# Final Report

for ONR Contract
N00014-94-C-0017 (JAC 2042)

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Jason Associates Corporation
1501 Wilson Blvd., Suite 1200
Arlington, VA 22209-9998

12625 High Bluff Drive, Suite 205A
San Diego, CA 92130-2053

## Final Report - Program Objective and Scope

Jason Associates has completed the work defined in the ONR Contract N00014-94-C-0017 (JAC 2042) Statement Of Work under the tasks of (1) Analysis, (2) Modeling, and (3) Simulation. This Final Report satisfies task (4) Documentation.

Under this SOW, Jason has worked closely with the Office of Naval Research (ONR), the Center for Naval Analyses (CNA), members of the Navy requirements community and research laboratories, and staff officers and civilians within various PEOs, Systems Commands, and Warfare Centers to evaluate modeling and simulation technologies for use in support of analyses for systems operations, cost effectiveness tradeoffs, and technology evaluations.

The primary role of JAC personnel has been in direct support of the project director and technical staff at CNA. We have assisted in the analyses, modeling, and simulation efforts designed by the project director in the Mine Countermeasure (MCM) and Littoral warfare areas.

Littoral warfare and MCM were selected as an initial task by the Technology Directorate of ONR to focus the simulation and modeling efforts in evaluating various mine hunting sonar technologies and discovering operational employment strategies and limitations involved with the use of those technologies.

This final report details the tasks performed in support of these efforts at CNA, but does not discuss the analytical results. Those results are generated by CNA personnel and may be classified.



## Task 1 - Analysis

Jason personnel participated with CNA analysts in a study and industry survey of various simulation and battle management software products to fulfill the needs of the project. The study focused on the direction and the requirements of the MCM technology trade off and how the analytical goals could be supported through the use of comprehensive simulation.

The goals of the MCM technology trade off study were to compare the tactical employment and the technological limitations of three distinctly different mine hunting sonars: the high-frequency SQQ-32 sonar, the LANTIRN-based blue-green laser sonar, and the superconducting gradiometer. The analysts at CNA worked to develop an assortment of scenarios to compare the employment of these sonars in a littoral environment. In

conjunction with CNA, Jason developed the computer software simulation requirements that would support those scenarios and allow a variety of ways to model the new sensors.

The requirements for the simulation were:

- an ability to manage joint forces in a littoral environment
- provide a mechanism for modeling sensors and weapons in an aggregate manner for general results
- provide a mechanism for modeling sensors and weapons in a specific, physics-based manner for highly accurate results (i.e. integrate existing Navy models)
- provide changeable performance characteristics of the platforms, weapons, and sensors
- supply results of the simulation in a format that can be tailored to meet the needs of the analysts

During a survey of both commercial and government sources for this kind of simulation software product, only three viable options were identified: Trident Systems' CAAM, Naval Surface Warfare Center MARS, and Virtual Prototypes' STAGE product.

The Combined Area Analysis Model (CAAM), built under a Naval Undersea Warfare Center (NUWC, New London, Connecticut) contract by Trident Inc., is a semi-object oriented simulation battle management software product. CAAM incorporates many visually appealing user interface features and smoothly integrates the underlying physics models for simulating primarily anti-submarine warfare (ASW) scenarios. Although CAAM is has many valuable features, it was determined that it could not be easily extended into MCM work and would have difficulty in integrated new models into its architecture. This is because many of CAAM's component parts are designed with various levels of object oriented abstraction; there is a lack of consistent design vision throughout the product. Further, the Navy was conducting a series of meetings at that time and decided that the NSWC MARS battle manager was a more viable option for comprehensive, joint simulation scenarios.

The Naval Surface Warfare Center (NSWC, White Oak, Maryland) had begun the development of its own simulation battle manager called MARS. This software product, although endorsed by the Navy, had only just barely begun its development cycle and was very immature, certainly not capable of supporting a large-scale littoral warfare scenario with active MCM sensors. Additionally, the MARS product was written in a computer programming language called MODSIM that does not lend itself to easy integration of different language physics models, and has no direct support for user interface elements.

The Virtual Prototypes STAGE (Simulation Toolkit And Generation Environment) simulation battle management product was determined to be a good compromise to the CAAM and MARS options because of its inherent flexibility in accepting third party

models and an innovative way of describing weapons and sensors performance characteristics. Although STAGE did not have the depth of support for a specific warfare area, as CAAM and MARS could show, it did have a clearer path for modifying and extending its basic capabilities. STAGE was selected and installed in the computer facility at CNA by Jason Associates personnel.

In addition to this simulation analyses, JAC participated in evaluating several industry maintained software models in the three sonar technology areas. Raytheon was selected for a detailed "probability of detection" ($P_d$) model of the SQQ-32 sonar because Raytheon is the principal under contract to the Navy to develop and supply actual SQQ-32 sonar hardware to the MCM ships. Arete Corporation has been under contract to develop blue-green laser models based on their previous work for the LANTIRN sensor program, and was brought in to supply both a graphical model of the laser sensor operation and a $P_d$ model. The Navy's Coastal System Station (CSS) in Panama City, Florida was identified as having specific expertise in the modeling of the superconducting gradiometer and was contracted to supply a modified version for the project.

## Task 2 - Modeling

Jason Associates personnel assisted CNA in using the information and models collected in Task 1 by integrating them into the STAGE simulation software. This was accomplished by tailoring the performance characteristics of the platforms in terms of accelerations, minimum turning radius, maximum altitude, etc. STAGE has built-in general motion models that are "tuned" to react like a specific platform by supplying these types of values. These parametric models were sufficient that no detailed performance modeling was required.

An attempt was made to integrate the sonar models into the STAGE software. Virtual Prototypes delivered STAGE with the appropriate software source code to insert the sonar system subroutine calls but this proved difficult due to the large number of source code files that required modification and an inability to change the sonar sensor parameters from within the STAGE simulation as it was running. As a result, Jason and CNA used the delivered sensor models to tailor the built-in, aggregate level sensor models within STAGE to approximate the new sensor. Results from this tailoring proved to be within acceptable limits and the CNA analysts generated results for several studies.

The STAGE simulation product generates a series of outpout files as a result of the simulation. Each set of files consistutes the complete record of platform movements and sensor performance (in terms of target acquisition or probability of detection per sensor sweep). STAGE has a built-in random number generator which computes a random draw value to base the "hit" probability of the sesnor in a given pass. By iteratively running the same scenario, in a monte-carlo fashion, various Measures of Effectiveness (MOEs)

can be derived from value averaging and other statistical formulae. The analysts at CNA can then use these MOEs to support military worth decisions based on a record of simulated sensor performance data.

## Task 3 - Simulation

Under direction from CNA, Jason developed several littoral warfare MCM scenarios to test the validity of the sensor employments. In these scenarios, each sensor (SQQ-32 sonar, blue-green laser, and the superconducting gradiometer) was modeled parametrically to achieve an aggregate performance simulation. This means that the sensor's performance within a given environmental range was "averaged" or "indexed", using lookup tables or detection curves ($P_d$ vs. Range), to generate a response indicative of that sensor.

The simulation scenarios developed focused on a very specific area, usually limited to reduce the number of platforms within the simulation. (STAGE simulation execution slows to an unacceptable speed when large numbers of platforms are used.) Underwater mines are considered platforms and not weapons in the STAGE model. Each platform in the simulation was driven by a "script" that related sensor detections to weapons launch and detonation.

Generally speaking, the same minefield configuration was swept using the different sensor gear and the results guided the analysts in offering conclusions based on the tactical employment of those sensors. The simulation highlighted the areas of high performance each sensor exhibited and contrasted the areas of overlap (or not) between them.

Jason Associates developed and presented simulations of various MCM systems in support of the Navy's decision to validate the MCM concept of operations.

## Task 4 - Documentation

This Final Report document satisfies the requirements for this task under the Statement Of Work.

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