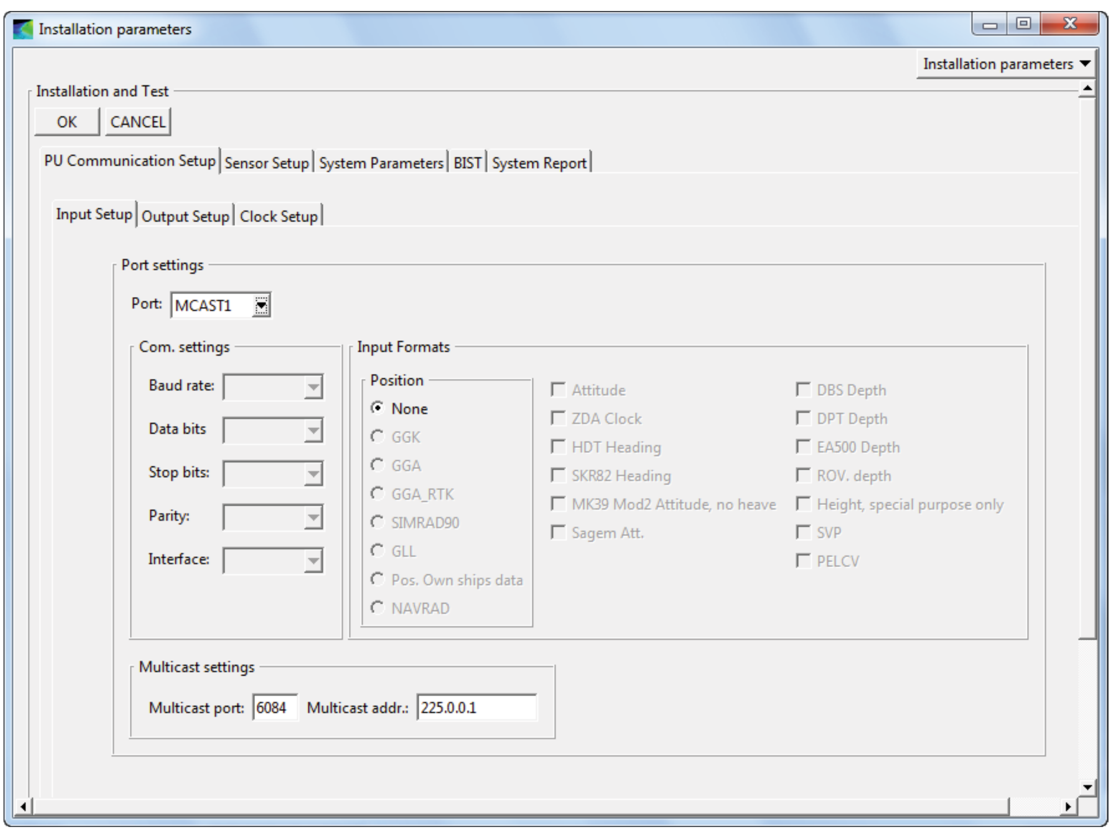

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: COM3
Com. settings
Baud rate: 19200
Data bits 8
Stop bits: 1
Parity: NONE
Interface: RS232
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

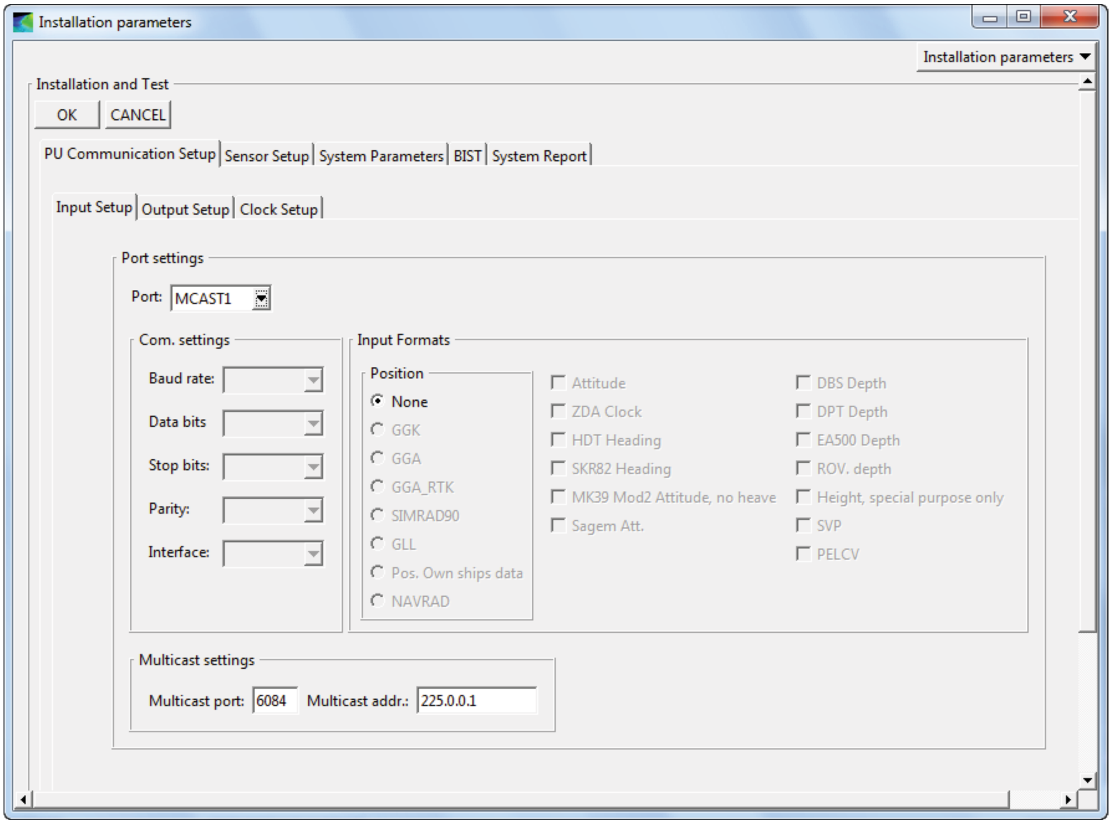

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: COM4
Com. settings
Baud rate: 9600
Data bits 8
Stop bits: 1
Parity: NONE
Interface: RS232
Input 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

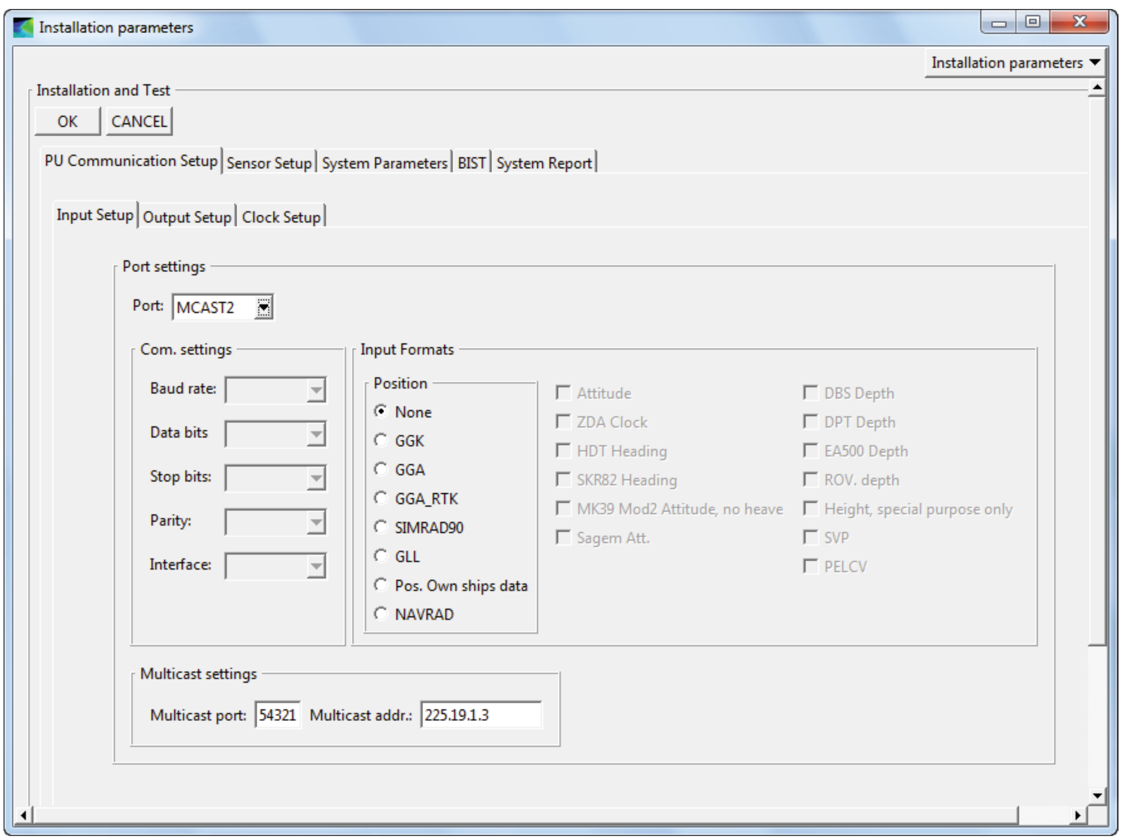

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: UDP2
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
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

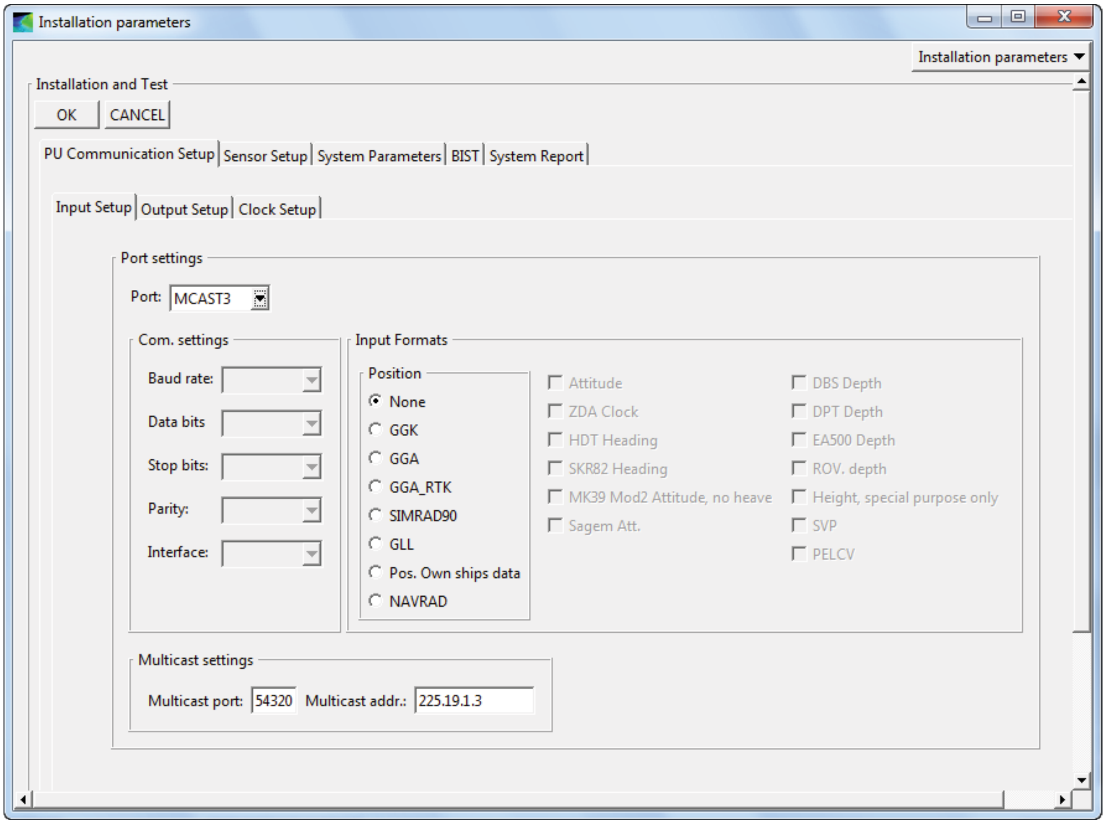

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: UDP5
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
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

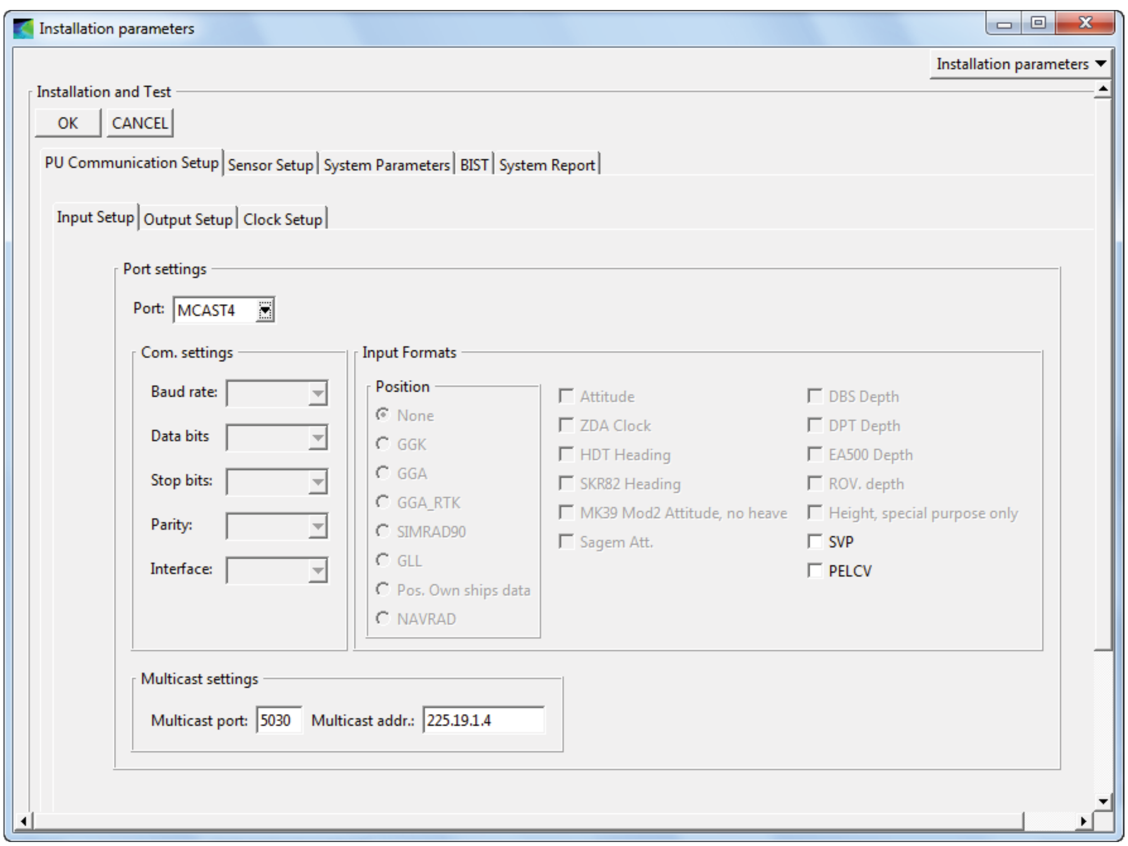

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: UDP6
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
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

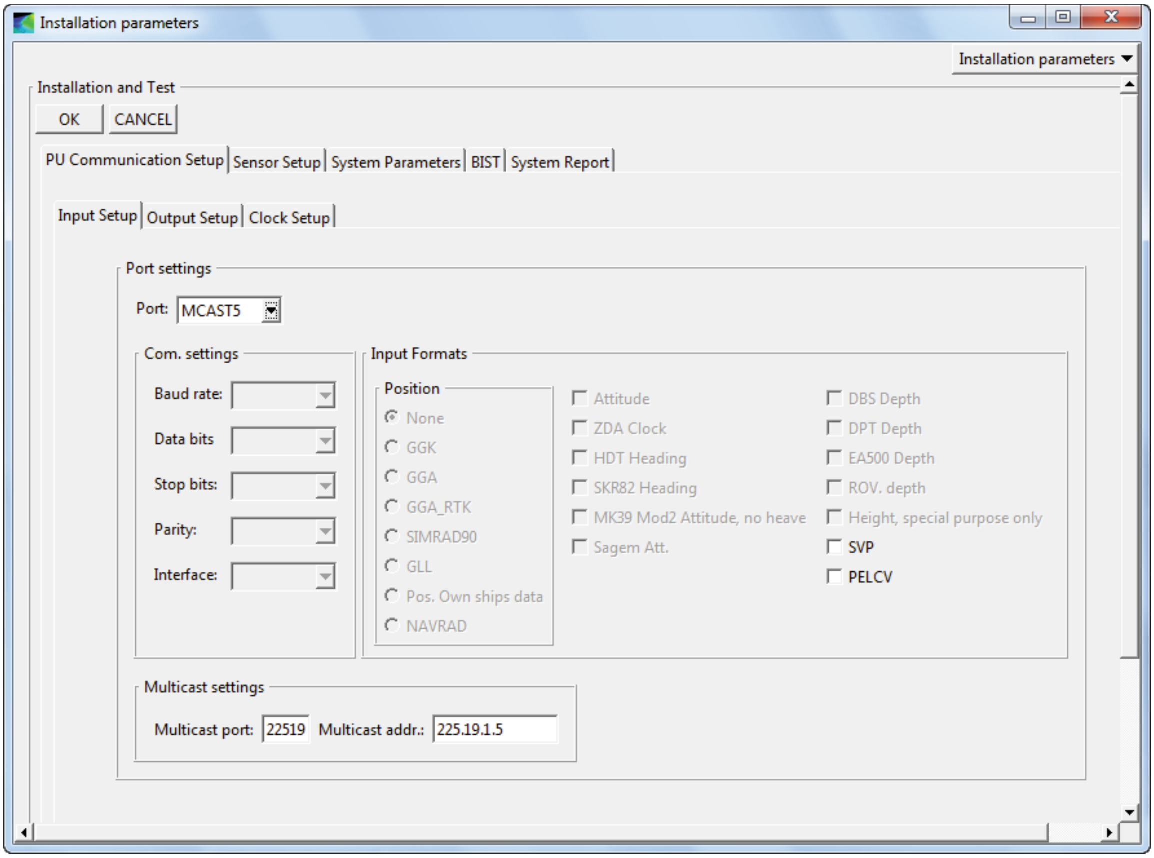

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: MCAST1
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
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

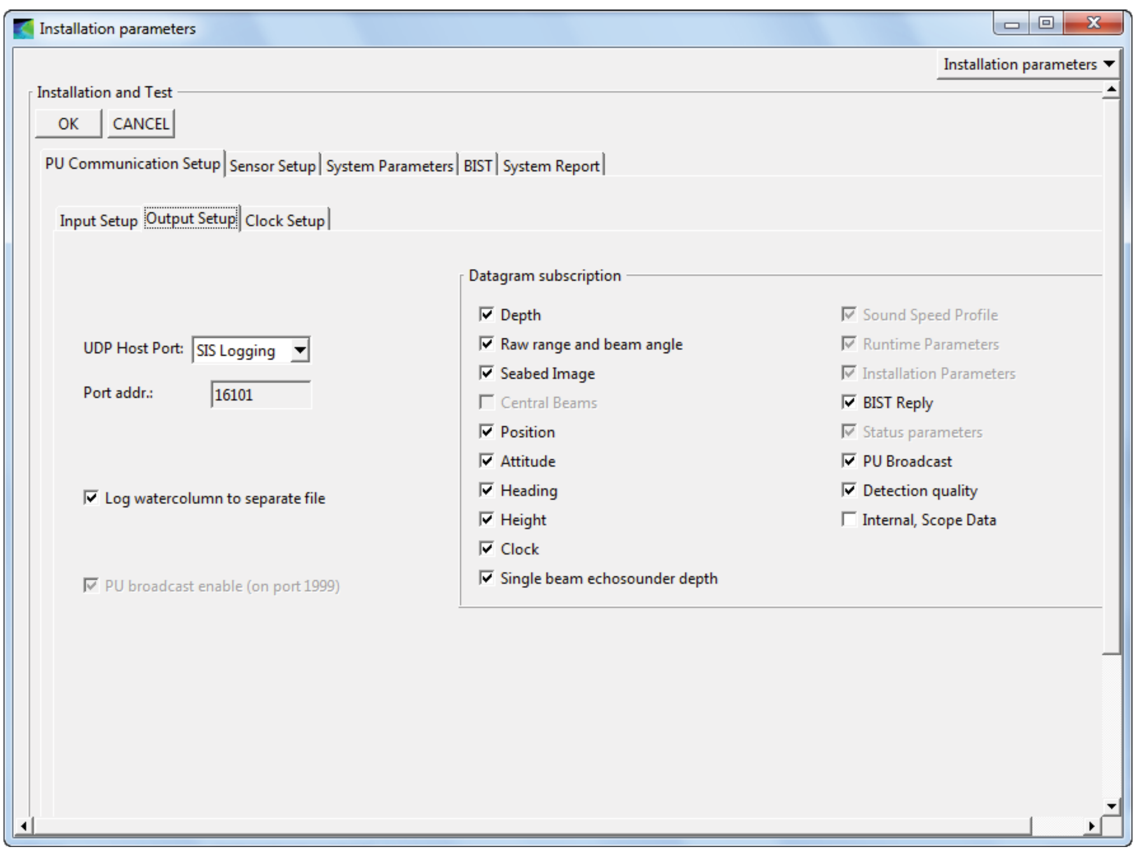

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port:
MCAST1
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
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

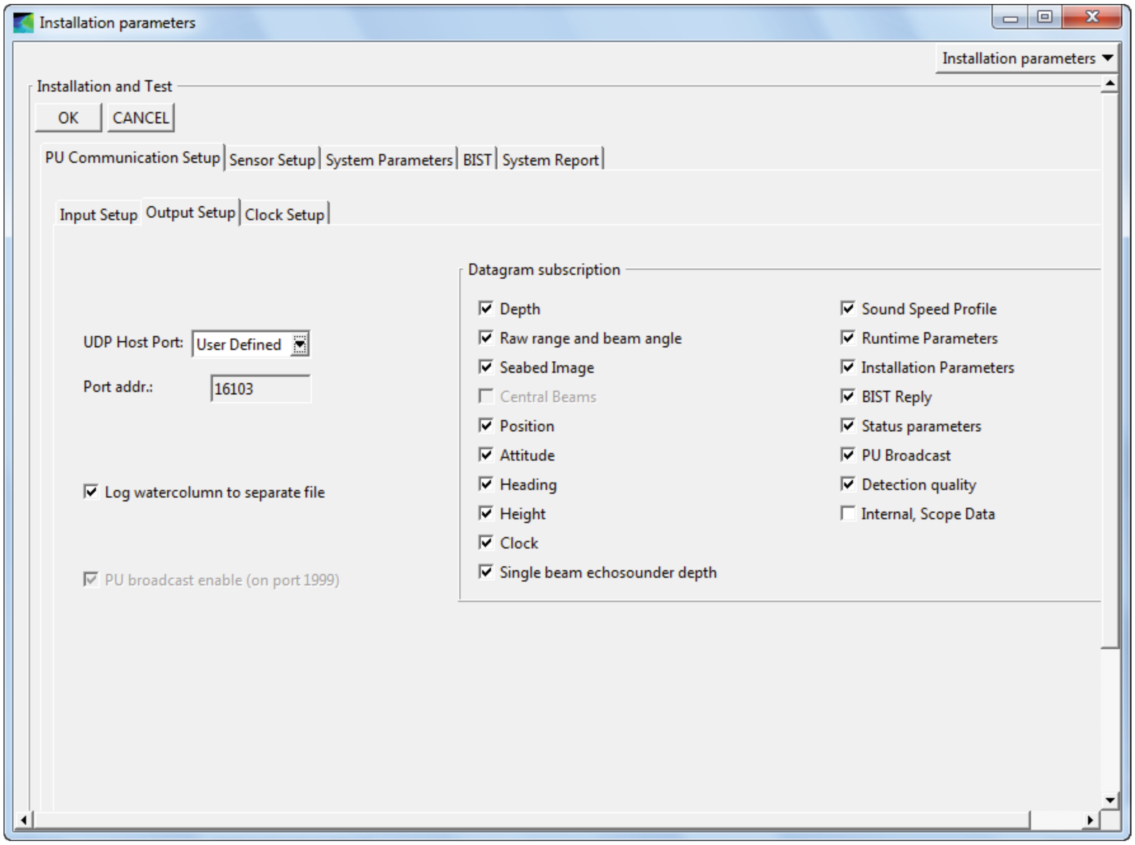

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port:
MCAST2
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
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

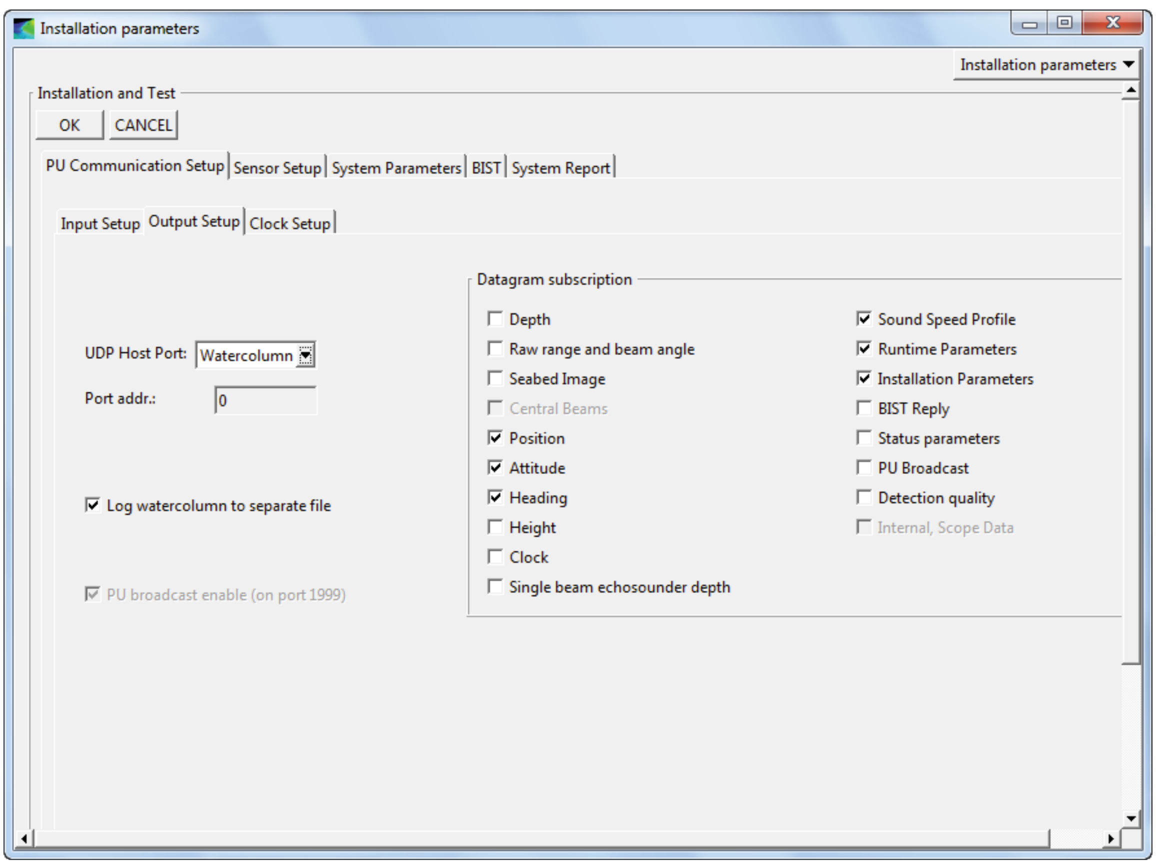

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port:
MCAST3
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
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

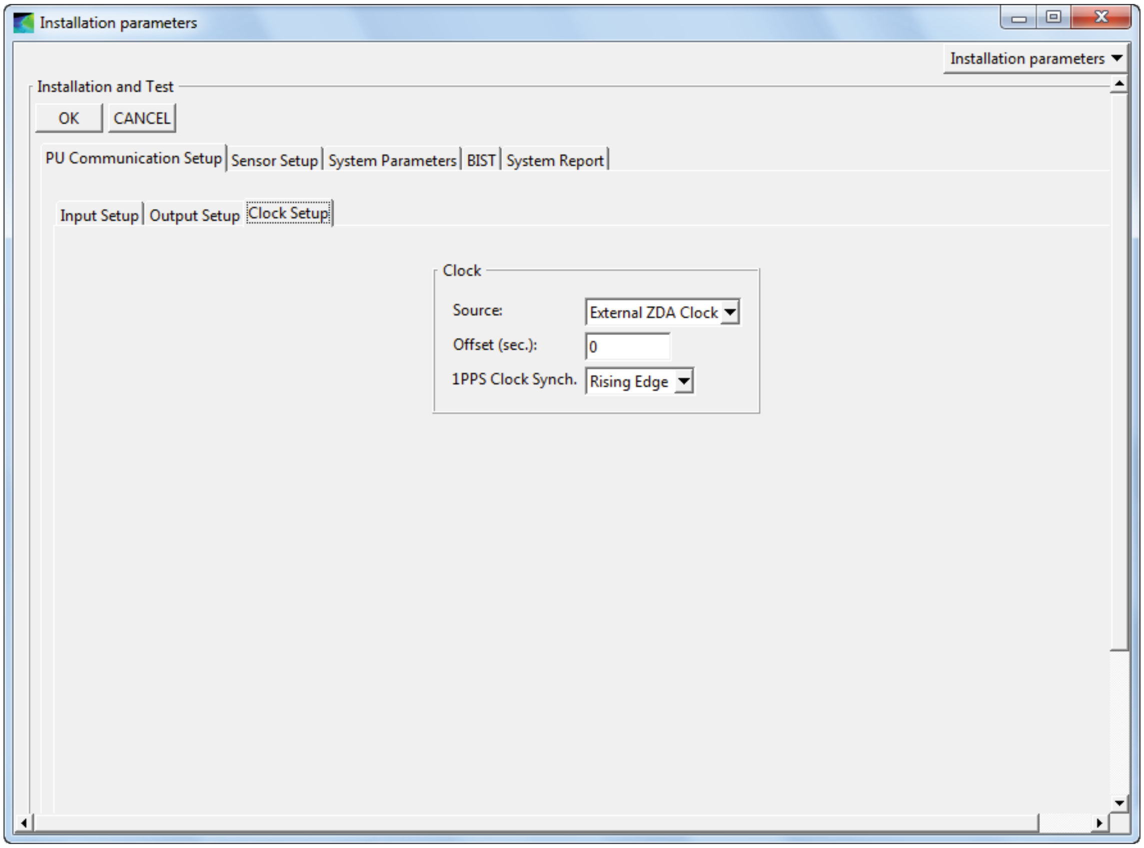

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port:
MCAST4
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
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

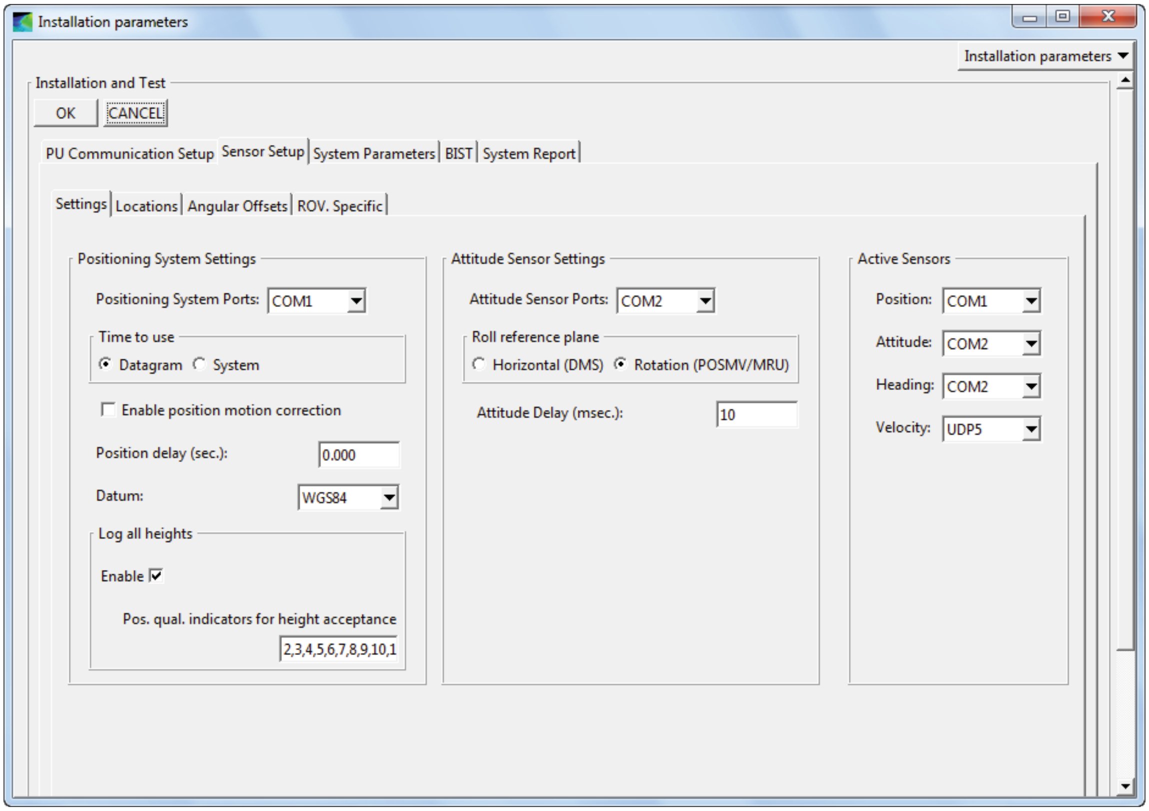

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: MCAST5
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
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

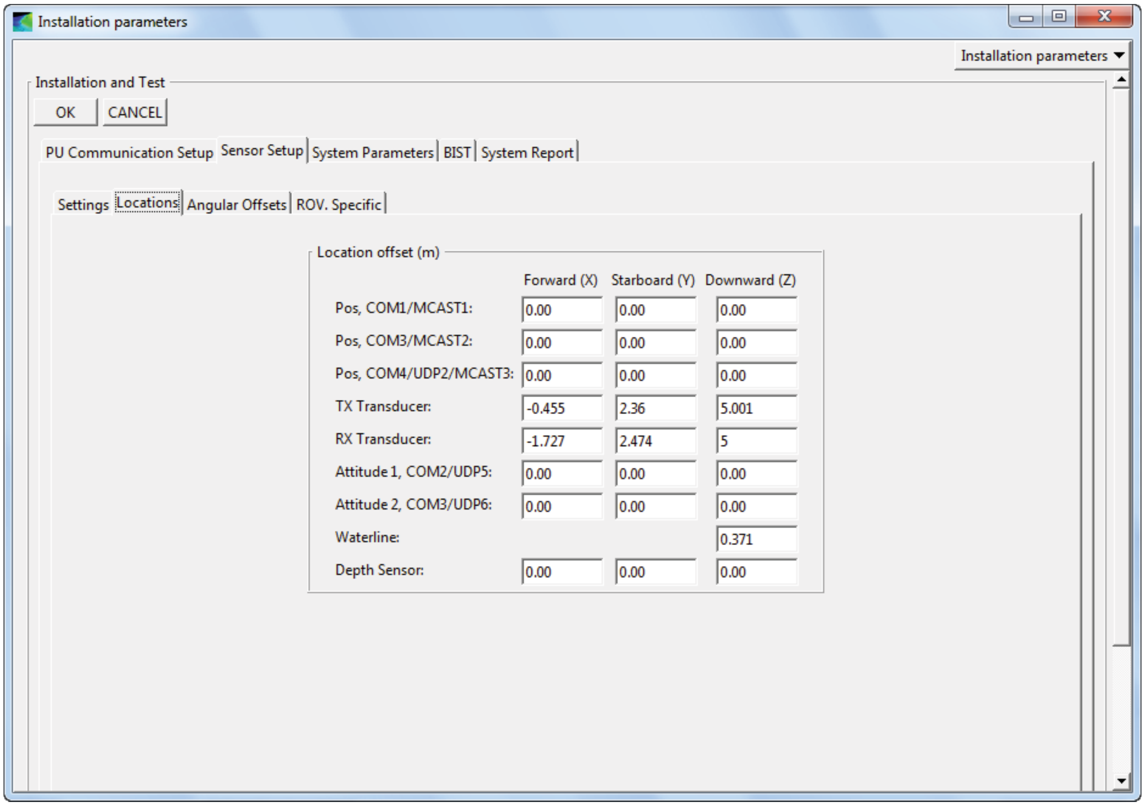

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port: SIS Logging
Port addr.: 16101
Log watercolumn to separate file
PU broadcast enable (on port 1999)
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

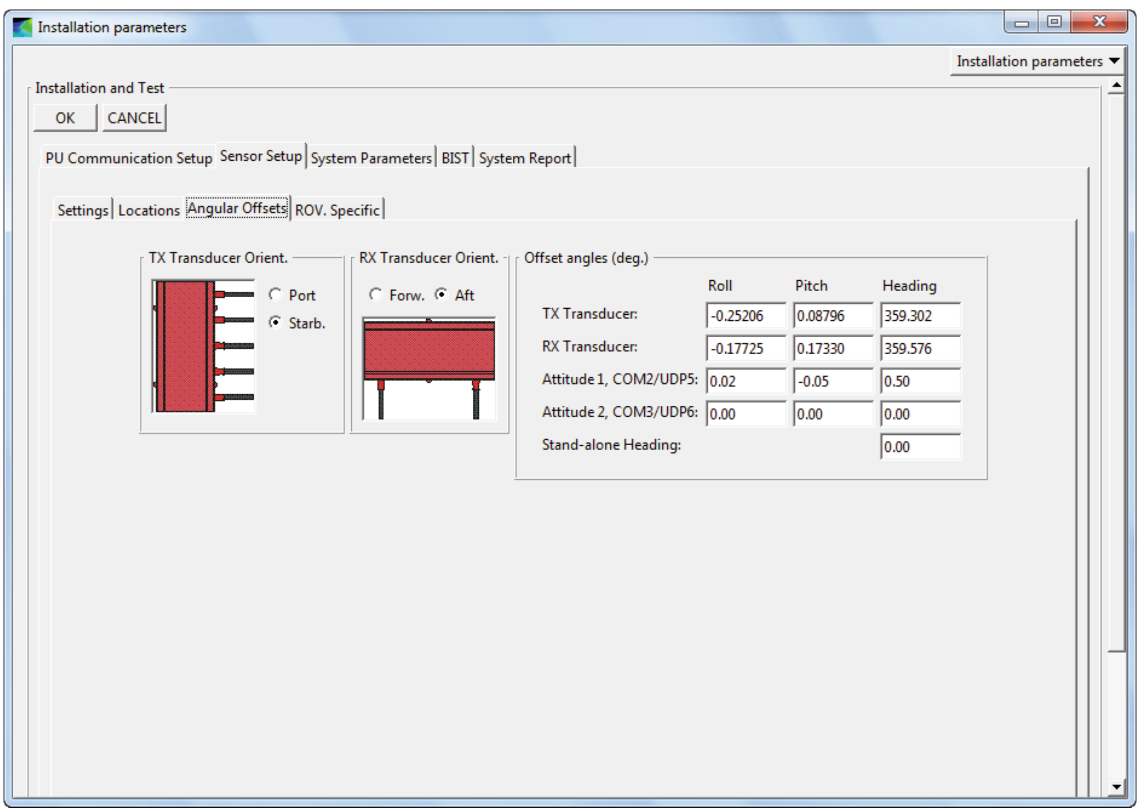

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port:
User Defined
Port addr.:
16103
Log watercolumn to separate file
PU broadcast enable (on port 1999)
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

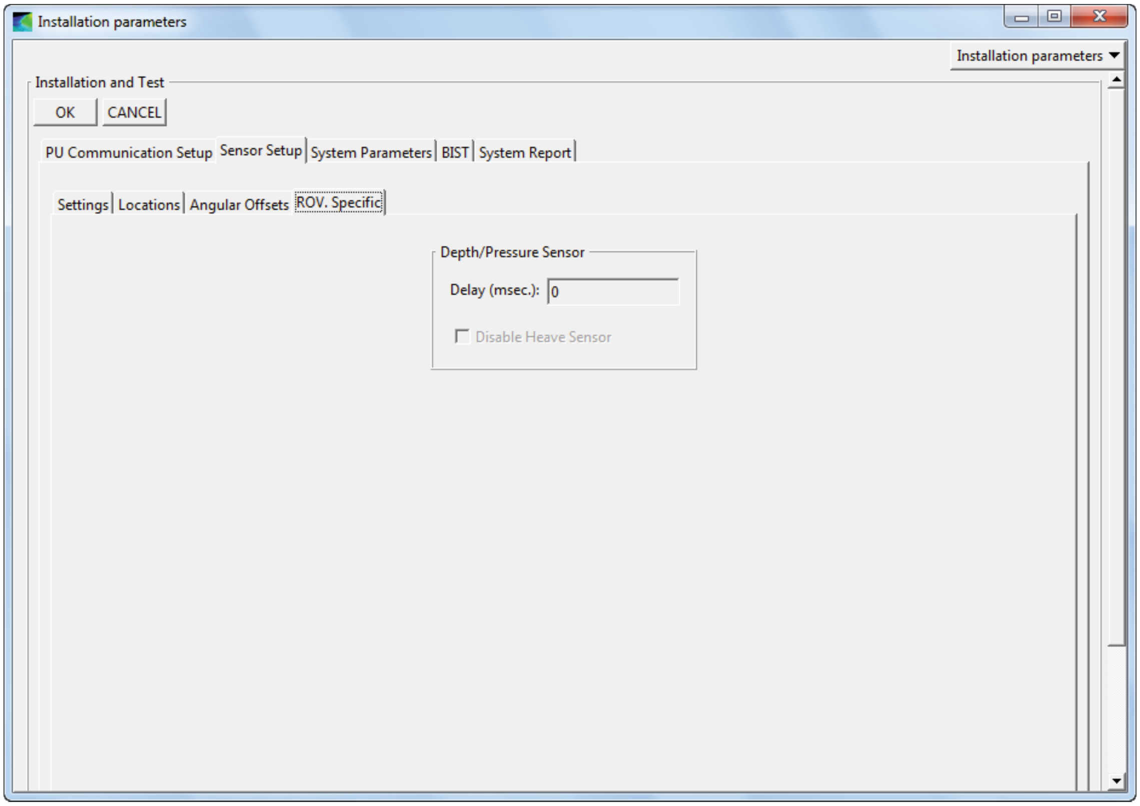

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port:
Watercolumn
Port addr.:
0
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram 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

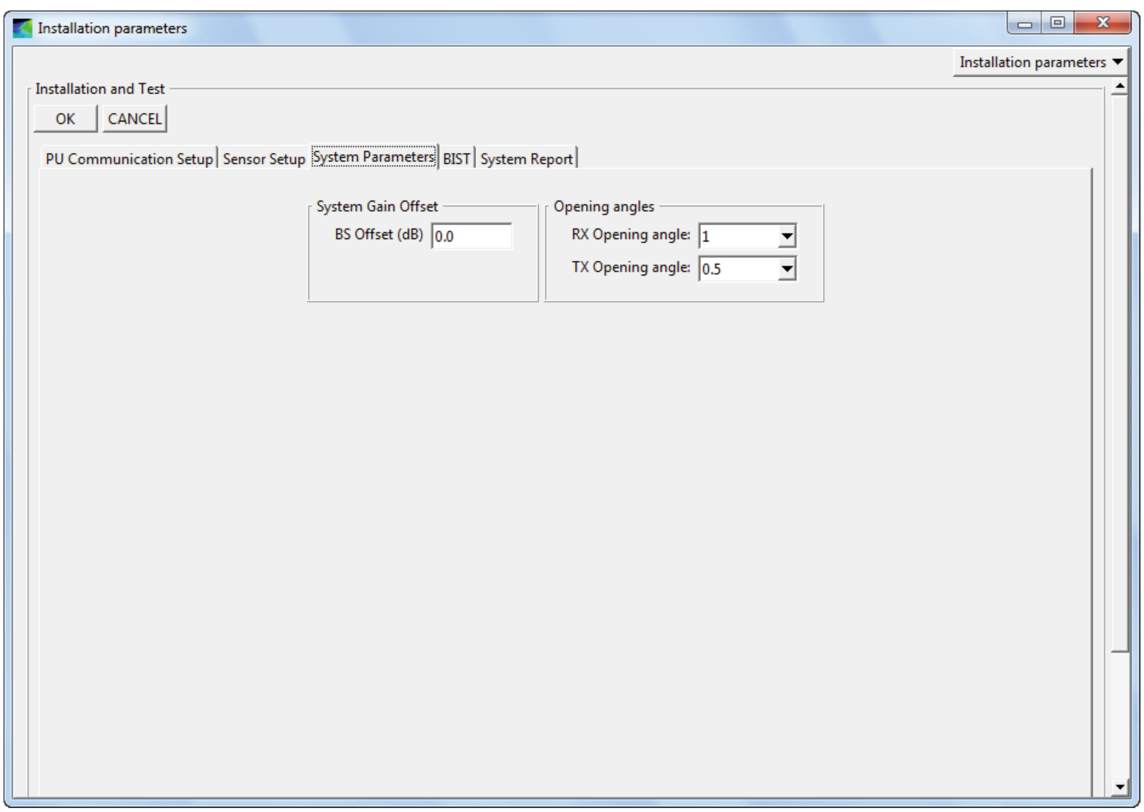

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
Positioning System Settings
Positioning System Ports:
COM1
Time to use
Datagram
System
Enable position 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

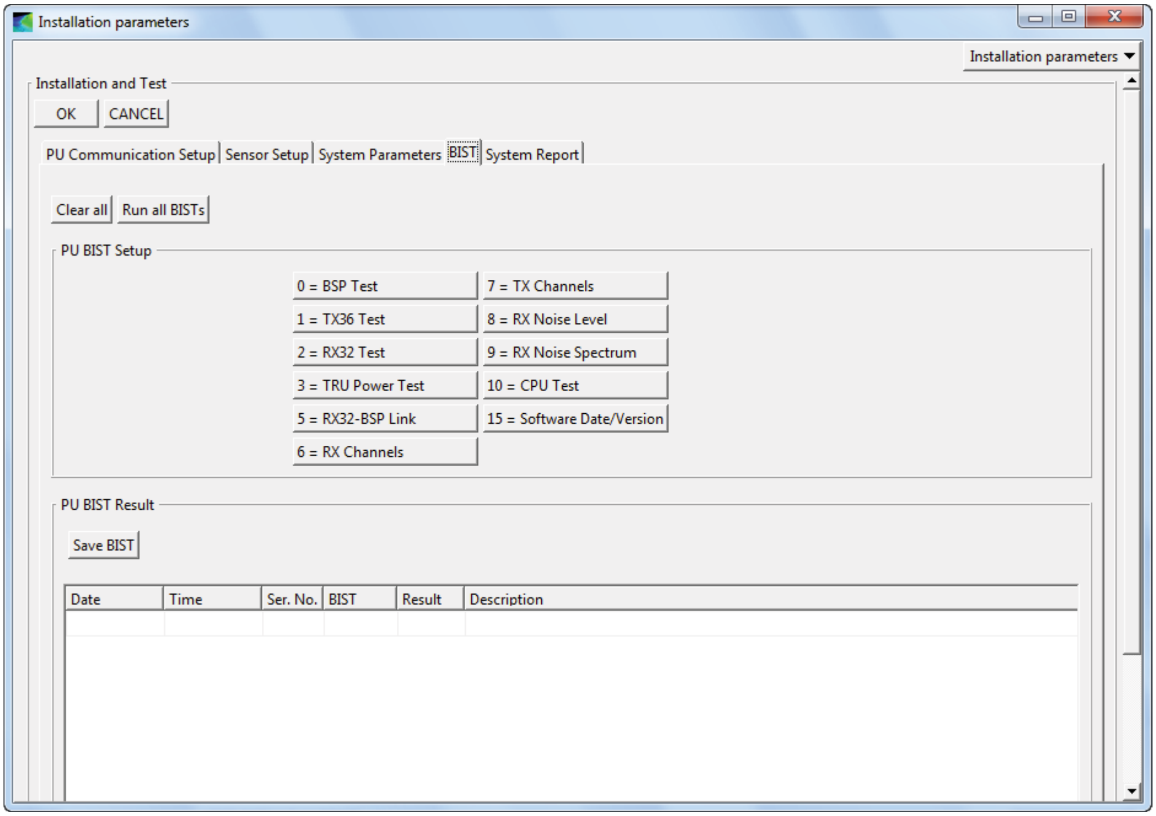

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
TX Transducer Orient.
Port
Starb.
RX Transducer Orient.
Forw.
Aft
Offset angles (deg.)
Roll
Pitch
Heading
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

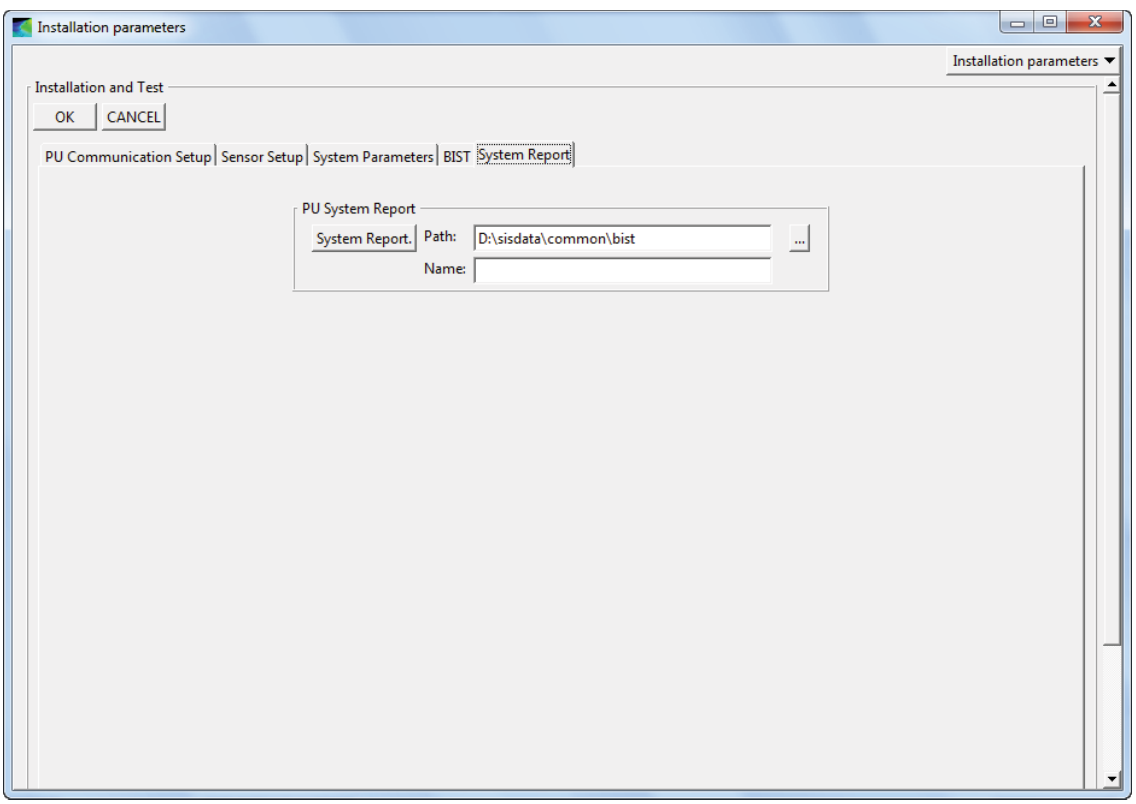


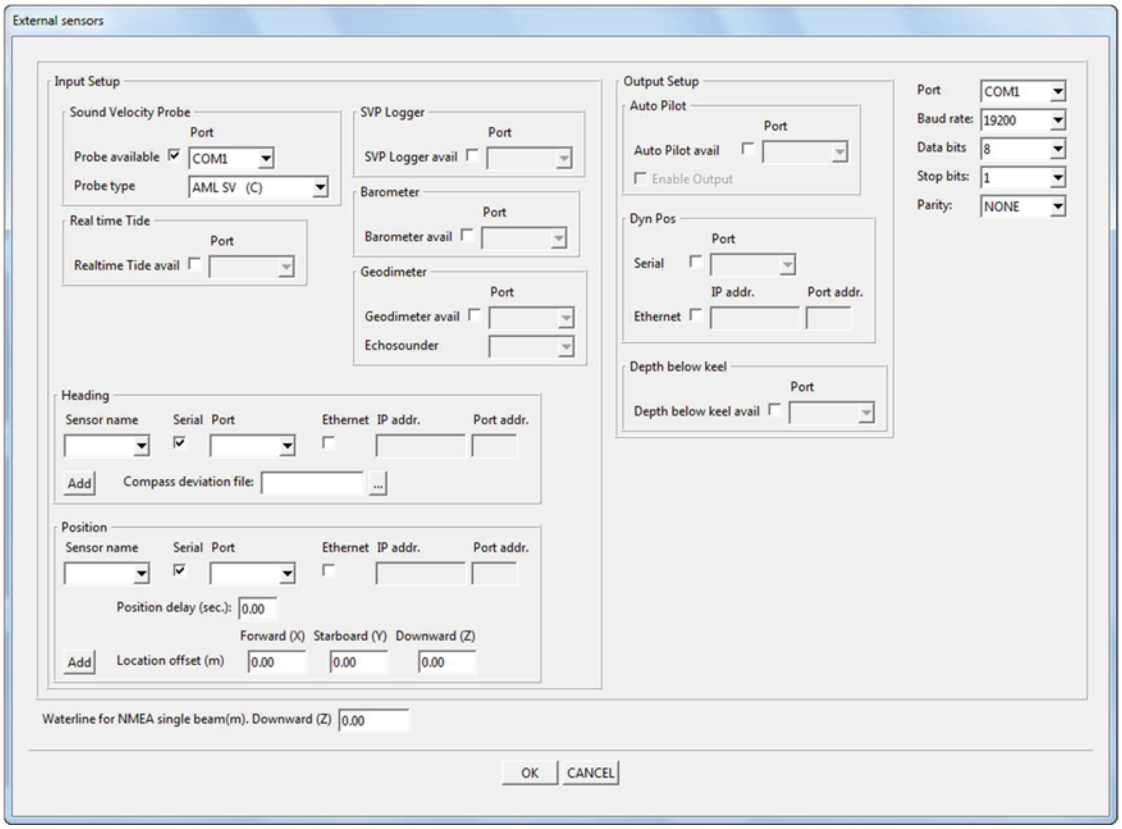
Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
Depth/Pressure Sensor
Delay (msec.):
0
Disable Heave Sensor

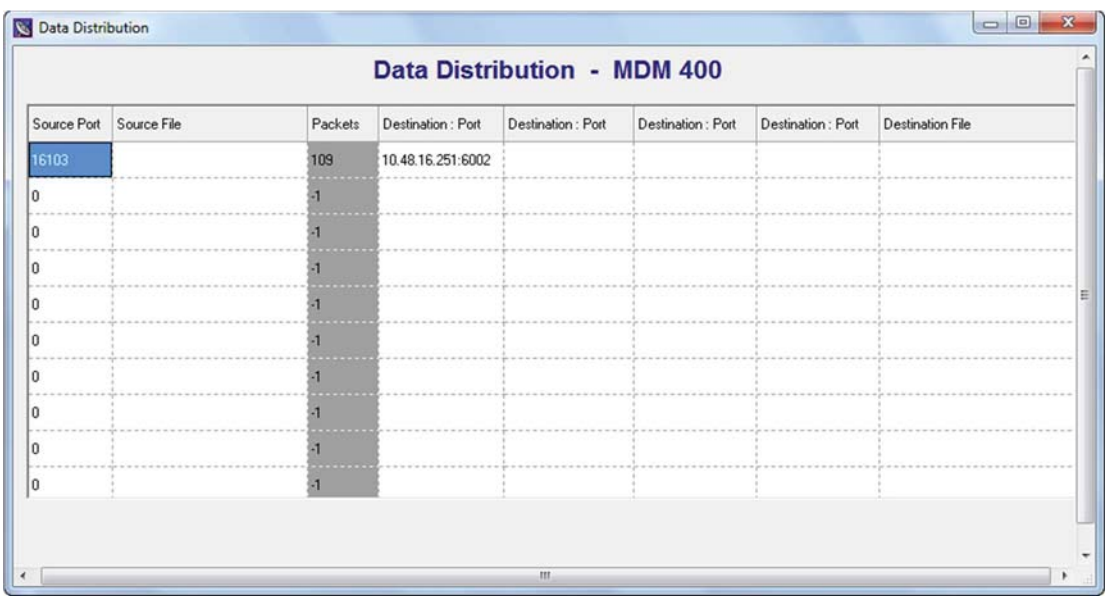


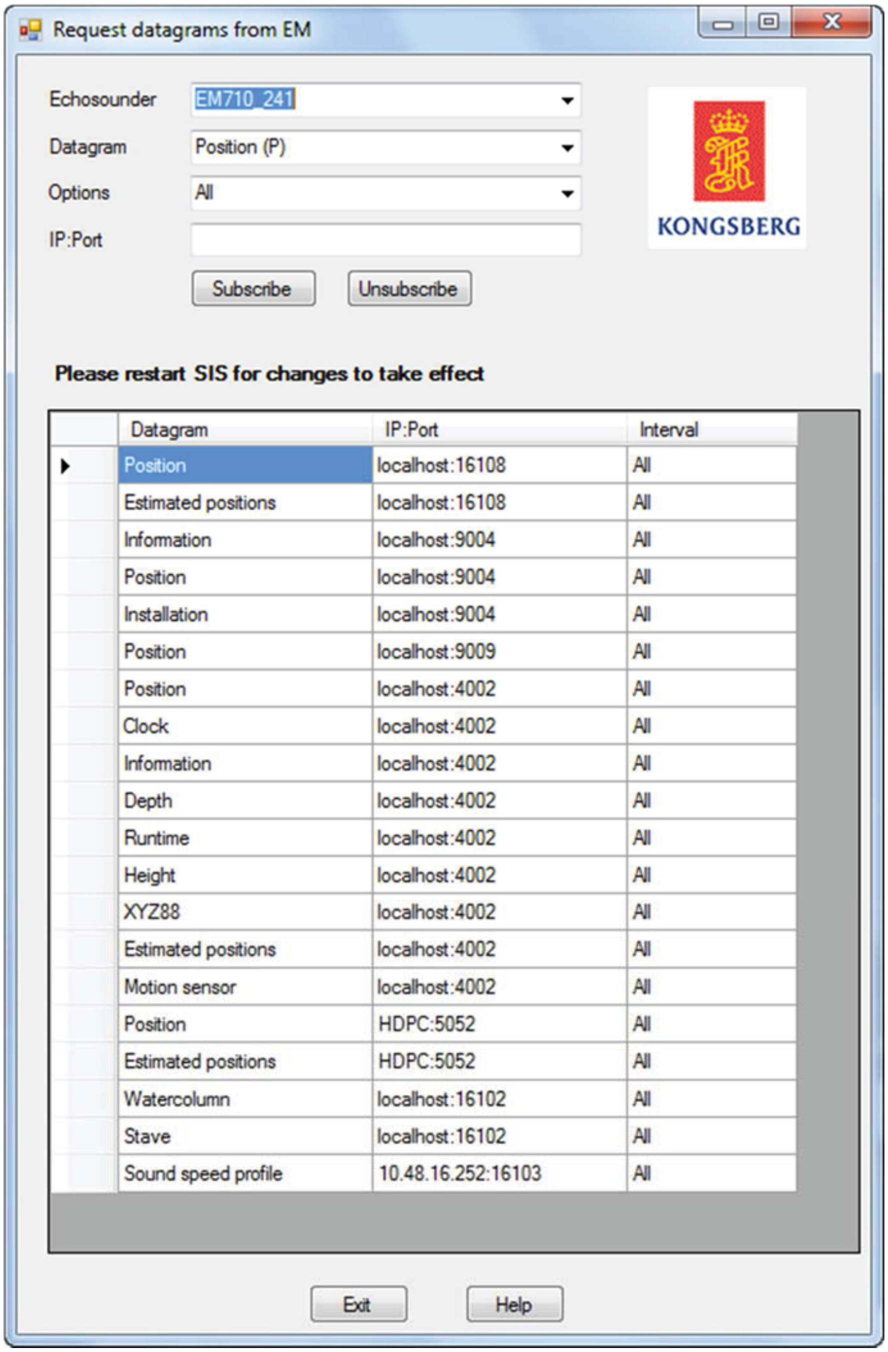
Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
System Gain Offset
BS Offset (dB)
0.0
Opening angles
RX Opening angle:
1
TX Opening angle:
0.5


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
1 = TX36 Test
2 = RX32 Test
3 = TRU Power Test
5 = RX32-BSP Link
6 = RX Channels
7 = TX Channels
8 = RX Noise Level
9 = RX Noise Spectrum
10 = CPU Test
15 = Software Date/Version
PU BIST Result
Save BIST
Date
Time
Ser. No.
BIST
Result
Description

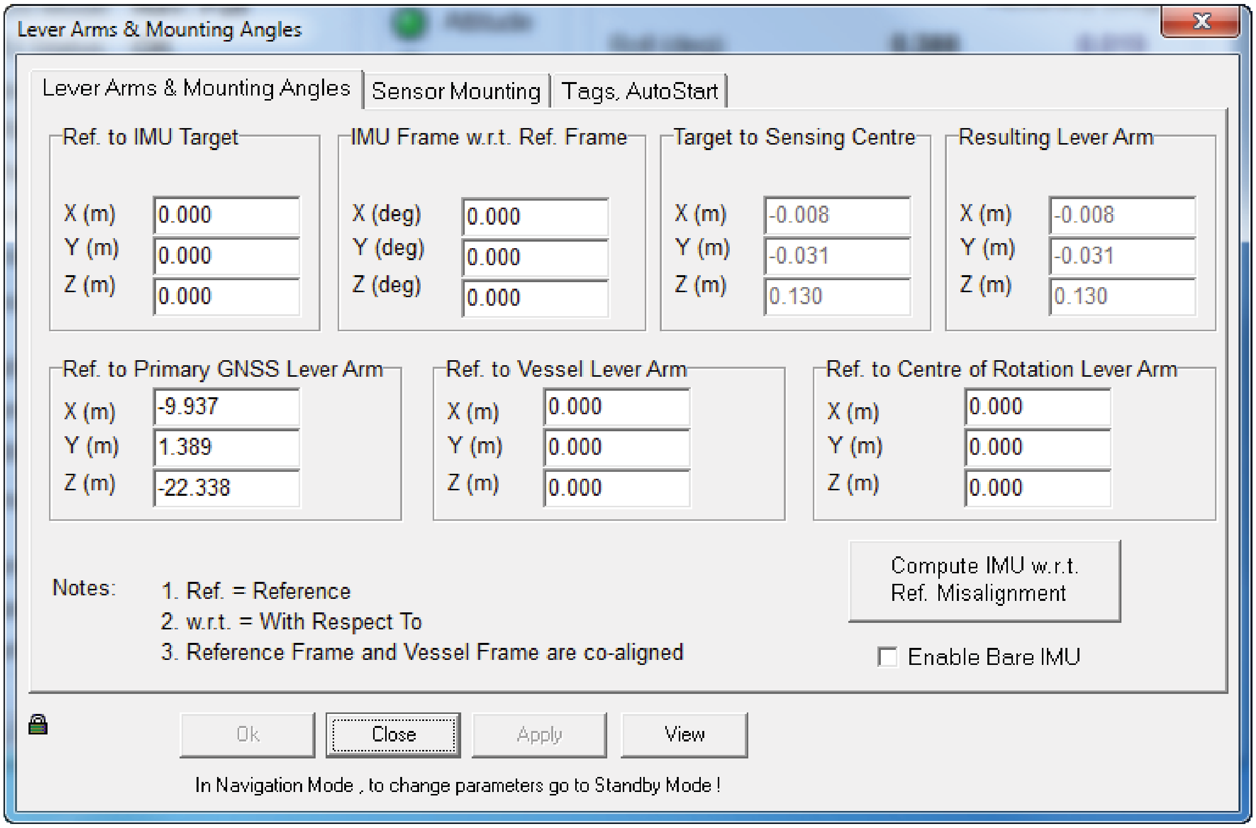

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
PU System Report
System Report.
Path:
D:\sisdata\common\bist
...
Name:

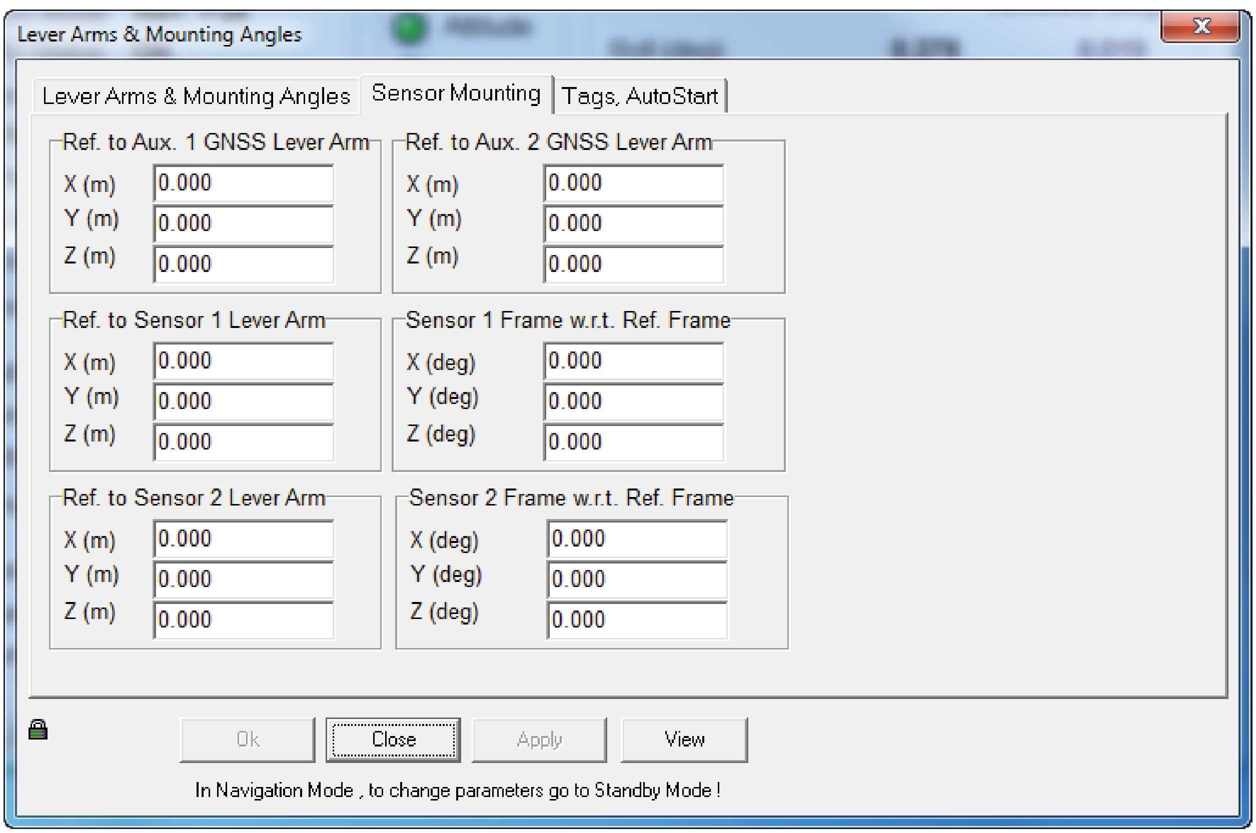

External sensors
Input Setup
Sound Velocity Probe
Port
Probe available
COM1
Probe type
AML SV (C)
SVP Logger
Port
SVP Logger avail
Barometer
Port
Barometer avail
Real time Tide
Port
Realtime Tide avail
Geodimeter
Port
Geodimeter avail
Echosounder
Heading
Sensor name
Serial
Port
Ethernet
IP addr.
Port 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

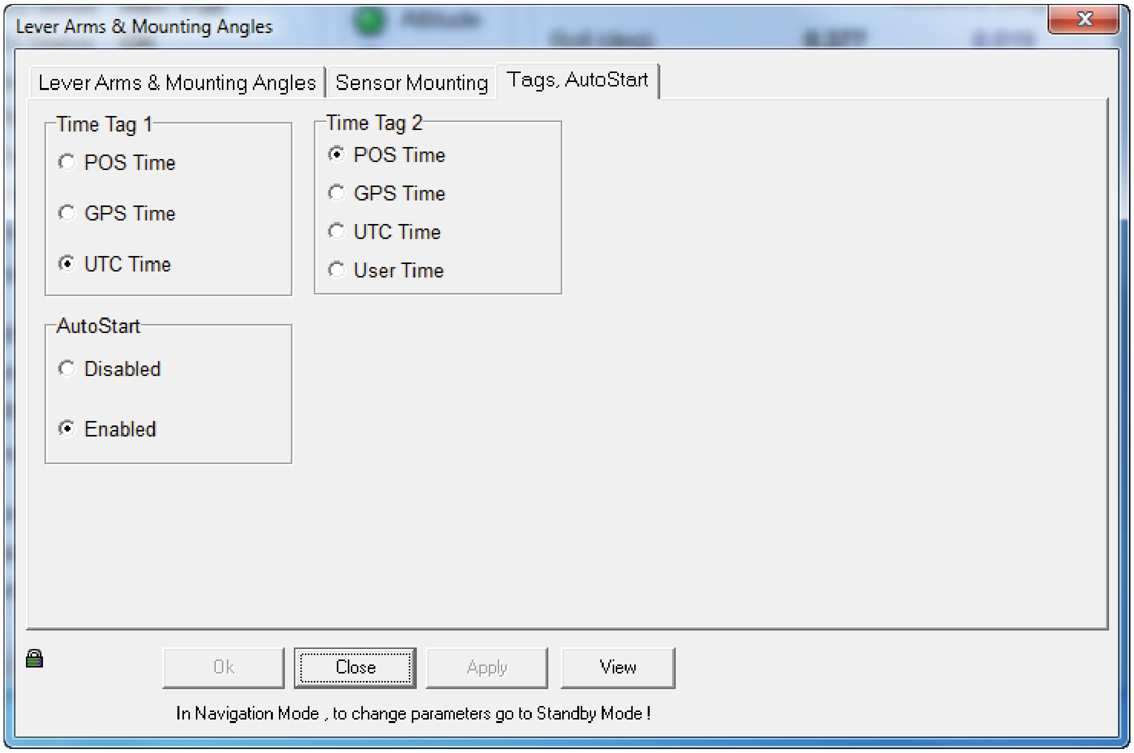

Data Distribution
Data Distribution - MDM 400
Source Port
Source File
Packets
Destination : Port
Destination : Port
Destination : Port
Destination : Port
Destination File
16103
109
10.48.16.251:6002
0
-1

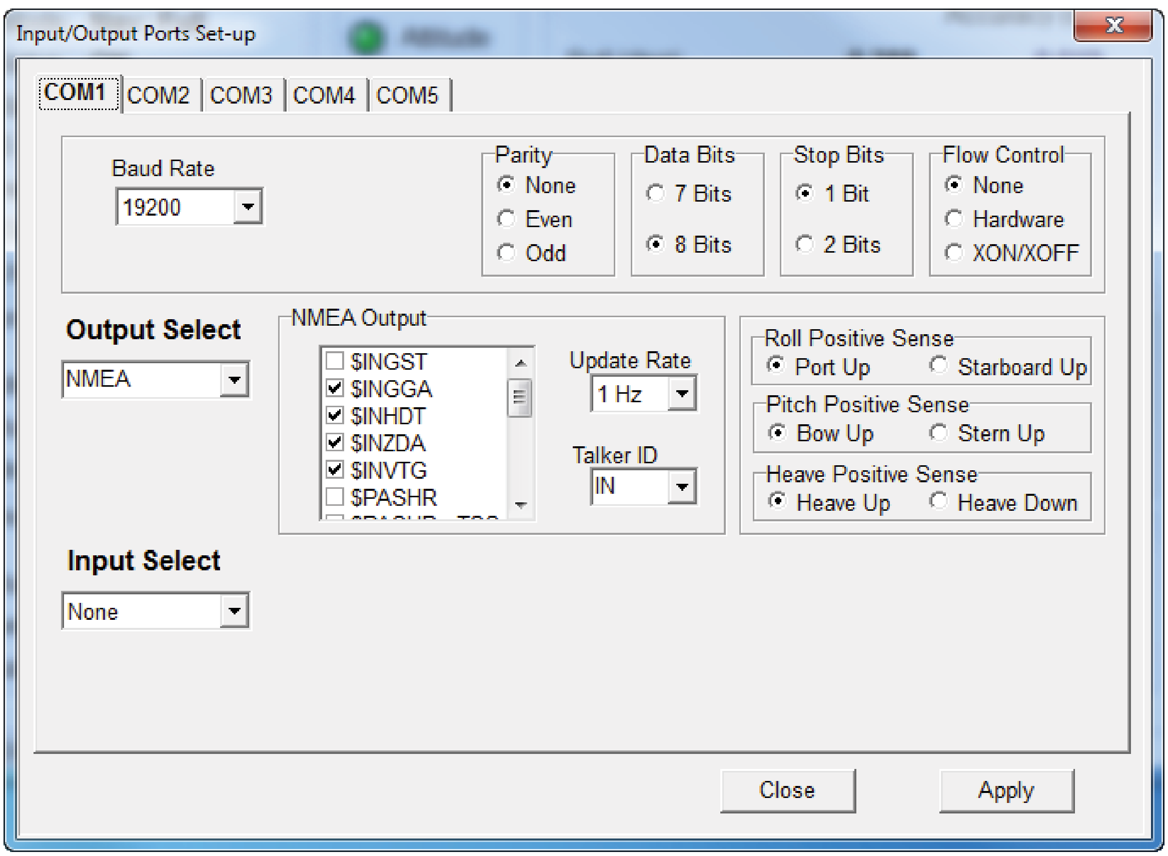

Request datagrams from EM
Echosounder
EM710_241
Datagram
Position (P)
Options
All
IP:Port
Subscribe
Unsubscribe
KONGSBERG
Please restart SIS for changes to take effect
Datagram
IP:Port
Interval
Position
localhost:16108
All
Estimated positions
localhost:16108
All
Information
localhost:9004
All
Position
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

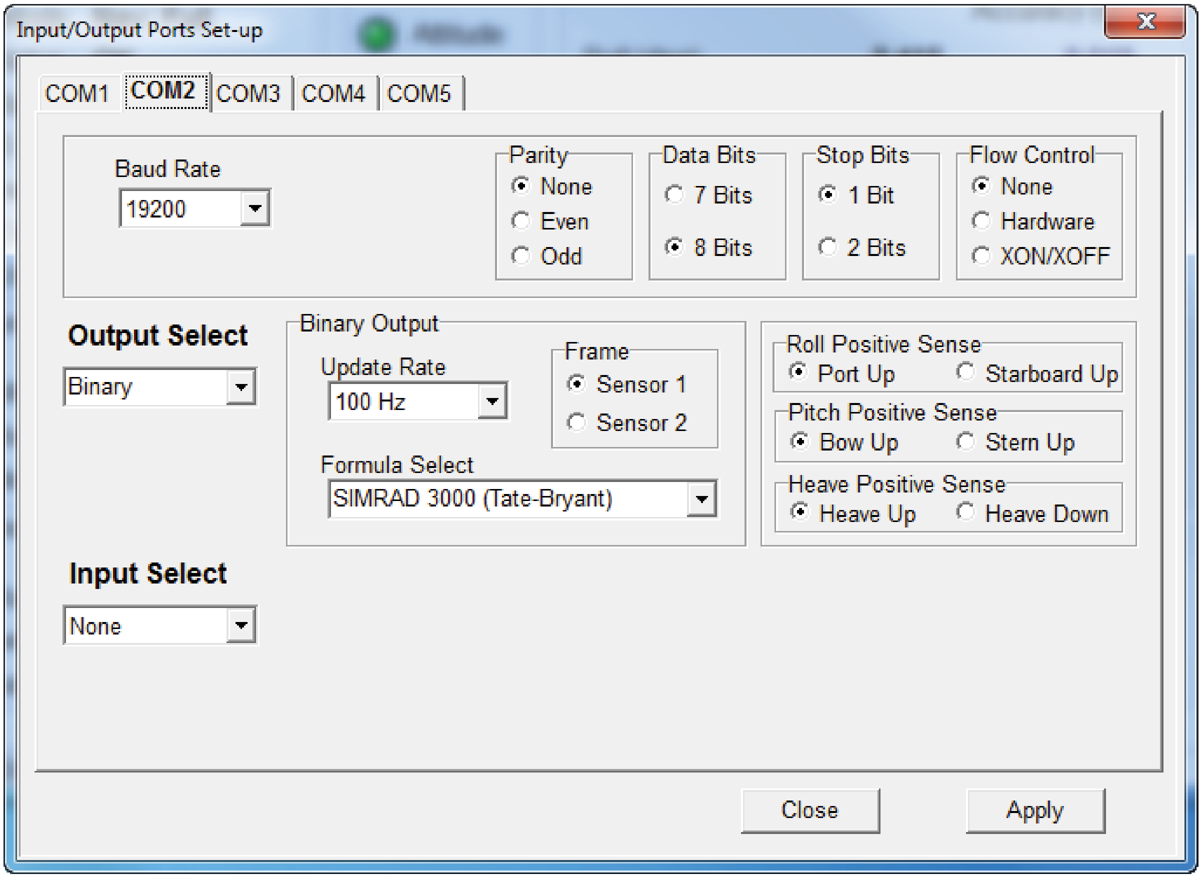
10.1.2 POS M/V

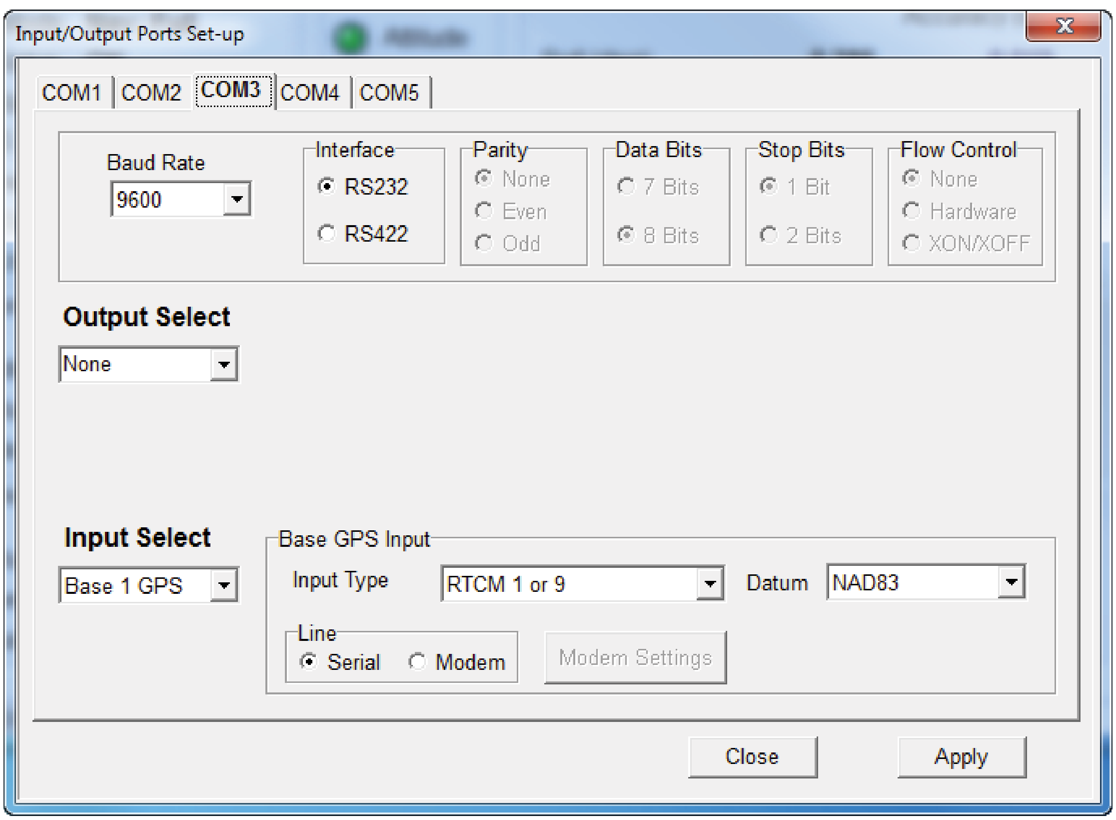

Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, AutoStart
Ref. to IMU Target
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
IMU Frame w.r.t. Ref. Frame
X (deg) 0.000
Y (deg) 0.000
Z (deg) 0.000
Target to Sensing Centre
X (m) -0.008
Y (m) -0.031
Z (m) 0.130
Resulting Lever Arm
X (m) -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 !

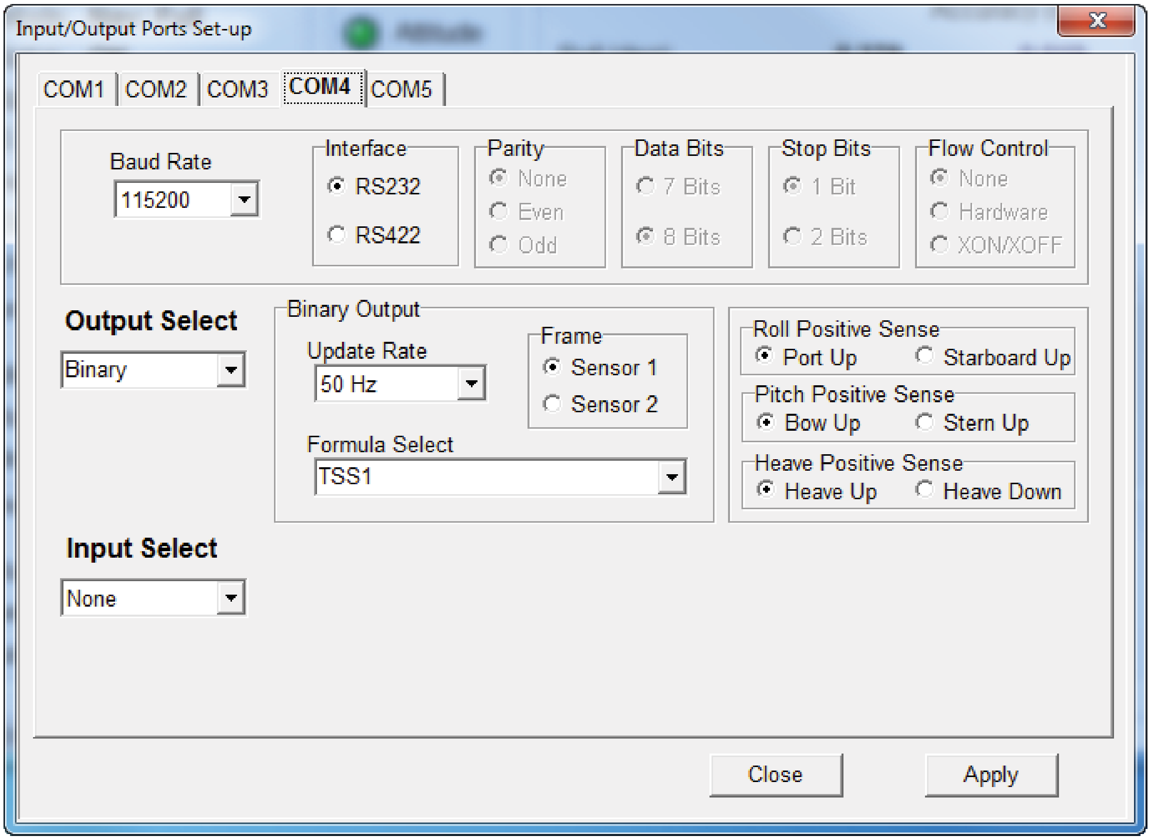

Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, AutoStart
Ref. to Aux. 1 GNSS Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Aux. 2 GNSS Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Sensor 1 Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Sensor 1 Frame w.r.t. 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 !

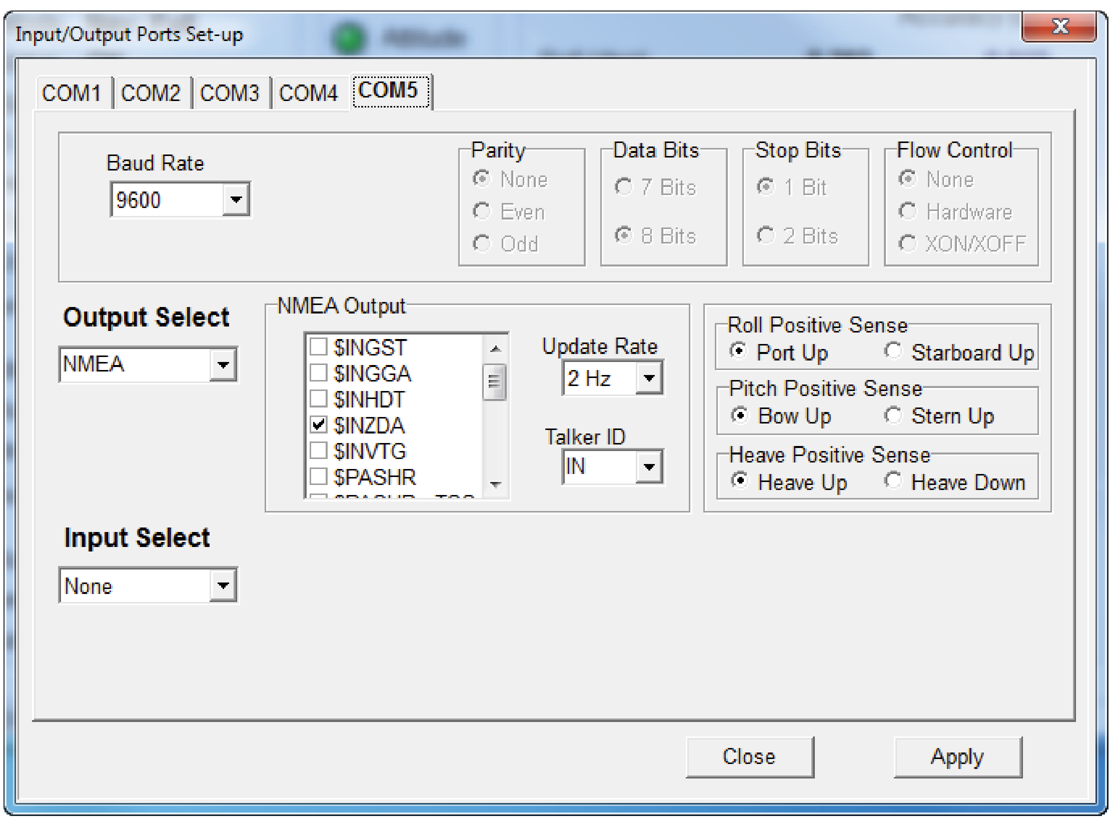

Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
19200
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$INGST
$INGGA
$INHDT
$INZDA
$INVTG
$PASHR
Update Rate
1 Hz
Talker ID
IN
Roll Positive Sense
Port Up
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

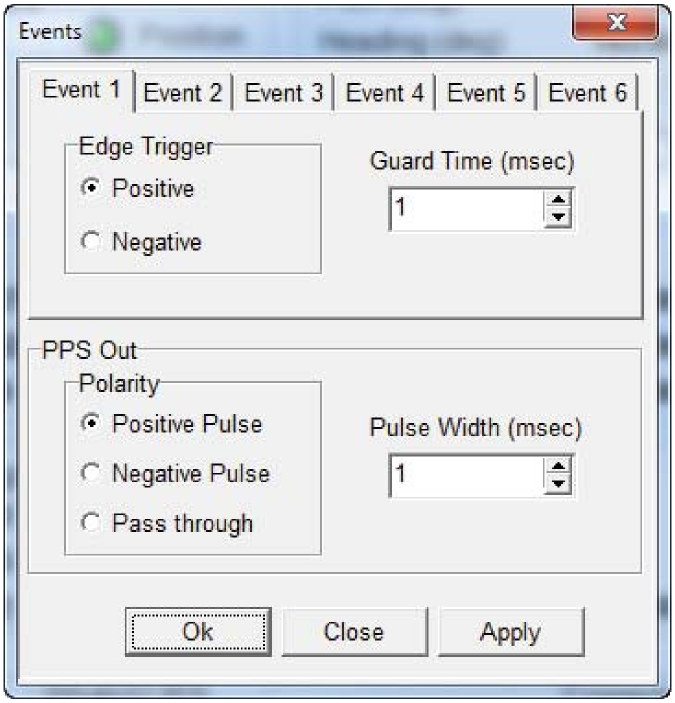

Input/Output Ports Set-up
COM1 COM2 COM3 COM4 COM5
Baud Rate
9600
Interface
RS232
RS422
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
None
Input Select
Base 1 GPS
Base GPS Input
Input Type
RTCM 1 or 9
Datum
NAD83
Line
Serial
Modem
Modem Settings
Close
Apply

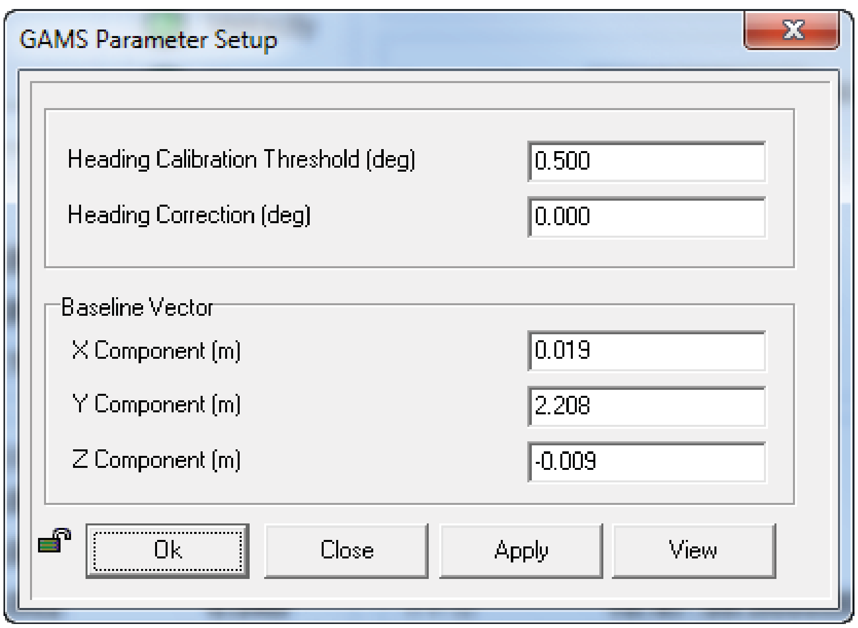


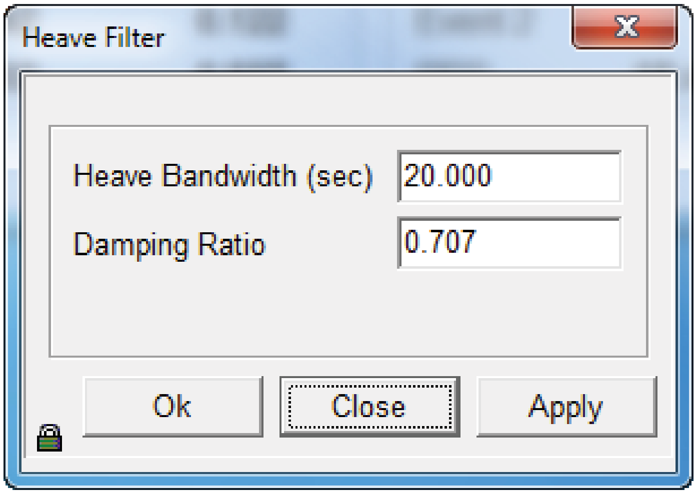
Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
115200
Interface
RS232
RS422
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
Binary
Binary Output
Update Rate
50 Hz
Frame
Sensor 1
Sensor 2
Formula Select
TSS1
Roll Positive 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 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														
01														
02														
03														
04														
05														
06														
07														
08	36°57.2'N	076°17.9'W	CLR	NSW	10T	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°58.4'N	76°20.7'W	FEW	-BR	10+	060	12	1021.1	–	–	–	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	087	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	THOMAS JEFFERSON S-222	TIME ZONE	DAY OF WEEK	DATE (dd mmm yyyy)
		+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	1019.6	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° 07.7'W	CLR	NSW	10	250	4	1018.7	—	—	—	19.6	18.5	17.5
09	—	—	—	NOT		OBSERVED			—	—	—	—	—	—
10	37° 35.7'N	076° 05.8'W	CLR	Patchy Fog	10	224	5	1019.1	—	—	—	19.8	17.1	17.1
11	37° 37.6'N	076° 10.5'N	PC	NSW	10	233	9	[illegible]8.5	—	—	—	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	2.0	1016.5	–	–	–	20.7	20.5	17.5
18	37° 38.5'N	076° 09.9'W	PC	NSW	10	045	6.0	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° 34 N	076 06.3'W	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 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	37°35.0'N	Ø76° Ø6.0'W	OVC	+BR	1Ø	355	23.3	102Ø	2-3	340	2-3	19.8	19.1	15.6	
01	37°35.7'N	Ø76°Ø7.3'W	OVC	+BR	1Ø+	ØØ1	23	1Ø21	2-3	34Ø	1-2	19.9	19.Ø	16.5	
02	37°28.8'N	Ø76°Ø6.2'W	OVC	+BR	1Ø+	354	27	1Ø22	Ø-1	34Ø	Ø-1	19.8	17.Ø	16.Ø	
03	37°23.7'N	Ø76°Ø6.Ø'W	OVC	+BR	1Ø+	352	22	1Ø22	Ø-1	34Ø	Ø-1	2Ø.2	17.Ø	16.Ø	
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	CFSD	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	Ø76 19.9'W	SCT	~~SCF~~ NSW	1Ø	Ø22	12	1025.7	1	191	1	2Ø.Ø	17.Ø	12.5	NBW
15	36°05.0'N	076 20.1'W	SCT	NSW	10	039	38	1025.7	1	Ø55	1	2Ø.Ø	17.Ø	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	1Ø	Ø74	12.7	1Ø26.5	2-3	Ø4Ø	3-4	19	15.2	11.8
01	37° 22'N	Ø74° 53.6'W	FAIR	NSW	1Ø	Ø5Ø	1Ø	1Ø26.7	2-3	Ø45	3-4	18.4	15.2	11.8
02	37° 25'N	Ø74° 49'W	FAIR	BR	1Ø	Ø6Ø	13	1026.7	2-3	Ø5Ø	3-4	18.5	15.3	11.7
03	37° 31'N	074° 41.0'W	FAIR	BR	1Ø	Ø7Ø	11	1Ø26	1-2	Ø7Ø	3-4	17.8	15.6	11.7
04	37° 26.8'N	Ø74 35.2'W	FAIR	BR	1Ø	Ø8Ø	11	1025.8	1-2	020	3-4	18.2	15.8	11.6
05	37° 42.1'N	Ø74° 28.5'W	FAIR	BR	1Ø	Ø15	8	1025.8	1-2	030	1-2	18.3	15.9	11.8
06	37° 48.3'N	Ø74° 21.3'W	FAIR	BR	1Ø	015	3	1025.9	1-2	030	1-2	17.8	16.0	12.0
07	37° 53.6'N	Ø74° 15.6'W	FAIR	BR	1Ø	350	7	1026.7	1-2	080	1-2	18.9	16.3	12.7
08														
09	37° 53.1'N	Ø74° 15.5'W	FAIR	-BR	10	02Ø	8	1027.9	1-2	Ø7Ø	1-2	18.7	16.5	13.2
10	37° 52.9'N	Ø74° 15.6'W	FAIR	BR	1Ø	033	13	1028.5	1-2	Ø7Ø	1-2	18.6	16.4	13.2
11	37° 52.9'N	Ø74° 14.18'W	FAIR	BR	1Ø	Ø3Ø	13	1Ø28.1	1-2	Ø75	1-2	18.6	16.4	13.4
12	37° 53.7'N	Ø74° 15.0'W	CLR	BR	1Ø	Ø33	13	1028	1-2	Ø8Ø	1-2	18.8	18.Ø	13.8
13	37° 52.4'N	Ø74° 14.3'W	HZ	BR	1Ø	Ø38	15	1027.1	1-2	Ø7Ø	2-3	18.9	17.1	14.3
14	37° 51.7'N	074° Ø9.Ø'W	FEW	-BR	1Ø+	Ø37	13	1Ø26.6	1-2	Ø7Ø	1-2	20.3	17.8	14.4
15	37° 48.7'N	Ø74° Ø6.N'W	FEW	-BR	1Ø+	Ø65	1Ø	1Ø26.4	1-2	Ø6Ø	1-2	20.4	19.8	14.9
16	37° 52.3'N	Ø74° 03.1'W	FEW	NSW	10+	105	13	1025.8	1-2	Ø5Ø	1-2	20.2	18.6	14.0
17														
18	38° 11.0'N	Ø73° 51.5'W	FEW	NSW	10+	115	12	1025.5	<1	Ø4Ø	1-2	20.6	18.0	12.9
19	38° 19.9'N	Ø73° 43.7'W	FEW	-BR	10+	095	12	1025.8	1-2	Ø45	2-3	20.4	17.9	13.6
20	38° 27.1'N	Ø73° 34.6'W	FEW	-BR	10+	103	11	1025.8	1-2	Ø45	2-3	20.5	17.5	13.Ø
21	38° ~~31.29'~~ 35.2'N	Ø73° 24.8'W	FEW	-BR	10+	122	9	1025.8	1-2	Ø45	2-3	20.Ø	17.Ø	12.5 KS
22	38° 43.0'N	Ø73° 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	Ø73° 04.4'W	FEW	-BR	10+	136	9	1025.6	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	SUNDAY ~~SATURDAY~~	16 OCT 2016

TIME	POSITION		SKY CON-DITION	PRESENT WEATHER	VISI-BILITY	WIND		SEA LEVEL Press.	SEA WAVE Height	SWELL WAVES		TEMPERATURE (°C)		
	LATITUDE	LONGITUDE			(nm)	Dir. (true)	Speed (kts)	(mb)	(ft)	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°01.0'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°36.2'W	PC/SCT	NSW	10+	225	6	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
MO 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	FEW	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	Ø72° 21.1'W	CLR	FAIR	1Ø	245	205	1015.6	1-2	24Ø	2-3	21.5	19.8	16.8
01	Ø39° 18.6'N	072 21.5'W	CLR	BR	1Ø	~~21~~ 253	~~253~~ 21	1015.9	1-2	24Ø	2-3	21.6	2Ø.Ø	17.Ø
02	39° 19'N	072° 19.9'W	CLR	BR	1Ø	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	Ø72° 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	Ø72° 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	Ø72° 11.57'W	PC	BR	1Ø+	243	19	1013.4	3	255	3	21.9	21.5	19.1
12	39° 18.7'N	Ø72° 12.2'W	CLR	BR	1Ø+	247	19	1013.8	2-3	275	2-3	21.7	20.8	18.9
13	← NOT OBS; DRILLS →													
14	39° 17.4'N	Ø72° 12.4'W	CLR	BR	1Ø+	259	18	1012.8	2-3	275	2-3	21.8	21.2	18.6
15														
16	39° 18.1'N	Ø72° 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	Ø72° 10.9'W	CLR	BR	1Ø+	242	14	1012.2	2-3	21Ø	2-3	21.6	21.5	18.9
18	39° 16.4'N	072° 13.7'W	CLR	BR	10	226	14	1012.0	2	210	2-3	21.9	21.0	18.9
19	39° 17.1'N	Ø72° 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	Ø72° 14.0'W	CLR	BR	10	226	18	1012.6	1-2	200	2-3	22	21.3	19.7
22	39° 03.4'N	Ø72° 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	Ø72° 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 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° 55.15'N	072° 03.95'W	CLR	BR	10+	237	15	1013.5	1-2	–	2-3	22.1	22.3	19.1
01	39° 01.1'N	071° 58.0'W	CLR	BR	10+	242	17	1013.6	1-2	–	2-3	22.1	22.2	18.8
02	38° 57.35'N	072° 03.8'W	CLR	BR	10+	243	19	1013.6	1-2	–	2-3	23.0	22.1	19.6
03	38° 59.9'N	072° 08.1'W	CLR	BR	10+	235	17	1013.4	1-2	–	2-3	23.1	21.9	19.8
04	39° 10.5'N	072° 14.5'W	CLR	+BR	10	235	18	1013.3	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° 22.0'W	FEW	-BR	10+	220	12	1014.1	1-2	190	2-3	21.4	21.5	20.0
09	39° 18.5'N	072° 21.1'W	FEW	-BR	10+	213	11	1014.6	1-2	210	2-3	21.5	21.5	20.1
10	39° 24.1'N	072° 25.4'W	FEW	-BR	10+	209	12	1014.4	1-2	210	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	072° 37.3'W	CLR	BR	10+	228	18	1013.5	0-1	200	1-2	20.6	18.6	19.3
13	39° 29.4'N	072° 44.7'W	CLR	BR	10+	215	19	1012.9	0-1	200	1-2	20.0	20.6	19.2
14	39° 22.4'N	072° 50.7'W	CLR	BR	10+	215	19	1012.6	0-1	190	0-1	21.0	20.8	19.2
15	39° 17.5'N	072° 56.1'W	CLR	BR	10+	208	18	1012.3	1	190	1-2	19.5	20.8	19.1
16	39° 09.3'N	073° 03.8'W	CLR	BR	10	210	19	1012.4	1	190	1-2	18.7	20.5	19.2
17	39° 00.1'N	073° 12.3'W	CLR	BR	10+	203	19	1012.2	1	190	1-2	18.6	20.4	19.4
18	38° 52.8'N	073° 19.4'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	073° 33.9'W	CLR	BR	10	200	20	1012.7	1-2	190	1-2	18.9	20.8	19.4
21	38° 26.2'N	073° 44.7'W	CLR	BR	10+	205	23	1013.0	1-2	190	2	19.2	21.1	19.6
22	38° 18.6'N	073° 51.7'W	CLR	BR	10	212	24	1013.3	2-3 ~~1-2~~	190	~~2-3~~	19.3	20.8	19.4
23	38° 10.6'N	073° 59.0	CLR	BR	10	215	25	1013.7	3-4	200	4-5	18.4	20.4	18.8

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	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	∅74° 04'W	FAIR	BR	1∅	222	23	1∅14	2-3	220	2-3	18.2	2∅.2	18.8
01	37°55.1'N	∅74° 14.2'W	FAIR	+BR	1∅+	21∅	25	1∅14.4	2-3	22∅	2-3	18.9	2∅.2	19.2
02	37°52.5'N	∅74°16.7'W	FAIR	BR	1∅+	216	2∅	1∅14.7	2-3	22∅	2-3	18.9	2∅.∅	19.2
03	37°53.3'N	∅74°15.5'W	FAIR	BR	1∅	222	19	1∅14.2	2-3	22∅	2-3	19.∅	2∅.3	19.∅
04	37°53.2'N	074°15.5'W	CLR	BR	1∅	228	21	93.8	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	1∅	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°00.35'N	074°14.17'W	FEW	BR	1∅	215°	18	1015.2	2	220	2-3	18.8	20.0	19.0
09	37°53.68'N	074°15.63'W	FEW ~~HZ~~	HZ	10	225	15.6	(inside) 1017.5	2-3	196	3	ENG 16.1	20.0	19.5
10	37°53.6'N	∅74° 15.3'W	FEW	HZ	1∅	223	15	1015.8	2-3	20∅	3	18.9	2∅.6	19.1
11	37°53.716'	074°15.88'W	FEW	HZ	1∅	225	16	SCS 1016.15	2-3	200	3	18.9	19.96	19.0
12	37°53.6'N	∅74°15.5'W	CLR	HZ	1∅	224	14	1∅15.5	1-2	19∅	2-3	19.1	2∅.6	19.4
13	37°53.7'N	∅74°15.2'W	CLR	BR	1∅+	224	13	1∅15.3	1-2	19∅	1-2	19.1	2∅.1	19.1
14	37°53.7'N	∅74°15.1'W	CLR	BR	1∅+	227	11.7	1015.1	1-2	19∅	2	19.∅	2∅.9	19.1
15	3													
16	37°52.9'N	074°14.3'W	FEW	BR	10	230	13	1014.9	1-2	19∅	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	∅74°38.6'W	FEW	-BR	10	239	4	1∅16.6	1-2	200	1-2	19.1	20.0	19.7
21	37°29.2'N	∅74°44.5'W	FEW	-BR	10	2∅2	7	1∅16.6	1-2	200	1-2	19.8	2∅.2	19.9
22	37°22.1'N	∅74°52.4'W	FEW	HZ	10	193	7	1∅17.1	1-2	200	1-2	19.8	2∅.2	19.9
23	37°15.1'N	∅75°00.0'W	FEW	HZ	10	193	9	1∅17.∅	1-2	200	1-2	19.8	2∅.6	2∅.2

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	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° Ø7.Ø'N	Ø75° Ø8.Ø'W	CLR	NSW	1Ø	2Ø3	11	1017.Ø	1-2	19Ø	1-2	20.Ø	2Ø.9	2Ø.4
01	37°03.0'N	Ø75°12.9'W	CLR	NSW	1Ø	204	9.7	1017.Ø	1-2	19Ø	1-2	19.9	21.1	20.5
02	37°02.0'N	Ø75°18.5'W	CLR	NSW	1Ø	198	10.2	1016.7	1-2	180	0-1	20.4	21.3	20.5
03	37°Ø3.1'N	Ø75°13.2'W	CLR	NSW	1Ø+	195	1Ø	1Ø16.3	1-2	18Ø	1-2	2Ø.1	2Ø.9	2Ø.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	19Ø	10	1016.2	1-2	180	1-2	20.5	21.1	20.4
06	37°03.5'N	075°14.9'W	FAIR	-BR	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°03.0'N	075°16.9'W	CLR F	BR	10	179	12	1016.9	<1	180	1	20.2	21.3	20.3
09	37°02.63'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.

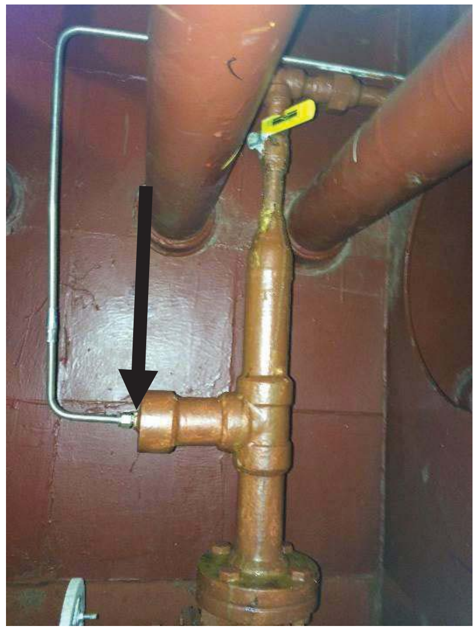


Figure 1: Bubbler gauge orifice and vent line. Vent valve has yellow handle and should be OPEN. Arrow indicated surveyed position of orifice and the location of the measured draft.

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.

$$wl = -PSI \frac{6894.7 Pascal / psi}{\rho * g} - orificeZ \tag{1}$$

where *wl* is the height of the reference point above the waterline, ρ 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:

$$wl = -0.68718(\mathrm{PSI}) + 3.908 \tag{2}$$

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.

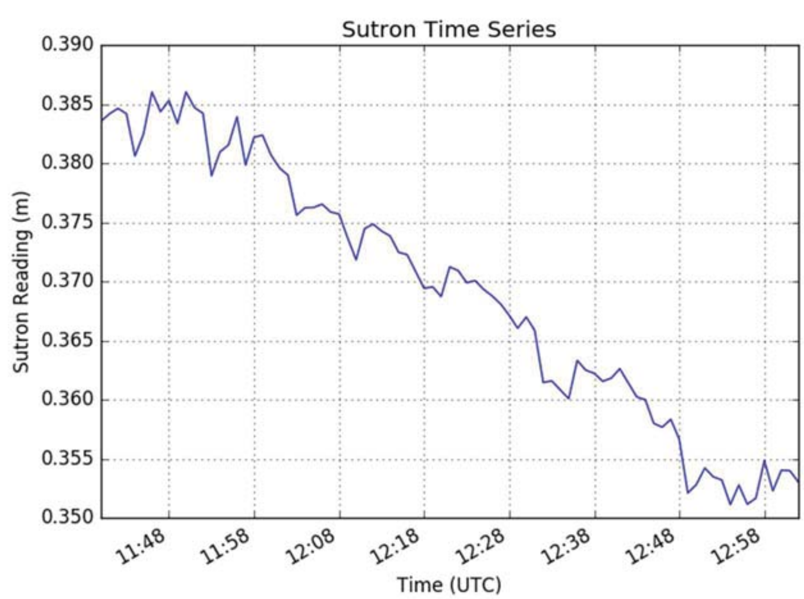


Figure 2 - The Sutron time series.

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.

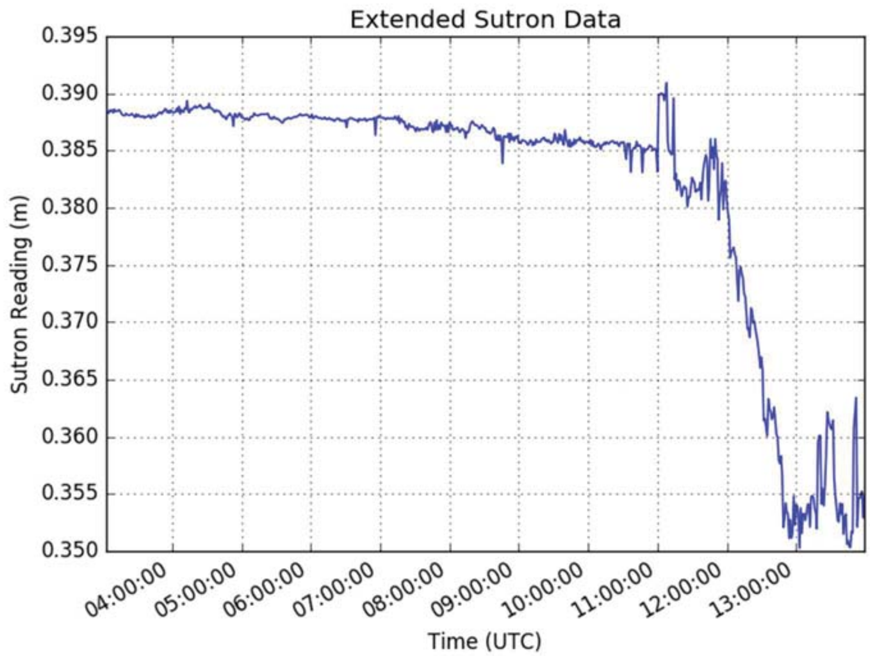


Figure 3 – The Sutron time series from 2016-10-12 for a period before and after the static draft test.

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.

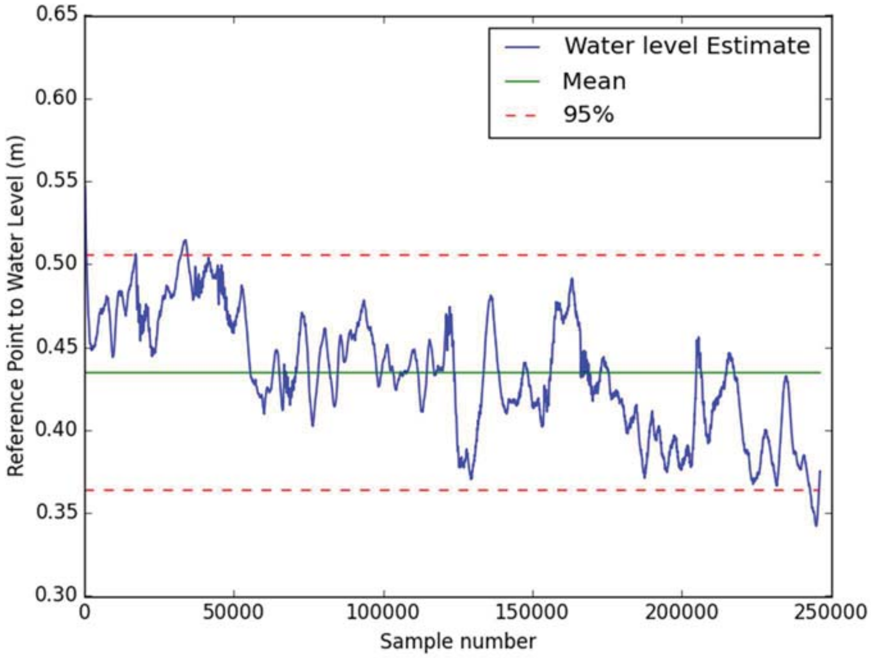


Figure 4 - SBET values relative to the ellipsoid referenced water levels from Money Point over the time period.

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.

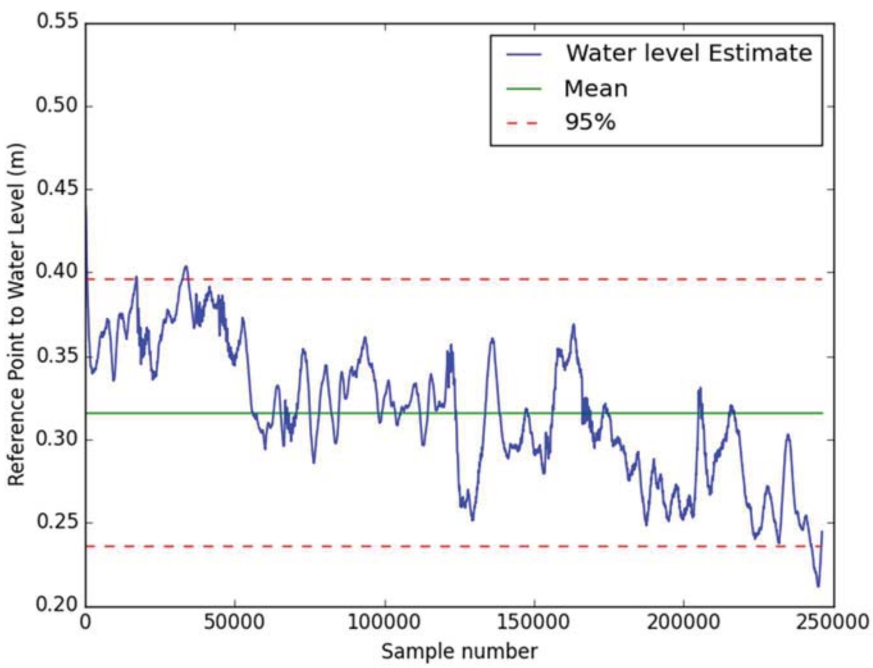


Figure 5 - SBET values relative to the ellipsoid referenced water levels from Sewell's Point over the time period.

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

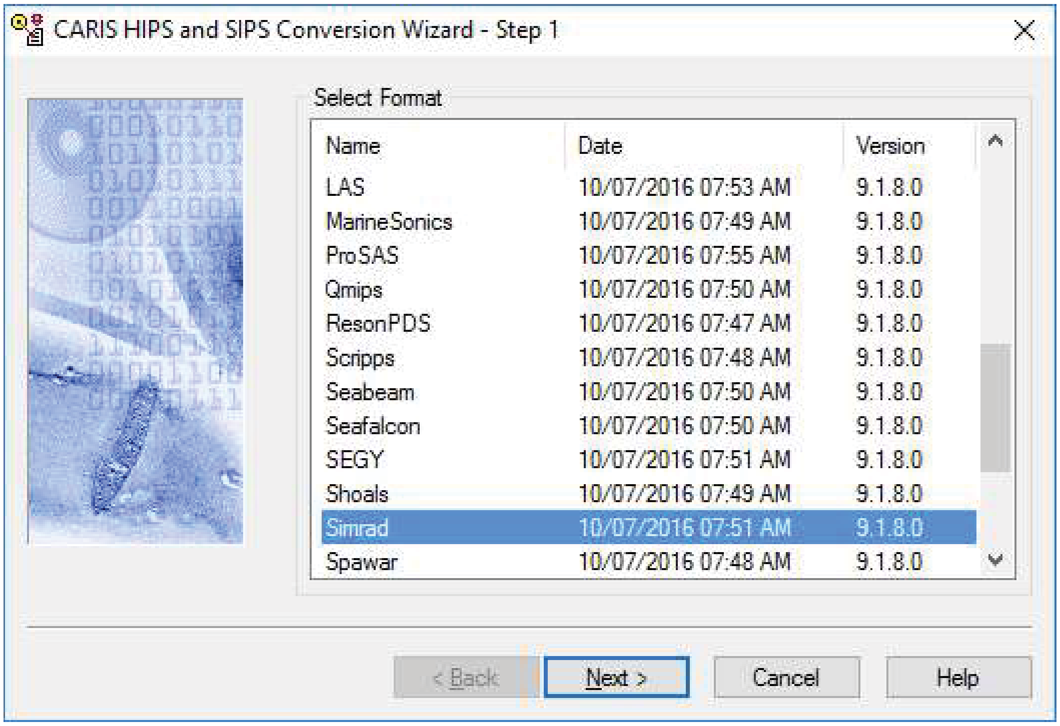
The two methods are as follows:

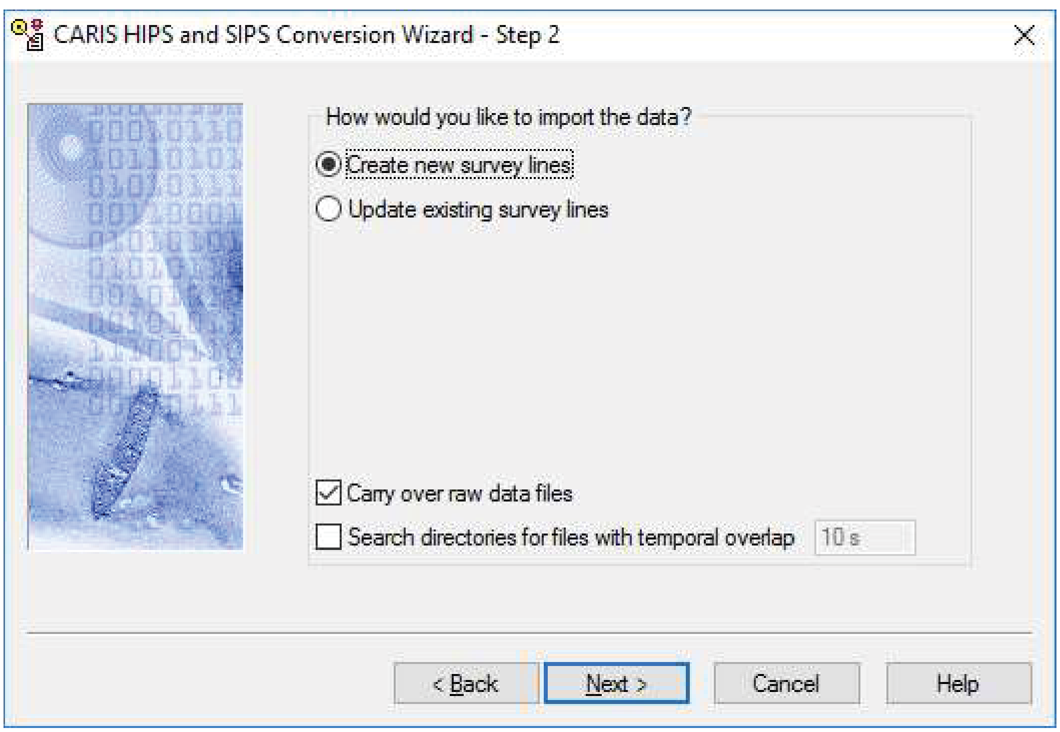
1) ERS
    a. Convert MBES data → Load Delayed Heave → Sound Velocity Correct → Compute GPS Tides → Merge with GPS Tides → TPU

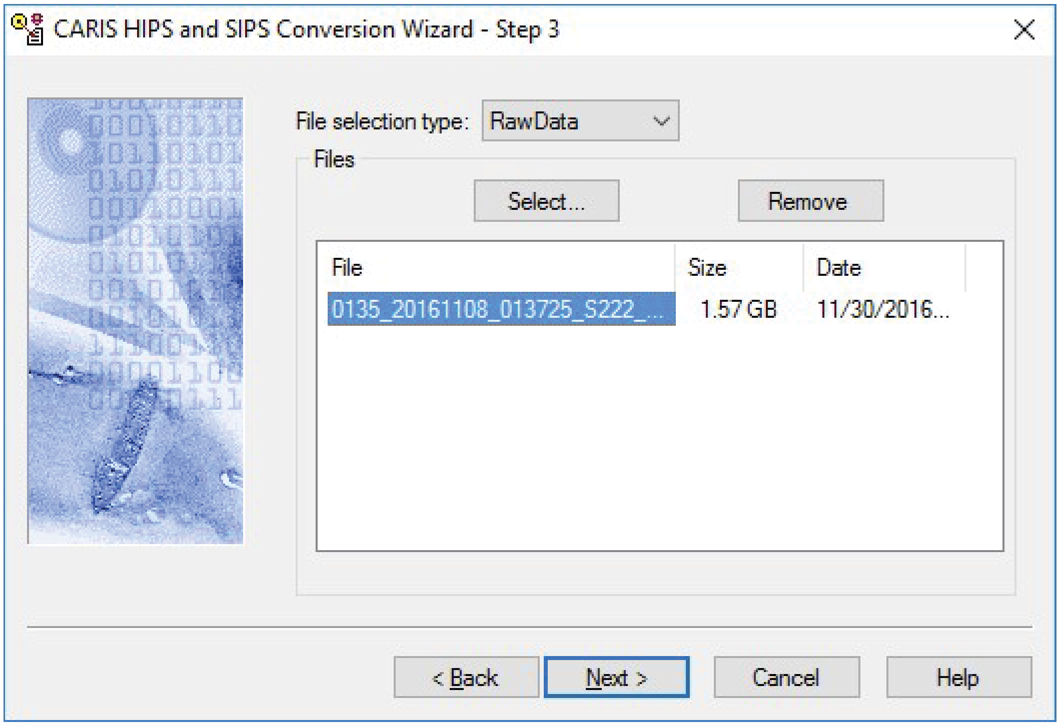
2) Traditional Water Levels
    a. Convert MBES data → Load Delayed Heave → Load Tides → Sound Velocity Correct → Merge → TPU

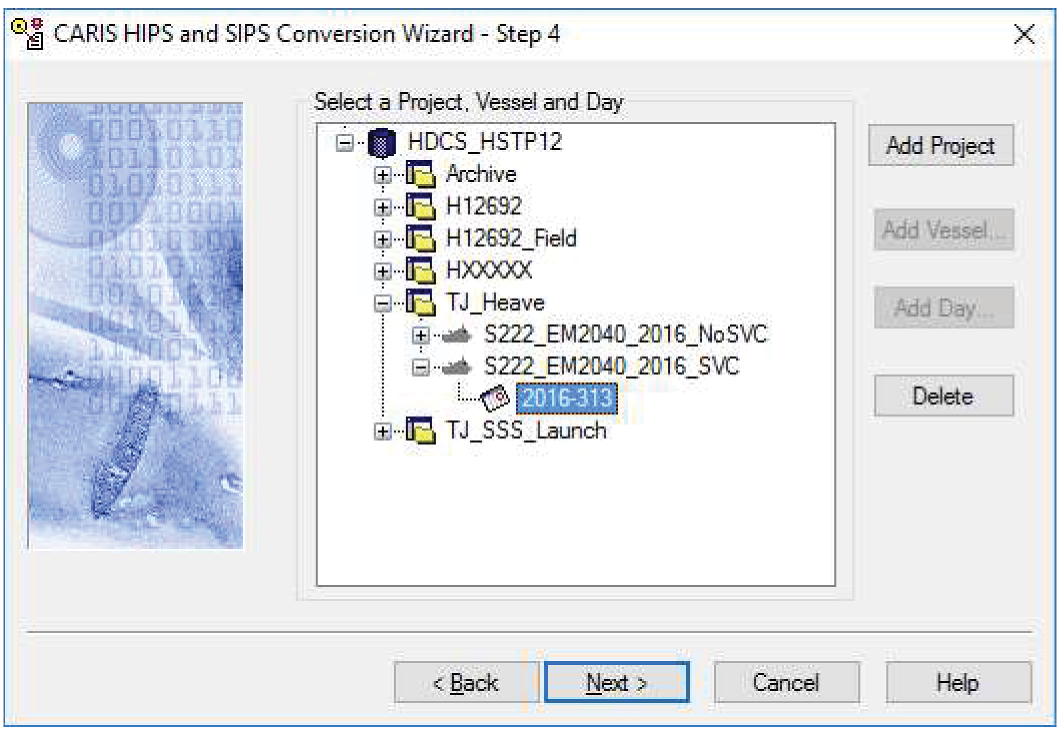
Procedure

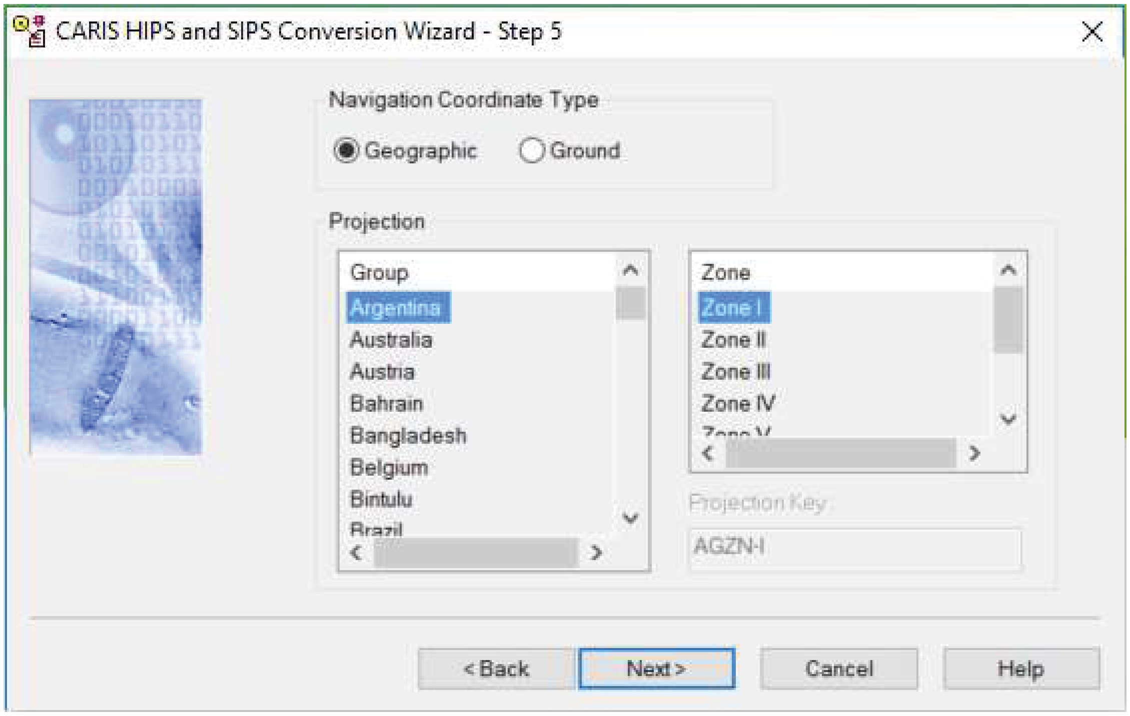
Conversion (both methods, 1 and 2)

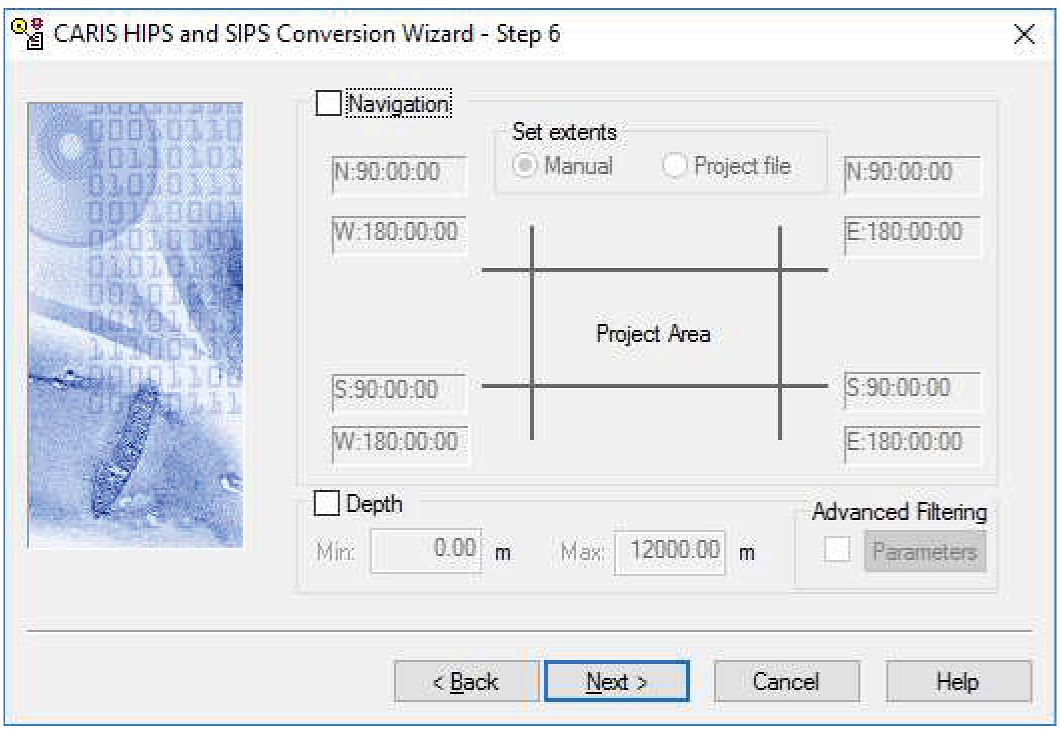




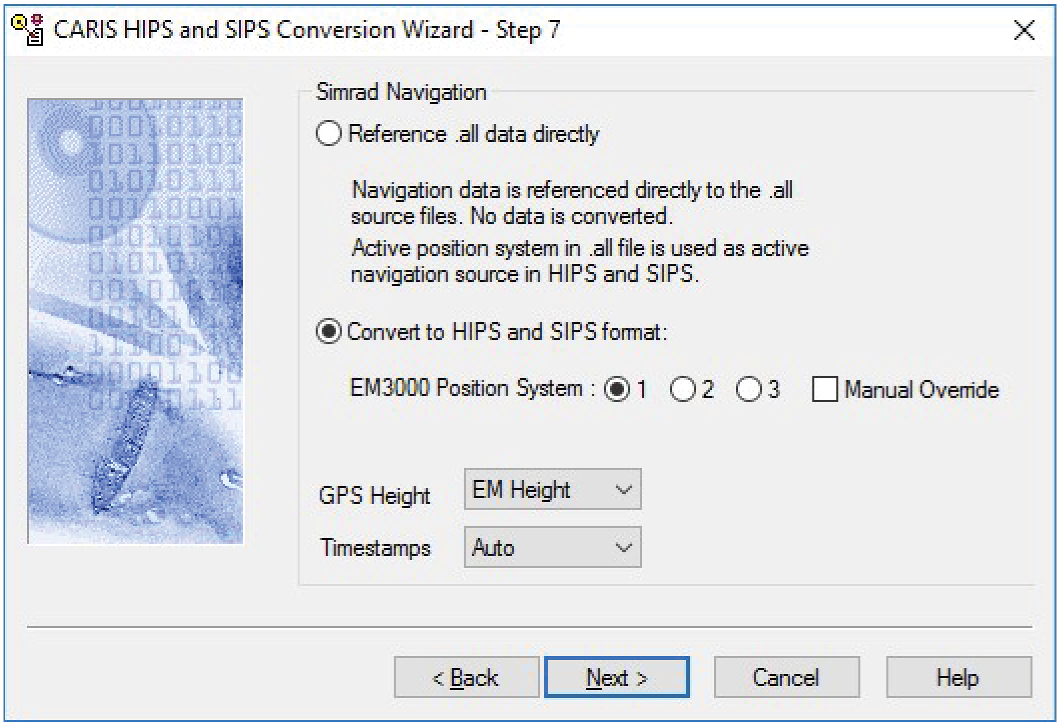

CARIS HIPS and SIPS Conversion Wizard - Step 3
File selection type:
RawData
Files
Select...
Remove
File
Size
Date
0135_20161108_013725_S222_...
1.57 GB
11/30/2016...
< Back
Next >
Cancel
Help

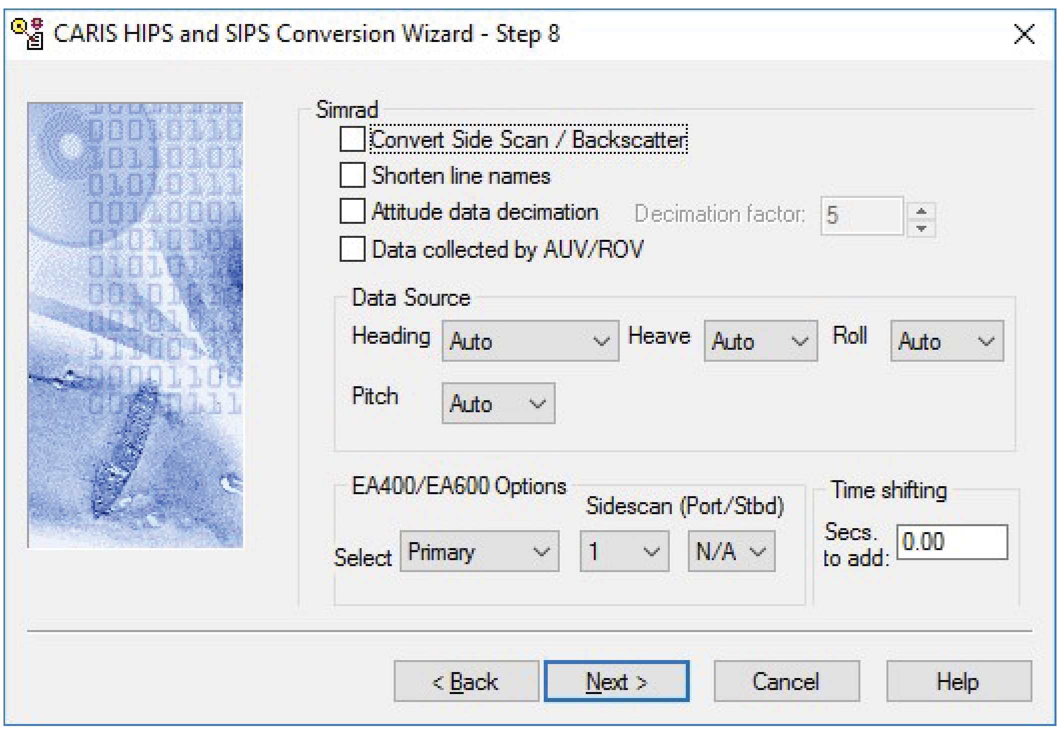

CARIS HIPS and SIPS Conversion Wizard - Step 4
Select a Project, Vessel and Day
HDCS_HSTP12
Archive
H12692
H12692_Field
HXXXXX
TJ_Heave
S222_EM2040_2016_NoSVC
S222_EM2040_2016_SVC
2016-313
TJ_SSS_Launch
Add Project
Add Vessel...
Add Day...
Delete
< Back
Next >
Cancel
Help

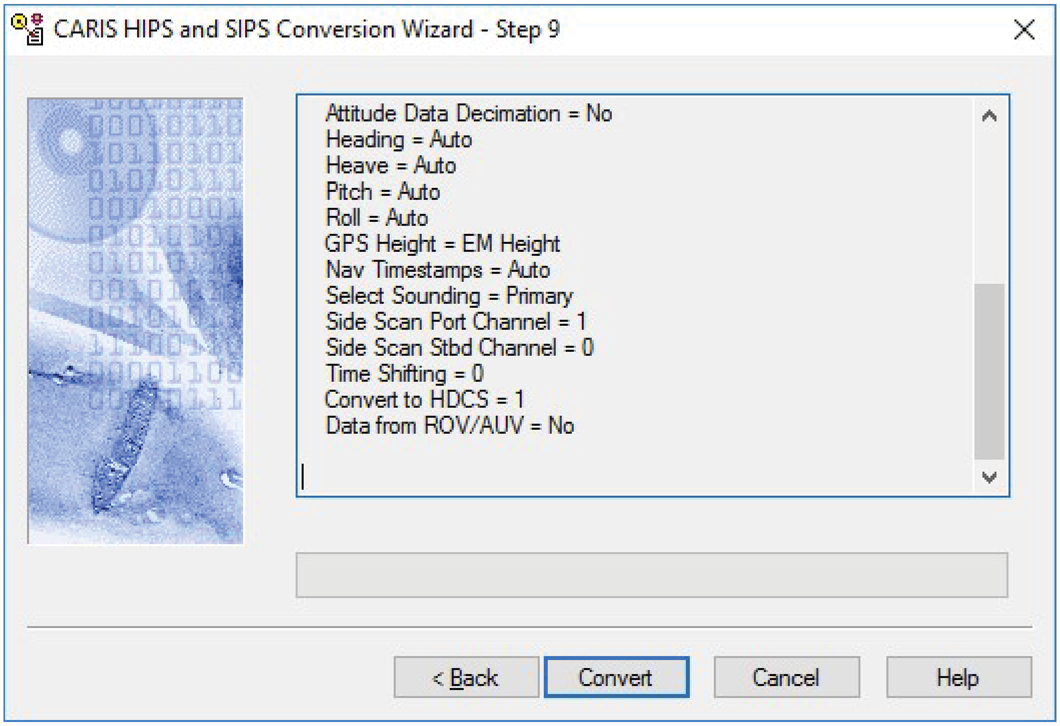

CARIS HIPS and SIPS Conversion Wizard - Step 5
Navigation Coordinate Type
Geographic
Ground
Projection
Group
Argentina
Australia
Austria
Bahrain
Bangladesh
Belgium
Bintulu
Zone
Zone I
Zone II
Zone III
Zone IV
Projection Key
AGZN-I
< Back
Next >
Cancel
Help


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

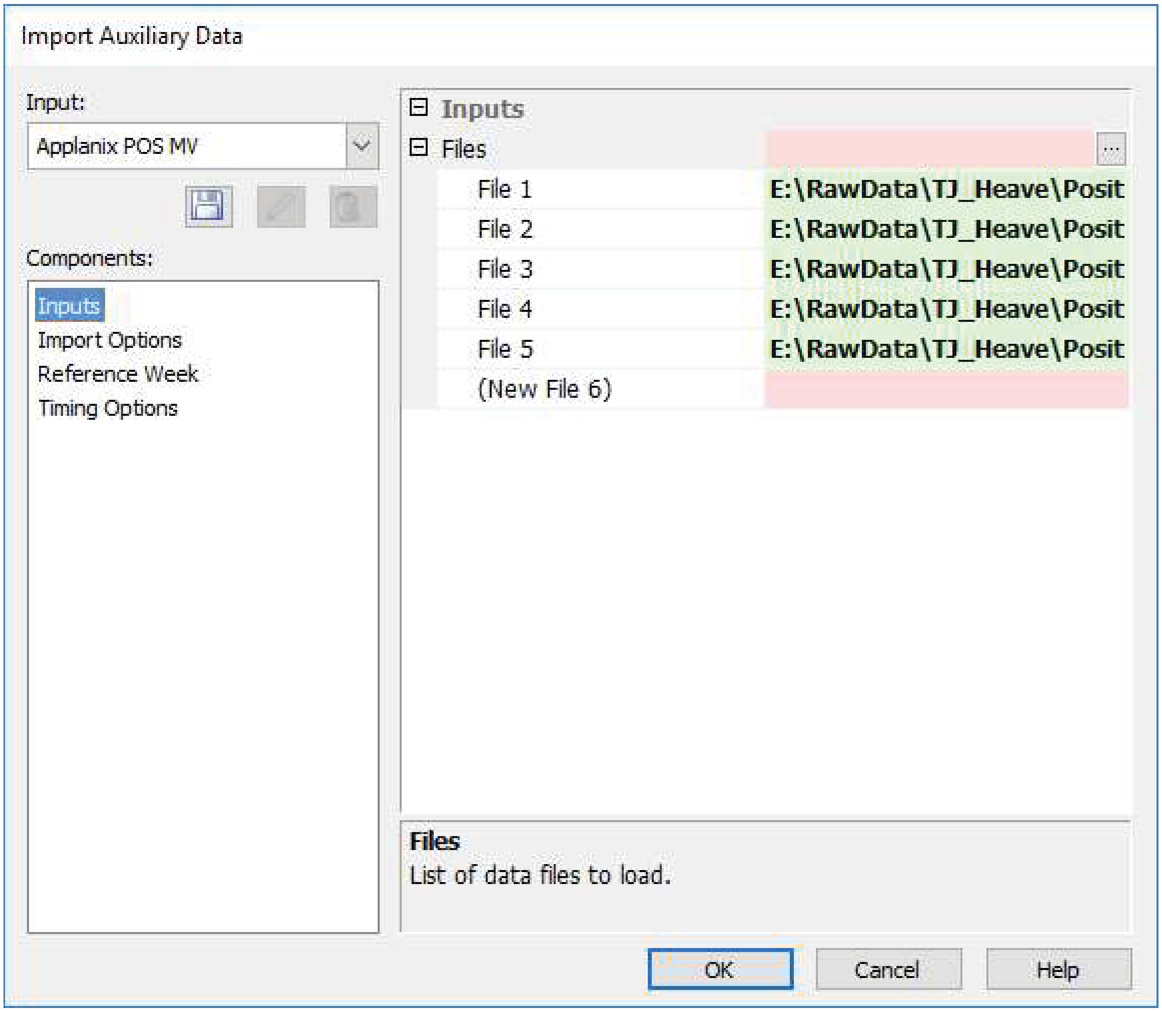
Data sources are set to "Auto" in the following dialogues because CARIS conversion algorithms are capable of reading the .all file (and other file types; ie: hsx) and determining data source.

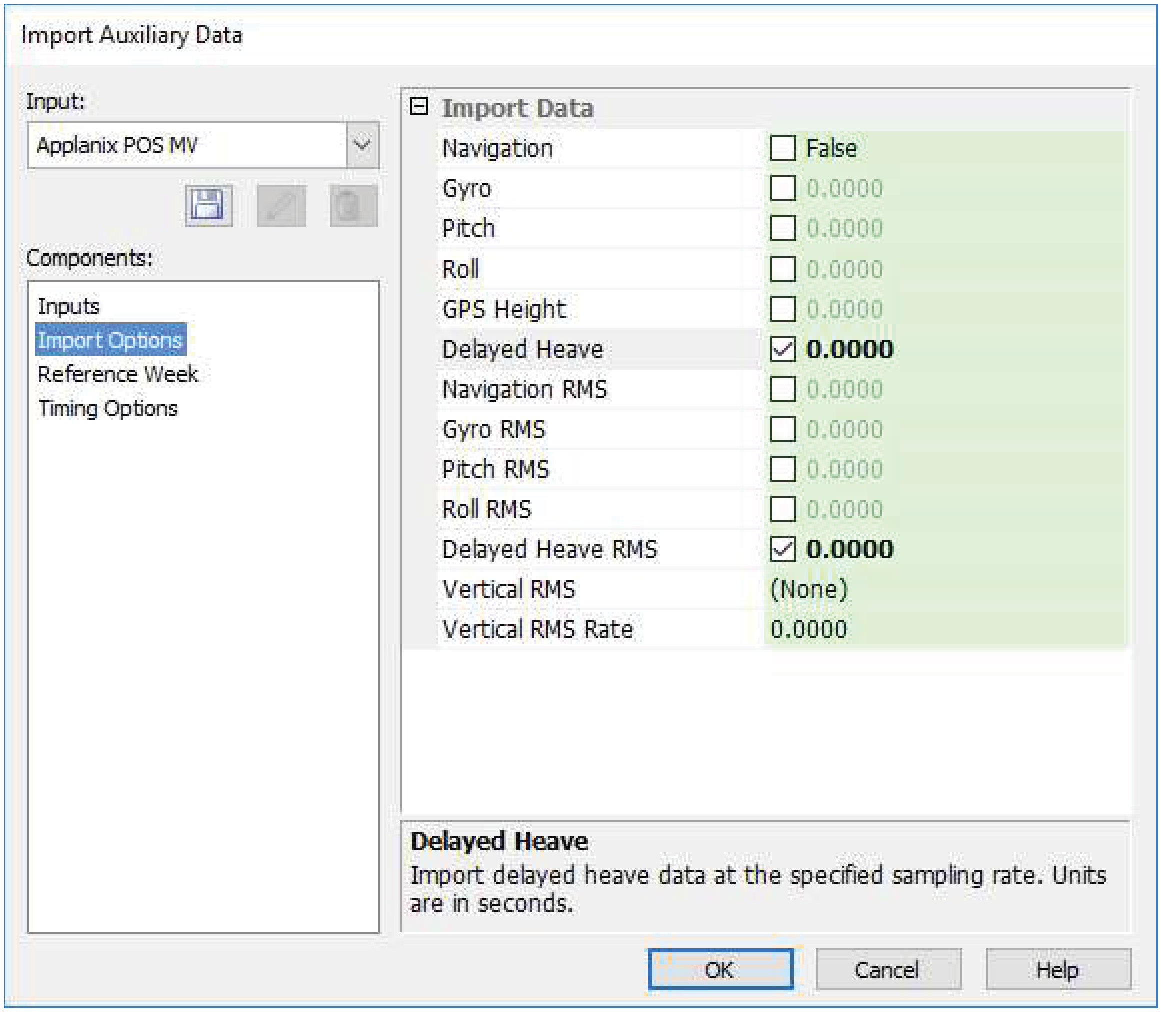


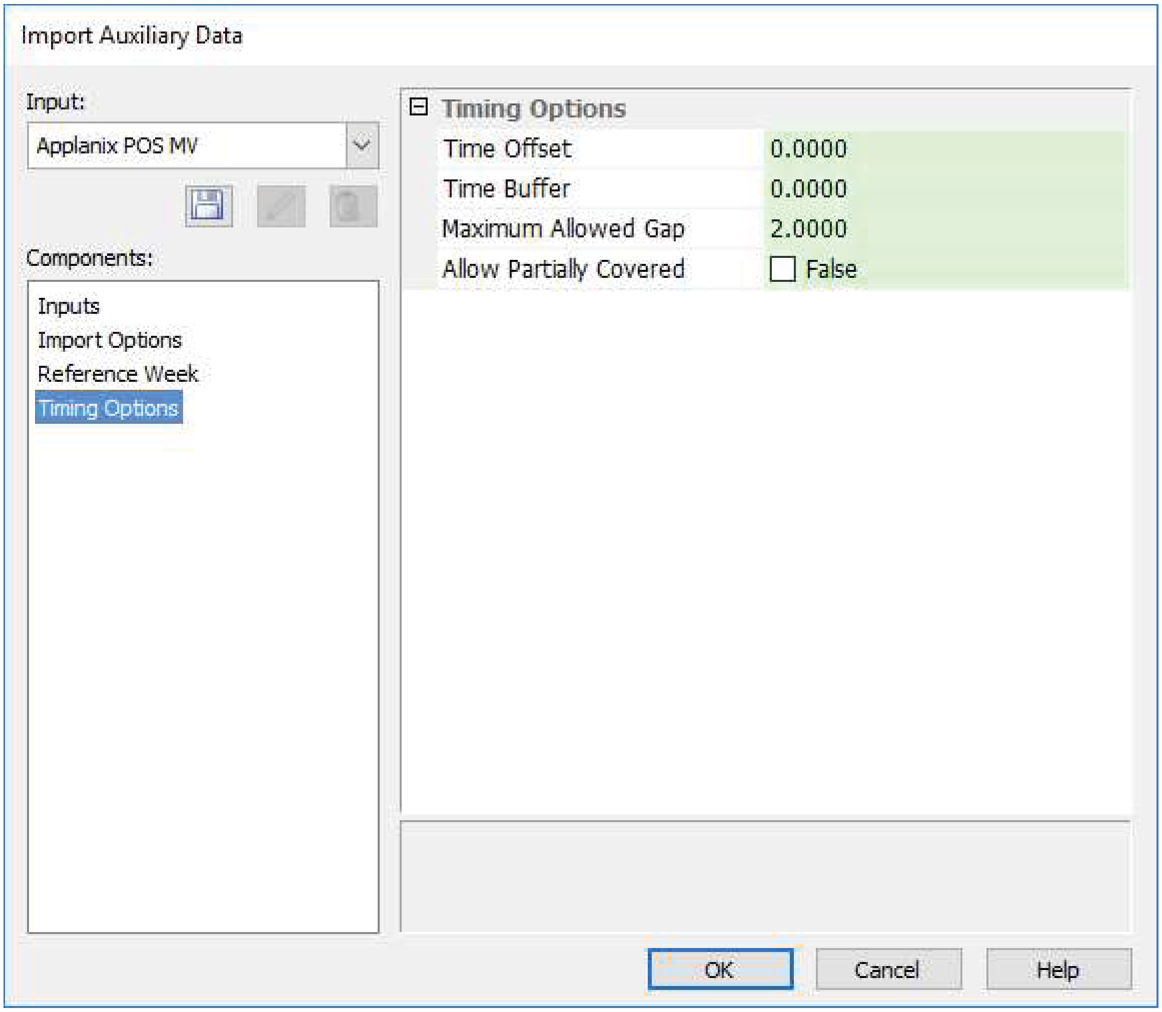



CARIS HIPS and SIPS Conversion Wizard - Step 9
Attitude Data Decimation = No
Heading = Auto
Heave = Auto
Pitch = Auto
Roll = Auto
GPS Height = EM Height
Nav Timestamps = Auto
Select Sounding = Primary
Side Scan Port Channel = 1
Side Scan Stbd Channel = 0
Time Shifting = 0
Convert to HDCS = 1
Data from ROV/AUV = No
< Back
Convert
Cancel
Help

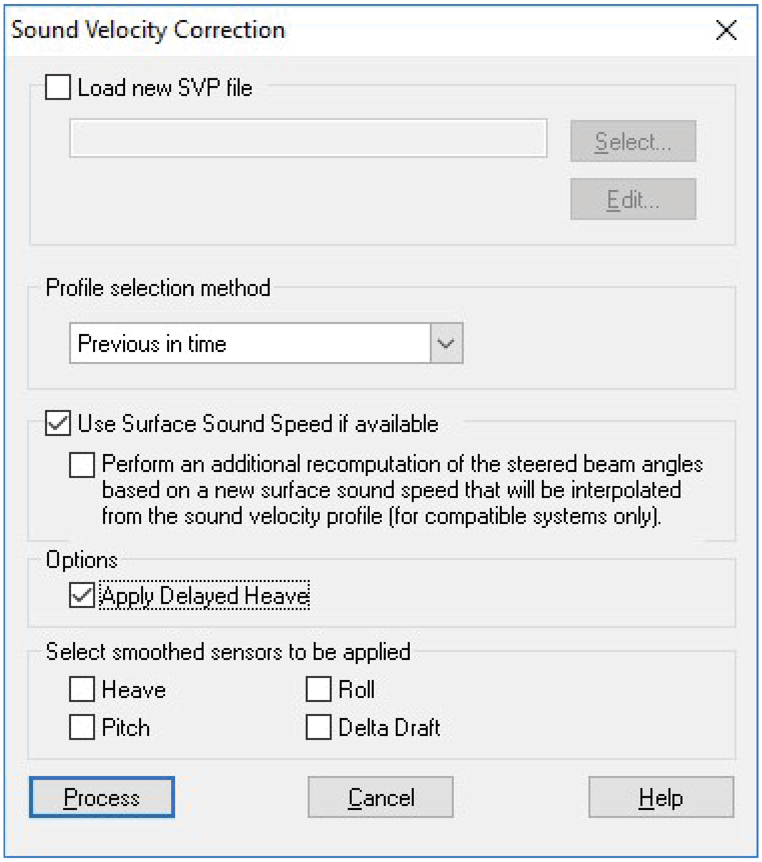
Import Delayed Heave (both methods, 1 and 2)




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.

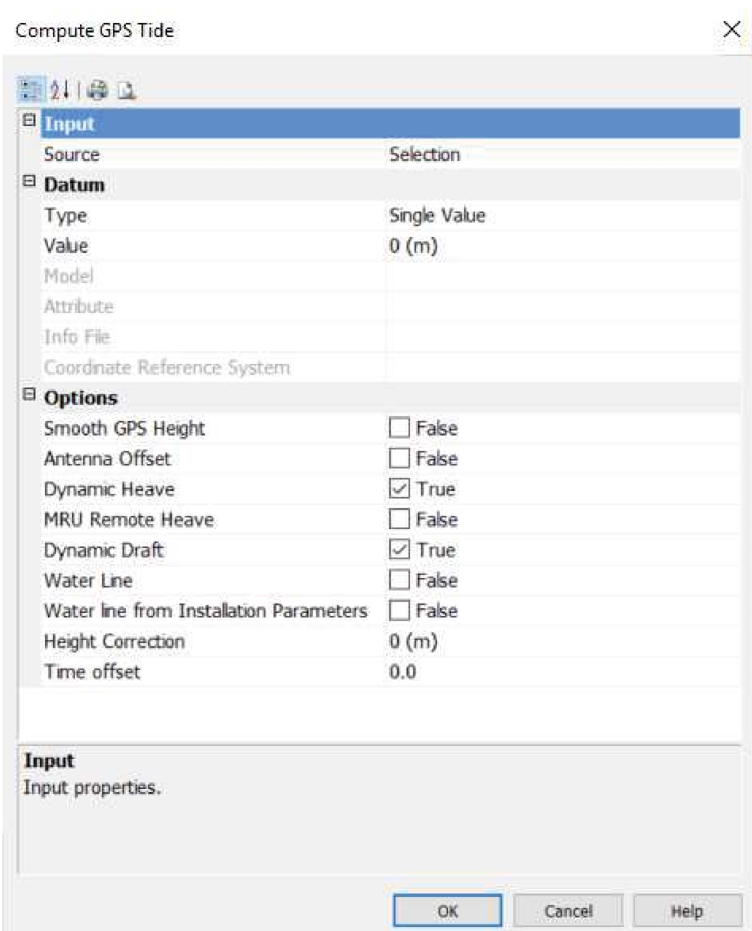
- Antenna offset is not selected because offsets from GPS antennas to the IMU accounted for in POS M/V

-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.

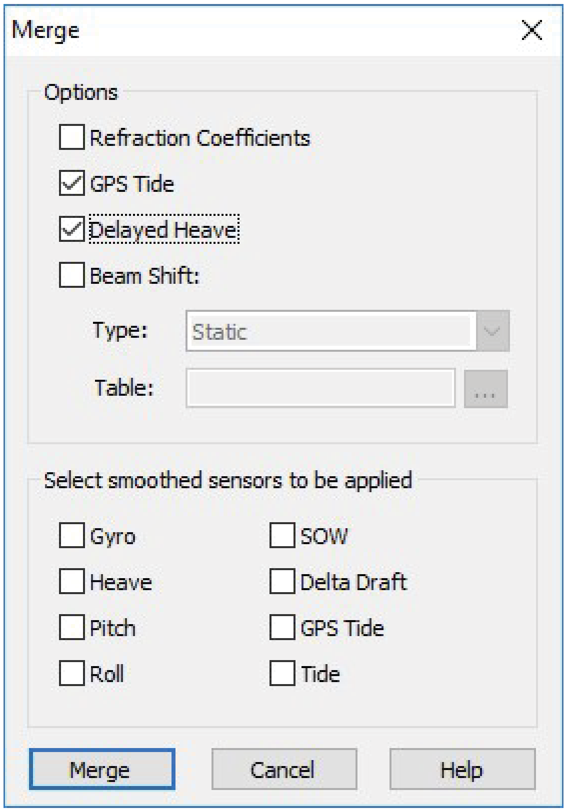
-Dynamic Draft (DD) is selected for congruence with HVF; DD is applied to the bathymetry per the HVF, so the GPS Height must be compensated to match.

-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.

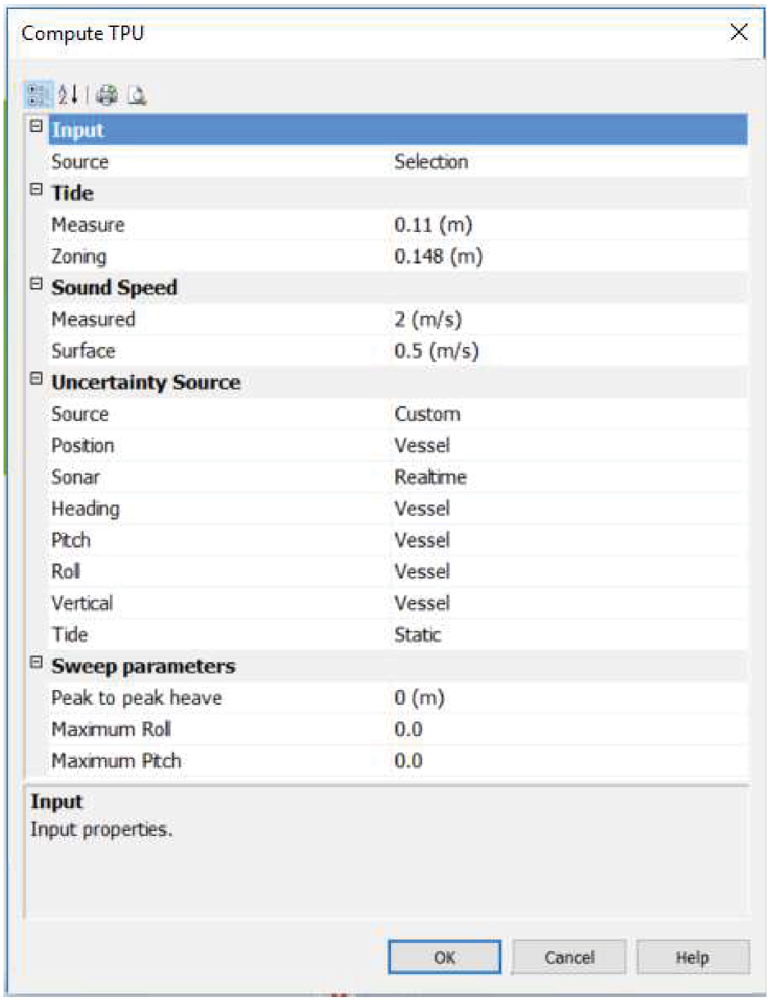


Merge and Compute TPU - Method 1 (ERS)

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.

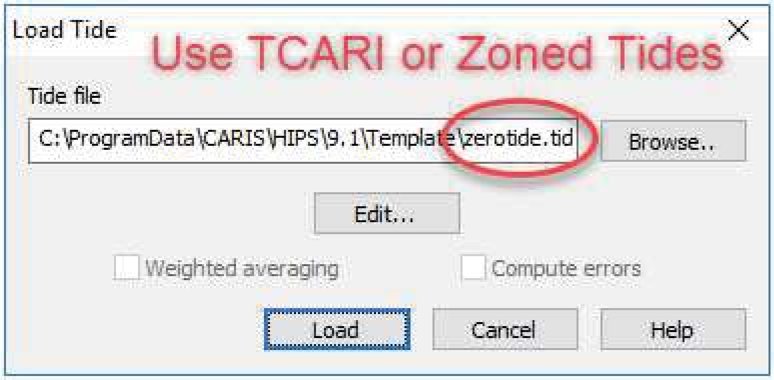


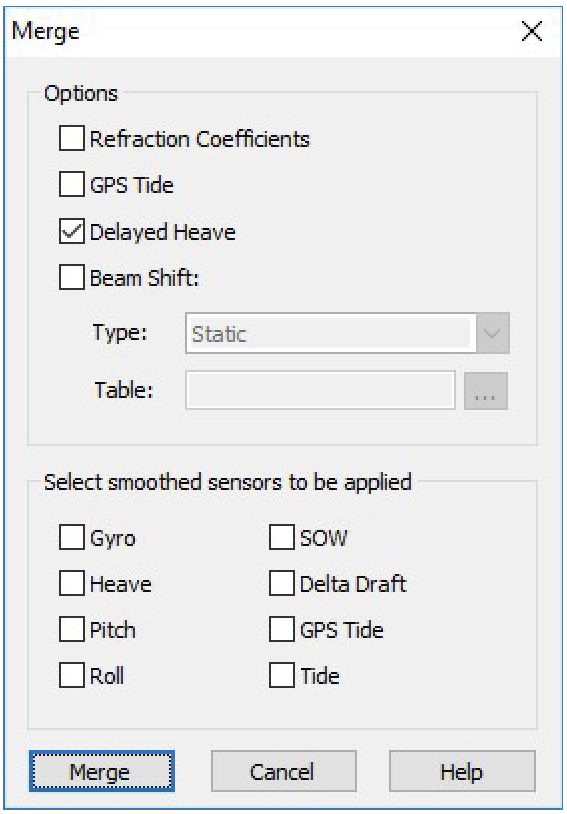
TPU for the vertical datum when surveying to the ellipsoid is a variance summation of the uncertainties associated with (1) MarineStar-aided POS MV height and (2) the datum separation (SEP) model. The MarineStar uncertainty is placed in the Tide / Measured section of the TPU dialog as 0.11 meters. The 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.



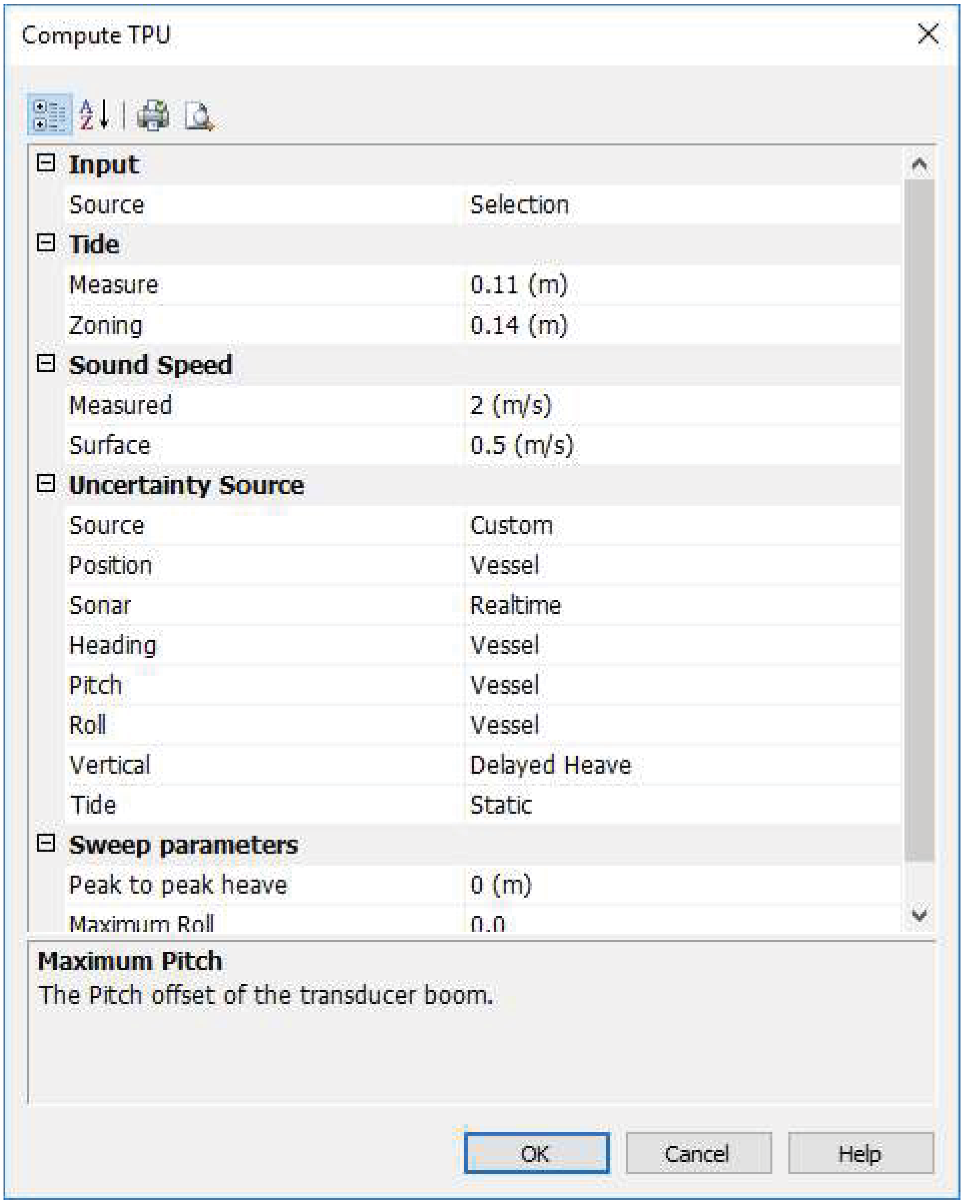

```
====== ComputeTPU start: Dec 7, 2016 8:00:36 AM ======
E:\ProcData\HDCS_Data\TJ_Heave\S222_EM2040_2016_SVC\2016-313\0135_20161108_013725_S222_EM2040. The following error sources were applied:
Warning: Realtime gyro errors not available. Vessel settings used instead.
Warning: Realtime pitch errors 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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Industrial **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:

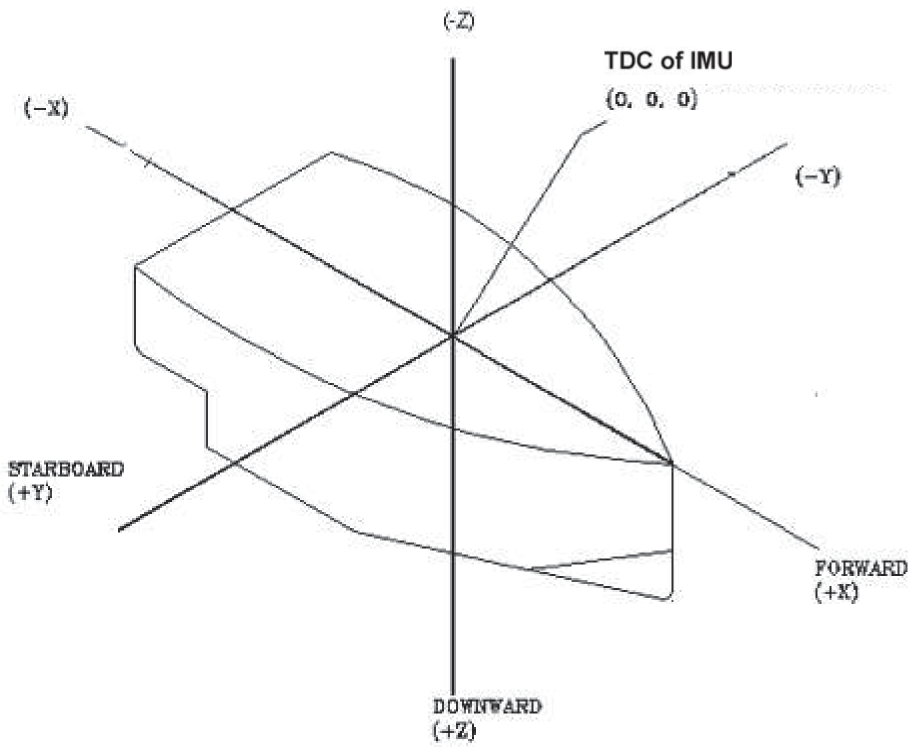


Figure 1 – Vessel Coordinate System

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)

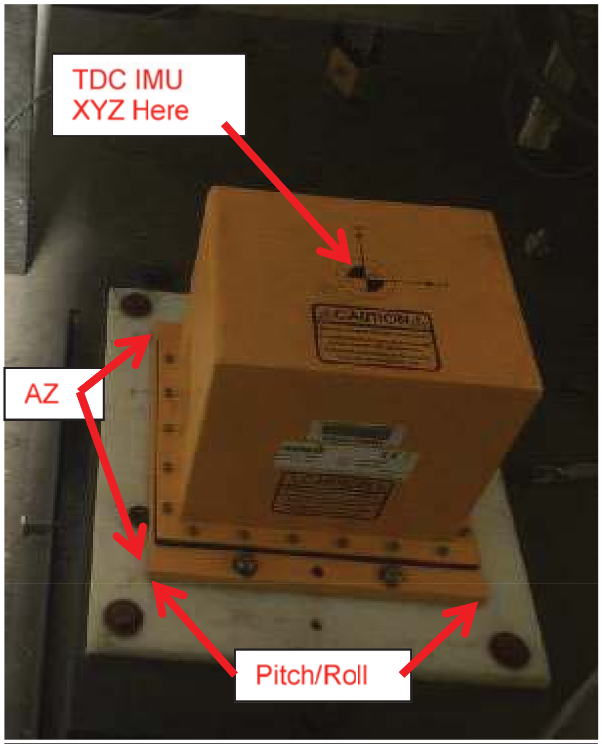


Figure 3- Inertial Measurement Unit (IMU)

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.

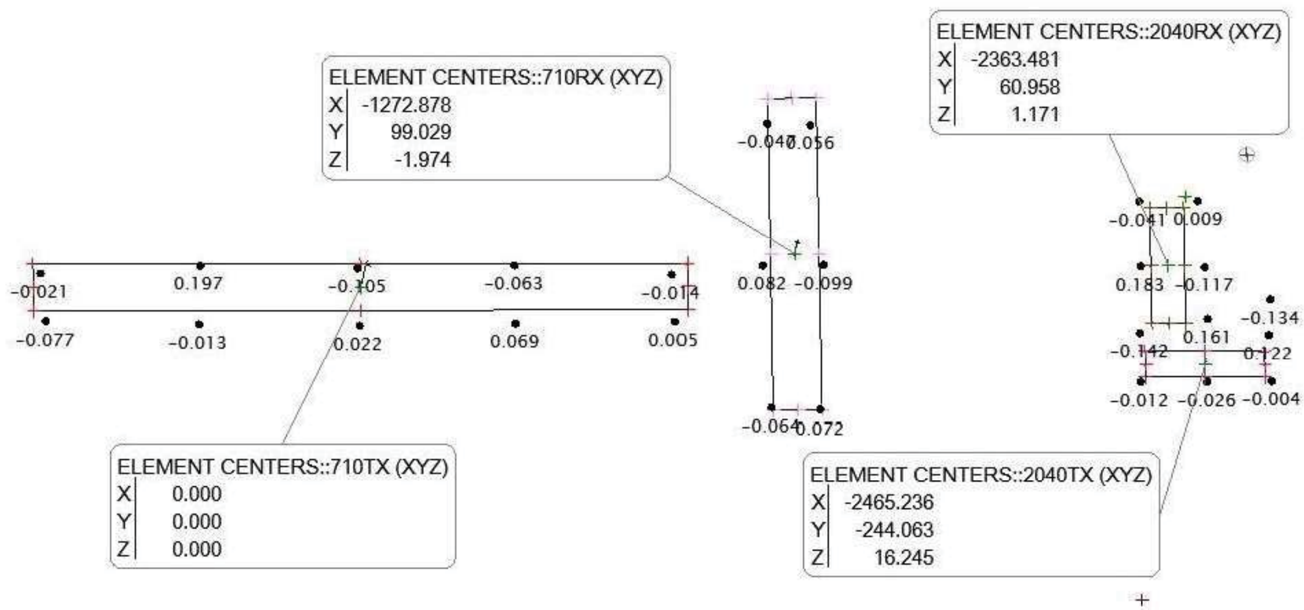


Figure 4-Flatness EM710 TX/RX and EM2040 TX/RX as Installed (mm)

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.

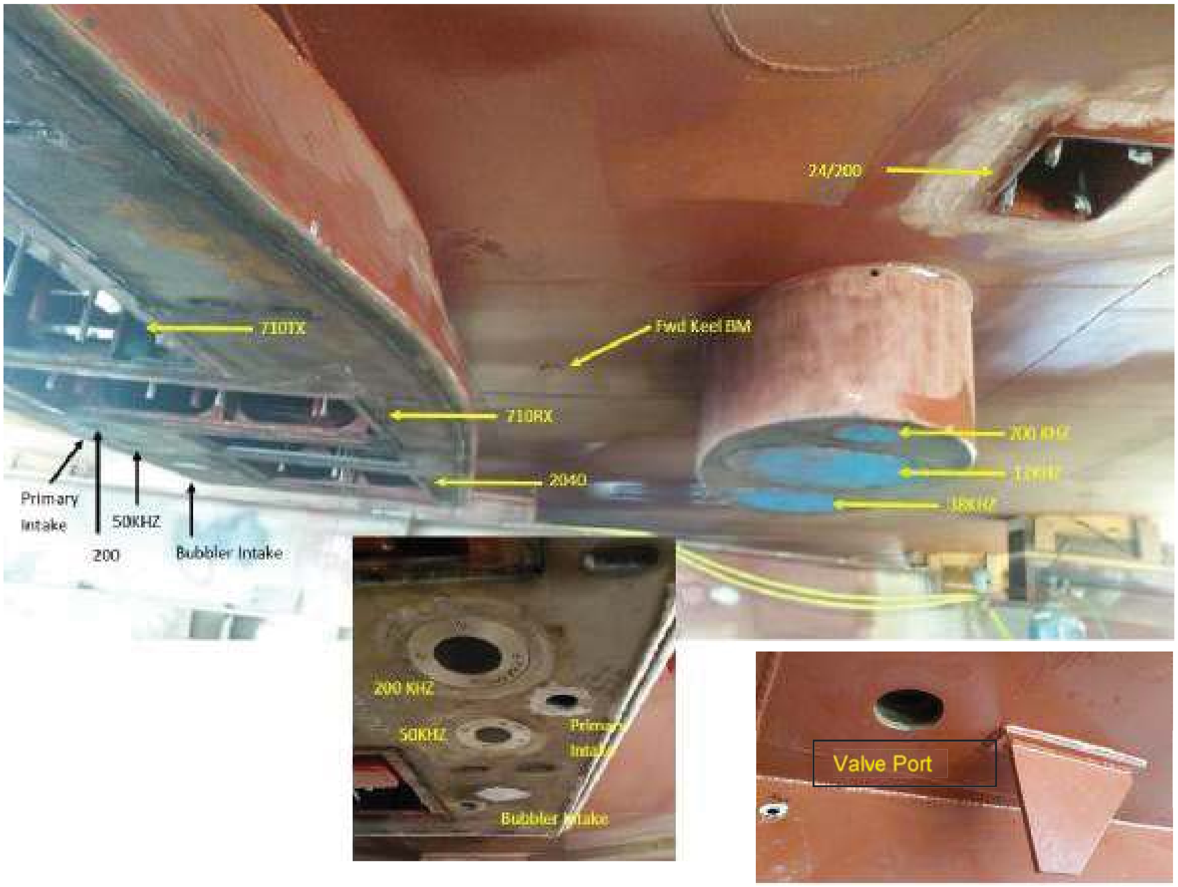


Figure 5-Elements at Bottom of Hull

Figure 6-Elements at Starboard side of Gondola

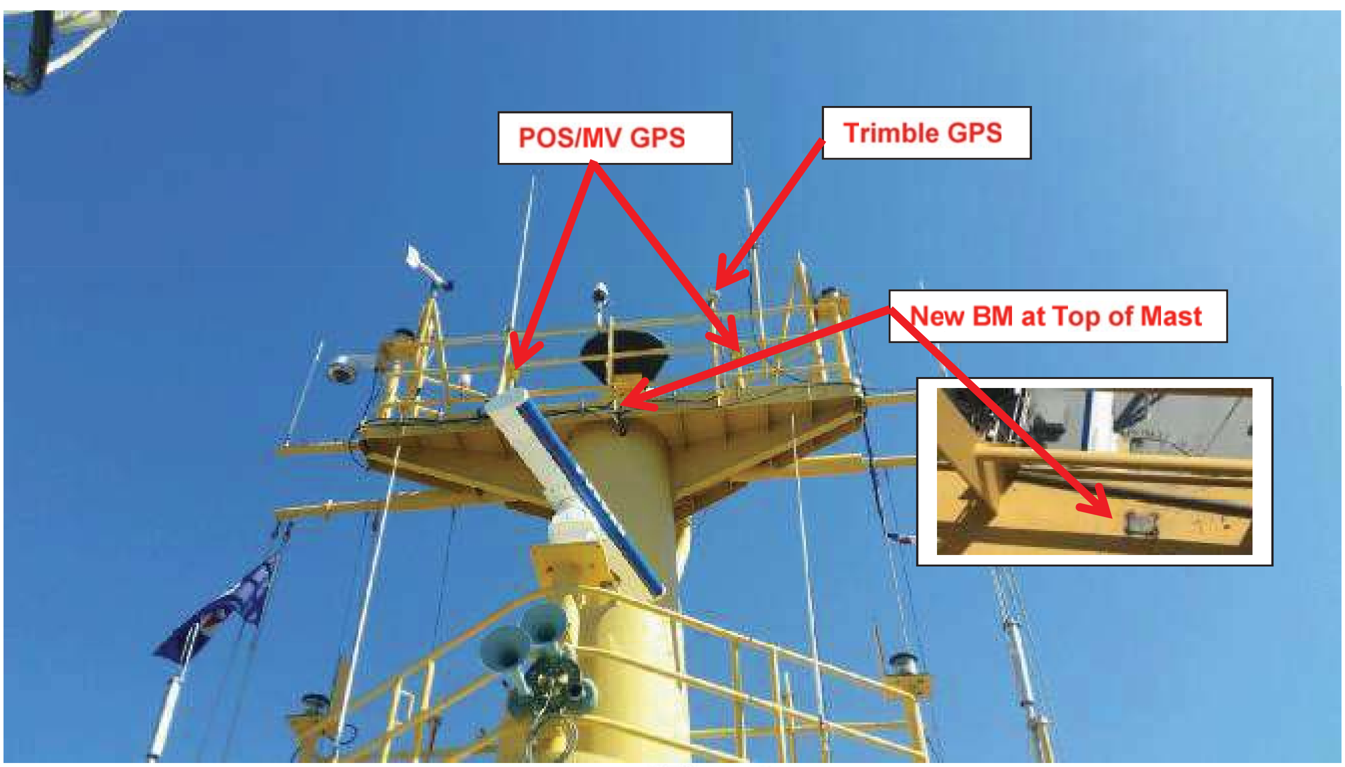


Figure 7- Mast Elements



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 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: [signature] 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

NOAA Ship Thomas Jefferson S-222 V2 2016 Sidescan Calibration
Klein5000 V2 100m Range Scale
Contact is: charted 55ft obstn (presumably an anchor)

MBES Position of Contact

Lat	Long	
32.002342	-80.457863	***average of all SSS contacts

SSS Contacts	Lat	Long	Line Hdg	Line Hdg (rad.)	Lat Diff (m)	Long Diff (m)	Dist. (m)	Along Trk (m)	Across Trk (m)	Dist. (m)
1	32.0023500	-80.4578490	359.828	6.28	0.89	1.32	1.59	1.32	0.885	1.59
2	32.002343	-80.457878	179.859	3.14	0.11	-1.41	1.42	1.41	-0.115	1.42
3	32.002334	-80.457871	269.795	4.71	-0.89	-0.75	1.17	-0.89	0.757	1.17
4	32.002339	-80.457852	180.179	3.14	-0.33	1.04	1.09	-1.04	0.330	1.09
5	32.002333	-80.457857	89.555	1.56	-1.00	0.57	1.15	1.00	0.558	1.15
6	32.002334	-80.457866	179.927	3.14	-0.89	-0.28	0.93	0.28	0.889	0.93
7	32.002344	-80.457869	179.36	3.13	0.22	-0.57	0.61	0.56	-0.229	0.61
8	32.002346	-80.457873	269.844	4.71	0.44	-0.94	1.04	0.45	0.941	1.04
9	32.00235	-80.457849	180.541	3.15	0.89	1.32	1.59	-1.31	-0.901	1.59
10	32.002346	-80.457863	0.436	0.01	0.44	0.00	0.44	0.00	0.444	0.44
11										
12										

N	12	Average:	-0.01	0.03	1.10	0.01
DOF: 2N-1	23	StDev:	0.72	0.98	0.38	0.84

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

359.68

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)	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	0.8	1.1	

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

Error	1.6	**2.2**	**PASS**

Note: FPM method of 1.96*RMS standard deviation

Error:	2.4	**PASS**

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

Error	1.8	**PASS**

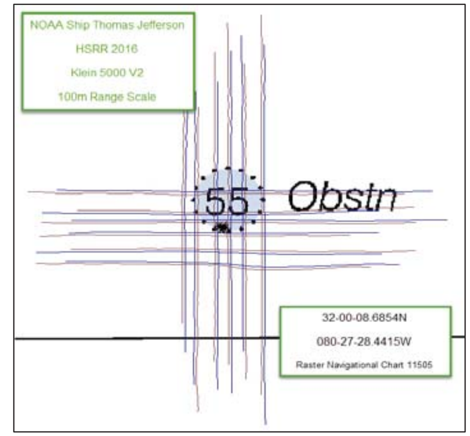


Figure 1: 55 ft Obstruction on NOAA RNC 11505.

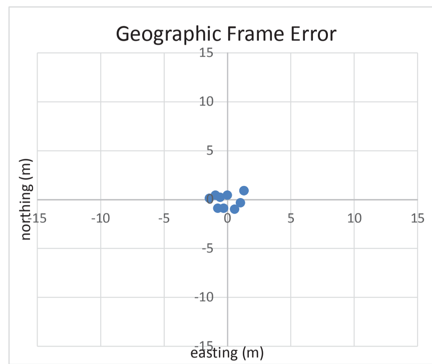


Figure 2: Contact position errors in a geographic reference frame.

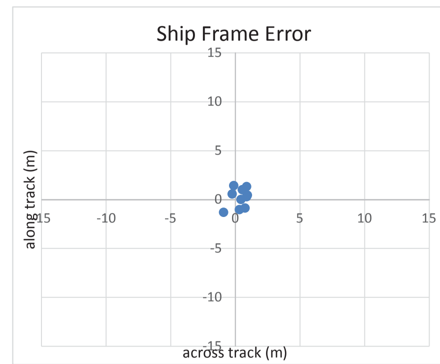


Figure 3: Contact position errors in a ship aligned reference frame.

NOAA Ship Thomas Jefferson S-222 V2 2016 Sidescan Calibration
Klein5000 V2 100m Range Scale
Contact is: charted 55ft obstn (presumably an anchor)

MBES Position of Contact

Lat	Long	
32.002394	-80.457893	***average of all SSS contacts

SSS Contacts	Lat	Long	Line Hdg	Line Hdg (rad.)	Lat Diff (m)	Long Diff (m)	Dist. (m)	Along Trk (m)	Across Trk (m)	Dist. (m)
1	32.0023770	-80.4578950	179.777	3.14	-1.89	-0.19	1.90	0.20	1.888	1.90
2	32.002409	-80.457871	90.692	1.58	1.67	2.07	2.66	-1.69	2.053	2.66
3	32.002417	-80.457908	359.68	6.28	2.56	-1.41	2.92	-1.40	2.564	2.92
4	32.002383	-80.457852	0.122	0.00	-1.22	3.86	4.05	3.87	-1.214	4.05
5	32.002428	-80.457903	89.948	1.57	3.78	-0.94	3.89	-3.78	-0.939	3.89
6	32.002385	-80.457914	180.063	3.14	-1.00	-1.98	2.22	1.98	1.002	2.22
7	32.002392	-80.457866	269.65	4.71	-0.22	2.54	2.55	-0.24	-2.543	2.55
8	32.00238	-80.45791	179.865	3.14	-1.56	-1.60	2.23	1.61	1.552	2.23
9	32.002383	-80.457909	270.312	4.72	-1.22	-1.51	1.94	-1.23	1.501	1.94
10										
11										
12										

N	12	Average:	0.10	0.09	2.71	0.10
DOF: 2N-1	23	StDev:	2.05	2.16	0.79	2.04

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

359.68

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)	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	2.0	2.7	
And the 95% confidence inteval of the positioning error is:			
Error	4.0	**5.3**	**FAIL**

Note: FPM method of 1.96*RMS standard deviation

Error: 5.8 **FAIL**

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

Error 4.3 **PASS**

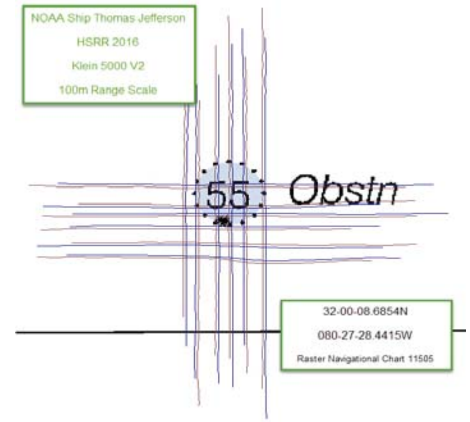


Figure 1: 55 ft Obstruction on NOAA RNC 11505.

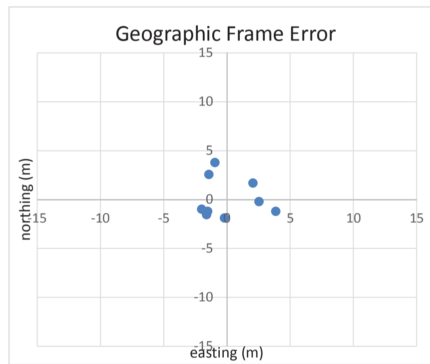


Figure 2: Contact position errors in a geographic reference frame.

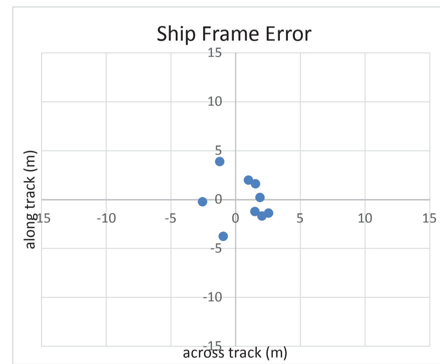


Figure 3: Contact position errors in a ship aligned reference frame.

Appendix III
Position and Attitude Calibrations

POS/MV Calibration Report

Field Unit: Thomas Jefferson

SYSTEM INFORMATION

Vessel: S222

Date: 10/13/2016 Dn: 287

Personnel: Ligon

PCS Serial # 6497

IP Address: 129.100.1.231

POS controller Version (Use Menu Help > About) version 8.46

POS Version (Use Menu View > Statistics) MV-320 version 5

GPS Receivers

Primary Receiver BD982 SN5409086558

Secondary Receiver n/a

CALIBRATION AREA

Location: Chesapeake Bay

Approximate Position:

	D	M	S
Lat	37	33	38.5
Lon	76	7	34.9

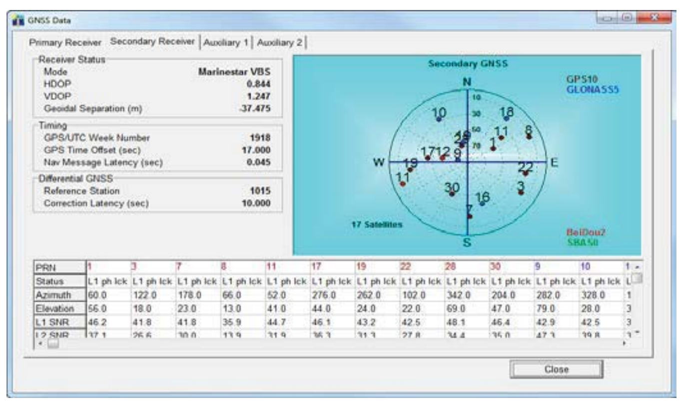
DGPS Beacon Station: Marinestar

Frequency: n/a

Satellite Constellation

(Use View> GPS Data)

Primary GPS (Port Antenna)



HDOP: 0.844

VDOP: 1.247

Sattelites in Use: 10

PDOP 1.880 (Use View> GAMS Solution)

POS/MV CONFIGURATION

Settings

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

User Entries, Pre-Calibration

n/a	Two Antenna Separation (m)
0.50	Heading Calibration Threshold
0	Heading Correction

Baseline Vector

0.024	X Component (m)
2.204	YComponent (m)
-0.001	Z Component (m)

POS/MV CALIBRATION

Calibration Procedure:

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

Start time: 1139

End time: 1145

Heading accuracy achieved for calibration: 0.018

Calibration Results:

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

POS/MV Post-Calibration Values

n/a	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? x

Save Settings? x

****POST PROCESSED VALUES ARE USED IN POS VIEW SETUP

Baseline Vector

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

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

File Name: S222_Pos_Config_13October2016.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:

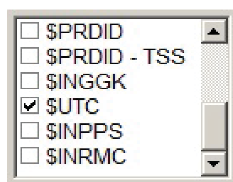
a) Heading rotation - apply a right-hand screw rotation θz about the z-axis to align one frame with the other.

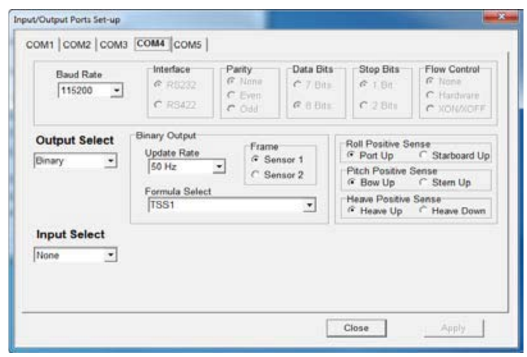
b) Pitch rotation - apply a right-hand screw rotation θy about the once-rotated y-axis to align one frame with the other.

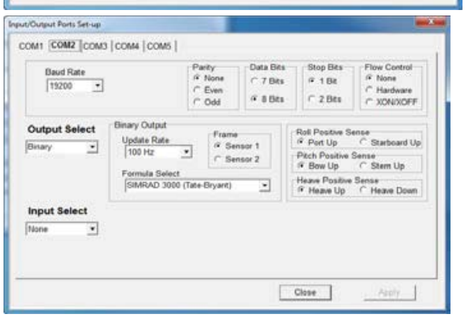
c) Roll rotation - apply a right-hand screw rotation θx about the twice-rotated x-axis to align one frame with the other.

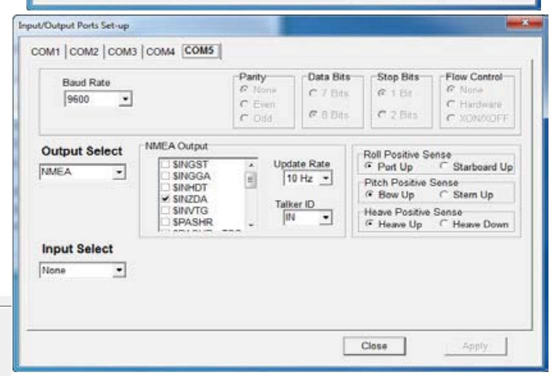
SETTINGS (insert screen grabs)

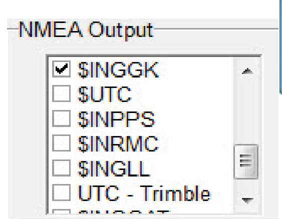
Input/Output Ports (Use Settings > Input/Output Ports)





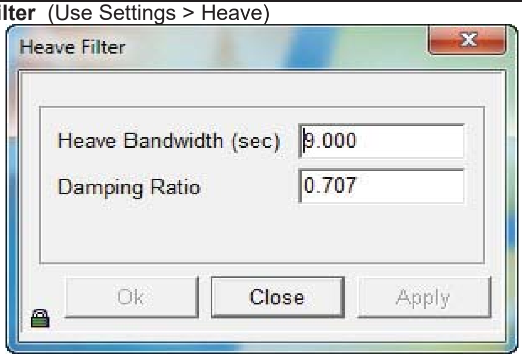




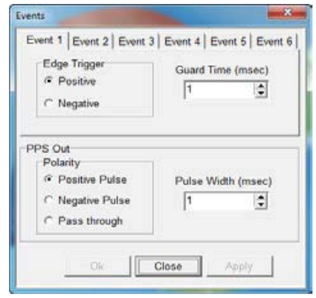


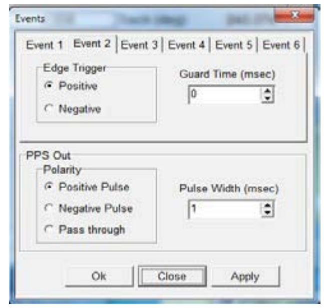
NOTE:

Heave Filter (Use Settings > Heave)



Events (Use Settings > Events)



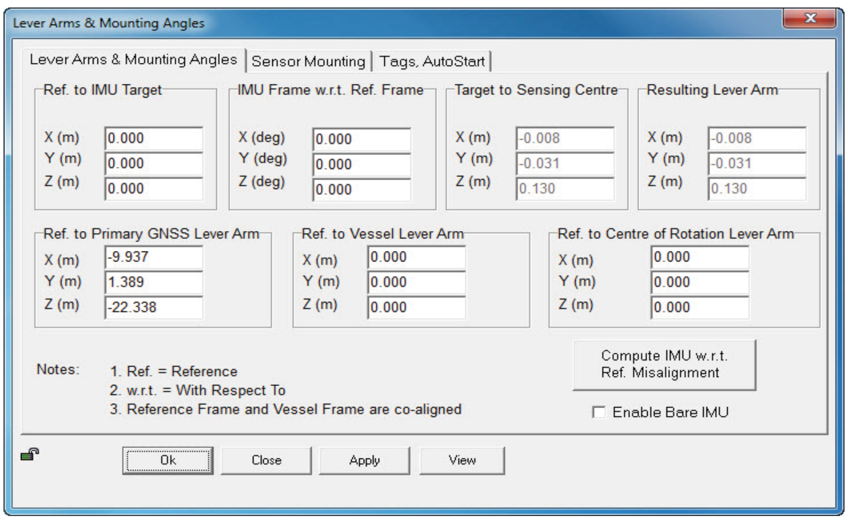


All other events are the same as event 2

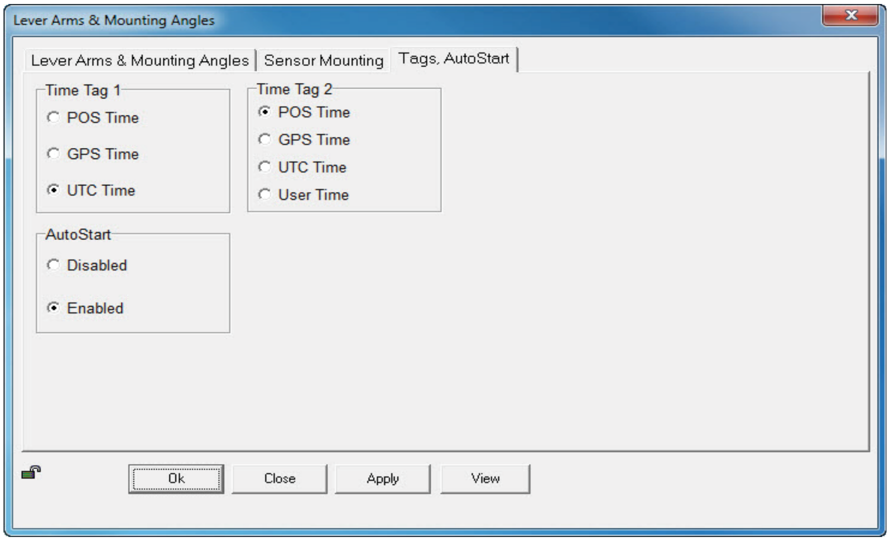
Time Sync (Use Settings > Time Sync)

Does not exist on the POS/MV Version 5

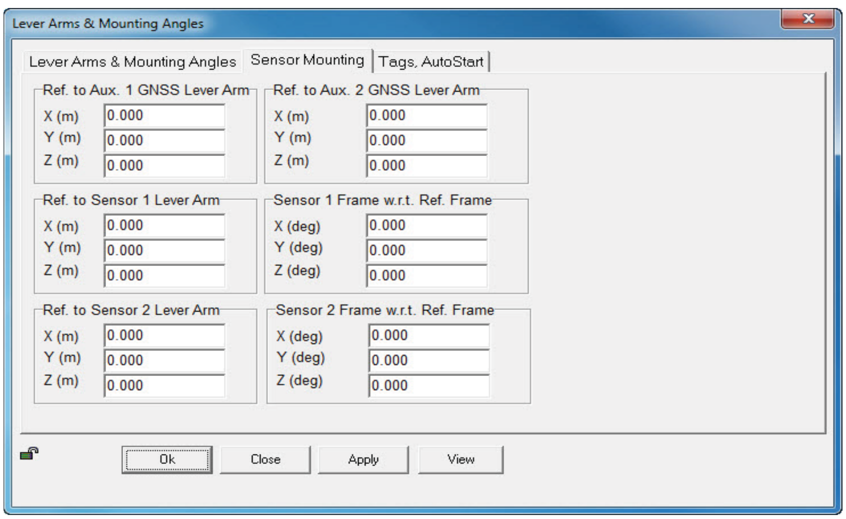
Installation (Use Settings > Installation)



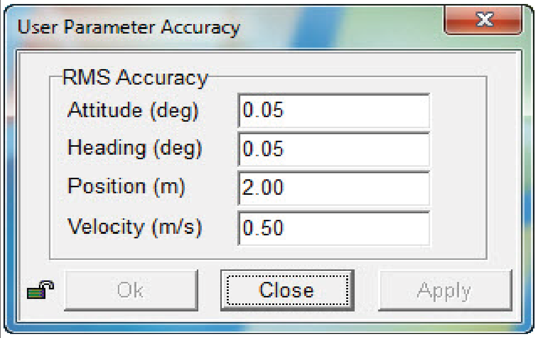
Tags, Multipath and Auto Start (Use Settings > Installation > Tags, Multipath and Auto Start)



Sensor Mounting (Use Settings > Installation > Sensor Mounting)



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

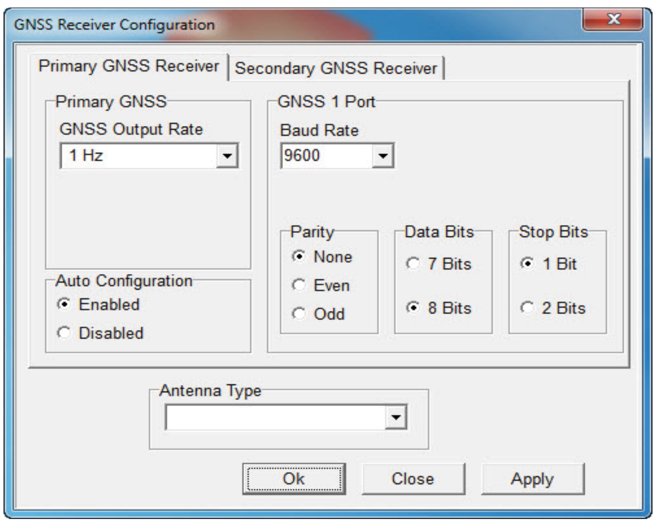


Frame Control (Use Tools > Config)

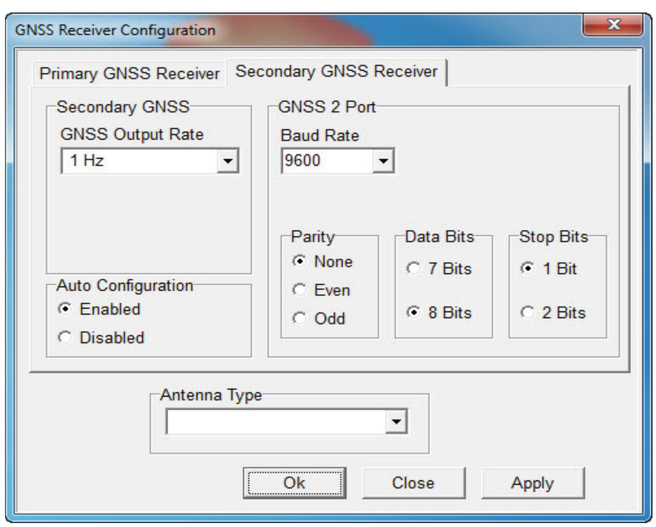
Does not exist on the POS/MV Version 5

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

Primary GPS Receiver



Secondary GPS Receiver



Appendix IV
Sound Speed Calibration Reports

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 (TTH)**

Serial Number(s) **33711**

Pressure Test **10 Bar**

Date of Despatch **21st October 2014**

Valeport Limited, St. Peter's Quay, Totnes, Devon, TQ9 5EW. U.K.
Tel: +44 (0)1803 869292 Fax: +44 (0)1803 869293
E-mail: sales@valeport.co.uk Web: www.valeport.co.uk

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

Calibration Certificate Number:	39627

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.

Instrument Type:	**Modus SVS**
Instrument Serial Number:	**33711**
Calibrated By:	**L.Bicknell**
Date:	**17/10/2014**
Signed:	LB

Full details of the results from the calibration procedure applied to each fitted sensor are available in separate documents. This summary certificate should be kept with the instrument.

Valeport Limited, St. Peter's Quay, Totnes, Devon, TQ9 5EW. U.K.
Tel: +44 (0)1803 869292 Fax: +44 (0)1803 869293
E-mail: sales@valeport.co.uk Web: www.valeport.co.uk

Instrument Serial Number	33711
Transducer Type, mm	50
Transducer Ser No	52297
PCB Part No	0400554B
PCB Ser No	53049
SV Firmware Version	04007149B0
Module Number	12

Calibration Equipment used		
Instrument	Type	Serial No
Temp Bridge	MICRO K	311063/1
PRT	909L	107

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
2.3752	1414.031	7430014	3.830610E+05	1414.031	0.000	±0.001	Pass
15.7887	1468.677	7167814	1.003552E+07	1468.677	0.000	±0.001	Pass

Stage 2: Enter calibration string

#024;12;1;15;0;0;0;0;1.003552E+07;3.830610E+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
15.7884	1468.676	1468.675	-0.001	±0.005	Pass

Name:	L.Bicknell
Date:	17/10/2014
Signature:	LB

Instrument type	Modus SVS
Serial number	33711
Baud rate set ex factory	AUTO

Calibration History:	Certificate	Date
	26504	14/09/2010
	39627	17/10/2014

Fitted Parts	Original Manufacture							Modification						
	Part	Iss	Firmware	Iss	PCB SN	Sensor SN	Mod	Part	Iss	Firmware	Iss	PCB SN	Sensor SN	Mod
PSU (main)	0400512	D			15930									
PSU (sub)	N/A													
Microprocessor	0400500	F	4007112	A	51686									
RAM	N/A		N/A											
Flash Memory	N/A		N/A											
SV (round)	400554	A	04007149	B0	53049	52297								
			0650714	A						0650714	C			
Name	P Tremlett							S.Bowles						
Date	14/09/2010							16/10/2014						
Signed														

Fitted Parts	Modification							Modification						
	Part	Iss	Firmware	Iss	PCB SN	Sensor SN	Mod	Part	Iss	Firmware	Iss	PCB SN	Sensor SN	Mod
PSU (main)														
PSU (sub)														
Microprocessor														
RAM														
Flash Memory														
SV (round)														
Name														
Date														
Signed														

Calibrations for each sensor/PCB are on separate sheets, with filenames defined by the sensor serial number

Certificate of Calibration

Customer:	NOAA - OMAO
Asset Serial Number:	007761
Asset Product Type:	Micro CTD, Fixed Sensors, for Brooke MVP -
Calibration Type:	Temperature
Calibration Range:	-2 to +32 Dec C
Calibration RMS Error:	.0011
Calibration ID:	007761 888888 007761 110416 101313
Installed On:	

Coefficient A:	-9.498746E+0	Coefficient H:	0.000000E+0
Coefficient B:	9.268214E-4	Coefficient I:	0.000000E+0
Coefficient C:	-1.320699E-8	Coefficient J:	0.000000E+0
Coefficient D:	3.599358E-13	Coefficient K:	0.000000E+0
Coefficient E:	-6.379873E-18	Coefficient L:	0.000000E+0
Coefficient F:	6.857165E-23	Coefficient M:	0.000000E+0
Coefficient G:	-2.971719E-28	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 11/4/2016

Certified By:

AML Oceanographic

Robert Haydock

President, AML Oceanographic

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Certificate of Calibration

Customer:	NOAA - OMAO
Asset Serial Number:	007761
Asset Product Type:	Micro CTD, Fixed Sensors, for Brooke MVP -
Calibration Type:	Pressure
Calibration Range:	1000 dBar
Calibration RMS Error:	.0675
Calibration ID:	007761 999999 007761 150416 134241
Installed On:	

Coefficient A:	1.809010E+4	Coefficient H:	1.051234E-14
Coefficient B:	-1.220359E+0	Coefficient I:	-8.862421E-6
Coefficient C:	2.749514E-5	Coefficient J:	6.218871E-10
Coefficient D:	-2.090448E-10	Coefficient K:	-1.454745E-14
Coefficient E:	-9.632484E-1	Coefficient L:	1.134265E-19
Coefficient F:	6.501725E-5	Coefficient M:	0.000000E+0
Coefficient G:	-1.432178E-9	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 15/4/2016

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Certificate of Calibration

Customer:	NOAA - OMAO
Asset Serial Number:	007761
Asset Product Type:	Micro CTD, Fixed Sensors, for Brooke MVP -
Calibration Type:	Conductivity
Calibration Range:	0 to 70 mS/cm
Calibration RMS Error:	.0078
Calibration ID:	007761 999999 007761 110416 101313
Installed On:	

Coefficient A:	-1.098864E-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:	2.491968E-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

Calibration Date (dd/mm/yyyy): 11/4/2016

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	007591
Asset Product Type:	Micro SV&P for Brooke MVP -
Calibration Type:	Pressure
Calibration Range:	1000 dBar
Calibration RMS Error:	.0612
Calibration ID:	007591 129146 0TE599 060116 073714
Installed On:	

Coefficient A:	-2.573882E+3	Coefficient H:	-5.916234E-15
Coefficient B:	1.820538E-1	Coefficient I:	-1.762715E-5
Coefficient C:	-4.133096E-6	Coefficient J:	1.123850E-9
Coefficient D:	2.932489E-11	Coefficient K:	-2.388330E-14
Coefficient E:	5.711750E-1	Coefficient L:	1.691618E-19
Coefficient F:	-3.660197E-5	Coefficient M:	0.000000E+0
Coefficient G:	8.071607E-10	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 6/1/2016

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	007591
Asset Product Type:	Micro SV&P for Brooke MVP -
Calibration Type:	Sound Velocity
Calibration Range:	1400 to 1600 m/s
Calibration RMS Error:	.0119
Calibration ID:	007591 131945 201783 070116 224447
Installed On:	

Coefficient A:	7.156173E-4	Coefficient H:	0.000000E+0
Coefficient B:	-7.434818E-5	Coefficient I:	0.000000E+0
Coefficient C:	6.005343E-7	Coefficient J:	0.000000E+0
Coefficient D:	-2.368344E-7	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

Calibration Date (dd/mm/yyyy): 7/1/2016

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	004988
Asset Product Type:	Smart SV&P for Brooke MVP -
Calibration Type:	Pressure
Calibration Range:	1000 dBar
Calibration RMS Error:	.0602
Calibration ID:	004988 021407 0XE111 060116 102710
Installed On:	

Coefficient A:	-1.568568E+3	Coefficient H:	-5.412054E-9
Coefficient B:	-8.337370E-1	Coefficient I:	8.887834E-9
Coefficient C:	2.784933E-3	Coefficient J:	-2.154370E-11
Coefficient D:	1.651412E-4	Coefficient K:	-1.798432E-12
Coefficient E:	4.765522E-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

Calibration Date (dd/mm/yyyy): 6/1/2016

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	004988
Asset Product Type:	Smart SV&P for Brooke MVP -
Calibration Type:	Sound Velocity
Calibration Range:	1400 to 1550 m/s
Calibration RMS Error:	.0196
Calibration ID:	004988 011712 139859 070116 224434
Installed On:	

Coefficient A:	1.529674E+3	Coefficient H:	0.000000E+0
Coefficient B:	-1.120437E+2	Coefficient I:	0.000000E+0
Coefficient C:	8.727113E+0	Coefficient J:	0.000000E+0
Coefficient D:	-6.024493E-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

Calibration Date (dd/mm/yyyy): 7/1/2016

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	005340
Asset Product Type:	Smart SV&P for Brooke MVP -
Calibration Type:	Pressure
Calibration Range:	1000 dBar
Calibration RMS Error:	.0182
Calibration ID:	005340 127028 0TE689 060116 141722
Installed On:	

Coefficient A:	-1.917255E+3	Coefficient H:	1.044152E-8
Coefficient B:	-1.399663E+0	Coefficient I:	1.213073E-8
Coefficient C:	2.217375E-2	Coefficient J:	-1.508418E-10
Coefficient D:	-1.520440E-4	Coefficient K:	8.793572E-12
Coefficient E:	5.847980E-2	Coefficient L:	-1.896560E-13
Coefficient F:	4.658058E-5	Coefficient M:	0.000000E+0
Coefficient G:	-9.419392E-7	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 6/1/2016

Certified By:

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	005340
Asset Product Type:	Smart SV&P for Brooke MVP -
Calibration Type:	Sound Velocity
Calibration Range:	1400 to 1550 m/s
Calibration RMS Error:	.0176
Calibration ID:	005340 126551 201222 060116 222823
Installed On:	

Coefficient A:	1.530665E+3	Coefficient H:	0.000000E+0
Coefficient B:	-1.074192E+2	Coefficient I:	0.000000E+0
Coefficient C:	8.165884E+0	Coefficient J:	0.000000E+0
Coefficient D:	-6.196314E-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

Calibration Date (dd/mm/yyyy): 6/1/2016

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	004823
Asset Product Type:	Smart SV&T
Calibration Type:	Sound Velocity
Calibration Range:	1400 to 1550 m/s
Calibration RMS Error:	.026
Calibration ID:	004823 011243 139857 070116 224434
Installed On:	

Coefficient A:	1.524047E+3	Coefficient H:	0.000000E+0
Coefficient B:	-1.025687E+2	Coefficient I:	0.000000E+0
Coefficient C:	2.646339E+0	Coefficient J:	0.000000E+0
Coefficient D:	1.704442E+0	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

Calibration Date (dd/mm/yyyy): 7/1/2016

Certified By:

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	004823
Asset Product Type:	Smart SV&T
Calibration Type:	Temperature
Calibration Range:	-2 to +32 Deg C
Calibration RMS Error:	.003
Calibration ID:	004823 030407 T12501 070116 080905
Installed On:	

Coefficient A:	-4.642083E+1	Coefficient H:	0.000000E+0
Coefficient B:	2.897658E-3	Coefficient I:	0.000000E+0
Coefficient C:	-4.708305E-8	Coefficient J:	0.000000E+0
Coefficient D:	4.804253E-13	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

Calibration Date (dd/mm/yyyy): 7/1/2016

Certified By:

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	005649
Asset Product Type:	Smart SV&T Instrument, 500m Housing
Calibration Type:	Sound Velocity
Calibration Range:	1400 to 1600 m/s
Calibration RMS Error:	.0111
Calibration ID:	005649 002051 204120 070116 224434
Installed On:	

Coefficient A:	7.148284E-4	Coefficient H:	0.000000E+0
Coefficient B:	-7.426892E-5	Coefficient I:	0.000000E+0
Coefficient C:	3.528940E-7	Coefficient J:	0.000000E+0
Coefficient D:	-2.640132E-7	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

Calibration Date (dd/mm/yyyy): 7/1/2016

Certified By:

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Certificate of Calibration

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	005649
Asset Product Type:	Smart SV&T Instrument, 500m Housing
Calibration Type:	Temperature
Calibration Range:	-2 to +45 Deg C
Calibration RMS Error:	.0019
Calibration ID:	005649 002099 400180 060116 174100
Installed On:	

Coefficient A:	-1.735968E+1	Coefficient H:	0.000000E+0
Coefficient B:	1.652831E-3	Coefficient I:	0.000000E+0
Coefficient C:	-3.523371E-8	Coefficient J:	0.000000E+0
Coefficient D:	8.645099E-13	Coefficient K:	0.000000E+0
Coefficient E:	-1.242330E-17	Coefficient L:	0.000000E+0
Coefficient F:	9.905392E-23	Coefficient M:	0.000000E+0
Coefficient G:	-2.569366E-28	Coefficient N:	0.000000E+0

Calibration Date (dd/mm/yyyy): 6/1/2016

Certified By:

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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: 0285
CALIBRATION DATE: 13-Jan-16

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

COEFFICIENTS:

```
g =  -4.07424315e+000
h =   4.86097982e-001
i =   1.16276806e-003
j =  -1.95838076e-005
```

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

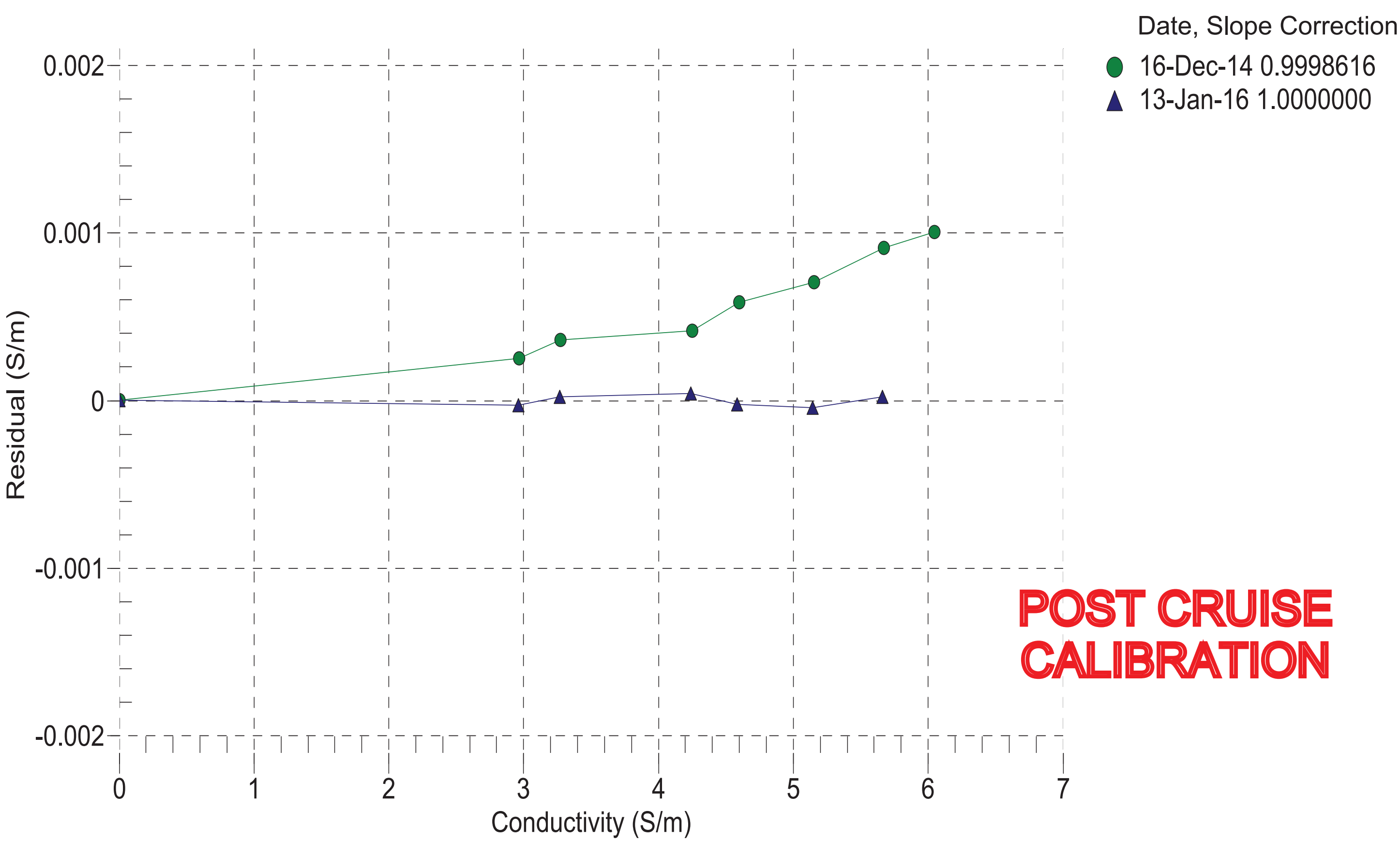
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2.88563	0.00000	0.00000
1.0000	34.6096	2.95997	8.25324	2.95995	-0.00003
4.5000	34.5901	3.26548	8.61696	3.26550	0.00002
15.0000	34.5484	4.24221	9.68699	4.24225	0.00004
18.5000	34.5398	4.58563	10.03560	4.58561	-0.00002
24.0000	34.5304	5.14078	10.57451	5.14073	-0.00004
29.0000	34.5256	5.66004	11.05448	5.66006	0.00002
32.5000	34.5228	6.03057	11.38446	6.03072	0.00015

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = 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.
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: 0285
CALIBRATION DATE: 04-Jan-16

SBE 19 PRESSURE CALIBRATION DATA
FSR: 5000 psia S/N 86209976 TCV:

QUADRATIC COEFFICIENTS:

PA0 = 2.491043e+003
PA1 = -6.502022e-001
PA2 = -1.851852e-008

STRAIGHT LINE FIT:

M = -6.502105e-001
B = 2.490932e+003

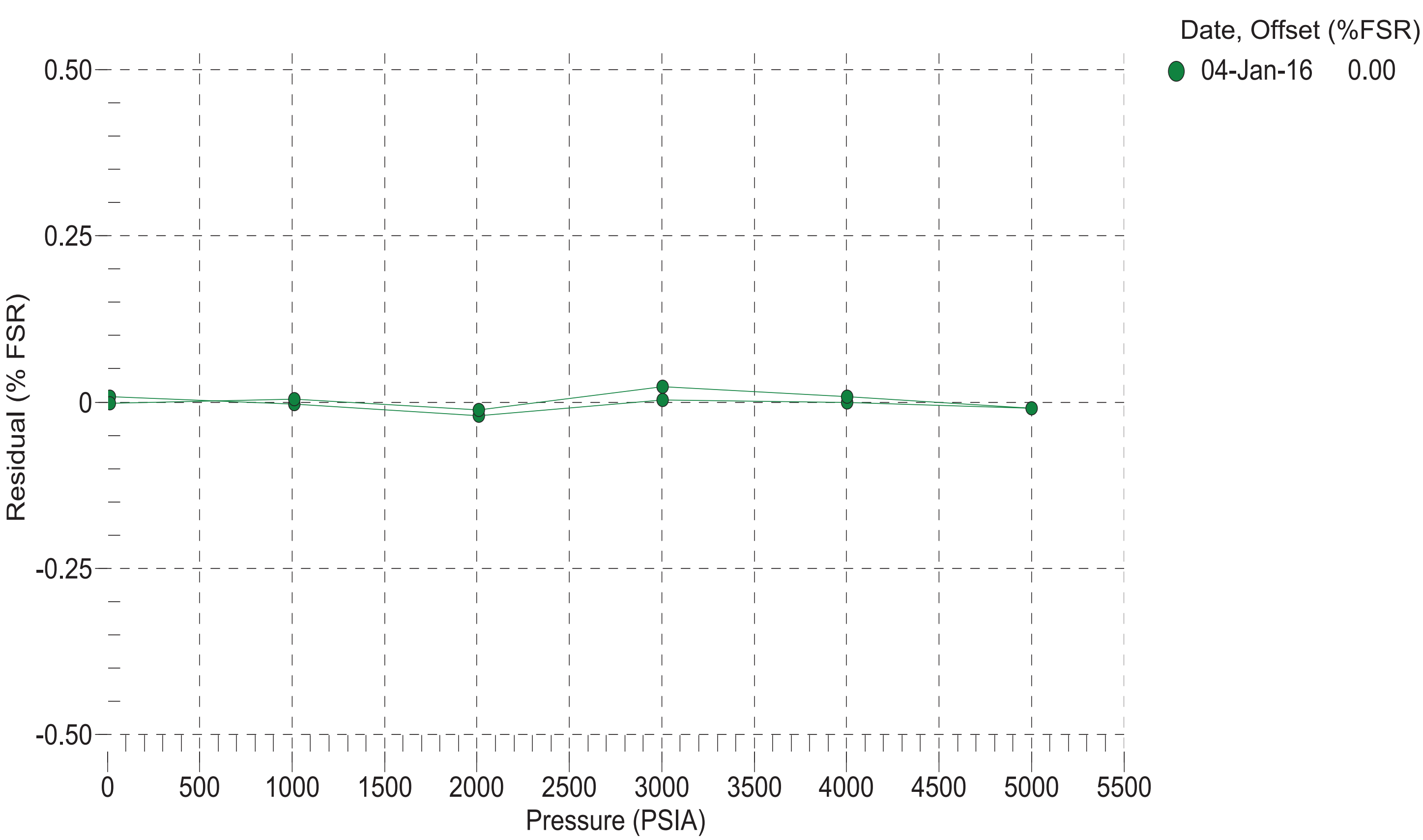
PRESSURE (PSIA)	INSTRUMENT OUTPUT (counts)	COMPUTED PRESSURE (PSIA)	RESIDUAL (%FSR)	LINEAR FIT (PSIA)	LINEAR RESIDUAL (%FSR)
14.46	3807.9	14.87	0.01	15.00	0.01
1011.26	2276.0	1011.09	-0.00	1011.05	-0.00
2008.28	744.0	2007.28	-0.02	2007.18	-0.02
3005.28	-791.1	3005.41	0.00	3005.31	0.00
4002.29	-2324.4	4002.27	-0.00	4002.28	-0.00
4999.32	-3857.4	4998.86	-0.01	4999.05	-0.01
4002.25	-2325.0	4002.66	0.01	4002.67	0.01
3004.78	-791.9	3005.93	0.02	3005.83	0.02
2008.25	743.4	2007.67	-0.01	2007.57	-0.01
1011.30	2275.3	1011.54	0.00	1011.51	0.00
14.46	3808.7	14.35	-0.00	14.48	0.00

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



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SENSOR SERIAL NUMBER: 0285
CALIBRATION DATE: 13-Jan-16

SBE 19 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

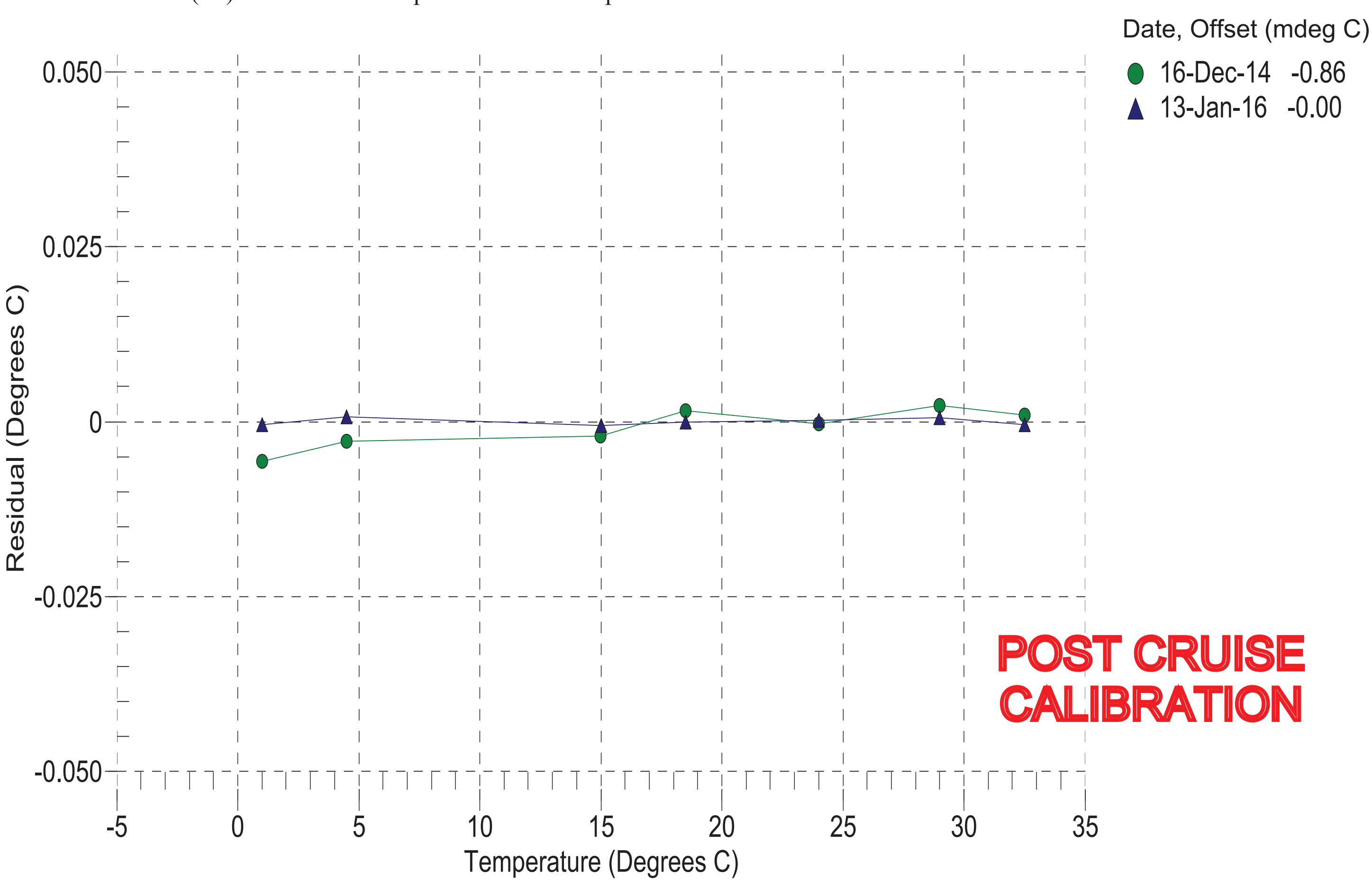
```
g =  4.12531391e-003
h =  5.76172682e-004
i = -3.65969797e-008
j = -2.84357970e-006
f0 =  1000.0
```

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	2297.536	0.9996	-0.00040
4.5000	2490.712	4.5007	0.00072
15.0000	3139.079	14.9994	-0.00058
18.5000	3379.526	18.4999	-0.00010
24.0000	3783.254	24.0002	0.00020
29.0000	4178.845	29.0006	0.00060
32.5000	4472.438	32.4996	-0.00045

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



POST CRUISE CALIBRATION