Multibeam Advisory Committee
Mapping System SAT/QAT Checklist

V1.1 (May 09 2022)

Purpose

This document provides an overview of typical Sea Acceptance Testing (SAT) and Quality Assurance Testing (QAT) procedures performed by the Multibeam Advisory Committee. SAT and QAT procedures are critical for establishing baseline performance; comparing performance across similar systems; identifying and resolving problems; and delivering high quality data for clients and downstream users throughout the multibeam echosounder service life.

The outlines and time estimates provided below are for general planning purposes only. The specific time commitments for each SAT and QAT depend on the sensor installations; available documentation and quality of survey reporting; test locations and sea state; shipyard schedules; and other unforeseen factors.

Detailed SAT and QAT reports for the UNOLS fleet are available on the MAC website at http://mac.unols.org/. Reports for similar testing aboard other vessels (not funded by NSF) are also available for reference.

Pre-SAT/QAT Planning

1. **Vessel survey planning**
    a. MAC guidelines for planning and reporting the vessel / sensor offset survey

2. **Initial system geometry review**
    a. MAC and vessel personnel review the survey and discuss/develop a clear, unanimous interpretation of results for sensor offsets to apply in echosounder and position/attitude system configurations, maintaining a consistent origin and translating each offset into the appropriate sensor reference frame and sign convention
    b. This is a fundamental step for calibration (and, thus, data quality) with ample opportunity for error; this process is vastly improved by a high-quality survey that is reported according to MAC guidelines noted above
    c. The initial review of the survey report must be completed with ample window to resolve ambiguities with the surveyor and/or sensor manufacturers

3. **Develop test plan**
    a. MAC and vessel personnel identify suitable test sites within reasonable distance from the desired ports of call / transit plan
    b. MAC develops more detailed line plans and time estimates, with clear priority of operations
    c. MAC and vessel personnel agree on staffing, workflow, line plans, and time estimates for SAT/QAT operations (details below) that are reasonably expected to fit within schedule

Pre-QAT Review

These topics help to ensure an up-to-date understanding of the mapping system and adequate/complete plan for testing, taking into consideration any changes since the SAT or last QAT.

1. What has changed since last MAC visit or review?
    a. Any sensors replaced, removed, and/or reinstalled?
    b. Any damage or repairs?
    c. Any upgrades to hardware or software?

2. Is there any new documentation?
    a. Updated survey of vessel and/or sensors?
    b. Updated guidance or service notes from manufacturers?
    c. Any performance notes from normal operations or other testing?

3. Is there any recent data that can be provided for review?
    a. Ideally, these data would be collected under ‘normal’ operations with routine sound speed profiling; data covering a wide range of depths may be helpful for comparing swath width versus depth as an early indicator of performance limitations
    b. Any recent ‘problem’ datasets should be assessed, with follow-up testing incorporated into QAT as appropriate

SAT/QAT Procedures

1. **System geometry review**
   Full dimensional control review by multiple personnel to confirm pre-SAT/QAT configurations.
    a. Vessel survey review and sensor configuration (SAT or after new survey)

    b. Configuration review (QAT or after any change); note any changes (and sources/reasons for each change) in the following:

        i. Multibeam echosounder system installation parameters
            1. Multibeam echosounder system origin
            2. TX/RX array lever arms
            3. TX/RX array installation angles
            4. Position/attitude source lever arms
            5. Position/attitude source installation angles

        ii. Position/attitude system installation parameters
            1. Position/attitude system origin
            2. GNSS antenna lever arms
            3. Motion sensor lever arms
            4. Motion sensor installation angles
            5. Point at which position/attitude output is considered valid

2. **Dockside testing and review**

a. Prior to departure, at least one day should be planned for:
    i. on-board configuration review
    ii. line plan review with operators / bridge (e.g., waypoints and time estimates)
    iii. pre-cruise system testing (e.g., BISTs for hardware health)

3. **Antenna calibration**
GNSS antenna baseline calibration according to the manufacturer's procedure.
    a. Applanix POS/MV
        i. GAMS calibration is performed *at sea* and time commitments vary widely; one hour should be budgeted per iteration, with repeated tests to confirm that the calculated antenna baseline closely matches the surveyed baseline (configured)
    b. Seapath
        i. Antenna calibration is performed *dockside* using the built-in calibration wizard, requiring at least two hours per iteration; this should be repeated as time allows to verify the antenna baseline, applying the surveyed position for the primary antenna and the average baseline result in the configuration
    c. Other systems
        i. Refer to manufacturer recommendations

4. **Geometric calibration**
Ship and MAC personnel confirm suitable sites, waypoints, and time estimates for patch testing.
    a. Typical time windows for the most common frequencies; these estimates are time on-site for *one run* through the calibration line plan, with ample margin for weather and troubleshooting:
        i. 12 kHz: 24 hours
        ii. 30 kHz: ~12-24 hours
        iii. 40/70-110 kHz: ~6-12 hours
        iv. 200-400 kHz: ~2-3 hours
    b. The calibration line plan for each system depends on available seafloor features in the desired operational area; in some cases, seafloor features may be suitable for two systems of different frequencies that may be calibrated simultaneously
    c. Time estimates above are for a single calibration, which is typically sufficient for a QAT with no sensor relocations/reinstallations since the last calibration
    d. SATs and QATs after any motion sensor removal/adjustment start with installation angles set to zero; these cases require initial calibration *plus a second run-through for verification (i.e., double the time estimates above)*

5. **Accuracy testing**
Survey high-quality, high-density reference surfaces and run crosslines under typical mapping configurations to assess swath accuracy in different modes. Data collection and processing generally follow the MAC process for swath accuracy assessment.
    a. Time estimates depend on number of modes, availability of suitable seafloor, availability of pre-surveyed reference surfaces, weather, sound speed profiling methods (e.g., XBT/CTD)
    b. Time on-site can range from ~24 hours for a deepwater reference surface survey and crosslines (e.g., a 12-kHz system in the abyssal plain) to <1 hour for very shallow crosslines over an existing reference surface (e.g., a 400 kHz system on the shallow continental shelf)
    c. Ideally, accuracy testing covers all modes that would be used under normal mapping operations (e.g., Very Shallow, Shallow, Medium, Deep, Very Deep for Kongsberg systems)
    d. Some reference sites may be suitable for testing multiple depth modes

e. Two crosslines are run on opposite headings for each mode; if a site is suitable for multiple systems, crosslines are run for only one system and one mode at a time to avoid interference
f. The total number of modes tested is often limited by time and availability of suitable depths for reference sites within the vessel's desired operational area; under these circumstances, the test plan should prioritize the modes expected to be used most frequently during normal operations (e.g., Shallow, Medium, and Deep modes with automatic swath and pulse parameters)

6. **Swath coverage testing**
Swath coverage data are collected in fully automatic modes with open swath angles during all transits; additional time should be planned to survey up and down the continental slope with a course perpendicular to contours for establishing baseline swath coverage performance and identifying potential complications (e.g., noise or hardware issues). Data collection and processing generally follow the MAC instructions for swath coverage testing.

7. **RX noise testing**
For Kongsberg systems, RX Noise and RX Spectrum Build-In Self-Test (BIST) testing assesses the vessel, machinery, and flow noise characteristics as perceived by each multibeam echosounder; data acquisition generally follows the MAC approach for routine noise testing.

a. **Noise vs. speed** testing is performed over a wide range of speeds in calm seas; with typical engine configurations online, the vessel starts drifting and increases speed in 1-2 kt increments up to maximum speed (~1-2 hours, depending on number of speed steps and time to settle at each speed)
b. **Noise vs. heading** testing is performed at eight headings (separated by 45°) relative to the prevailing swell; these tests are conducted at typical speed and engine configuration for normal mapping operations (~2 hours, depending on sea state and time to settle at each heading)
c. These tests are passive and can be run for multiple systems at each speed or heading

8. **Vessel and machinery noise testing**
More detailed noise testing is recommended for new vessels and when troubleshooting noise complications for existing installations; these services (and time estimates) are typically provided by a subcontractor for the MAC or for the vessel, depending on the scope of work.

9. **Backscatter normalization**
Data collection during accuracy crosslines and calibration may also be useful for normalizing inter-sector and inter-mode backscatter imbalances (i.e., generating a new BSCorr file for SIS; see Kongsberg BSCorr 'calibration' procedure).

10. **Target detection**
Typically not performed for MAC SAT/QAT procedures; defer to other partners / procedures.

11. **Interference / synchronization testing**
After assessment of the multibeam echosounders, it is useful to identify echosounder configurations and synchronization schemes that minimize interference while maximizing data resolution for given science objectives. For example, a set of tradeoffs were identified for a variety of echosounders aboard the NOAA Ship Okeanos Explorer and formalized in a number of standard configurations to prioritize specific data (with input from R/V Sikuliaq): Sonar synchronization tradeoffs (RVTEC 2019)