2021

Modeling SIGINT

Miller, Scot A.; Romero, Ric

Monterey, California: Naval Postgraduate School

http://hdl.handle.net/10945/69853

NPS NRP Executive Summary

Modeling the Operational Value of SIGINT on Anti-Submarine Warfare

Period of Performance: 10/18/2020 – 10/23/2021

Report Date: 10/22/2021 | Project Number: NPS-21-N114-A

Naval Postgraduate School, Graduate School of Operational and Information Sciences (GSOIS)

NAVAL RESEARCH PROGRAM

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MODELING THE OPERATIONAL VLAUE OF SIGINT ON ANTI-SUBMARINE WARFARE

EXECUTIVE SUMMARY

Principal Investigator (PI): CAPT Scot Miller, USN (ret), Graduate School of Operational and Information Sciences (GSOIS), Information Sciences Department

Additional Researcher(s): Dr. Ric Romero (Co-PI), Graduate School of Engineering and Applied Sciences (GSEAS), Electrical and Computer Engineering Department; Dr. Luqi, Graduate School of Operational and Information Sciences (GSOIS), Computer Science Department; Dr. Curtis Blais, Graduate School of Operational and Information Sciences (GSOIS), Modeling, Virtual Environments, and Simulation (MOVES) Institute, Computer Science Department

Student Participation: LT Christina Reeder, USN, Electrical and Computer Engineering Department

Prepared for:

Topic Sponsor Lead Organization: N9 - Warfare Systems

Topic Sponsor Organization(s): Office of the CNO Director of Air Warfare (OPNAV N98)

Topic Sponsor Name(s): Mr. Richard Holcomb, Resource Officer

Topic Sponsor Contact Information: Richard.H.Holcomb.ctr@navy.mil, 703-695-1256

This research is supported by funding from the
Naval Postgraduate School, Naval Research Program (PE 0605853N/2098).

Project Summary
The Navy is considering installing signals intelligence (SIGINT) equipment onto manned and unmanned maritime patrol aircraft to add another source of detection capabilities for anti-submarine warfare (ASW). However, the influence of SIGINT on mission effectiveness is unclear since existing simulations do not explicitly quantify SIGINT sensor impact. To address this deficiency, this study investigated a modeling approach for quantifying the operational effectiveness of SIGINT. The project team investigated existing SIGINT modeling methods, focusing on two simulation tools in use by the sponsor organization: the Naval Simulation System (NSS) and the Advanced Framework for Simulation, Integration, and Modeling (AFSIM). The project team formulated a mathematical model of probability of signal detection using parameters describing transmitter and receiver performance characteristics together with antenna patterns and characteristics of the dynamic scenario environment. The team used the MATLAB mathematical modeling tool to compute look-up tables for the probability of detection for integration into the simulation tools. The team proposed an operational scenario for implementation in a simulation to evaluate the contribution of SIGINT information to warfighting effectiveness.

The physics-based transmitter-receiver model enabled representation of a range of systems through performance parameters. Modelers in the sponsor organization can represent specific systems through substitution of performance values for those systems into the equation.

The project team recommends that Naval Air Systems Command (NAVAIR) modelers use the MATLAB implementation of the transmitter-receiver equations to generate a probability of detection look-up table for integration in AFSIM. Recommendations for future study include: (1) examining how a platform using SIGINT can collaborate with a similarly enabled SIGINT-capable platform; (2) examining how that platform can collaborate with other SIGINT sensors (e.g., ground-based or space-based); and (3) further investigating fusion modeling capabilities in AFSIM to enhance its application to these studies.

Keywords: *signals intelligence; SIGINT; electronic intelligence; ELINT; communications intelligence; COMINT; modeling and simulation; Navy Analytic Agenda; fusion; Naval Simulation System; NSS; Advanced Framework for Simulation, Integration, and Modeling; AFSIM; MATLAB*

Background
The Naval Air Systems Command (NAVAIR) Mission Engineering and Analysis Department (MEAD) conducts an annual cycle of engineering and mission-level modeling to support investment decisions for the Office of the Chief of Naval Operations Director of Air Warfare (OPNAV N98). The Navy is considering installing signals intelligence (SIGINT) equipment onto the P-8A Poseidon maritime patrol aircraft and MQ-4C Triton unmanned surveillance aircraft to generate an additional source of detection capabilities in support of anti-submarine warfare (ASW). However, SIGINT influences on mission effectiveness are unclear since existing simulations do not explicitly quantify SIGINT sensor impact. This study investigated a modeling, simulation, and analysis approach for quantifying the operational effectiveness of such systems.

The study team focused on two principal considerations. The first was to formulate the complex transmitter-receiver equations associated with SIGINT sensor performance. Modeling SIGINT sensing involves well-established but complex physics-based mathematics. Real-world input factors are highly classified and hard to obtain. The researchers decided to take a general approach by parameterizing the transmitter-to-receiver equations across many relevant factors, leaving the actual determination of specific factor values to the NAVAIR modelers. The Office of Naval Intelligence (ONI) has the specific threat emitter factors, and the SIGINT sensor program office possesses the factor specifications related to the sensing receivers. On the transmit side, this includes such factors as power, gain, frequency, wavelength, waveform, range, and duration. On the sensor side, factors include sensitivity, filtering, frequency, dynamic range, directionality, and number of receivers. Antenna gain on both sides depends on antenna patterns and the transmitter-receiver geometry, which is generally highly dynamic and scenario/operations-dependent.

The second principal consideration was conversion of the SIGINT sensor performance into mission-level tactics, followed by determining which of the sponsor's available simulation tools, AFSIM or NSS, was suitable for this investigation. NSS possesses data processing architecture options that allow information from multiple sensors to be "fused" in a platform. AFSIM possesses a modern simulation software architecture, providing users greater flexibility in model development. Moreover, its sizable and growing user community offers opportunity for model sharing, reuse, and adaptation. Because of its flexibility and long-term improvement potential, the study team chose AFSIM as the preferred simulation for this study.

The study team, including NPS student involvement, implemented the transmitter-receiver equations in the MATLAB mathematical modeling tool for computing output values across the range of input parameters. The researchers found that computed results can be integrated with AFSIM through look-up tables, the computations can be called through software linkage to MATLAB, or the computations can be implemented directly in AFSIM scripts.

The study team also outlined an operational scenario to represent a tactical situation within which the effects of availability of SIGINT data can be evaluated. However, the sponsor's modeling team already had an operational scenario they were using, so they were most interested in the transmitter-receiver signal equations.

Findings and Conclusions

The study team determined that SIGINT modeling requires attention to detail but is executable using a combination of MATLAB for executing the complex transmitter-receiver equations and AFSIM for representing and executing the mission-level scenario dynamics. The team was able to use MATLAB to generate a table of results across a large number of relevant input parameters. This makes the resultant MATLAB code and the table unclassified, since the equations and results do not involve information about specific real-world sensors or transmitters. MATLAB can be linked to the AFSIM software or the equation can be implemented in AFSIM scripts so that AFSIM can execute the equations each time a

SIGINT sensor could possibly detect a signal. If there were thousands of computations per run—for instance in a mission assessment where the targets of interest included surface ships as well—then pre-computing the data and using look-up tables may be more efficient. For real-world considerations, modelers need to consult experts to obtain specific values for input parameters related to target-of-interest transmissions and own-force sensor performance.

Investigation of the sponsor's prominent simulation tools, NSS and AFSIM, showed that the transmitter-receiver computations can be implemented through look-up tables or through direct integration of the mathematical formulation. The most direct way to integrate the computations in NSS is through look-up tables; however, the NSS developer would need to be contracted to do the work. Compared to NSS, AFSIM provides a more flexible software architecture for embedding this computation while also supporting a growing community of modelers in the Navy.

In conclusion, researchers determined that SIGINT modeling is achievable using a combination of MATLAB for executing complex transmitter-receiver equations and AFSIM for modeling the mission dynamics. The sponsor's modelers found great value in the ability to compute probability of detection using the mathematical formulation.

For applying the study results, the study team recommends that the NAVAIR modelers use the MATLAB code to generate a multi-dimensional look-up table so that when their mission model calls for a possible SIGINT detection, the collected factors can be used to determine the probability of detection. From there, the rest of the modeling is a matter of executing preset tactics tables, something these modelers are already proficient in doing.

The study team also recommends that the modelers use AFSIM for their mission modeling, for several reasons. First, in AFSIM it is easy to create a call to a look-up table. Second, if it became necessary, AFSIM can link to the MATLAB software to initiate execution of the computations or the computations can be implemented directly in AFSIM scripts. These AFSIM model adjustments do not require contractor work nor any special license accesses. Furthermore, AFSIM has a robust user group where help is readily available from other developers/users.

Recommendations for Further Research

One of the factors in the transmitter-receiver signal detection equations deals with how the receiver captures the signal. Researchers calculated three options: (1) a very conservative assumption, called the *non-coherent conservative* assumption; (2) a second less conservative assumption called the *non-coherent envelope*; and (3) a third, more optimistic assumption, called the *coherent signal*. Given the same distance between the transmitter and the receiver, look-up tables showed a significant difference in probability of detection based on which of these factors is selected. The study team recommends discussing this critical factor with the Office of Naval Intelligence (ONI, for information on threat systems) and the signals intelligence (SIGINT) sensor program office to ensure the correct selection is made for calculating the probability of detection.

While the Advanced Framework for Simulation, Integration, and Modeling (AFSIM) is the recommended mission modeling approach, there are cases where the Naval Simulation System (NSS) might be appropriate. If understanding SIGINT signal fusion across similar and dissimilar platforms and sensors is important in future modeling, then NSS may be a more appropriate tool, since NSS has specific modeling capabilities for fusion techniques. Alternatively, AFSIM could be used, but fusion algorithms may need to be added to the AFSIM mission model, which would require fusion algorithm expertise. The literature review indicates that Naval Air Systems Command (NAVAIR) possesses such expertise. Moreover, the user base for AFSIM is rapidly growing, creating a large community of developers who may already be pursuing these kinds of improvements in AFSIM modeling capabilities.

Additional recommendations for future study include: (1) examining how a platform using SIGINT can collaborate with a similarly enabled SIGINT-capable platform; (2) examining how that platform can collaborate with other SIGINT sensors (e.g., ground-based or space-based); and (3) further investigating fusion modeling capabilities in AFSIM to enhance its application to these studies.

Acronyms

AFSIM	Advanced Framework for Simulation, Integration, and Modeling
ASW	anti-submarine warfare
COMINT	communications intelligence
DOD	Department of Defense
ELINT	electronic intelligence
MEAD, AIR 4.0M	Mission Engineering and Analysis Department
NAVAIR	Naval Air Systems Command
NSS	Naval Simulation System
ONI	Office of Naval Intelligence
OPNAV N98	Office of the Chief of Naval Operations Director of Air Warfare
SIGINT	signals intelligence