NOAA Ship Okeanos Explorer
Acoustic Systems Shakedown
EX1902: May, 2019

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image credit: NOAA
EX1902 Acoustic Shakedown Onboard Activities

The primary shakedown activities included:

1. 2019-05-12: depart Pascagoula, MS
2. EM302 and POS MV geometry / config. review
3. EM302 dockside BISTs (incl. TX channels)
4. Geometric calibration (‘patch test’)
5. Backscatter calibration (for Kongsberg processing)
6. Roll verification
7. Swath extinction data collection during transits
8. EM302 RX noise vs. speed testing
9. Acoustic interference testing across all systems
10. K-Sync SAT and testing with Kongsberg support
11. EK60/80 target strength calibrations
12. POS MV GAMS calibration
13. 2019-05-24: arrive Key West, FL

Not all onboard activities are reported in this document; at left, an overview of data collected during EX1902 shown in QPS Qimera
1. The EM302 RX array was replaced in 2018; see the EX1810 EM302 Sea Acceptance Test (SAT) report for details of the most recent vessel survey and system configurations prior to EX1902.

2. The TX and RX arrays, POS MV IMU, and GNSS antennas are not known to have been removed, reinstalled, or otherwise modified since completion of the EX1810 SAT.

3. Review of EM302 and POS MV configurations at the start of EX1902 showed no changes since the EX1810 SAT.

4. Post-EX1902 system configurations to be used for 2019 are included in the appendices.
1. At the start of EX1902, the EM302 Installation Parameters remained unchanged from post-EX1810 (below)

2. The granite block remains the origin for all sensor reference frames

3. The Attitude 1 (POS MV IMU) angular offsets were left unchanged prior to the EX1902 calibration
1. No changes were made to the POS MV lever arms or installation angles prior to the EX1902 calibration

2. Due to time constraints outside of mapping team control, a GAMS calibration was not performed prior to EM302 calibration

3. There is no indication of antenna modification in dry dock; the EM302 heading calibration and (later) GAMS results support this conclusion
EM302 Calibration

Site Selection and Data Collection

1. The EX1902 calibration site on Pascagoula Dome was successfully used during EX1801.
2. This site was originally selected based on availability of seafloor features with suitable slopes and bathymetric relief within acceptable transit distances from port.
3. Calibration lines were run at 6 kts in the order of:
   1. Pitch (A→B and B→A)
   2. Roll (C→D and D→C)
   3. Heading (E→F and G→H)
4. No verification lines were planned, due to time constraints; roll verification was conducted later.

<table>
<thead>
<tr>
<th>Waypoint</th>
<th>Decimal Degrees</th>
<th>Degrees Decimal Minutes</th>
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<tbody>
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<td>Calibration</td>
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<td>-88.028958</td>
</tr>
<tr>
<td></td>
<td>B 28.955602</td>
<td>-88.028243</td>
</tr>
<tr>
<td></td>
<td>C 29.032900</td>
<td>-87.953957</td>
</tr>
<tr>
<td></td>
<td>D 28.961899</td>
<td>-87.939049</td>
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<td>E 29.027711</td>
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<td>F 28.955515</td>
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<td>G 29.027884</td>
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<td></td>
<td>H 28.955688</td>
<td>-88.016956</td>
</tr>
</tbody>
</table>
EM302 Calibration

Site Selection and Data Collection

5. The line plan was developed to follow the necessary order of calibration steps within the time constraints.

6. While it is acknowledged that the area includes relief that is not ‘ideal’ for roll calibration, this site had been used successfully in 2018 and the roll results in 2019 were readily identified with the same level of confidence as the pitch and heading.

7. Roll verification was later conducted using two backscatter calibration lines over terrain with less relief; results confirmed the initial roll calibration.

8. XBTs were conducted prior to the first pitch line and first roll line; all sound speed profiles were processed in Sound Speed Manager using World Ocean Atlas 2013 salinity data and applied in SIS prior to data collection.

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1. No changes were made to the SIS Installation Parameters prior to EX1902 calibration

2. Calibration data were examined with the patch test tool in QPS Qimera; results were agreed upon by multiple personnel before application in SIS

3. Results of each test were updated in the SIS Installation Parameters for Attitude 1 angular offsets prior to the subsequent test

4. No positioning latency test was performed, as this test is inconclusive in deep water; no attitude latencies were readily apparent
EM302 Calibration

Results: Pitch

Pitch calibration lines shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: -0.35 °
2. Calibration adjustment: -0.07 °
3. Final pitch offset: -0.42° in SIS
Roll calibration lines shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: -0.08°
2. Calibration adjustment: -0.03°
3. Verification adjustment: 0.00°
4. Final roll offset: -0.11° in SIS
EM302 Calibration

Results: Roll

Roll verification shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: -0.08°
2. Calibration adjustment: -0.03°
3. Verification adjustment: 0.00°
4. Final roll offset: -0.11° in SIS
EM302 Calibration

Results: Heading

Heading calibration lines shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: 0.00°
2. Calibration adjustment: 0.00°
3. Final hdg. offset: 0.00° in SIS
Results: Configuration in SIS

1. The small adjustments for pitch and roll are reasonable for post-dry-dock calibration and indicate no significant changes since the EX1810 SAT.

2. The zero heading adjustment indicates no significant changes in heading feed (i.e., suitable GAMS parameters during calibration).

3. The Installation Parameters: Angular Offsets shown at left should be maintained until any modification is made to the POS MV or EM302 arrays, or another calibration becomes necessary for other reasons.
Results: Configuration in POSView

1. GAMS calibration was conducted on 23 May 2019; this was performed after the EM302 calibration due to ship timing constraints, with the understanding that a significantly different GAMS result would require additional EM302 heading calibration lines (and possibly roll and pitch lines, depending on magnitude of resulting heading adjustments).

2. The average X (0.000 m) and Y (2.303 m) antenna baseline results fell within a few mm of the pre-EX1902 antenna baseline vector; the average Z result differed by 2 cm from the initial value, but this offset is less reliably determined from the small number of GNSS measurements at sea and has the least impact on POS MV heading.

3. Because POS MV antenna locations are not known to have changed since EX1810, and the pre-GAMS EM302 heading calibration adjustment was 0.00°, the decision was made to maintain the post-EX1810 antenna baseline used during EX1902 (shown at left with X = 0.007 m, Y = 2.302 m, Z = 0.013 m).
During transits and most mapping activities throughout EX1902, the EM302 was run in automatic ping mode with swath angle limits of ±75° in order to let the system select its preferred modes and attempt to maximize swath coverage over depths of 50-3300 m. The outermost port and starboard valid soundings for all pings were plotted using MAC/NOAA tools to evaluate trends in the achieved swath width versus depth. This coverage curve is useful for survey line planning as well as providing an early indication of performance degradation; among other vessels, reductions in coverage have indicated increased vessel noise levels or other hardware issues, such as reduced transmission strength. Note that transits were conducted at 10 kts rather than a typical survey speed of 8-9 kts, which may negatively impact swath coverage (see the RX Noise BIST section for details).
Results: 50-3300 m

EX1902 extinction data show symmetric coverage and suggest no systemic coverage limitations from vessel noise or hardware. As in EX1810, the EM302 generally achieved coverage of 6-7X water depth (WD) down to 200 m and 5-6X WD down to 500 m; the system then reported 4-5X WD coverage down to 1500 m before beginning to show rapid ‘roll-off’ due to acoustic attenuation at greater depths.

Throughout EX1902, the EM302 automatically switched depth modes as expected to maximize swath width.

Swath coverage trends in the deepest modes are not well represented because EX1902 covered little terrain deeper than 2000 m (and none beyond 3300 m); ping rates are significantly reduced at these ranges, further limiting data availability.
EM302 Swath Coverage

Results: Comparison to EX1810

EX1902 extinction data (colored by depth) are plotted over EX1810 data (gray).

Other comparisons of swath coverage from 2017 and 2018 are presented in the EX1810 EM302 RX array SAT report.

Comparison of EX1810 and EX1902 data show similar total coverage achieved down to depths of 3300 m (maximum in EX1902), just beyond the transition from Deep 2 (CW/FM mixed) to Very Deep (FM only).
Major limitations of multibeam performance can stem from elevated noise levels due to hull design, engines and other machinery, sea state, biofouling, electrical interference, etc.

Series of tests were run using the EM302 Built-In Self-Test (BIST) routines for RX Noise and RX Spectrum to characterize the vessel’s platform noise environment over a range of speeds.

The speeds are estimated through water, based on speed over ground and current estimates in the alongship direction from the bridge’s Doppler speed log (used prior to testing but secured at the circuit breaker during BIST recording).

The plot at left shows RX Noise results (10 tests at each speed) versus speed for the EM302 during EX1902.

The vertical stripes occurring early in each of the 6- and 8-kt datasets are likely caused by swell impacting the hull, and not representative of machinery or flow noise perceived by the EM302.
The results show small changes in noise levels with speeds up to 8 kts, indicating acceptable flow noise over the recently cleaned and painted hull; however, the noise levels at 10.5 kts through water (165 RPM) show a clear departure from previous tests (see next).

The top-speed test was repeated twice (total of 20 BISTs) at 165 RPM in different sea states (3-5 ft for first test and 5-7 ft for second test, both with following seas) approximately 16 hours apart; these showed similar results, strongly indicating a change in shipboard noise levels at 165 RPM speed since EX1810.

Engineering logs show that generators #2, #3, and #4 were online during both tests; it is not clear whether this elevated noise level at 165 RPM is related to new trends in machinery noise or new conditions of the propellers and hull that may induce cavitation.

Several RX modules showing elevated levels across all tests appear as horizontal stripes; this behavior was observed in BIST data collected in previous years with the original RX array and its replacement, indicating no recent changes for those modules.

The following slide includes RX noise data from other pre- and post-dry dock tests (EX1705, EX1706, and EX1810) for comparison.
RX Noise BIST Assessment

**EX1705**
(pre-shipyard, heavy biofouling)

**EX1706**
(post-shipyard, after hull cleaning)

**EX1810**
(post-shipyard, new RX array)

**EX1902**
(post-shipyard, after hull cleaning)
The EM302 transmitter element impedance can be checked through the transceiver’s Built-In Self-Test (BIST) routines, providing a useful proxy for the condition of the TX array.

The BIST results include some additional electronics and differ from direct measurements of transmitter element impedance (e.g., performed by Kongsberg technicians using the Cypher impedance analyzer at the element terminals).

The first dockside pre-cruise TX Channels BIST (left) showed intermittent dropouts of most channels on Slot 22; this is suspected to result from loose Ethernet cables, as related to unpredictable TX board errors and possibly to anomalies reported in certain backscatter data (see following Backscatter Calibration section).

After the initial TX Channels BIST and Ethernet jack troubleshooting (i.e., reseating cables) dockside in Pascagoula, several more BISTs were run on 11-12 May 2019 to ensure no slot failures pre-cruise (see following slide).
TX Channels BIST Assessment

BIST Results: Pre-EX1902, Round 2
**TX Channels BIST Assessment**

**BIST Results: Comparison to 2016**

TX Channels BIST plots are useful for monitoring transducer health over its service life, particularly in tracking the development of open-circuit (high-Z) and short-circuit (low-Z) channels.

The post-EX1902 (dockside) TX Channels BIST is shown at far left for comparison to another BIST collected over three years earlier during EX1605L1 (center).

In general, the locations of high- and low-Z channels have not changed, and the total number of anomalous channels falls below the 10% threshold set by Kongsberg for proper TX array function.

Additional BISTs should be run in 2019 to track the low-Z channels (16-23) that appear for slots 2 and 5.
EM302 Backscatter Calibration

Data Collection

Backscatter calibration (read: normalization) data were collected in Shallow, Medium, Deep, and Very Deep modes for processing by Kongsberg.

Two lines were collected on opposite headings with parameters set by Kongsberg for each mode; Very Deep and Deep were collected at a suitably deep site, then Deep, Medium, and Shallow were collected at a suitably shallow site (Deep mode was collected at both sites to provide continuity between the two seafloor types in processing).

Loose TX board Ethernet cable jacks caused unpredictable dropouts of the backscatter data (very high/low values) early in EX1902, which appear as acrosstrack stripes in FMGT mosaics.

A script was written to remove ping records with anomalous mean backscatter values and write new .all files; mosaics of the same file before and after ping removal are shown at left; the new .all files are appended “_BS_trimmed.all” and available for Kongsberg processing.
SIS Updates

1. SIS was reinstalled to fix a grid engine failure and updated to version 4.3.2 by Tony Dahlheim (Kongsberg) during his visit (17-22 May)

2. This update addresses a range error across the swath for all $0.5^\circ \times 1^\circ$ and $1^\circ \times 1^\circ$ EM302 installations; the difference is 0.7 m in detection range at 1500 m/s, meaning ~0.7 m at nadir and ~0.35 m at $60^\circ$

3. QPS Qimera was used to compute surface differences of (pre-upgrade) EX1402 and (post-upgrade) EX1902 data collected at the same location in depths of ~200 m; the overlapping region contained >136,000 grid cells showing a mean difference of 2.60 m and median difference of 2.53 m, with a standard deviation of 1.38 m

4. The post-upgrade bathymetric surface is deeper than the pre-upgrade surface, suggesting a shoal bias in pre-upgrade data; additional review is required for the EX1402 and EX1902 SIS configurations and tide to ensure there are no waterline Z offset and/or water level discrepancies of this magnitude between datasets

5. The surface difference reported here is of approximately the same magnitude as mean biases seen during EX1810 (EM302 RX array SAT) accuracy testing over an EM302 reference surface collected by the R/V Sikuliaq; however, in those tests, the Okeanos Explorer (pre-SIS-upgrade) reported 3.2-3.5 m deeper than the R/V Sikuliaq reference; additional follow-up with Kongsberg is recommended to resolve these offsets

6. SIS and the TRU were configured by Tony Dahlheim to interact with the K-Sync, receiving triggers and sending the depth datagram for cases where K-Sync may estimate ping intervals for other systems

7. The Datagram Distribution executable was also set to start automatically with SIS

8. See the Kongsberg service report (Tony Dahlheim, 17-22 May 2019) for details
Appendix 1: Post-EX1902 EM302 Configuration
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Appendix 2: Post-EX1902 POS MV Configuration
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[Image of a computer interface for setting up COM ports with options for baud rate, parity, data bits, stop bits, and flow control.]
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![Input/Output Ports Set-up](image)
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![SBAS Settings]

- Marinestar Auto
- Marinestar VBS
- Marinestar HP
- Marinestar GPS - XP
- Marinestar GPS - HPXP
- Marinestar GNSS - G2
- Marinestar GNSS - HPG2
- Disable

- WAAS
- EGNOS
- MSAS
- Disable

Satellite ID
- Auto
- Custom
Appendix 2: Post-EX1902 POS MV Configuration
Appendix 2: Post-EX1902 POS MV Configuration

In Navigation Mode, to change parameters go to Standby Mode!
Appendix 2: Post-EX1902 POS MV Configuration

![Configuration Window](image)

<table>
<thead>
<tr>
<th>Lever Arms &amp; Mounting Angles</th>
<th>Sensor Mounting</th>
<th>Tags, AutoStart</th>
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</tr>
<tr>
<td>- POS Time</td>
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<tr>
<td>- GPS Time</td>
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<tr>
<td>- POS Time</td>
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<tr>
<td>- GPS Time</td>
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<td>- UTC Time</td>
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<tr>
<td>- User Time</td>
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</tbody>
</table>

**AutoStart**

- Disabled
- Enabled

*In Navigation Mode, to change parameters go to Standby Mode!*
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![Marinestar Status]

- **Fully Tracking Satellite**

- **Satellite Information**
  - Frequency (MHz): 1557.8450
  - Bit Rate (bits/second): 1200
  - SNR (dB-Hz): 48

- **Operation Status**
  - Library Active Flag: Active
  - Engine Mode used by Library: GNSS G2
  - Subscription Start Date (mm/dd/yyyy): 1/6/1980
  - Subscription Expiration Date: 4/16/2020
  - Subscribed Engine Mode: GNSS G2
  - Receiver Operation Mode: Kinematic
  - Marinestar Operation Mode: Kinematic
Appendix 2: Post-EX1902 POS MV Configuration