Multibeam Advisory Committee
Looking back on seven years of multibeam echosounder system acceptance and quality assurance testing for the ships of the U.S. Academic Fleet

Paul Johnson
Vicki Ferrini
Kevin Jerram
Giuseppe Masetti

Supported under NSF Grant No. 152485

Why?

https://www.gmrt.org/
Motivation for the MAC

The MAC is funded to improve multibeam data quality by:

- Standardizing the tools and approach for system assessment
- Documenting and reporting system performance metrics
- Provide on-board and remote support
- Sharing best practices among ships

https://mac.unols.org

The U.S. Academic Fleet

The MAC supports multibeam data quality improvement across NSF-supported vessels:

- 11 active RVs
- 1 USCG icebreaker

Total of 14 Kongsberg EM systems (15 after R/V Roger Revelle in 2019)
Additional Partners

Additional partners for developing tools and comparing data:

- **NOAA hydrographic and science vessels**
- **Non-UNOLS oceanographic institutes**
- **Private ocean exploration vessels**

MAC Approaches

The MAC is involved throughout the multibeam life cycle:

**Sea Acceptance Testing (SAT)**
establishing baseline performance of new installations (11)

**Quality Assurance Testing (QAT)**
assessing performance of existing installations, especially before/after shipyard periods (20)

**Acoustic Noise Testing (ANT)**
characterizing vessel noise and troubleshooting acoustic interference (MAC & Gates Acoustics) (9)
SAT and QAT procedures include:

1. Geometry review
2. Configuration review
3. Calibration (patch test)
4. Swath accuracy
5. Swath coverage (extinction)
6. RX noise testing
7. Impedance testing
8. Documentation and back-up

1. Geometry Review: MAC Approach

- The vessel survey is the foundation for correct sensor integration and high data quality

- MAC reviews survey report and advises operator on translation / interpretation for:
  1. mapping system origin
  2. motion sensor and antenna offsets
  3. transducer array offsets
  4. waterline
1. Geometry Review: Lessons from the Fleet

- Survey reports are referenced for decades by operators, shipyards, and other surveyors
- Wide range of vessel survey report quality
- The cost of a high-quality survey is trivial compared to the costs of:
  1. lost sea days
  2. incorrect calibration results
  3. poor data quality
  4. difficulty reestablishing the vessel frame


1. Geometry Review: Lessons from the Fleet

- Survey results are typically correct, but often reported in unclear or inconsistent formats
- May need to ‘sanity check’ the survey
- Operators must demand clarity in reporting:
  1. Origin of survey
  2. Axes, units, and sign conventions (KM)
  3. Images of all survey points
  4. Internal review before publishing
  5. Delivery with time for client review

Westlake survey of MGL
2. Configuration Review: MAC Approach

- Advise operator on unified mapping sensor reference frame; this is typically aligned with vessel frame, but not always coincident.
- Ensure multiple reviewers independently agree on offsets for each sensor in unified frame.
- Clarify with surveyor and/or manufacturer (e.g., antenna phase center height).
- Talk to the ship techs about what has changed!

2. Configuration Review: Lessons from the Fleet

- A physical marker for the origin (e.g., granite block or MRU target) is technically unnecessary but extremely valuable for discussions of reference frames and offsets.
- Incorrect settings sneak in and persist for years, even on carefully monitored installations.
- As operators and scientists come and go, clear documentation of the most recent correct configuration is critical.
3. Calibration: MAC Approach

- Provide calibration lines, runtime parameters, and time estimates
- On-board or **remote** support for data acquisition, analysis, and final configuration
- Residual pitch, roll, and heading are attributed to the motion sensor and applied in SIS

| Line Acquisition Information | Test | Pre-test settings | Transit to Cal | Pitch Verification Pass 1 | Turn | Pitch Verification Pass 2 | Transit to C | Roll Verification Pass 1 | Turn | Roll Verification Pass 2 | Transit to H | Roll Verification Pass 3 | Transit to T | Yaw Verification Pass 1 | Transit to A | Yaw Verification Pass 2 | Transit to A | Transit to A | Est. Time for Cal. Hours | Est. Cost | Est. Cost |
|------------------------------|------|-------------------|----------------|--------------------------|------|--------------------------|-------------|--------------------------|------|--------------------------|-------------|--------------------------|-------------|--------------------------|--------------|--------------------------|--------------|--------------------------|-------------|--------------------------|
| Off Pitch to Line | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No | No |
| Roll Point (see figure) | 10 | 5 | 3 | 10 | 5 | 3 | 10 | 5 | 3 | 10 | 5 | 3 | 10 | 5 | 3 | 10 | 5 | 3 | 10 | 5 | 3 | 10 | 5 | 3 |
| Roll Point (see figure) | 200 | 4.3 | 5.3 | 200 | 4.3 | 5.3 | 200 | 4.3 | 5.3 | 200 | 4.3 | 5.3 | 200 | 4.3 | 5.3 | 200 | 4.3 | 5.3 | 200 | 4.3 | 5.3 | 200 | 4.3 | 5.3 |
| New roll results | 1028 | 43 | 10 | 43 | 10 | 43 | 10 | 43 | 10 | 43 | 10 | 43 | 10 | 43 | 10 | 43 | 10 | 43 | 10 | 43 | 10 | 43 | 10 |
| Pre-assumed angles (roll, yaw, pitch) | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.16 | 0.17 | 0.18 | 0.19 | 0.20 | 0.21 | 0.22 | 0.23 | 0.24 | 0.25 | 0.26 | 0.27 |

3. Calibration: Lessons from the Fleet

- Planning windows for calibrations vary widely (usually months, sometimes just minutes)
- Overcoming ‘it is just for science’
- Calibrations can be planned and executed opportunistically
- Have more than one person evaluate the data.
3. Calibration: Lessons from the Fleet

- Calibration process can reveal greater issues...

4. Swath Accuracy: MAC Approach

- Ensure all other acoustic systems are secured
- Collect a high-density reference surface over flat terrain in depths suitable for frequency
- Mask grid cells with low sounding density, high standard deviation, and/or high slopes
- Collect crosslines in ‘typical’ survey mode for that site
4. Swath Accuracy: MAC Approach

- Calculate differences between soundings and corresponding reference surface cells
- Group differences by beam angle, plot mean and std. dev. of differences across swath
- Repeat reference surface and crosslines in shallower and deeper sites as time allows

4. Swath Accuracy: Lessons from the Fleet

- Useful for detecting changes in performance
- Sea state can overwhelm performance issues
- Problems with refraction and tidal correction can make interpretation challenging as well.
- Documenting and reusing reference sites can save significant time, provide more direct comparison among similar systems
5. Swath Coverage: MAC Approach

- Collect data over wide range of depths in fully automatic mode with maximum swath limits
- Ensure all other acoustic systems are secure
- Hopefully gentle slopes and lines perpendicular to the slopes
- Extract outermost valid soundings and remove those with extremely high / low reflectivity
- Plot soundings vs. depth

5. Swath Coverage: Lessons from the Fleet

- Coverage testing data can be easily and routinely collected on transits or after a survey
- Calculated following each SAT, QAT, or cruise using either scripts or commercial programs
- Changes from baseline data are easily seen
- Very useful for ship to ship, system to system comparison
- Up-to-date swath coverage plots are extremely useful for survey planning
6. RX Noise Testing: MAC Approach

- Collect RX Noise and RX Spectrum BISTs to examine perceived platform noise under various circumstances:
  1. Noise vs. speed / RPM
  2. Noise vs. machinery / engine lineup
  3. Noise vs. heading (rel. prevailing seas)
- Ensure all other echosounders are secure
- Run 10-20 BISTs at each speed / setting / heading, then remove outliers and average

6. RX Noise Testing: Lessons from the Fleet

- RX noise data is critical for identifying problems and monitoring changes over time (e.g., improvement after array cleaning)
- Use with swath coverage plots to identify:
  1. noise sources in hardware vs. vessel
  2. optimal speeds, machinery lineups
  3. impacts of sea state and biofouling
6. RX Noise Testing: Lessons from the Fleet

Having baseline data is critical!

7. Impedance Testing: MAC Approach

• Collect TX Channels and RX Channels BISTs to monitor:
  1. TX transducer acoustic impedance
  2. RX receiver electrical impedance
  3. RX transducer electrical impedance

• Not a replacement for direct measurements at each element (e.g., KM Cypher tool), but a proxy for hardware health over service life
7. Impedance Testing: Lessons from the Fleet

- In combination with RX noise data, RX & TX impedance critical for troubleshooting symptoms, isolating array degradation
- Annual (or more frequent) evaluation helps owners plan array replacement

8. Documentation: MAC Approach

- SAT, QAT, & ANT reports available at http://mac.unols.org
- Full documentation of system geometry and layout
- Screenshots of all post-calibration Installation Parameters, communication settings, and positioning / attitude system configurations
- Backups of PU Parameters and BISTs

http://mac.unols.org
8. Documentation: Lessons from the Fleet

- Fleet-wide reports help operators share best practices and improve data quality over time
- Efficiencies for all in reusing calibration sites and reference surfaces for similar systems, map services coming
- Reports build on each other; previous settings and performance have been critical at times (e.g., NBP EM122 replacement)
- Contributions from non-MAC sources.

9. Tools: SmartMap

- Developed and funded by MAC & NOAA
- Present up-to-date sound speed variability from RTOFS and likely effects on multibeam data quality
- Helps operators plan surveys around sound speed forecast and manage profiling regimen
- Useful for planning transit mapping and understanding / correcting transit data

https://www.hydroffice.org/smartmap
9. Tools: Sound Speed Manager

- Developed and funded by MAC & NOAA
- Simplifies processing and application of sound speed data for wide range of systems
- Warns users when profiles are needed, based on real-time variability and global databases
- Apply RTOFS/WOA data automatically when operators are not available for monitoring
- Archives all profiles in database

https://www.hydroffice.org

Main Takeaways

- Vessel surveys must be correct and clearly reported using KM conventions
- Vessel noise should be tracked with BISTs for baseline and after shipyard periods
- Swath coverage reductions may be first indicators of complications
- Impedance should be tracked with BISTs as a proxy for hardware health
- Routine/opportunistic testing catches problems early
- Documentation is critical as systems and crews change over time