# A system-of-systems for at-sea evaluation of modern sonars

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**ABSTRACT**

Submarine sonar systems are advancing in capability due to the developments in sensor technology and the application of modern algorithms. Measuring performance of a modern sonar system at sea is a complex problem that requires a multi-disciplined approach to ensure the aims of a trial are achieved. The underwater acoustic environment is complex and it is rare to experience conditions that support every aim of any trial. Decisions made through system development will impact the ability for a system to achieve successful sell-off via sea trial; the possibility for calibration and an ongoing measurement-based maintenance program.

This system-of-systems plays a pivotal role supporting the evaluation and transition-to-use of on-board systems, primarily through the conduct of at-sea trial activities. This support encompasses all phases of test including pre-trial planning, trial data collection and monitoring and post-trial data analysis. The monitoring of trials conduct and data collection must make efficient use of trials staff and post-analysis must support required turn-around times to allow for trials windows to be used effectively.

This paper considers the requirements on the systems supporting successful evaluation of sonar performance, particularly in a sea trials environment. The support systems described include physical items such as transducers, software systems used during a trial and systems engineering techniques that ensure stated requirements can be demonstrated in a wide variety of at-sea conditions. These same systems are also key enablers for continuous improvement via access to real-world recordings, and the introduction of machine learning algorithms.

**BACKGROUND**

Test and evaluation of a military sonar system in its operating environment is a difficult proposition to undertake. In order to meet the theoretical capabilities of a modern sonar, the ocean would need to be free from interfering noise sources and support propagation of sound out to ranges that are unlikely to be supported on any day; let alone the day chosen to run a sea trial. This presents sonar developers and their customers with the challenge of determining whether a sonar is able to demonstrate its required performance during a trial event. To answer this question the trial must capture far more than the performance of the sonar; it must also capture enough information about the environmental conditions on the day to allow experts to estimate theoretical performance in that environment to support comparison with the performance observed during the trial.

The qualification of a sonar systems begins long before the trial event. The initial systems engineering that sets the requirements against which the sonar will be compared must be cognisant of how theoretical performance translates into real-world performance and ensure that requirements have the flexibility to allow verification of the sonar in a variety of environments. Translation from theory to practice is highly dependent on the hardware and algorithms being verified. Capable sonar houses should have rules in place to do this translation based on previous delivery of similar product; or based on measurements taken from prototypes of the system under test.

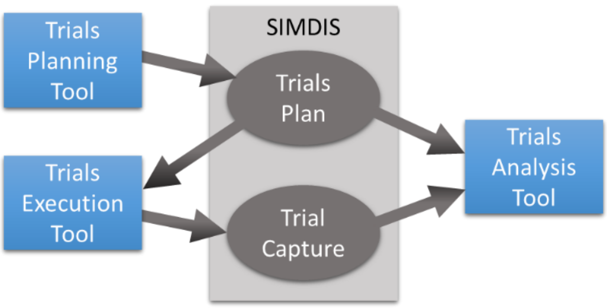
Once development of a system that has appropriate real-world requirements is complete and that system is placed into an environment for qualification, the trials team can expect to spend significant effort measuring the environment in addition to evaluating the system under test. Significant pre-work is possible to ensure bathymetry maps of the area are up-to-date, weather predictions and history are available and the required people and equipment are prepared for the trials period. At a minimum, the trial must record the sound speed profile for the trials area so that this be later used to predict the propagation of sound during the trial. Additions to this information will be system-dependent but are likely to include:

- Alternate/additional measurements of acoustic emissions,
- Positioning information for all entities in the area; and
- Details of known interferences in the area.

**TRIALS TOOLING**

The tools required to execute a successful trial fall into three categories. Planning tools used prior to the trial, execution tools used during the trial and analysis tools used following the trial. An integrated trials suite enables these tools to interact with each other and simplifies reporting at various stages of the trial. It ensures trials operators are able to monitor their progress against the trial plan and allows trial analysts to compare the executed trial against the planned trial. Tooling to monitor the trial progress as the trial is still underway is crucial in order to detect and workaround issues as they occur. Live monitoring enables operators to correct for problems that might otherwise invalidate the results of the trial.

*Figure 1: Integrated Sonar Trials Toolset*




Sonartech is currently working towards a fully integrated sonar trial suite supporting customers through the planning, execution and analysis of a sonar trial event. The key to this integration is that each tool in the suite uses open formats to represent trials data. This enables sharing within the suite, and also allows the use of 3rd party tools on the same data. The enabling standards for this integration are the SIMDIS toolset available from the U.S. Navy Research Laboratory (NRL) and the Mission Data File (MDF) format available from Sonartech. The use of open, industry standards for scenario definition and data capture allows our sea trial tools to integrate with planning, visualisation and analysis tools available from 3rd parties, including the SIMDIS 3D display tool available from NRL. Example use cases of this integration could be:

- 3D planning and fly-through of the sea trial scenario.
- Execution of 'What-If' modifications to each scenario.
- Live comparison between the planned scenario and trial during execution.
- Automated control of trial equipment based on the planned scenario.
- Comparison between the recorded trial and planned trial.

The complexity of a sonar trial environment can cause results from multiple runs within the same trial to be significantly different from each other. To cater for this complexity, the system should be able to manage the results from multiple trial runs and multiple sensors within the trial and present a progressive view of the trial as each result is received. An intelligent system can also monitor the differences between measurements and recommend when enough data has been captured to achieve the goals of a trial; based on the remaining variances in the data.

Using open formats in this context allows each of the planning, execution and analysis tools to potentially be developed by different organisations. It also allows a single system to capture the truth data for a sea trial and share that data with each organisation that will analyse the trials data. The use of open formats will promote interaction between OEMs and allow each OEM to focus on developing the tooling that is required to test their own system rather that developing the entire suite required to plan, execute and analyse the trial.

**SONAR PRODUCT DESIGN FOR TRIAL**

Noting that sonar systems generally require interactions with one or more operators, it is important to understand the information presented to the operator during each event within a trial. To enable this, the sonar system should be able to record not only the data received, but also any operator interactions with the system during the trial. This information can then be used to recreate the trial experience from the operator's perspective and understand moments when an operator's response was not as expected.

Modern sonar systems will undergo calibration trials in addition to measurement/acceptance trials. Where a sonar has the ability to be adapted to its installed operating environment, the method by which it can receive calibration data should be considered during the initial specification. Ideally, the sonar system will be able to interact directly with the logs recorded during the trial, but at a minimum the system should be able to accept calibration data without the need for special equipment or significant operational downtime.

The next step for sonar trial and calibration is the addition of measurement and calibration features to the primary product. Such a system takes the integration presented above and merges it into the deployed system, enabling the operational crew to perform opportunistic trials when conditions are most suitable. This will allow the trial and calibration of the sonar system to be refined as the system is exposed to new environments and contact types; and to account for any drift in calibration as the system ages. Once deployed, it also reduces the need to execute specific trial events as much of the trial requirements can be met while the system is operational.

## MACHINE LEARNING IN A SONAR TRIALS ENVIRONMENT

Modern sonars output an enormous amount of data that must be captured, in addition to capturing data from supporting sensors available in the trials environment. This presents a data management issue as the data must be captured, stored, catalogued and made available to downstream systems. Sonartech is very active in this field and offers a suite of recorders and data analysis systems which work with the open MDF format and have been adopted by the local and international customers.

This is an area where modern Machine Learning algorithms can help refine the performance of the sonar system. Libraries of sea trial data already exist in MDF and other formats that can be mined to compare the performance observed during a trial to an established ground truth of that event. This data forms training sets that can be used to train Machine Learning algorithms on the issues a sonar may experience while under trial so that those algorithms can search for patterns within the data. The aim of such an undertaking is for the algorithm to provide recommendations on best practices for the trial; and to add an interpretation of the results that considers influences which human analysts may not consider.

An adaptive sonar that is able to monitor the results generated from all sensors fitted to a platform in realtime would be able to systematically learn the biases inherent in each sensor, environment and signal type. Such a system could gradually adapt the processing results to be more correct, based on the biases it learns. The first generation of such an adaptive system may work with the tracker data provided by each sensor; however future generations are likely to interact directly with the sensor data to detect an localise contacts earlier than possible with the current, static systems.

## CONCLUSION

This paper has discussed the difficulties of measuring performance of a sonar during a sea trials event, proposed a technical solution to enable integration across the sonar trials industry and discussed a future direction of opportunistically calibrated sonar systems. The concepts discussed in this paper are currently deployed, in development, or achievable using existing technology.