# Table of Contents

1. [Cruise Participants](#)
2. [Executive Summary](#)
3. [Introduction](#)
4. [Onboard Multibeam Activities](#)
5. [Survey System Components](#)
6. [System Geometry Review](#)
   1. Seapath 330-5+
   2. EM302
7. [EM302 Calibration (Patch Test)](#)
8. [EM302 Noise Assessment](#)
   1. RX Noise – Analysis
   2. RX Noise – Main Engine
   3. RX Noise – Jet Pump
9. [EM302 Accuracy Analysis](#)
   1. Deep Accuracy
   2. Shallow Accuracy
10. [EM302 Swath Coverage (Extinction)](#)
Table of Contents
11. Transducer Health
12. Water Column – Seep Detection
13. EM302 Sound Speed

Appendix Sections
1. RX Noise - NA127 - Main Engine - Pitch - Into Seas
2. RX Noise - NA127 - Main Engine - Speed - Into Seas
3. RX Noise - NA126 - Main Engine - Pitch - Into Seas
4. RX Noise - NA126 - Main Engine - Pitch - With Seas
5. RX Noise - NA126 - Main Engine - Speed - Into Seas
6. RX Noise - NA126 - Main Engine - Speed - With Seas
7. RX Noise - Noise Dampening
8. SIS Configuration
9. Seapath Configuration
10. Seapath Antenna Calibration
11. Sound Speed Manager Configuration
12. BSCorr
## NA126 Personnel

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allison Fundis</td>
<td>Lead Scientist</td>
<td>OET</td>
</tr>
<tr>
<td>Lindsay Gee</td>
<td>Expedition Leader</td>
<td>OET</td>
</tr>
<tr>
<td>Josh Chernov</td>
<td>ROV engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Robert Waters</td>
<td>ROV engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Michael Hannaford</td>
<td>ROV engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Dan Cormany</td>
<td>ROV engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Mychal Valle</td>
<td>ROV engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Mark Deroche</td>
<td>Deck Chief</td>
<td>OET</td>
</tr>
<tr>
<td>Paul Johnson</td>
<td>Mapping Expert</td>
<td>OET</td>
</tr>
<tr>
<td>Erin Heffron</td>
<td>Mapping Coordinator</td>
<td>OET</td>
</tr>
<tr>
<td>Renato Kane</td>
<td>Lead Navigator</td>
<td>OET</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anne Hartwell</td>
<td>Navigator/Mapper</td>
<td>OET</td>
</tr>
<tr>
<td>Samantha Wishnak</td>
<td>Navigator/Mapper</td>
<td>OET</td>
</tr>
<tr>
<td>Lila Ardor-Bellucci</td>
<td>Science Manager</td>
<td>OET</td>
</tr>
<tr>
<td>Matt Koskela</td>
<td>Data Engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Tim Burbank</td>
<td>Data Engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Michael Labriola</td>
<td>Data Engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Dave Robertson</td>
<td>Lead Video Engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Bruce Cousineau</td>
<td>Video Engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Jeff Dennerline</td>
<td>Video Engineer</td>
<td>OET</td>
</tr>
<tr>
<td>Jonathan Fiely</td>
<td>Communications</td>
<td>OET</td>
</tr>
</tbody>
</table>
Executive Summary

• The 2021 EM302 Quality Assessment Tests (QATs) were conducted primarily during NA126, the engineering shakedown cruise, with some additional ship self-noise data collected during NA127. This years QAT was very important as in 2020 during NA118/NA119 it was discovered that there was a significant increase in the self-noise of the Nautilus introduced during the installation of a new propulsion system, which was not identified during over the course of the 2020 season. This issue, coupled with the relocation of the two Seapath antennas, as well as a lengthening of the aft portion of the ship meant that there was a high level of interest in assessing the multibeam system performance prior to the start of the 2021 season.

• Prior to the start of NA126 engineering shakedown, two major activities were conducted to help with these issues:
  1. Anannd Hiroji of the University of Southern Mississippi surveyed in the locations of the newly relocated Seapath antennas, as well as many additional benchmarks around the ship.
  2. Gates Acoustics conducted a full assessment of the ship’s noise to determine what the potential source(s) of the acoustic noise were. During their testing, they observed that the noise issue detected during the 2020 QAT was still present, and believed that it was coming from just starboard of the EM302 array.

• Prior to the start of NA126 the Seapath MRU had been sent to Kongsberg for calibration. During re-installation Gee noted that the unit was not providing PPS and was showing an error status on the Seapath’s User Interface. After further troubleshooting by Gee, Heffron, and Johnson, and consultation with Kongsberg, a spare Seapath system was provided by Kongsberg. Upon installing the spare MRU, the Seapath system reported that it was fully functional. This then allowed Johnson and Heffron to calibrate the system’s antennas prior to sailing on NA126. Upon return of the ship’s original MRU, it is highly suggested that another Patch Test be undertaken following installation. Please consult with Johnson on locating an optimum location to do this.
Executive Summary

• NA126 re-occupied the same site that had been previously used in 2017, 2018, 2019, and 2020 to conduct a Patch Test. The MBES was calibrated for residual angular offsets using the Seapath 330-5+ as the primary positioning/attitude system. The NA126 patch test revealed only very slight pitch, roll, and heading adjustments. These biases were entered into the SIS installation parameters for Attitude 1, COM2/UPD5, and should not be changed unless modifications are made to the system (e.g., when re-installing the ship’s original Seapath MRU) or if there is evidence that another ‘patch test’ is necessary. If any changes are made to these values, please notify Johnson for amendment of this report.

• Initial noise testing was conducted during the transit across Catalina Basin from the patch test site to the deep accuracy site. Testing was done using the Built-In Self Test functionality in SIS. This testing revealed the same higher than expected self-noise as seen during the 2020 QAT (NA119) and what was seen by Gates Acoustics. Noise testing conducted prior to 2020 had shown noise levels between 40 to 45 dB. Initial testing in 2021 (and 2020) in Catalina Basin showed values were now between 50 to 55+ dB over the full range of speeds.

• Using the information provided by Gates Acoustics that a potential source for the additional noise could be located just starboard of the EM302 transducer, Gee working with the Nautilus’s engineering crew, attempted to mitigate the noise through acoustic dampening measuring on the bulkhead between the engine room and the sonar room with limited success. Towards the conclusion of NA126 Gee, Johnson, and the engineering crew identified a vibrating fuel line return pipe as a potential source of the noise. Through isolation of this pipe from the bulkhead followed by additional noise testing in the San Pedro channel the noise floor was successfully dropped down by 5 dB. Additional work was done to further isolate this fuel return between NA126 and NA127, followed by additional noise testing during the NA127 transit north, where the new noise floor was observed to be between 45-48 dB, a great improvement over 2020, especially as this data was collected during an elevated sea state.
Executive Summary

• While early results are promising that the fuel return pipe was the source of the additional noise, it is
  recommended that more noise data be collected. If any additional data is recorded, please submit it to Johnson
  for analysis and inclusion in an amended report.

• A swath accuracy assessments was conducted over the existing deep and shallow reference surfaces that had
  been collected during the NA079 in 2017. Three different operational settings were run and analyzed. Results
  show a reduced swath width and increased depth standard deviation as a function of water depth as compared
  to earlier quality assessments. This is once again likely due to the aforementioned noise issue which was
  identified after the swath accuracy work was done. As the potential noise source has been identified, if there is
  a chance to pass over one of the existing reference surfaces during a transit, please send the data to Johnson for
  analysis.

• Swath performance (extinction) data were collected and analyzed during NA126 transits. Data was collected
  between the depths of ~80 meters and ~3600 meters and analyzed for swath width as a function of depth. As
  had been noted during the swath accuracy assessment, NA119’s swath performance was also reduced at all
  depths covered during the test.

• It would be well worth the time to conduct further analysis on the swath performance at greater depths to
  determine how much apparent self-noise issue is having on data collected when signal to noise becomes more
  of an issue. If more data is collected during the 2020 field season, please transfer the data to Johnson for
  analysis.
Executive Summary

• From a strictly qualitative assessment, the bathymetric data that looked at appeared very clean with few flyers and excellent bottom tracking. This was especially apparent at the patch test site where the pitch and yaw lines on the slopes were much easier to work with than the data during other patch tests.

• There is good agreement between the CTD, Underway-CTD, and XBT.

• The EM302 was once again able to easily detect the seep which had been mapped in previous years. An analysis of the data seemed to indicate that using water column intensity picks VS seafloor exit picks had better agreement in location, this is an ongoing project and will be investigated further.

• Heffron updated the Sound Speed Manager software (https://www.hydrooffice.org/soundspeed/main) to the most recent version and it was used during NA126.

• Johnson cleared the SIS list of prior surveys

• Please contact Paul Johnson, pjjohnson@ccom.unh.edu, if there are any questions on any of these matters or any other future questions.
Introduction

• The E/V Nautilus undertook a multibeam echosounder quality assurance test from July 3rd to July 8th, 2021 during an engineering shakedown leg (NA126) in order to perform a quality assessment of the vessel’s Kongsberg EM302 multibeam echosounder.

• Data were collected near the Southern Channel Islands offshore from San Pedro, California.

• This report presents:
  • an overview of the data collected, and the processing methods applied to it
  • a history of all changes made to the system configuration, starting from the initial install and up through the most recent path test calibration
  • amplitudes of vessel self-noise measured by the multibeam receiver at various speeds/pitches relative to a prevailing swell
  • an accuracy assessments of the system over a deep-water and shallow-water reference surface
  • swath coverage analysis across depths transited during NA126 and NA127
  • EM302 impedance data to document receiver and transducer health
  • Water column detection analysis
  • Verification of water column profiling methods
## NA126 Onboard Multibeam Activities

<table>
<thead>
<tr>
<th>Dates</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021-06-30 to 2021-07-02</td>
<td>Seapath - MRU Replacement</td>
</tr>
<tr>
<td></td>
<td>Seapath - System Review (New Hiroji, 2021 Offset Survey)</td>
</tr>
<tr>
<td></td>
<td>Seapath - Configuration Modification</td>
</tr>
<tr>
<td></td>
<td>Seapath – Calibration</td>
</tr>
<tr>
<td></td>
<td>EM302 – Configuration Review</td>
</tr>
<tr>
<td>2021-07-03 to 2021-07-04 (Overnight)</td>
<td>EM302 – Health Assessment (TXchannels &amp; RXchannels)</td>
</tr>
<tr>
<td></td>
<td>Patch Test</td>
</tr>
<tr>
<td></td>
<td>Noise Testing (Speed &amp; Octagon)</td>
</tr>
<tr>
<td></td>
<td>Swath Performance (Extinction)</td>
</tr>
<tr>
<td></td>
<td>Deep Accuracy</td>
</tr>
<tr>
<td>2021-07-04 to 2021-07-05 (Overnight)</td>
<td>Noise Testing (Jet Pump)</td>
</tr>
<tr>
<td></td>
<td>Deep Accuracy (continued)</td>
</tr>
</tbody>
</table>
## NA126 Onboard Multibeam Activities

<table>
<thead>
<tr>
<th>Dates</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021-07-04 to 2021-07-05 (Overnight)</td>
<td>Swath Performance (Extinction) - Continued</td>
</tr>
<tr>
<td>2021-07-05 to 2021-07-06 (Overnight)</td>
<td>Swath Performance (Extinction) – Continued</td>
</tr>
<tr>
<td></td>
<td>Deep Accuracy (continued)</td>
</tr>
<tr>
<td>2021-07-06 to 2021-07-07 (Overnight)</td>
<td>Shallow Water Accuracy</td>
</tr>
<tr>
<td></td>
<td>Swath Performance (Extinction) – Continued</td>
</tr>
<tr>
<td></td>
<td>Seep Water Column Mapping</td>
</tr>
<tr>
<td></td>
<td>Backscatter Equalization Lines</td>
</tr>
<tr>
<td>2021-07-07 to 2021-07-08 (Overnight)</td>
<td>Sound dampening tests</td>
</tr>
<tr>
<td>2021-07-08</td>
<td>Sound dampening tests</td>
</tr>
</tbody>
</table>
The mapping system consists of the following primary components:

1. Kongsberg Maritime EM302 multibeam echosounder (30 kHz), v1.3.1, s/n 110
2. Kongsberg Maritime Seafloor Information System (SIS), v4.3.2
3. Kongsberg Seatex Seapath 330-5+ vessel navigation system
   I. Seapath 330+ GNSS antennae
   II. MRU 5+, s/n C126NS2018
4. AML Oceanographic AML-3 Sound Speed Sensor
5. Sippican MK21 expendable bathythermograph (XBT) profiling system
6. Teledyne Oceanscience Underway CTD with Seabird Electronics CTD Profiler
Survey System Components

**EM 302 Transceiver Unit (TRU)**
- Surface Sound Speed Velocimeter
- J-Box
- UPS

**Sonar Room**
- Seapath Control Unit
- Surface Velocimeter Access
- Seapath MRU
- Master Reference Plate
Survey System Components

Data Lab Computer Room

- Knudsen Sub-Bottom Profiler
- EM302 Remote Power and Pump Control
- Seapath HMI
- Sippican XBT Deckbox
- EM302 Acquisition Computer

Starboard Rail – Midship – Looking Forward

- Seapath Aft Antenna (Primary)
- Seapath Forward Antenna
System Geometry Review

The term ‘system geometry’ means the linear and angular offsets of the primary components of the multibeam mapping system, including the transmit array (TX), receive array (RX), and ship navigation sensor (MRU).

<table>
<thead>
<tr>
<th>Date</th>
<th>Cruise ID</th>
<th>Location</th>
<th>Event</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 April</td>
<td>NA030</td>
<td>Toulon, France</td>
<td>EM302 sea acceptance trials; MRU angular offsets determined by patch test and applied in SIS</td>
<td>UNH/IFREMER Sea Acceptance Trials (SAT) report, Gates Acoustic Services report</td>
</tr>
<tr>
<td>2013 June</td>
<td>NA030</td>
<td>Gulf of Mexico</td>
<td>Original MRU 5+ unit replaced with spare by KM engineer at start of NA030</td>
<td>2014 EM302 Multibeam Echosounder System Review</td>
</tr>
<tr>
<td>2014 May</td>
<td>NA040</td>
<td>Gulf of Mexico</td>
<td>Original MRU 5+ unit reinstalled by KM engineer at start of NA040; EM302 system performance review; residual angular offsets determined by patch test and applied in SIS</td>
<td>2014 EM302 Multibeam Echosounder System Review</td>
</tr>
<tr>
<td>2015 April</td>
<td>NA055</td>
<td>Gulf of Mexico</td>
<td>EM302 system performance review; residual angular offsets determined by patch test and applied in SIS</td>
<td>2015 EM302 Multibeam Echosounder System Review</td>
</tr>
<tr>
<td>2016 April</td>
<td>NA070</td>
<td>Victoria, British Columbia</td>
<td>EM302 system performance review; residual angular offsets determined by patch test and applied in SIS</td>
<td>2016 EM302 Multibeam Echosounder System Review</td>
</tr>
<tr>
<td>2017 May</td>
<td>NA079</td>
<td>San Pedro, California</td>
<td>MRU 5+ reinstalled after factory service; EM302 system performance review; residual angular offsets determined by patch test and applied in SIS</td>
<td>2017 EM302 Multibeam Echosounder System Review</td>
</tr>
<tr>
<td>2018 June</td>
<td>NA093</td>
<td>San Pedro, California</td>
<td>EM302 system performance review; residual angular offsets determined by patch test and applied in SIS</td>
<td>2018 EM302 Multibeam Echosounder System Review</td>
</tr>
<tr>
<td>2019 May</td>
<td>NA105</td>
<td>San Pedro, California</td>
<td>System installation review for the Seapath 330-5+ following a firmware update to the topside unit. EM302 system performance review; residual angular offsets determined by patch test and applied in SIS</td>
<td>2019 EM302 Multibeam Echosounder System Review</td>
</tr>
<tr>
<td>2020 July</td>
<td></td>
<td>San Pedro, California</td>
<td>Survey by Anand Hiroji, University of Southern Mississippi, of the new locations of the Seapath antennas.</td>
<td>EV Nautilus Seapath offset survey report - 2020</td>
</tr>
</tbody>
</table>
System Geometry Review

The term ‘system geometry’ means the linear and angular offsets of the primary components of the multibeam mapping system, including the transmit array (TX), receive array (RX), and ship navigation sensor (MRU).

<table>
<thead>
<tr>
<th>Date</th>
<th>Cruise ID</th>
<th>Location</th>
<th>Event</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020 August</td>
<td>NA118 NA119</td>
<td>San Pedro, California</td>
<td>System installation review for the Seapath 330-5+ following change of location of antennas. EM302 system performance review; residual angular offsets determined by patch test and applied in SIS</td>
<td>2020 EM302 Multibeam Echosounder System Review</td>
</tr>
<tr>
<td>2021 July</td>
<td>NA126</td>
<td>San Pedro, California</td>
<td>System installation review for the Seapath 330-5+ following change of location of antennas. EM302 system performance review; residual angular offsets determined by patch test and applied in SIS</td>
<td>2021 EM302 Multibeam Echosounder System Review</td>
</tr>
</tbody>
</table>
System Geometry Review

2013 Vessel Survey

- Vessel survey conducted by Parker Maritime AS in Istanbul, Turkey from March 16-20, 2013
- Survey reviewed by UNH/IFREMER team during Sea Acceptance Trials, April 2013, in Toulon France.
- **Origin** of survey reference (the Coordinate Reference Point, CRP) is at x=0 at centerline, y=0 at AP/ frame 0.
- **Linear offsets** reported in meters
  - +X starboard (= +Y in KM/Seapath convention)
  - +Y forward (= +X in KM/Seapath convention)
  - +Z up (= -Z KM/Seapath convention)
- **Angular offsets** reported in decimal degrees
  - +Roll with starboard side down (agrees with KM/Seapath convention)
  - +Pitch with bow down (agrees with KM/Seapath convention)
  - +Heading with bow rotation to stbd and port (does not agrees with KM/Seapath convention)
Seapath Antennas were relocated during the Spring 2020 shipyard period.

Initial plan was to survey in the new locations while the ship was still in drydock. However, due to COVID19 restrictions this was not able to take place prior to floating the vessel.

Vessel survey was then conducted by Anand Hiroji of the University of Southern Mississippi from July 28 to July 30, 2020 on the floating vessel which was dockside in San Pedro, California.


Survey results were reported in the 2013 ship reference frame.

Linear offsets reported in meters
+X starboard (= +Y in KM/Seapath convention)
+Y forward (= +X in KM/Seapath convention)
+Z up (= -Z KM/Seapath convention)
System Geometry Review

2021 Antennae Survey

• Seapath Antennas were relocated on to a new 2 pole mast system during the Spring 2021 shipyard period.

• Initial plan was to survey in the new locations while the ship was still in drydock. However, due to travel restrictions the survey was not able to take place prior to moving the vessel to San Pedro.

• Vessel survey was then conducted by Anand Hiroji of the University of Southern Mississippi from June 6 to June 12, 2020 on the floating vessel which was dockside in San Pedro, California.


• Survey results were reported in the 2013 ship reference frame.

• Linear offsets reported in meters
  +X starboard (= +Y in KM/Seapath convention)
  +Y forward (= +X in KM/Seapath convention)
  +Z up (= -Z KM/Seapath convention)
System Geometry Review

**Ship Convention**
Source: Parker Report (Document 1306029-13000225) and the Hiroji 2020 & 2021 Reports

X, Y, Z, and heading convention are different

**Kongsberg Convention**
Source: Kongsberg EM302 Installation Manual

**Seapath Convention**
Source: Seapath Installation Manual

### Coordinate Systems

#### 4.3.1 Vessel reference system

The following has to be surveyed:

- All vessels have a defined Cartesian coordinate system that all sensors can be referenced to. In this right hand system, the X-axis is positive forwards, which is parallel to the centre line of the vessel, the Y-axis, positive towards starboard, and the Z-axis, which is positive downward.
- The origin in the vessel reference system is typically frame 0 at keel level or the surveyed origin in a survey report, i.e. where X, Y, and Z are all 0.
- The coordinate reference point (CRP) is defined to be in the intersection between stem, keel, and keel line and keel. In case the keel is not parallel with the base line, the reference is CRP is where the keel crosses the vertical section amidships. The location of CRP vs the origin is configurable, and is typically set based on the survey report.
- The reference plane in this system must be well defined and described. This can be a Best Fit Plane on main deck, or a Best Fit Plane through the draught marks on the hull. This is particularly important on a floating vessel, as it is not possible to project the horizontal plane from land.
- The chosen convention must be made clear to all parties involved, both survey personnel performing the survey and the users of the survey results. Any deviation from the defined coordinate system, shown in the figure Definition of Origin on vessel and positive X, Y and Z axes directions on page 54, should be well described in both text and drawings to avoid common misunderstandings.
Seapath antennas were relocated again in 2021 in order to strengthen the mounting system. They are now installed on an antenna beam on 2 poles on the starboard rail of the ship.

During prior to the NA126 engineering trials, vibration was noticed on the beam so dampening measures were undertaken by Gee.

Antenna locations as entered into the Seapath 330+ control software are referenced to an origin at the centerline of the ship (Y=0) at frame 0 at the aft end of the ship.

All distances are in meters.

Antenna 1 (aft)
- X = 19.4477  (was 20.3194 in 2020)
- Y = 4.6595  (was 4.6313 in 2020)
- Z = -15.2727 (was -15.237 in 2020)

Antenna 2 (fwd)
- X = 21.9463  (was 22.8197 in 2020)
- Y = 4.5821  (was 4.5996 in 2020)
- Z = -15.2526  (was -15.2459 in 2020)

The Seapath Calibration wizard was run to successfully validate the survey results (see Appendix 10).
System Geometry Review

Seapath IMU Lever Arms

- Parker surveyed the center of top plate for the IMU
- Parker result were used for the lever arm distances from the origin to the IMU in Seapath configuration (‘MRU Geometry’)

**Primary IMU Position Distance From Origin:**
- X: 33.657 meters
- Y: -0.067 meters
- Z: -2.628 meters

- The IMU is the reference point in the Kongsberg coordinate system.

**Primary IMU Position Kongsberg Reference Frame (this is not a Seapath setting):**
- X: 0.000 m
- Y: 0.000 m
- Z: 0.000 m
System Geometry Review

Seapath IMU Mounting Angles

- Parker surveyed the center of top plate for the IMU
- Angular offsets from the Parker report were transformed into the Kongsberg convention.

**Primary IMU Angles:**
- Roll: 179.400 degrees
- Pitch: 1.760 degrees
- Yaw: -0.510 degrees
System Geometry Review

TX & RX Linear Offsets

- Linear offsets from Parker report were transformed into the Kongsberg convention
  - Origin at MRU center of top plate
  - All units in meters
  - +X forward
  - +Y starboard
  - +Z down

- Values entered into the SIS installation parameters Locations panel were verified to match those determined during the system geometry review.

**EM302 TX Transducer**
- X: 3.496 m
- Y: -0.137 m
- Z: 2.731 m

**EM302 RX Transducer**
- X: 1.516 m
- Y: 0.033 m
- Z: 2.732 m
TX & RX Angular Offsets

• Angular offsets from Parker report were transformed into the Kongsberg convention
  • All units in degrees
  • +Roll starboard side down
  • +Pitch bow up
  • +Heading bow to starboard (compass convention)

• Values entered into the SIS installation parameters Angular Offsets panel were verified to match those determined during the system geometry review.

• **EM302 TX Transducer**
  - Roll: 0.61 degrees
  - Pitch: 0.01 degrees
  - Heading: 0.22 degrees

• **EM302 RX Transducer**
  - Roll: 0.72 degrees
  - Pitch: 0.32 degrees
  - Heading: 0.08 degrees
The waterline previously entered in the Installation Parameters /Locations tab was derived during the 2013 SAT.

The Parker Report Sets the Waterline at 5m in ship coordinates

Pre-2021 Results:
- By evaluating the 2013 pre-departure draft marks at the front of the vessel and rear it was determined that the ship rests slightly bow up by about ~0.8 meters.
- Using this information, a waterline adjustment of 0.6 meters was calculated in the ship’s reference plan at the TX array face. This adjustment changed the water line z from -2.372 to -1.77 (see 2020 QAT report).

Calculated NA126 2021 Water Levels (as determined dockside).
- Forward: 4.6 meters
- Stern: 5.1 meters
- The ship rests slightly bow up, by ~0.5 m
- The length at the waterline is approximately 61.3 m
- Ship has a static positive trim of atan(0.5/61.3) = 0.467 deg
- The center of the TX array is approximately 43.3 m from the stern
- The draft at the sonar head is 5.1(m) – 43.3(m) * tan(0.467 deg) = 4.74 m
- 5.1 m – 4.74 m = 0.36 m
- WLZ = -2.372 m + 0.36 m = -2.012 m

NOTE: The historic value of -1.77m was left in following NA126.
System Geometry Review

Bow View

EM302 Waterline

Stern View
Plan used to determine the length of the ship for waterline calculation prior to 2021.

Plan used to determine additional length of the ship for waterline calculation for 2021.
1. The calibration site used for NA126 had been successfully during the QATs in 2017 (NA079), 2018 (NA093), 2019 (NA105), and 2020 (NA119). This area was selected because of the availability of seafloor features with optimal slopes, bathymetric relief, and proximity to the operations area.

2. Lines were run at 8 kts in order to maximize the amount of time available for other tests.

3. An XBT was collected prior to the start of the calibration process.

4. It should be noted that the EM302 tracked the slopes of the pitch and heading lines very well, with a minimal amount of noise.
EM302 Calibration

Pre-Calibration Configuration

1. All Attitude 1, COM2/UDP5 angular offsets were left with the offsets determined during the 2020 NA119 QAT in the SIS Installation Parameters / Angular offsets panel (see figure to left).

2. Calibration data were examined independently by Johnson and Heffron using patch test tools in both SIS and Qimera; results were agreed based on a consensus from the determined biases.

3. The final determined bias from each test was updated in the SIS Installation Parameters for Attitude 1, COM2/UDP5 prior to the start of the next test, in order to reduce the effects of coupling.

4. As the biases were very small, there was no need or time to run verification lines to test the results.

5. No latency test was conducted as previous testing of the system had not revealed any latency and no latency-related artifacts have been observed.

Pre-NA126 Calibration

Results determined during NA119. For reference only!!
EM302 Calibration

Results: Pitch

- Pitch bias solved using SIS Calibration Tool and Qimera Patch Test Tool
- NA126 Pitch lines shown in Qimera (left)
  1. Pre-NA126 (NA119) pitch offset value: -0.19°
  2. NA126 calculated bias: +0.05°
  3. Final pitch offset: -0.14° entered into the SIS Installation Parameters/Angular Offsets panel.
EM302 Calibration

Results: Roll

- Roll bias solved using SIS Calibration Tool and Qimera Patch Test Tool
- NA126 Roll lines shown in Qimera (left)

1. Pre-NA126 (NA119) roll offset value: +0.13°
2. NA126 calculated bias: +0.02°
3. Final roll offset: +0.15° entered into the SIS Installation Parameters/Angular Offsets panel.
EM302 Calibration

Results: Heading

- Heading bias solved using SIS Calibration Tool and Qimera Patch Test Tool
- NA126 Heading lines shown in Qimera (left)
- 1. Pre-NA126 (NA119) pitch offset value: -0.01°
- 2. NA126 calculated bias: +0.02°
- 3. Final heading offset: +0.01° entered into the SIS Installation Parameters/Angular Offsets panel.
EM302 Calibration

Post-Calibration Configuration

1. The very small offsets applied to the pitch, roll, and heading in the *Attitude 1* angular offsets reflect a very stable system with no significant changes in either the system geometry or integration. This was especially important as it was necessary to change out the MRU prior to the cruise.

2. The *Installation Parameters: Angular Offsets*, shown at left, should not be changed, unless a new patch test is undertaken.

3. As the currently installed MRU is on loan and will eventually need to be replaced with the ship’s normal MRU, when that happens it is highly recommended to conduct another patch test to verify the installation of the MRU.

4. If new values are determined during the 2021 field season, please let Johnson know so that this report can be updated to reflect the current values.
EM302 Noise Level Assessment

Overview

• A potentially major limitation of multibeam performance can stem from elevated noise levels due to hull design, engine and other machinery, sea state, biofouling, electrical interference, etc.

• It had been noted during QAT conducted during NA119 that noise level were significantly elevated as compared to earlier years results.

• Prior to the start of NA126, Gates Acoustics conducted a comprehensive test to identify the potential source(s) of ship self-noise. Following testing, Gates Acoustics proposed a potential source forward of engine room, close to the ship’s sonar room.

• Initial acoustic noise testing during NA126 included a series of tests to identify contributions to the noise environment perceived by the EM302 receiver array due to vessel speed/propeller pitch. This testing was done without any changes to any components on the ship.

• These tests were run using a script which initiated...
Overview

• These tests were run using a script which initiated and recorded 20 individual RXnoise Built-In Self-Tests (BIST) under different speed/pitch combinations and in direction relative to the seas (into or out of).

• As additional time was available towards the conclusion of NA126, Gee and Johnson working with the ship’s engineering staff began additional acoustic noise testing to isolate potential source(s) of the noise.

• This testing and noise mitigation changes included:
  • Noise baffling along the aft-lower bulkhead between the sonar room and engine room
  • Manual mitigation of pipe vibration (holding)
  • Physical mitigation of pipe vibration (tightening of clamps)
  • Relocation of pipe mounts
EM302 Noise Level Assessment

Catalina Basin (2021-07-04)

- Wind Speed: 8 kts
- Wind Direction (from): 248 degrees
- Swell Height: 0.5 – 1 meter
- Swell Direction (from): 260 degrees
- Swell Period: 7 seconds

<table>
<thead>
<tr>
<th>Speed</th>
<th>Pitch</th>
<th>Heading</th>
<th>IS/WS</th>
<th>File</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>260</td>
<td>IS</td>
<td>EM302_RXnoise_07042021_094958_1kt_0p.txt</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>260</td>
<td>IS</td>
<td>EM302_RXnoise_07042021_095806_2kt_3p.txt</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>260</td>
<td>IS</td>
<td>EM302_RXnoise_07042021_100612_4kt_6p.txt</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>260</td>
<td>IS</td>
<td>EM302_RXnoise_07042021_102605_6kt_11p.txt</td>
</tr>
<tr>
<td>8</td>
<td>14</td>
<td>260</td>
<td>IS</td>
<td>EM302_RXnoise_07042021_113758_8kt_14p.txt</td>
</tr>
<tr>
<td>10</td>
<td>22</td>
<td>260</td>
<td>IS</td>
<td>EM302_RXnoise_07042021_120141_10kt_22p.txt</td>
</tr>
<tr>
<td>12</td>
<td>26</td>
<td>260</td>
<td>IS</td>
<td>EM302_RXnoise_07042021_131502_12kt_26p.txt</td>
</tr>
<tr>
<td>12</td>
<td>25</td>
<td>80</td>
<td>WS</td>
<td>EM302_RXnoise_07042021_123514_12kt_25p.txt</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>80</td>
<td>WS</td>
<td>EM302_RXnoise_07042021_122332_10kt_20p.txt</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
<td>80</td>
<td>WS</td>
<td>EM302_RXnoise_07042021_105736_8kts_15p.txt</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>80</td>
<td>WS</td>
<td>EM302_RXnoise_07042021_110939_6kt_11p.txt</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>80</td>
<td>WS</td>
<td>EM302_RXnoise_07042021_112108_4kt_6p.txt</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>80</td>
<td>WS</td>
<td>EM302_RXnoise_07042021_125222_2kts_2p.txt</td>
</tr>
<tr>
<td>1.2</td>
<td>0</td>
<td>80</td>
<td>WS</td>
<td>EM302_RXnoise_07042021_131112_1kt_0p.txt</td>
</tr>
</tbody>
</table>
EM302 Noise Level Assessment

Analysis – Main Engine

- 2020 noise levels with the main engine as the propulsion source showed significant increases in measured noise over the full range of pitch/speed settings when compared to measurements made during 2019’s NA105 and 2014’s NA025.

- The swath extinction plots during 2020 cruises also showed about 15% reduced swath width.

- Gates Acoustic conducted a series of self-noise tests in Catalina Basin during mobilization, 14 June 2021. The tests confirmed that the main engine was the source of the noise and that it appeared to be coming from just starboard of the EM302 transducer.

- Initial NA126 noise testing conducted during a transit across the Catalina Basin from the patch test area to the deep reference site also showed similar elevated levels. Initial testing showed values between ~47 dB to ~60 dB (Top Figure Left), as compared to ~38 dB to ~45 dB as seen in 2014 baseline testing.

- During NA126 we worked with the Nautilus engineering department and found that the main engine fuel return line was vibrating and had two brackets on the aft bulkhead of the engine room that was adjacent to the sonar compartment.

- The fuel line had a flexible coupling from the main engine, but vibrations were still transferred to the main pipe. At the end of NA126 the engineers added rubber to the pipe mount and a test showed significant (>5 db) reduction in the self noise. The pipe was slightly re-routed and the mounts were removed during the following port stop. (See Slides 42 & 43)
A reduced set of RXnoise BISTs run on NA127 confirmed the improved results (see figure to the left). It is recommended that a full set of self-noise tests be conducted over a full range of pitch/speed settings and with headings relative to the seas (into or out of) to verify these results. In addition, the trials should include a drifting trial with the main engine shutdown and then running but the shaft declutched.

Data collected with just the jet pump as the source of propulsion source show little difference (~3 dB) between measurements collected during 2019 and those collected during 2020 (see next page).

The full set of test plots can be seen in Appendixes 1-7.
EM302 Noise Level Assessment

Fuel Line Return - Noise Remediation

Return Fuel Line Coupler

Mounting Bracket Removed

Sonar Room Behind
EM302 Noise Level Assessment

Pitch Analysis – Main Engine
NA127 VS 2014 Baseline

NA127 - 2021

2014 - Baseline - EM302 Self Noise vs Pitch - With Seas
EM302 RX Noise – Main Engine

NA127 – Pitch – Into Seas

NA127 - Transit - EM302 Self Noise vs Pitch - IS

NA127 - Transit - EM302 Self Noise vs Pitch - IS

Median
Mean (log.)
Mean (lin.)
EM302 RX Noise – Main Engine

NA126 – Pitch – Into Seas

NA126 - CatalinaBasin - EM302 Self Noise vs Pitch - IS

NA126 - CatalinaBasin - EM302 Self Noise vs Pitch - IS
EM302 RX Noise – Main Engine

NA126 – Speed – With Seas

NA126 - CatalinaBasin - EM302 Self Noise vs Speed - WS
EM302 RX Noise – Main Engine

Noise Dampening – San Pedro Channel
Pitch 18, Speed 8.2 kts
Test 01

NA126 - SanPedro_NoiseDamp01 - Self Noise vs Pitch - WS - 18

![Graph showing self noise vs pitch for NA126-SanPedro_NoiseDamp01 with data points and various lines indicating different statistics such as median, mean (log.), and mean (lin.).]

NA126 - SanPedro_NoiseDamp01 - Self Noise vs Pitch - WS 18

![Histogram showing frequency distribution of self noise with different statistics displayed as vertical bars and lines on the right side of the graph.]

Median = 39.3, Logarithmic Mean = 40.2516, Linear Mean = 46.5453
EM302 RX Noise – Main Engine

Noise Dampening – San Pedro Channel
Pitch 18, Speed 8.2 kts
Test 01

NA126 - SanPedro_NoiseDamp02 - Self Noise vs Pitch - WS 18

[Graph showing self noise vs pitch with median, mean (log.), and mean (lin.) lines]

NA126 - SanPedro_NoiseDamp02 - Self Noise vs Pitch - WS 18

[Histogram showing self noise distribution with median, mean (log.), and mean (lin.) values]
EM302 RX Noise – Main Engine

Noise Dampening – San Pedro Channel
Pitch 18, Speed 8.2 kts
Test 02
EM302 RX Noise – Jet Pump

Speed - Into Seas – 90% Thrust

NA126 - JetPump - Self Noise vs Speed - IS - 1.5 (kts)

Self Noise (dB re 1μPa/Hz)

Channel

0 16 32 48 64 80 96 112

Self Noise (dB re 1μPa/Hz)

Frequency (%)

0 5 10 15 20 25 30 35 40 45

Self Noise (dB re 1μPa/Hz)

30 35 40 45 50 55 60 65 70

NA126 - JetPump - Self Noise vs Speed - IS 1.5 (kts)

Median

Mean (log.)

Mean (lin.)

HX Module

0 10 20 30 40 50 60 70

Test #

30 35 40 45 50 55 60 65 70
EM302 RX Noise – Jet Pump

Speed - With Seas – 90% Thrust
1. Accuracy of a multibeam echosounder under ‘normal’ survey conditions can be assessed by examining soundings collected during a single-pass survey lines over a trusted bathymetric surface (a reference surface).

2. Reference surfaces typically cover flat or gently sloping terrain that have been carefully and densely surveyed, providing a large sample count and high degree of confidence in the depth of each grid cell.

3. Accuracy assessments during quality assessment testing provides a baseline to judge system performance against previous years results. This testing can help reveal both potential changes to the system itself, as well as changes to the operation environment.

4. With rigorous testing protocols and consistent analysis methods, accuracy performance data can provide a critical window into performance over the system’s service life and may help to identify early signs of component failure.
5. For a complete evaluation, accuracy data should be collected in all operational modes over reference surfaces in depths appropriate for those modes.

6. By using the NA079 reference surfaces, a significant amount of time was saved by not needing to survey the whole of the surface.
EM302 Accuracy Testing

1. Swath accuracy over ‘deep’ terrain (relative for the 30-kHz EM302) was assessed by running a series of crosslines over a ‘deep’ reference surface in 1250-1350 m depths which had been collected during the 2017 NA079 QAT. Figure to the left shows the reference lines run in thick blue trending WNW/ESE.

2. Crosslines (shown in thick red in the figure to the left) were oriented to maximize coverage across reference surface and were orthogonal to the lines used to collect the data contributing to the surface, in order to reduce any potential coupling of EM302 biases across the swath.

3. Deep accuracy crosslines were run in five settings, starting with the most conventional configuration for the environment (changes from previous settings are shown in red in the table on the next page).

4. An XBT profile was collected prior to crosslines.

5. All lines were run at 8 knots and over 3 different nights with similar weather conditions.
## EM302 Accuracy Testing

### EM302 Deep Accuracy Settings

Xline1: Winds from 264 @ 8 kts, 1 Meter Seas, Small Swell  
Xline2 & 3: Winds from 288 @ 20 kts, 1 Meter Seas, Small Swell  
Xline4 & 5: Winds from 22 @ 15 kts, 1 Meter Seas, Small Swell

### Primary Line Acquisition Information

<table>
<thead>
<tr>
<th>Patch Test Step</th>
<th>Reference Lines</th>
<th>Cross Lines Settings 1</th>
<th>Cross Lines Settings 2</th>
<th>Cross Lines Settings 3</th>
<th>Cross Lines Settings 4</th>
<th>Cross Lines Settings 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey Name</td>
<td>NA126_20210704_DeepAccuracy</td>
<td>NA126_20210704_DeepAccuracy</td>
<td>NA126_20210704_DeepAccuracy</td>
<td>NA126_20210704_DeepAccuracy</td>
<td>NA126_20210704_DeepAccuracy</td>
<td></td>
</tr>
<tr>
<td>BIS Line</td>
<td>2, 5</td>
<td>12, 14</td>
<td>17, 19</td>
<td>33, 35</td>
<td>37, 39</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Distance (nm)</td>
<td>5.50</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td>Bearing</td>
<td>112.00</td>
<td>202.00</td>
<td>202.00</td>
<td>202.00</td>
<td>202.00</td>
<td></td>
</tr>
<tr>
<td>Time (minutes)</td>
<td>41.25</td>
<td>37.50</td>
<td>37.50</td>
<td>37.50</td>
<td>37.50</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** Reference lines were collected during the 2017. See NA079 for info on these lines.

### SONAR RUN TIME PARAMETERS

<table>
<thead>
<tr>
<th>Sector Coverage</th>
<th>Reference Lines</th>
<th>Cross Lines Settings 1</th>
<th>Cross Lines Settings 2</th>
<th>Cross Lines Settings 3</th>
<th>Cross Lines Settings 1</th>
<th>Cross Lines Settings 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max angle (port)</td>
<td>65</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>52*</td>
</tr>
<tr>
<td>Max angle (stbd)</td>
<td>65</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>52*</td>
</tr>
<tr>
<td>Max Coverage (port)</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>Max Coverage (stbd)</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>Angular Coverage Mode</td>
<td>Auto</td>
<td>Auto</td>
<td>Auto</td>
<td>Auto</td>
<td>Auto</td>
<td>Auto</td>
</tr>
<tr>
<td>Beam Spacing</td>
<td>HIDE EQDIST</td>
<td>HIDE EQDIST</td>
<td>HIDE EQDIST</td>
<td>HIDE EQDIST</td>
<td>HIDE EQDIST</td>
<td>HIDE EQDIST</td>
</tr>
</tbody>
</table>

### Depth Settings

<table>
<thead>
<tr>
<th>Reference Lines</th>
<th>Cross Lines Settings 1</th>
<th>Cross Lines Settings 2</th>
<th>Cross Lines Settings 3</th>
<th>Cross Lines Settings 1</th>
<th>Cross Lines Settings 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force Depth</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Min depth (m)</td>
<td>1100</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Max depth (m)</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>Dual swath mode</td>
<td>DYNAMIC</td>
<td>DYNAMIC</td>
<td>DYNAMIC</td>
<td>DYNAMIC</td>
<td>DYNAMIC</td>
</tr>
<tr>
<td>FM disable</td>
<td>Unchecked (FM) - Mixed</td>
<td>Unchecked (FM) - Mixed</td>
<td>Checked (CW)</td>
<td>Unchecked (FM) - Mixed</td>
<td>Unchecked (FM) - Mixed</td>
</tr>
</tbody>
</table>

### Transmit Control

<table>
<thead>
<tr>
<th>Reference Lines</th>
<th>Cross Lines Settings 1</th>
<th>Cross Lines Settings 2</th>
<th>Cross Lines Settings 3</th>
<th>Cross Lines Settings 1</th>
<th>Cross Lines Settings 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch stabilization</td>
<td>ENABLED</td>
<td>ENABLED</td>
<td>ENABLED</td>
<td>ENABLED</td>
<td>ENABLED</td>
</tr>
<tr>
<td>Heading</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Bearing</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Auto Tilt</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Yaw stab. Mode</td>
<td>OFF</td>
<td>REL MEAN HDG</td>
<td>REL MEAN HDG</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Min Swath Dist</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
EM302 Accuracy Testing

Deep Accuracy: Analysis Procedure

1. The reference surface was gridded at 50 m (Fig 1) with Qimera from data collected during NA079. Data was then exported as a

2. Grid cells with <15 soundings in a node were removed from the reference surface (Fig 2).

3. Grid cells with slopes >5° were removed from the reference surface (Fig 3).

4. Grid cells with uncertainty greater than 10m were then removed from the reference surface (Fig 4).

5. The remaining grid cells with ≥15 soundings, slopes ≤5°, and uncertainty < 10m were used for analysis of the NA126 deep accuracy crossline data (next page).

6. The mean depth bias and depth bias standard deviations as a percentage of water depth were then computed in 1° angular bins across the swath for each configuration.
EM302 Accuracy Testing

Deep Accuracy: Analysis Procedure

• Final deep reference surface grid (left) with nodes with nodes with < 15 soundings, slopes > 5°, and uncertainty > 10m masked out.

• Grey overlay shows the area covered by the two passes for a crossline over the reference surface (ship track for the crosslines are shown in black).

NOTE: An accuracy plot has been made for each crossline setting from data collected during NA079 (2017), the year that the original reference surface data was collected, except for crossline settings 5 which were new this year (data was collected primarily for backscatter equalization).
Deep Accuracy: Results

- The EM302 provides fairly unbiased soundings over the majority of the swath the three different modes tested over the deep reference surface.

- As has been seen during previous years QATs, a noticeable non-linear refraction bias (frown) is present in the outer portions of the swath for each mode tested.

- Comparing the 2021 NA126 accuracy data to the 2017 NA079, acquired when the reference surface dataset was collected, shows that the NA126 data have very similar swath widths between the 2 different collection years.

- The 2021 data also shows an increase in the depth bias standard deviation as a percentage of water depth at shallower beam angles as compared to the 2019 data.

- The standard deviations about the mean bias are typically within +/-0.15% to +/-0.25% water depth (1-σ) at beam angles less than 60° in 2021, as compared to ~63° in 2017.

- As has been before, at TX sector boundaries (approx. ±32-35°) with FM enabled, the depth standard deviation tends to jump by ~0.03% WD

- It is recommended that additional passes are made over the reference surface with the identification of the possible acoustic noise source.
Deep Accuracy – Xline 1

Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA126
Deep / Dual Swath (Dynamic) / Mixed
Deep Accuracy – Xline 1

**NA126 – July 2021**

Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA126
Deep / Dual Swath (Dynamic) / Mixed

**NA079 – May 2017**

Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA079
Deep / Dual Swath (Dynamic) / Mixed
Deep Accuracy – Xline 2

**NA126 – July 2021**

Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA126
Deep / Dual Swath (Dynamic) / CW

**NA079 – May 2017**

Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA079
Deep / Dual Swath (Dynamic) / CW
Deep Accuracy – Xline 3

Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA126
Deep / Single Swath / Mixed

Reference Surface (Final)
Deep Accuracy – Xline 3

NA126 – July 2021
Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA126
Deep / Single Swath / Mixed

NA073 – May 2017
Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA079
Deep / Single Swath / Mixed
Deep Accuracy – Xline 4

Swath Accuracy vs. Beam Angle
EM 302 - Nautilus - Cruise N/A
Deep / Dual Swath (Dynamic) / Mixed

Reference Surface
EM 302 - Nautilus - Cruise N/A
DeepReference_50m_UTM_11N.xyz

Deep / Dual / Mixed / No Yaw Stabilization
Deep Accuracy – Xline 5

Swath Accuracy vs. Beam Angle
EM 302 - Nautilus - Cruise N/A
Very Deep / Single Swath / FM

Reference Surface
EM 302 - Nautilus - Cruise N/A
DeepReference_50m_UTM_11N.xyz

Very Deep / Single / FM / No Yaw Stabilization
1. Swath accuracy over ‘shallow’ terrain (relative for the 30-kHz EM302) was assessed by running a series of crosslines over a ‘shallow’ reference surface in 100-150 m depths collected during the 2017 NA079 QAT (thick blue lines trending NW/SE).

2. Crosslines (thick red line trending WSW/ENE) were oriented to maximize coverage across reference surface and were orthogonal to the lines used to collect the data contributing to the surface in order to reduce any potential coupling of EM302 biases across the swath.

3. Shallow accuracy crosslines were run in three settings, starting with the most conventional configuration for the environment (changes from previous settings are red in the table on the next page).

4. An XBT profile was collected prior to crosslines

5. All lines were run at 8 knots
EM302 Accuracy Testing

Shallow Accuracy: Analysis Procedure

1. Bathymetric data were corrected for tide using the Oregon State tidal model (below).

2. The reference surface was gridded at 5 m (Fig 1) with Qimera from data collected during NA079. Data was then exported as a

3. Grid cells with <15 soundings in a node were removed from the reference surface (Fig 2).

4. Grid cells with slopes >5° were removed from the reference surface (Fig 3).

5. Grid cells with uncertainty greater than 5m were then removed from the reference surface (Fig 4).

6. The remaining grid cells with ≥15 soundings, slopes ≤5°, and uncertainty < 5m were used for analysis of the NA126 deep accuracy crossline data (next page).

7. The mean depth bias and depth bias standard deviations as a percentage of water depth were then computed in 1° angular bins across the swath for each configuration.
• Final deep reference surface grid (left) with nodes with nodes with < 15 soundings, slopes > 5°, and uncertainty > 10m masked out.

• Grey overlay shows the area covered by the two passes for a crossline over the reference surface (ship track for the crosslines are shown in black)

NOTE: An accuracy plot has been made for each crossline setting from data collected during NA079 (2017), the year that the original reference surface data was collected.
EM302 Accuracy Testing

Shallow Accuracy: Results

- The EM302 provides mostly unbiased soundings over the majority of the swath the three different modes tested over the deep reference surface.
- Unlike previous year, a noticeable non-linear refraction bias (smile) is present in the outer portions of the swath for each mode tested.
- Within +/-15° the data shows ‘Erik’s Horns`, a nadir-ring bottom tracking artifact. Which has been seen before when mapping in shallow water.
- Comparing the 2021 NA126 accuracy data to the 2017 NA079, acquired when the reference surface dataset was collected, the NA126 data shows very similar swath widths between the 2 different collection years.
- The 2020 data also shows an increase in the depth bias standard deviation as a percentage of water depth at shallower beam angles as compared to the 2019 data.
- The standard deviations about the mean bias are typically within +/-0.15% to +/-0.25% water depth (1-σ) at beam angles less than 60° in 2021, as compared to ~63° in 2017.
- As has seen before, at TX sector boundaries (approx. ±32-35°) with FM enabled, the depth standard deviation tends to jump by ~0.03% WD.
Shallow Accuracy – Xline 1

Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA126
Shallow / Dual Swath (Dynamic) / CW

Reference Surface
EM 302 - E/V Nautilus - NA126
ShallowRef_5m_UTM_11N.xyz

Shallow / Dual Swath / CW / RMH
Shallow Accuracy – Xline 2

Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA126
Shallow / Single Swath / CW

Reference Surface
EM 302 - E/V Nautilus - NA126
ShallowRef_5m_UTM_11N.xyz

Shallow / Single / CW / RMH
Shallow Accuracy – Xline 2

NA126 – July 2021
Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA126
Shallow / Single Swath / CW

NA079 – May 2017
Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA079
Shallow / Single Swath / CW
Shallow Accuracy – Xline 3

Swath Accuracy vs. Beam Angle
EM 302 - E/V Nautilus - NA126
Shallow / Dual Swath (Dynamic) / CW

Reference Surface
EM 302 - E/V Nautilus - NA126
ShallowRef_5m_UTM_11N.xyz

Shallow / Dual Swath / CW / No Yaw
Due to offshore weather, NA126 did not cover as wide a range of depths as a traditional swath performance test would have. However, during all transits, the EM302 was set to run in automatic ping mode with swath angle limits set to ±75°. This operational mode allowed the system to automatically select its preferred depth mode and attempt to maximize swath coverage.

Distance from nadir was then calculated for the outermost port and starboard soundings for each ping and then plotted against depth to evaluate trends in the achieved swath width versus depth.

Swath coverage determination was made from the raw NA126 .all files, as was the historic comparison data used for comparison which came from the Spring 2019 NA105 Engineering Shakedown.

The results provide a baseline swath coverage curve in depths of approximately 34-2054 m; this curve is useful for survey planning and comparison to future swath coverage data.

* NOTE: The lines used to calculate swath coverage were mostly run at 10-12 kts, rather than the traditional testing speed of 8 kts, used during most QATs. The lines were not run orthogonal to seafloor structure as normally preferred.
The plot to the left shows the calculated swath coverage (extinction) plot of the NA126 bathymetry in rainbow colors for the EM302 over the range of 34m to 2054 meters water depth.

The underlying grey points document the swath performance of the system from data collected during NA105, the spring 2019 Engineering Shakedown cruise.

Unfortunately, as this data was collected during transits, instead of dedicated swath performance lines, many lines contributing to the coverage calculation as a function of depth were oblique or even parallel to slope yielding less than ideal data for a coverage calculation. These orientations led to asymmetric coverage results between the port and starboard side. This situation unfortunately included the one time that the ship crossed water depths greater than ~1350 meters where only starboard side was able to ensonify the seafloor over a short run (see the figure below).

The NA126 achieved swath widths over almost the full range of depths are significantly less than that attained during NA105 (grey dots on left). That said, this data was collected prior to determining the vibrating fuel return pipe in the engine room (see noise section).

To more accurately portray the system performance with minimized ship noise, please submit any new transit data to Paul Johnson for further analysis.
EM302 Swath Coverage

NA19 swath coverage (rainbow) with NA105 underlay (grey)

Swath coverage with annotated water depth multiple lines

Swath coverage with annotated swath angle lines
EM302 Swath Coverage

Swath Coverage
Depth

Swath Coverage
Ping Mode

Swath Coverage
Pulse Form

NA126 Results
EM302 Swath Coverage

Swath Coverage
Swath Mode

Swath Coverage
Backscatter Strength

NA126 Results
• A full Built-In Self-Test (BIST) diagnostic routine was run prior to departure as well as a few times while underway to test the system in different operational environments.

• BISTs provide the ability to perform impedance measurements of the transmitter and receiver arrays and receiver.

• These types of test results may be used as proxies for the health of array transducer elements and receivers.

• Routine RX and TX Channel BISTs may aid early detection of element degradation. This is an important condition to monitor, as these arrays have been known to degrade with time.

• It is important to note that the BIST impedance measurements do not provide a full characterization of transducer properties as a function of frequency.
EM302 Transducer Health

**Impedance – RX Channels & Receiver**

- EM302 RX Channels impedance levels for receiver and transducer have been collected by BIST tests from 2013 to 2021.
- These plot includes all BISTs (543) which have been collected and stored on the EM302 acquisition machine, regardless of the reason they were collected.
- The most recent test, conducted on 2021-08-29, is shown as a thick black line.
- Y-Range for impedance is based on the acceptable range defined to pass a BIST test as defined by Kongsberg.
- Current receiver impedance values show relatively uniform levels across all channels and confirm no open or short-circuit conditions at the start of the system’s service life.
- There has been very little change in amplitude or variation in pattern over the 8 years of testing.
EM302 Transducer Health

NA126 RX Channels
July 2021

Shipboard Acceptance Trials RX Channels
April 2013

RX Channels BIST
EM302 (S/N 110)
2021/07/05 03:37:59.082
Frequency: 30 kHz

RX Channels BIST
EM302 (S/N 110)
2013/04/03 15:52:17.457
Frequency: 30 kHz

RX Impedance: Receiver

RX Impedance: Transducer
• The July 2021 NA126 TX channels impedance values look very similar to that observed during NA119 values collected during August of 2020 (see 2020 QAT report).

• All but one transmitter array element, Channel 15/Slot 12, impedance value fell within the expected normal ranges. This channel was first noticed in 2014 (shown in figure on right) and has not changed since.

• There does appear to be a general increase in impedance slots 10-18 and slots 22-24 when comparing values to the 2014 results, but the measured values do fall within the acceptable range for the system.
EM302 Transducer Health

Impedance – TX Channels

NA126 TX Channels
July 2021

NA40 TX Channels
May 2014

NA126 Transmitter Impedance

NA40 Transmitter Impedance
As with 2017, 2018 and 2019 QATs, we once again tested the seep detection capabilities of the E/V Nautilus’ EM 302 on a known seep in Santa Monica basin.

The test was conducted where the local seafloor depth of the seep was ~900m deep. A main pass was run from south to north nearly directly over the seep, followed by east-west trending passes starting nearly directly over the seep, 450 meters out to the south, 900 meters out to the south, and then 1350 meters out to the south (see line layout in the figure to the left).

The EM302 was restricted to +/- 65 deg. swath width and all the lines were run in the Deep mode. The seep was detected on each pass and there did not appear to be any detection differences on the either the starboard or port sides of the swath.

Figures on the next five pages show the water column data for the seep detection as well as the line offset from the seep.
Water Column

Directly Across Seep

Line Offset By 450 meters

Seep Detection Assessment
Water Column

• Directly Across Seep*, S-N pass
• 0000_20210707_054020_Nautilus

*the anomalies appear to be about 150 m from the center of the swath, so swath was not quite centered over the seep
Seep Detection Assessment

Directly Across Seep*, W-E pass

0002_20210707_064704_Nautilus

*the anomalies appear to be about 55 m from the center of the swath, so swath was not quite centered over the seep
Water Column

Seep Detection Assessment

- Line Offset by 450 m, E-W pass
- 0004_20210707_071359_Nautilus
Water Column

Seep Detection Assessment

- Line Offset by 900 m, W-E pass
- 0006_20210707_073012_Nautilus
Water Column

- Line Offset by 1350 m, E-W pass
- 0008_20210707_074410_Nautilus
Seep Detection Assessment

• Nautilus uses FM Midwater for routine processing and locating seeps. However, the geo-picked location of the seeps using that software are not correctly ray traced, and Qimera is used for ROV dive planning to provide a ray traced position with reduced uncertainty.

• The SOP is to geo-pick the seep in the Qimera water column display where it is estimated the seep is exiting the seafloor; the effectiveness of this approach and the quality of resulting picks varies depending on the angle and distance of the seep for the ship.

• For this analysis, the location of the seep was geo-picked from every line. On the left, the top image shows all picks with seafloor exit picks shown in blue and highest intensity picks shown in red. On the lines offset more than 450 m, only a high intensity pick could be made. For this seep, seafloor exit picks could often be made ‘coming and going’, where one could imagine seeing a seafloor exit in pings on either side of the seep location (thus there are multiple seafloor exit picks for some lines). Figures on the three pages that follow show images of the seafloor exit picks vs. the high intensity picks where they exist.

• This is a subjective assessment but shows that it is easier to pick high intensity, and there is higher agreement in this location between lines. We will continue to evaluate the best option for where to place location picks when evaluating seep data.

• Nautilus will continue to geolocate seeps and water column targets for ROV dives using the Qimera processing path.
Water Column

Seep Detection Assessment

- Directly Across Seep, S-N pass, 0000_20210707_054020_Nautilus
- Seafloor Exit Picks (left) vs. Highest Intensity Pick (right)
Water Column

Seep Detection Assessment

- Directly Across Seep, W-E pass, 0002_20210707_064704_Nautilus
- Seafloor Exit Picks (left) vs. Highest Intensity Pick (right)
Water Column

Seep Detection Assessment

• Line Offset by 450 m, E-W pass0004_20210707_071359_Nautilus
• Seafloor Exit Picks (left) vs. Highest Intensity Pick (right)
As in prior years, a goal of the QAT was to assess the quality of the sound velocity profiles derived from:

- Sippican MK21 XBT (primary launcher only)
- Teledyne Oceanscience Underway CTD
- Seabird SBE49 FastCAT CTD mounted on ROV Hercules

Profiles were collected at the conclusion of ROV dive H1849, near the location of the known seep in Santa Monica Basin.

The three profiles are consistent in shape but do have some differences in sound speed value, with differences being most pronounced between the Seabird CTD mounted on Hercules and the XBT/UCTD, in the top 200 m of water.
Sound speed values as calculated from XBT and OceanScience UCTD tend to be within 1 m/s of each other, even in the top 200 m.

The Seabird CTD, however, could vary 5-6 m/s from the XBT and UCTD at some depths.
Sound Speed Comparison

XBT, UCTD, & CTD Comparison

- The plot to left focuses on the top 60 m of water, where the most drastic differences occur between the Seabird CTD, XBT, and UCTD.
- Below ~60 m, differences decreased to 1-1.5 m/s.
- Below ~100m, differences decreased to 0.5-1 m/s.
Noise VS Pitch – Main Engine

NA127 – Pitch 14 – Into Seas

NA127 - Transit - Self Noise vs Pitch - IS - 14

- RX Module
- Test #
- Frequency (%)
- Self Noise (dB re 1μPa/Hz)

NA127 - Transit - Self Noise vs Pitch - IS - 14

- Channel
- Self Noise (dB re 1μPa/Hz)
Noise VS Pitch – Main Engine

NA127 – Pitch 22 – Into Seas

NA127 - Transit - Self Noise vs Pitch - IS - 22

NA127 - Transit - Self Noise vs Pitch - IS - 22

NA127 - Transit - Self Noise vs Pitch - IS - 22
Appendix 2 – RX Noise
NA127 - Main Engine
Speed – With Seas
Noise VS Speed – Main Engine

NA127 – Speed 6 kts – Into Seas
Noise VS Speed – Main Engine

NA127 – Speed 10 kts – Into Seas
Noise VS Speed – Main Engine

NA127 – Speed 12 kts – Into Seas

NA127 - Transit - Self Noise vs Speed - IS - 12.0 (kts)
Appendix 3 – RX Noise
NA126 - Main Engine
Pitch – Into Seas
Noise VS Pitch – Main Engine

NA126 – Pitch 3 – Into Seas

NA126 - Catalina Basin - Self Noise vs Pitch - IS - 3

Self Noise (dB re 1μPa/Hz)

Channel

Self Noise (dB re 1μPa/Hz)

Frequency (%)
Noise VS Pitch – Main Engine

NA126 – Pitch 6 – Into Seas

NA126 - Catalina Basin - Self Noise vs Pitch - IS-6

NA126 - Catalina Basin - Self Noise vs Pitch - IS-6

NA126 - Catalina Basin - Self Noise vs Pitch - IS-6

Self Noise (dB re 1μPa/Hz)

Channel

0 16 32 48 64 80 96 112

Self Noise (dB re 1μPa/Hz)

0 30 35 40 45 50 55 60 65 70

RX Module

Test #

0 5 10 15 20

0 16 32 48 64 96 128

0 16 32 48 64

0 16 32

0 5 10 15 20

Self Noise (dB re 1μPa/Hz)

Frequency (%)

0 5 10 15 20 25 30 35 40 45

0 30 35 40 45 50 55 60 65 70

Median

Mean (log.)

Mean (linear)
Noise VS Pitch – Main Engine

NA126 – Pitch 22 – Into Seas

NA126 - Catalina Basin - Self Noise vs Pitch - IS - 22

- Self Noise (dB re 1µPa/Hz)
- Channel

- RX Module
- Test #

- Frequency (%)
- Self Noise (dB re 1µPa/Hz)
Noise VS Pitch – Main Engine

NA126 – Pitch 26 – Into Seas
Appendix 4 – RX Noise
NA126 - Main Engine Pitch – With Seas
Noise VS Pitch – Main Engine

NA126 – Pitch 0 – With Seas

NA126 - CatalinaBasin - Self Noise vs Pitch - WS - 0

Self Noise (dB re 1µPa/Hz)

Channel

RX Module

Test #

Frequency (%)
Noise VS Pitch – Main Engine

NA126 – Pitch 2 – With Seas

[Graphs showing noise vs pitch data for NA126 in Catalina Basin, with self noise vs pitch for WS-2.]

Test #
0 10 20
RX Module
0 16 32 48 64 96 112 128
NA126 - CatalinaBasin - Self Noise vs Pitch - WS - 2

Self Noise (dB re 1uPa/Hz)
30 40 50 60 70
Channel
0 16 32 48 64 80 96 112

Frequency (%)
0 5 10 15 20 25 30 35 40
Self Noise (dB re 1uPa/Hz)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

[Statistics and analysis of noise data shown in graphical form.]
Noise VS Pitch – Main Engine

NA126 – Pitch 11 – With Seas

NA126 - Catalina Basin - Self Noise vs Pitch - WS 11

Self Noise (dB re 1μPa/Hz)

Channel

RX Module

Test #

dB

Med (log)

Mean (log)

Mean (lin)
Noise VS Pitch – Main Engine

NA126 – Pitch 20 – With Seas

NA126 - Catalina Basin - Self Noise vs Pitch - WS 20

NA126 - Catalina Basin - Self Noise vs Pitch - WS 20

Test #

RX Module

Channel

Frequency (%)

Self Noise (dB re 1μPa/Hz)

Self Noise (dB re 1μPa/Hz)

Median
Mean (log.)
Mean (linear)

Noise vs Pitch - Main Engine

NA126 – Pitch 20 – With Seas
Appendix 5 – RX Noise
NA126 - Main Engine Speed – Into Seas
Noise VS Speed – Main Engine

NA126 – Pitch – Into Seas
Noise VS Speed – Main Engine

NA126 – Speed 1 kt – Into Seas
Noise VS Speed – Main Engine

NA126 – Speed 4 kts – Into Seas

NA126 - Catalina Basin - Self Noise vs Speed - IS - 4.0 (kts)

- RX Module
  - 128
  - 112
  - 96
  - 80
  - 64
  - 48
  - 32
  - 16
  - 0

- Test #
  - 30
  - 35
  - 40
  - 45
  - 50
  - 55
  - 60
  - 65
  - 70

- Channel
  - 0
  - 15
  - 30
  - 45
  - 60
  - 75
  - 90
  - 105
  - 120

- Self Noise (dB re 1μPa/Hz)
  - 30
  - 40
  - 50
  - 60
  - 70

- Frequency (%)
  - 0
  - 5
  - 10
  - 15
  - 20
  - 25
  - 30
  - 35
  - 40
  - 45
  - 50
  - 55
  - 60
  - 65
  - 70

- Self Noise (dB re 1μPa/Hz)
  - Median
  - Mean (log.)
  - Mean (linit)
Noise VS Speed – Main Engine

NA126 – Speed 8 kts – Into Seas
Noise VS Speed – Main Engine

NA126 – Speed 12 kts – Into Seas

NA126 - Catalina Basin - Self Noise vs Speed - IS - 12.0 (kts)

Self Noise (dB re 1μPa/Hz)

Channel

Test #

RX Module

0 16 32 48 64 80 96 112 128

NA126 - Catalina Basin - Self Noise vs Speed - IS 12.0 (kts)

Frequency (%)

Self Noise (dB re 1μPa/Hz)

Median
Mean (log.)
Mean (lin.)

3M7 2021 Aug 09 18:09:04
Median= 50.1, Logarithmic Mean= 50.3166, Linear Mean= 53.4664
Appendix 6 – RX Noise
NA126 - Main Engine Speed – With Seas
Noise VS Speed – Main Engine

NA126 – Speed 1 kt – With Seas
Noise VS Speed – Main Engine

NA126 – Speed 6 kt – With Seas
Noise VS Speed – Main Engine

NA126 – Speed 8 kt – With Seas
Noise VS Speed – Main Engine

NA126 – Speed 12 kt – With Seas

NA126 - Catalina Basin - Self Noise vs Speed - WS - 12.0 (kts)

Test #

RX Module

Channel

Frequency (%)

Self Noise (dB re 1μPa/Hz)

Self Noise (dB re 1μPa/Hz)

NA126 - Catalina Basin - Self Noise vs Speed - WS - 12.0 (kts)

Median
Mean (log.)
Mean (linear)

0 5 10 15 20

30 35 40 45 50 55 60 65 70

30 35 40 45 50 55 60 65 70

0 5 10 15 20 25 30 35 40

0 30 60 90 120 150 180 210 240

0 5 10 15 20 25 30 35 40

0 30 60 90 120 150 180 210 240

153
Appendix 7 – RX Noise
NA126 - Main Engine
Pitch – With Seas
Noise Dampening Tests
## EM302 RX Noise – Main Engine

### Noise Dampening – Test 1
- **Pitch**: 18
- **Speed**: 8.2 kts
- **Test**: 01

The image shows a graph representing the noise dampening test results. The x-axis represents the test number, ranging from 0 to 10, while the y-axis represents the RX module, ranging from 0 to 128. The color bar indicates the noise level in dB, ranging from 30 to 70. The data suggests a pattern or trend that can be analyzed for performance improvements.
EM302 RX Noise – Main Engine

Noise Dampening – Test 2
Pitch 18, Speed 9.2 kts
EM302 RX Noise – Main Engine

Noise Dampening – Test 2
Pitch 18, Speed 8.2 kts
EM302 RX Noise – Main Engine

Noise Dampening – San Pedro Channel
Pitch 18, Speed 9.2 kts
Test 01

NA126 - SanPedro_NoiseDamp01 - Self Noise vs Pitch - WS - 18

NA126 - SanPedro_NoiseDamp01 - Self Noise vs Pitch - WS 18

Self Noise (dB re 1μPa/Hz)

Channel

30 35 40 45 50 55 60 65 70

Frequency (%)

30 35 40 45 50 55 60 65 70

Self Noise (dB re 1μPa/Hz)

Median
Mean (log.)
Mean (lin.)

3M7 2021 Jul 08 18:08:22

3M7 2021 Jul 08 18:08:25

Median= 39.3, Logarithmic Mean= 40.2516, Linear Mean= 46.5453
EM302 RX Noise – Main Engine

Noise Dampening – San Pedro Channel
Pitch 18, Speed 9.2 kts
Test 01

NA126 - SanPedro_NoiseDamp02 - Self Noise vs Pitch - WS - 18

Channel

Self Noise (dB re 1µPa/√Hz)

0 16 32 48 64 80 96 112

30 35 40 45 50 55 60 65 70

NA126 - SanPedro_NoiseDamp02 - Self Noise vs Pitch - WS 18

Frequency (%)

0 5 10 15 20 25 30 35 40 45

30 35 40 45 50 55 60 65 70

Self Noise (dB re 1µPa/√Hz)

Median
Mean (log.)
Mean (lin.)
Appendix 8 – SIS Configuration
Appendix 8: SIS Configuration

Installation Parameters
Appendix 8: SIS Configuration

Installation Parameters
Appendix 8: SIS Configuration

Installation Parameters
Appendix 8: SIS Configuration

Installation Parameters
Appendix 8: SIS Configuration

Installation Parameters
Appendix 8: SIS Configuration

Installation Parameters
Appendix 8: SIS Configuration

Installation Parameters

<table>
<thead>
<tr>
<th>PU Communication Setup</th>
<th>Sensor Setup</th>
<th>System Parameters</th>
<th>BST</th>
<th>System Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settings: Location Offsets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location Offset (m)</th>
<th>Forward (X)</th>
<th>Starboard (Y)</th>
<th>Downward (Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pos, COME</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Pos, COME</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Pos, COME/UDP1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>TX Transducer</td>
<td>0.406</td>
<td>-0.137</td>
<td>2.733</td>
</tr>
<tr>
<td>RX Transducer</td>
<td>1.516</td>
<td>0.039</td>
<td>2.722</td>
</tr>
<tr>
<td>Attitude 1, COME/UDP3</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Attitude 2, COME/UDP3</td>
<td>0.00</td>
<td>0.00</td>
<td>-1.77</td>
</tr>
<tr>
<td>Waterline</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Settings: Location Offsets

<table>
<thead>
<tr>
<th>Offset angles (deg)</th>
<th>Roll</th>
<th>Pitch</th>
<th>Heading</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX Transducer</td>
<td>0.01</td>
<td>0.01</td>
<td>0.22</td>
</tr>
<tr>
<td>RX Transducer</td>
<td>0.02</td>
<td>0.32</td>
<td>0.00</td>
</tr>
<tr>
<td>Attitude 1, COME/UDP3</td>
<td>0.15</td>
<td>-0.14</td>
<td>0.01</td>
</tr>
<tr>
<td>Attitude 2, COME/UDP3</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Stand-alone Heading</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 8: SIS Configuration

Installation Parameters

All BISTS passed 2021-07-08
Appendix 8: SIS Configuration
Appendix 8: SIS Configuration

Runtime Parameters

- Sector Coverage
- Depth Settings
- Transmit Control
- Yaw Stabilization
- Min. Swath Dist. (m): 0.3
- External Trigger
- 3D Scanning
- 3D Scan Elevation (deg): -1
- Max. Scan Elevation (deg): 10
- Step (deg): 0.2

Sounder Main
- Sound Speed Profile: 08200520_232002.ssv
- Abs. coeff. files, salinity: /datacommon/svps/AbsCoeff_08200520_232002_sav
- Abs. coeff. files, CTD: /datacommon/svps/AbsCoeff_08200520_232002

Sound Speed at Transducer:
- Source: PROFILE
- Sound Speed (m/sec): 1.521
- Sensor Offset (m/sec): 0.0
- Filter (sec): 20
Appendix 8: SIS Configuration

Runtime Parameters
Appendix 8: SIS Configuration

Runtime Parameters
Appendix 8: SIS Configuration

New AML surface sound speed sensor.
## PU Sensor Status

### PU Sensor Input Status

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>COM1</th>
<th>COM2</th>
<th>COM3</th>
<th>COM4</th>
<th>UDP2</th>
<th>UDP5</th>
<th>UDP6</th>
</tr>
</thead>
<tbody>
<tr>
<td>GGA</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GGK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GGA, RTK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIMRAD90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MV39 Modest Attitude, no heave</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDT Heading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKR82 Heading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROV, depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZDA Clock</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height, special purpose only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DBS Depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DPT Depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EAS900 Depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude/Velocity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1PPS Clock Synchronizer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **P** = active Position sensor
- **M** = active Motion/Attitude sensor
- **H** = active Heading sensor
- **A** = active Attitude/Velocity sensor

[Image of PU sensor status window]
Appendix 8: SIS Configuration

Parameters
Appendix 8: SIS Configuration

Parameters
Appendix 8: SIS Configuration
Appendix 8: SIS Configuration

Parameters

Parameters for Autopilot

Sound speed error limits etc.
Appendix 8: SIS Configuration

Parameters

- Network licence
  - Parameter Name: 'Path to licence server'
  - Data Type: String
  - Value: 'localhost'

- Parameters for Total Propagation Error (TPE)
  - Parameter Name: 'Error in sound speed if SFP is not present'
  - Data Type: Float
  - Value: '0.2'

Note: Please restart SIS to affect changes.
Appendix 8: SIS Configuration

Parameters

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Data Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>APOS Transponder ID used for positioning</td>
<td>String</td>
<td>B-7</td>
</tr>
<tr>
<td>Sensor options</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status options</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start options for system</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Please restart SIS to effectuate.
Appendix 8: SIS Configuration

Parameters

Setup for start of echo sounders and SIS

- Parameter Name
  - Parameter 3D
  - Ship
  - Platform
  - Turn parameters
  - Passwords
  - Display
  - Logging
  - Acoustic
  - Sound speed
  - Network service
  - Eponet parameters
  - APICs
  - Sensor options
  - Basic path of volume name used by SIS to recognize disks used for logging

- Data Type
  - Integer
  - String

- Value
  - 0
  - 3

Projections

- Parameter Name
  - Parameter 3D
  - Ship
  - Platform
  - Turn parameters
  - Passwords
  - Display
  - Logging
  - Acoustic
  - Sound speed
  - Network service
  - Eponet parameters
  - APICs
  - Sensor options
  - Projection directory for Gauss (N (green) & projection data)

- Data Type
  - String

- Value
  - Gaussian common background
Appendix 9 – Seapath Configuration

![Seapath Configuration Interface]

- **NRP**
  - N 33°20.6905'
  - W 118°18.7344'

- **Speeds**
  - 0.04 m/s (SL)
  - 0.02 m/s (ST)
  - 0.05 m/s (SOG)

- **Angles**
  - 0.93° Roll
  - 0.88° Pitch
  - -0.07 m Heave

- **HDG**
  - 146.2°

- **Satellite System**
  - GPS 9
  - GLO 4

- **GPS Integrity**
  - 99

- **HDOP**
  - 0.8

- **Time**
  - 2021-07-08 17:24:27
Appendix 9: Seapath Configuration

[Image of Seapath Configuration diagram]
NOTE: Antenna 1 & 2 locations were updated in 2021
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration

NOTE: Turn these on to collect raw Seapath for post-processing.
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration

Connected to Seapath 333

Connected to Seapath 330

198
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration

Connected to Seapath 330

Connected to Seapath 330
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration

Operator software configuration

Position Integrity settings
- Max ellips EPE: 11 m
- Ellipse diagram resolution: 5 steps

Compass settings
- Max speed: 10.00 m/s
- Number of speed ticks: 5 ticks
- Speed limit: 0.10 m/s
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration
Appendix 9: Seapath Configuration

Overview

In 2018 we had weird USBL cal results, and then dug in and found some reference frame discrepancies.

The seapath is sending motion data to the tracklink that is based off MP1. MP1 is 5 meters forward of the USBL transceiver - at the subbottom transducer. We suggested changing this by creating an MP2 that is based at the transceiver and sending motion data from that point to the tracklink. Further, we suggest sending data from the Nav Reference Point (NRP) (the location of the MRU) out as our canonical ship position. In 2018 ship position was recorded from the subbottom transducer (MP1).

The following is a testing/implementation plan that lays out all steps and when they are or are not appropriate to undertake. It had breakpoints for actions that should be done in port etc.

Testing/Implementation Path

1. Change Seapath LAN 4 to 10.1.70.100
   a) Restart required. Do this later, further down in this doc.

2. Wire spare Cat6 cable (labeled: Sonar Room A) in sonar room to back of seapath (LAN 4) in some way that won’t get ripped out. Connect Sonar Room A port in Rack Room patch panel to cross racks patch panel, port 13. Connect port 13 to instrument switch.

3. Create LAN 4 Seapath Binary data format #23 output of MP1, broadcasting (for now, just to test) to instrument network on port 14110 from Telegram 13 (Settings: Broadcast LAN 4, Seapath Binary #23, 0.200 second timer driven interval)

4. Create test iteration of capSeapath yaml config file with new port number (but same data from MP1)

5. Test that capSeapath is not doing anything funny and works with new source of data.
   a) Compared output of current (serial line spsol) data to new (lan4 broadcast) data, very slight time differences led to very small position differences (e.g. 0.1319 second difference means 0.0000016 degree latitude difference, which is equal to ~0.018 meter difference)

6. Create new moxa port (#7) that will receive MRU data from seapath (moxa config same as existing MRU (TSS) moxa port #2 configuration).

7. Restart Moxa for changes to take effect.

8. Close tracklink. Create new COM port on USBLNAV with NPort manager (COM 7)

9. Restart Tracklink and make sure existing COM port 3 (which gets TSS from rack room .86 moxa port #2) still works.

10. Create MP2 located at the tracklink USBL transceiver head. We won’t use the data from this for quite a few steps though.
Appendix 9: Seapath Configuration

11. Create LAN 4 GGA message on telegram 10 of NRP, UDP broadcast (importantly to to NavCook and dsLog) on port 14100. (Port Numbers also documented in Nautilus Network Port Assignment Procedure) Turn off for now.

12. Create LAN 4 GGA message on telegram 11 of MP1, UDP broadcast (importantly to to NavCook and dsLog) on port 14101. Turn off for now. (This is redundant to Seapath COM 13 to GGA the Moxa, but makes a more homogenous system, even if left off)

13. Create LAN 4 GGA message on telegram 12 of MP2, UDP broadcast (importantly to to NavCook and dsLog) on port 14102. Turn off for now.

14. Switch from `seapath serial->moxa->rovnav` spsol ini, to `seapath lan4->.70 broadcast` spsol ini and restart spsol.

15. Verify logging was not affected by switching to new seapath ini file. (i.e. still logging data, and data is not weird)

16. On Seapath: Stop telegram 6 output of binary seapath data on seapath COM 14. Create telegram 14 output of MRU (TSS) data from MP2 to tracklink through Seapath COM 14 (via the rack room moxa, using the same cable that previously gave binary data to now deliver a secondary TSS data fee) (mimic settings from telegram 4, which is the MP1 MRU data).

17. Reopen tracklink. Change config so VRU (MRU/TSS) data is now coming from port 7. Run Test -> VRU. (Now USBLNAV has MP1 VRU data on COM port 3, and MP2 VRU data on COM port 7)

18. Pause. Test with a dive!

19. When logging is already stopped: Restart seapath PU. Verify network change of LAN 4 took effect.
   a) Change did not take effect. Bugger.

20. Turn off telegram output 13 (Seapath binary #23 over LAN 4) & telegram output 14 (TSS from MP2 over seapath COM 14 to Rack Room Moxa port 7). Turn on telegram 6 (seapath binary #23 over seapath COM 14 to rack room Moxa port 4)

21. Swap cable from rack room moxa port 7 to port 4.

22. Change SPSOL config to use old port number & restart capSeapath.


24. Changed eth2 (LAN 4) to 10.1.70.100/255.255.0 using kongsberg’s instructions.

25. Rebooted Seapath PU and it came back with new/correct network address for LAN 4!

26. WAIT. DO NOT PROCEED DURING A CRUISE (Progressed up to here at end of 2018 season)

27. Create seapath outputs of the NMEA (GGA HDT ZDA VTG) strings and the SPSOL (Binary 23) data from NRP, MP1, MP2.

28. Surprise! NavCook doesn’t like the way Seapath sends LAN/UDP messages (All 4 at once in one long line, vs one NMEA string at a time via serial) So rather than edit NavCook code last minute, I created another serial line from Seapath COM1 to Moxa .86 (Rack Room) port 7 that is used for TSS MP2 data (and used the old Seapath binary com14 to now send GGA MP2 data). I used the blue wire from the bulk serial line coming from the Sonar Room to the back of Rack 3 in the rack room for TSS data.

29. Create iteration of NavCook yaml config file with new port number of NMEA/GGA MP2 data (14008), and offsets of MP2 to NRP, instead of current offsets of MP1 to tracklink transceiver head).

30. Test that NavCook is not doing anything funny and works with new source of data and the new MP2 yaml config (do not save data in real data tree, these are NRP sourced positions)
Appendix 9: Seapath Configuration

Testing/Implementation Path Continued

31. Stop capSeapath (not totally necessary as no config changes on capSeapath’s end, but data file has a clear gap in time in logging then)
32. Load capSeapath ini file that accepts data from MP2

33. Do we want to record MP2 or NRP?
34. Then deal with cascading changes below
35. Hypack drawing based off MP2 now. So make ship 5.131m longer in front and shorter in back. (MP2 is 0.087m higher than MP1 and 0.346m to port, which shouldn’t matter for drawings or measurements)
36. NavEst drawing and sensor offsets based off MP2 now as well
37. Changes to calEst?  
   a) No. It just runs off point sources
38. Update offset documents (include list here of said docs)  
   a) /mnt/nautilusfs/share/repos/data-docs/navOffsets-[DATE].pdf
39. Update data user guide verbiage

Current Setup
As of 2019-05-10 JKL

<table>
<thead>
<tr>
<th>Tgram</th>
<th>Output</th>
<th>Destination</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Com11</td>
<td>Moxa .86, Port 2</td>
<td>TSS of MP1 to Knudsen</td>
</tr>
<tr>
<td>5</td>
<td>Com13</td>
<td>Moxa .86, Port 1</td>
<td>GGA, HDT, ZDA, VTG of MP1 to Knudsen</td>
</tr>
<tr>
<td>6</td>
<td>Com14</td>
<td>Moxa .86, Port 8</td>
<td>GGA, HDT, ZDA, VTG of MP2 to Tracklink &amp; NavCook</td>
</tr>
<tr>
<td>13</td>
<td>Com1</td>
<td>Moxa .86, Port 7</td>
<td>TSS of MP2 to Tracklink</td>
</tr>
<tr>
<td>10</td>
<td>Lan 4</td>
<td>Broadcast</td>
<td>GGA, HDT, ZDA, VTG of NRP to .70 network</td>
</tr>
<tr>
<td>11</td>
<td>Lan 4</td>
<td>Broadcast</td>
<td>GGA, HDT, ZDA, VTG of MP1 to .70 network</td>
</tr>
<tr>
<td>12</td>
<td>Lan 4</td>
<td>Broadcast</td>
<td>GGA, HDT, ZDA, VTG of MP2 to .70 network</td>
</tr>
<tr>
<td>14</td>
<td>Lan 4</td>
<td>ROVNav</td>
<td>SPSOL (Binary 23) of NRP</td>
</tr>
<tr>
<td>15</td>
<td>Lan 4</td>
<td>ROVNav</td>
<td>SPSOL (Binary 23) of MP1</td>
</tr>
<tr>
<td>16</td>
<td>Lan 4</td>
<td>ROVNav</td>
<td>SPSOL (Binary 23) of MP2</td>
</tr>
</tbody>
</table>
Appendix 9: Seapath Configuration

Transcription of 1st Round of Notes

Current
1. COM 11 RS422 -> Moxa port 18, TSS of MP1 goes to Knudsen & Tracklink
2. COM 13 RS422 -> Moxa GGA, HDT, etc of MP1 goes to Knudsen (SubBottom Computer), NavCook (ROVNav), dsLog (capture) & dsLog reflector (shiphouse)
3. COM 14 RS422 -> Moxa binary seapath data to capSeapath

Future
1. COM 11 RS422 -> Moxa port 18, TSS of MP1 goes to Knudsen
2. COM 13 RS422 -> Moxa GGA, HDT, etc of MP1 goes to Knudsen
3. COM 14 RS422 -> Moxa TSS of MP2 to Tracklink
4. Lan 4 -> Moxa Port XX1, GGA, etc of NRP to NavCook (.NAV) & dsLog (.INNAV)
5. Lan 4 -> Moxa Port XX2, binary seapath data of NRP to capSeapath (.SPSOL)

Offset Changes Required
(LAN 4 would go on 10.1.70.x network)
1. Seapath
2. NavCook
3. Calest?
4. Hypack Drawing
5. NavEst drawing and sensor offset
6. Offsets doc x2
7. Data docs text
Appendix 10
Seapath Antenna Calibration
Appendix 10

Seapath Antenna Calibration

System is ready for antenna calibration

Calibration parameters:
- Baseline length accuracy: 0.000 m
- Height difference accuracy: 0.100 m

Calibration period:
- Duration: 120 min (Recommended 120 min)
- Message interval: 10 s (Recommended 10 s)
NOTE: Seapath screen dump software would not capture calibration screens.
NOTE: Seapath screen dump software would not capture calibration screens.
Appendix 10

Seapath Antenna Calibration

- Antenna 2 Calibration Results
  - X:
  - Y:
  - Z:

- Antenna 2 Survey Results
  - X:
  - Y:
  - Z:

NOTE: Seapath screen dump software would not capture calibration screens.
Appendix 11
Sound Speed Manager Configuration
Appendix 11

Sound Speed Manager Config
Appendix 11

Sound Speed Manager Config
Appendix 11

Sound Speed Manager Config
Appendix 12
BSCorr
## Alternative EM 302 beam pattern corrections for NOAA Okeanos Explorer

**KTU - September 09, 2008**

The values in the first three rows will be used instead of the program default values.

<table>
<thead>
<tr>
<th>Values</th>
<th>Default Parameters</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very shallow - not used</td>
<td>21570 0 16500</td>
<td></td>
</tr>
<tr>
<td>Shallow</td>
<td>21880 6000 2600</td>
<td></td>
</tr>
<tr>
<td>Single swath</td>
<td>21880 2800 4000</td>
<td></td>
</tr>
<tr>
<td>Dual swath 1</td>
<td>22100 6000 2600</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>21940 6000 2600</td>
<td></td>
</tr>
<tr>
<td>Single swath</td>
<td>21940 2800 4000</td>
<td></td>
</tr>
<tr>
<td>Dual swath 1</td>
<td>22110 6000 2600</td>
<td></td>
</tr>
<tr>
<td>Very Deep</td>
<td>22510 4300</td>
<td></td>
</tr>
<tr>
<td>Single swath</td>
<td>22510 2600</td>
<td></td>
</tr>
<tr>
<td>Deep</td>
<td>22510 1100</td>
<td></td>
</tr>
<tr>
<td>Single swath</td>
<td>22510 2600</td>
<td></td>
</tr>
<tr>
<td>Extra Deep</td>
<td>22510 1100</td>
<td></td>
</tr>
<tr>
<td>Single swath</td>
<td>22510 2600</td>
<td></td>
</tr>
</tbody>
</table>

## Source level

<table>
<thead>
<tr>
<th>Source level</th>
<th>Lobe angle</th>
<th>Lobe width</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very shallow - not used</td>
<td>21570</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Shallow</td>
<td>21880</td>
<td>6000</td>
<td>2600</td>
</tr>
<tr>
<td>Single swath</td>
<td>21880</td>
<td>2800</td>
<td>4000</td>
</tr>
<tr>
<td>Dual swath 1</td>
<td>22100</td>
<td>6000</td>
<td>2600</td>
</tr>
<tr>
<td>Medium</td>
<td>21940</td>
<td>6000</td>
<td>2600</td>
</tr>
<tr>
<td>Single swath</td>
<td>21940</td>
<td>2800</td>
<td>4000</td>
</tr>
<tr>
<td>Dual swath 1</td>
<td>22110</td>
<td>6000</td>
<td>2600</td>
</tr>
<tr>
<td>Very Deep</td>
<td>22510</td>
<td>4300</td>
<td></td>
</tr>
<tr>
<td>Single swath</td>
<td>22510</td>
<td>2600</td>
<td></td>
</tr>
<tr>
<td>Deep</td>
<td>22510</td>
<td>1100</td>
<td></td>
</tr>
<tr>
<td>Single swath</td>
<td>22510</td>
<td>2600</td>
<td></td>
</tr>
<tr>
<td>Extra Deep</td>
<td>22510</td>
<td>1100</td>
<td></td>
</tr>
<tr>
<td>Single swath</td>
<td>22510</td>
<td>2600</td>
<td></td>
</tr>
</tbody>
</table>