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Towards a Synthetic Environment for Maritime-Air Tactical Experiments

Dr. Fawzi Hassaine, Dr. Andrew L. Vallerand, Dr. Paul Hubbard
DRDC – Ottawa
3701 Carling Avenue
Ottawa, Ontario K1A 0Z4
CANADA

Fawzi.Hassaine@drdc-rddc.gc.ca

ABSTRACT

The Maritime Air Littoral Operations (MALO) Technology Demonstration Program was established to research and develop a Synthetic Environment to support the development and evaluation of maritime air operational tactics, doctrine and new concept, in the prospect of the integration of new equipment within the Canadian Forces Navy - Air component. Using two technologies, MALO is providing a Modeling and Simulation based experimental environment in which tactics, doctrine and new concepts for the new Maritime Helicopter and the modernized Aurora aircraft crews can be trialed, measured and validated.

MALO is developing two technologies in a four phases incremental build process. The 1st technology is a standalone physics-based simulation system, designed to support rapid experimentations, while still providing and open framework for models integration and support for external applications plug-ins. The 2nd technology is a distributed, HLA-based, high fidelity simulation to support virtual simulation experiments, and has a Computer Generated Forces capability to eventually allow for hybrid virtual-constructive simulations. This system will also provide functionalities for scenario building, entities customization, simulation controls, battlefield situational awareness, and finally data collection and analysis. Both technologies will be combined in one single experimentation process.

1.0 INTRODUCTION

The Maritime Air Littoral Operations (MALO) Technology Demonstration Program (TDP) was undertaken by the Future Forces Synthetic Environment (FFSE) at Defence Research and Development Canada (DRDC) Ottawa to develop a Modeling and Simulation (M&S) based experimental environment to support the development and evaluation of maritime air operational tactics, doctrine and new concepts[1].

The MALO team conceived an experimental strategy within a simulation environment consisting of two M&S technologies. Both technologies serve the same technical objectives but with significant differences in the level of fidelity of the physical entities and their behaviour, as well as the way the systems are utilized by the

[1] A military concept has been defined, by Schmitt, as "a description of a method or scheme for employing specified military capabilities in the achievement of a stated objective or aim [1]". Schmitt also has incorporated a temporal aspect, defining *historical* concepts, *current* concepts and *future* concepts

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operators. These systems are being developed in an incremental process of four phases, with demonstration at each phase, and final delivery [2] to the MALO TDP's partners, the Canadian Forces Maritime Warfare Centre (CFMWC) and Maritime Air Component Atlantic [MAC(A)]. The two main deliverable simulation systems are:

- A standalone simulation system to support rapid experimentations. This system results from the exploitation and integration of two products; the first, a Commercial Of The Shelf (COTS) application, called Satellite Tool Kit (STK) [3] from Analytical Graphics Inc, and the second is the simulation engine of Dangerous Waters [4] from Sonalysts Inc., a naval war-game with a strong capability for underwater scenario simulations.
- The MALO Synthetic Environment Analysis System (MSEAS), a High Level Architecture[2] (HLA) based simulation system that is using the US Joint Forces Command (JFCOM) Joint Semi-Automated Forces (JSAF). MSEAS will not only provide a high fidelity simulation capability to its users, but also the means to: facilitate scenario generation, provide the access to the entities' models and parameters, to do runtime monitoring, both for the simulation and for the simulation infrastructure, and finally and most importantly, to provide user-specified metrics from the simulation and the analytical tool to measure the credibility of the employed tactics.

This paper introduces the MALO users' community, and discusses how the MALO system fits into their experimentation program. The incremental project execution will then be examined and justified. It will be followed by a review of the standalone system and its objectives, the rationale behind this concept, and some details on its integration. The next section will be the subject of the MSEAS system. As - at the time of writing this paper - the project is in its mid-term, we will provide an update on the project development, and present the current MSEAS system, its architecture and its main components. A discussion of the future MSEAS system will expose some conceptual and architectural elements that might support the development of the final system, and we will finally conclude the paper with a few thoughts on how these technologies can be exploited.

2.0 CD&E WITHIN THE MARITIME-AIR COMMUNITY

The Maritime-Air operational community is comprised of a *maritime* component, which includes the various ship classes in the maritime fleet, and an *air* component which includes the CP140 Aurora aircraft fleet and the Maritime Helicopter aircraft fleet. In combination, the Maritime Air community manages sub-surface, surface, and air operations within the maritime domain. The maritime domain includes *blue water* or deep ocean operations, as well as *brown water* or littoral operations close to shore.

The CFMWC has the responsibility to conduct CD&E related to alternative maritime concepts, which includes alternative maritime air concepts. The CD&E process involves the investigation of:

- Alternative Doctrine;
- Alternative Tactics, Techniques, and Procedures;
- Alternative Technologies & Systems and their impact on operational performance and changes in required tactics to fully take advantage of them.

[2] There are two reference specifications of the HLA, one from the Defense Modeling and Simulation Office (DMSO) [5], the organisation within the US Department Of Defense (DOD) that developed the HLA; The second specification is the world adopted standard, from the IEEE [6].

Ideas for new technologies, tactics, or doctrine can come from a variety of sources including the full range of operational units, headquarters units, acquisition teams, R&D units, and the CFMWC itself. Experiments have historically been conducted using live simulation in workshops or live trials using the real platforms and systems. These are important methods for experimentation, but can be costly and difficult to schedule. As a result, it is desirable to increasingly use constructive simulations whereby all entities are simulated through computer models, and virtual simulation whereby Human-in-the-Loop (HITL) simulation devices are integrated with constructive simulation in synthetic environments. Constructive and virtual M&S capability will enable the CFMWC to rapidly and incrementally study alternative concepts, with a process that starts with early constructive studies followed by virtual simulation studies (standalone or distributed) followed by live simulation studies conducted as and when required.

The Maritime community is in the process of introducing a range of new technologies and systems into the operational capability. Sample technologies and systems include the planned introduction of the:

- Tactical Integrated Active/Passive Sonar (TIAPS);
- SSQ 110 Explosive Echo-Ranging (EER) Sonobuoy;
- CP140 Aurora Incremental Modernization Project (AIMP) which includes a wide range of improved mission system capabilities;
- Maritime Helicopter (CH148) replacement of the Sea King (CH124) fleet;
- Victoria Class submarine;
- Upgraded Canadian Patrol Frigate.

In 1997, a review of Research and Development (R&D) projects by the staff of the Canadian Forces Director of Air Requirements (DAR 3) highlighted that the above list of planned technologies resulted in a planned increase in capability for which tactics and doctrine were not fully developed.

In addition, it was noted that while the Maritime Surface and Maritime Air communities had extensive experience operating in blue water undersea warfare environments, these planned new capabilities, and a shift in operational focus to littoral environments, would require research and development of shallow water tactics and doctrine.

The research, development, and delivery of an M&S based tactics evaluation environment were identified as an important evolution to the maritime CD&E capability, and as an important enabler to the evolving CFMWC community.

3.0 MALO PROJECT INCREMENTAL STRATEGY

The MALO TDP was organized according to a spiral development and evaluation process, with four phases and specific experiments to be conducted in each phase; the main deliverables from the project are:

1. A standalone Synthetic Environment Research (SER) workstation, delivered early in the project to the Canadian Forces Maritime Warfare Centre (CFMWC), able to support rapid experimentation of operational scenarios and tactics alternatives evaluation;
2. A low fidelity simulation environment based on the HLA; this environment currently support the development and experimentation of selected maritime air scenarios within the JSAF Environment;

3. A higher fidelity HLA-based simulation environment to support the development and experimentation of the same scenarios and tactics but with greater resolution and fidelity;
4. And finally, the MALO Synthetic Environment Analysis System (MSEAS), a more capable analytical M&S based experimental environment that will build on the previous system.

This incremental strategy in the establishment of a simulation environment is believed to be unique in its kind, at least in Canada. It brought several benefits from which we can mention:

- The delivery of a simulation system (SER) to the client at an early stage of the project;
- The low fidelity HLA simulation reuses some of the models that we have integrated in the SER system;
- Based on the former argument, we have concentrated primarily during the second phase of the project in the establishment of the HLA synthetic environment;
- The higher fidelity simulation essentially reuses the architecture and the SE established for the low fidelity simulation; the main improvements being on the various models that drive the sensors, and the elements of the SE that are considered by these models (entities signatures and their propagation, environmental conditions, etc.);
- The analytical capability is needed only when the high fidelity simulation is built, and will come in the form of an additional (software) layer to the already built system;
- Finally the Verification and Validation (V&V) can occur in parallel with the project development. As the whole development is executed incrementally, the V&V of models at a given stage will also serve for the models V&V of subsequent phases.

4.0 STANDALONE SYSTEM

During the first phase of MALO a standalone simulation system was developed. This system was intended to be a “triage” tool for the maritime-air tactics “developers”, as well as a potential tool for the Operational Research community, which is heavily involved in the tactics “Validation” process. In order to comprehend those two essential application domains the SER was designed to include the following functional aspects:

1. 3D and 2D views (platforms, area of interest, etc.) for situation awareness, or for mission planning and tactics elaboration, and for other secondary purposes (briefing, debriefing, training, etc.);
2. Ability to import the user own terrain data for the area of interest, which can include elevation and bathymetry. The tool shall also accommodate different levels of terrain resolution;
3. Rapid scenario generation is a required feature as the tool is intended to be a triage tool, which necessitates the ability to:
   a. quickly set up scenarios;
   b. configure platform kinematics, armaments and most importantly sensors parameters;
   c. assign routes to platforms;
4. Provide (compute and visualize) sensors coverage of entire search area;
5. Run scenario simulation in constructive mode;

6. Ability to collect any simulation data as: position, speed and bearings, time(s) of detection, probability of detection, etc.;
7. Open Architecture, which will allow for:
    a. The integration of external (user own) models;
    b. Providing external inputs to the simulation, as a control on a Radar (On and Off at certain times);
    c. Ability to control the simulation (execution, input and output), in order to do, amongst other things, Monte-Carlo runs; this would be the only way - when using faster then real-time constructive simulations - to achieve some statistical significance [7], that will provide the credibility for the simulation outcome;
    d. Integration with other software;
8. Accommodate the integration of Air, Land, Surface and Subsurface domain platforms with their respective capabilities.

Figure 1 displays a snapshot from a vignette simulation playback (in STK); entities 3D models have been magnified to provide and easier reading of the 3D view.

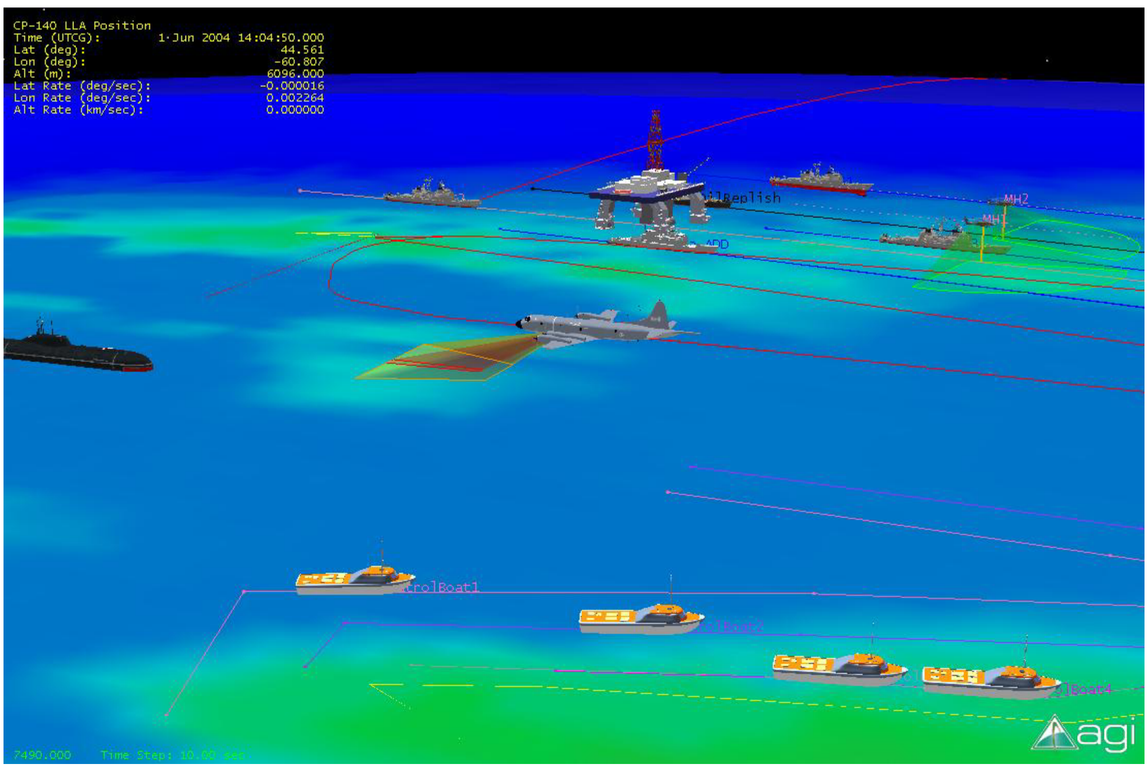

Figure 1: Simulation Playback in the STK environment.

For all these reasons, STK was selected as the target simulation platform. However, although STK is very strong in the Air and to a less extent in Land and Surface domains; at the time of executing phase 1 of the project STK had no support for the Subsurface domain. We have consequently integrated another war gaming tool with STK in order to remedy this capability deficiency; this game engine is the non-commercial version of "Dangerous Waters" from Sonalysts Inc., a naval war-game with a strong capability for underwater scenario simulations. Dangerous water brought several interesting aspect to the integrated package:

1. A very user friendly "Mission Editor" interface;
2. Programmable behavior[3] for the entities;
3. The ability to run in interactive mode;
4. The ability to run a multi-stations (distributed, multi user) mode.

Currently, we do not exploit the third and fourth features as the SER does not require them.

5.0 MALO HLA SIMULATION

The MALO project was driven with the fundamental assumption that the development, assessment and establishment of warfare tactics necessitate more than an approach that relies on the use of standalone simulations[4]. Therefore, it was proposed that in conjunction with the SER, MALO operators will have at their disposal a high fidelity HLA simulation (MSEAS), based on the assumptions that:

1. A high fidelity simulation environment would require complex models that are used to simulate the sensors, and to provide an acceptable environment representation. These models are very CPU intensive and usually run slower than real-time, eliminating by the same the viability of virtual simulations. One solution to this problem consists in the distribution of the processing of the various components of the SE over a set of computers, hence the requirement for a distributed computer simulation;
2. Also a simulation system built on the most advanced technology for distributed computer simulations and one of the established standard, i.e. the HLA, would benefit the MALO system when there will be a requirement to interface with other Canadian Forces or allied nations simulators; The subject standard is certainly known for providing the potential for interoperability amongst various simulations/simulators of the same (HLA) type;
3. Finally, it is very difficult to validate a Computer Generated Force (CGF) behaviour, which will in turn question the credibility of employed tactics in a war-game scenario using a CGF. For this very specific reason we have proposed that most of the experiments in MSEAS have human operators driving the entities; therefore, the requirement for virtual simulations.

MSEAS SE platform

These requirements for the MSEAS guided us in the selection of a known CGF, JSAF. JSAF is a simulation system that can provide entity level units that can range from a single infantryman to more complex entities, such as a group of fighter aircrafts; it will model the entities physical characteristics (sizes, signatures, etc.), kinematics properties (position, velocity, acceleration, climb rate, etc.), and equipment (weapons, defense

[3] Also referred to as the "Artificial Intelligence" or AI.

[4] It is a very common practice to focus on one single aspects of tactics warfare, as the search of optimal dip pattern for a helicopter using a dipping sonar, or for the optimization of a torpedo model, etc., with very poor inclusion of other aspects, as the command and control, the sensors data fusion, the environment representation, etc.

suite, communication devices, sensors, etc.). Each entity can be run in a SAF mode, whereby the entity is controlled by a "behaviour model" implemented in a Finite State Machine. All the entities in a JSAF scenario evolve in a (SE) representation of real world terrain, oceans, and weather conditions that affect their behaviors and their overall capabilities (line of sight, speed, sensors performance, probability of kill, etc.).

MSEAS Functional Elements

MSEAS will not only provide a robust, high fidelity simulation capability to its users, but also the means to: facilitate the scenario's generation, provide the access to the entities' parameters, do runtime monitoring both for the simulation and the simulation infrastructure (network communication, computer state, etc.), and finally and most importantly, to provide user-specified metrics from the simulation and the analytical tool to measure the viability of the selected tactics throughout the trialled mission. Figure 2 illustrates the various functions that will be implemented in the final MSEAS system.

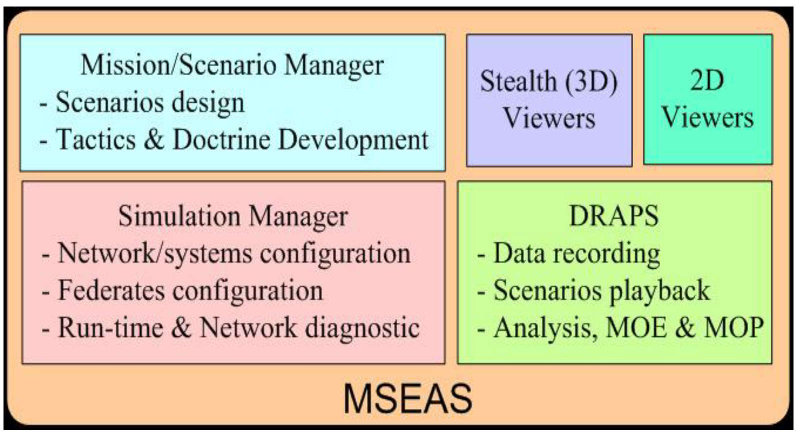

Figure 2: MSEAS Functional components.

A Proposed Architecture for a High Fidelity Simulation Environment

Although JSAF alone provided a good solution as a SE platform for the second phase of the project, it does not comply with the overall requirements for a high fidelity simulation environment. This assertion is particularly valid when we consider JSAF's capability in the three sensing domains: EO/IR, Radar and Acoustics, which proved to be rather weak (at least for the present MNE-4 version). The three sensing capabilities are essential in the context of the MALO scenarios, rather than the weapons system or the command and control aspects for instance.

In order to provide a simulation with credible sensor performance modeling in these domains, that is tailored to the required fidelity-level for tactics investigation experiments, both the SE representation of the natural environment and the entities, as well as a better physics-based modeling of the sensors need to be embraced. This addition to the phase II "JSAF only" simulation would require the integration to the current distributed simulation of additional nodes; the latter would be dedicated to the modeling of the various aspects of entities representation in a natural environment and the implementation of credible sensors performance models.

Also, in the prospect of reusing these developments and to maximize their interoperability with future simulations, it is intended to implement the additional capability in the form of (HLA) federates. A preliminary architecture of a federation is envisaged for this development, as shown in Figure 3.

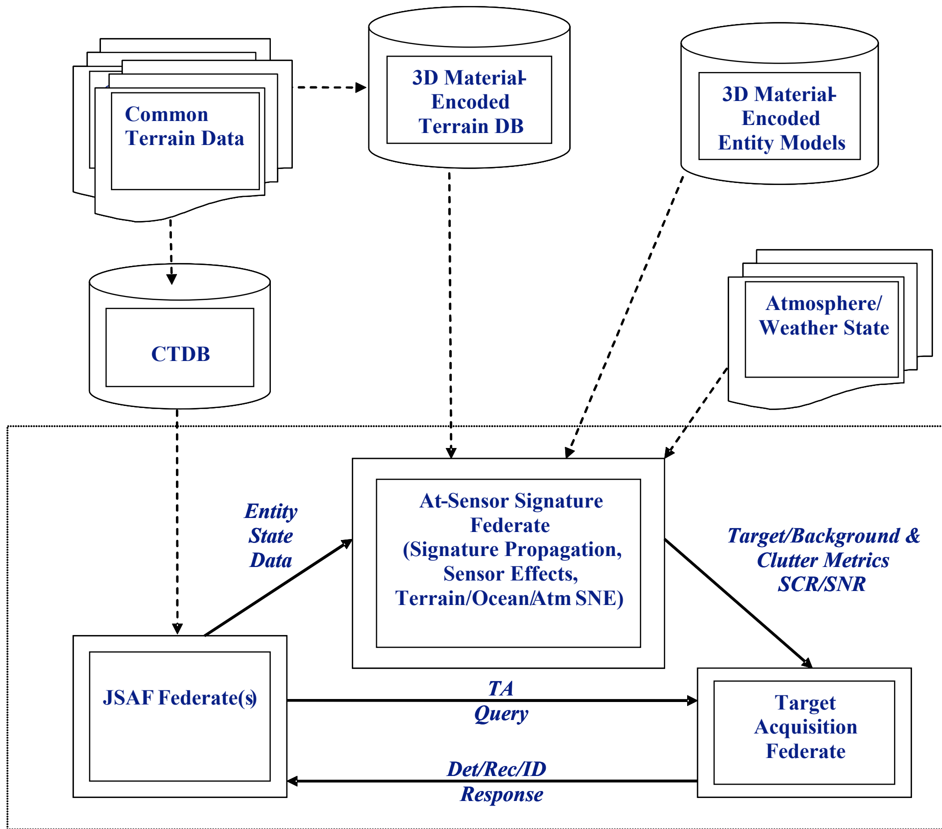

Figure 3: MALO High Fidelity HLA Simulation Architecture.

For each of the three sensor domains (EO/IR, Radar, Acoustics), there will be two federates. The first being the At-Sensor Signature Federate, which implements a high-fidelity, physics-based signature and propagation modeling of this signature to simulate the appropriate at-sensor signature quantities that drive target acquisition. The second federate, models the Target Acquisition consistent with at-sensor signature quantities published from the former federate. Its outputs will consist in target detection, classification and identification behavior decisions to JSAF.

7.0 CONCLUSION

MALO TDP proposed an innovative way to develop an M&S-based analytical capability for the Maritime-Air tactics development. It is through a four phased incremental development process that two simulation systems are being built and delivered to the MALO partners, the CFMWC and MAC(A). These two radically different technologies are however envisaged to be part of the same experimental process.

The 1st technology, or the SER, is a standalone system, for use in a constructive mode. Its value-added is seen as a rapid "triage" tool for tactics trial, or during the early phase of a concept development and experimentation. Also, this system compensates its low fidelity sensors modeling and its poor representation of the environment, by providing a Monte-Carlo capability, allowing the users to have the statistical significance to provide for the credibility of the simulation results. This system came out from the integration of two COTS, STK and “Dangerous Waters”, resulting in a physics-based Synthetic Environment simulation capability for the Maritime-Air community.

The 2nd system is a robust distributed, HITL HLA simulation system. We have developed an early version of this system that has a similar level of fidelity than the SER. However, the next phase of the TDP will bring in an incremental way, the sensors fidelity as well as the environment modeling to a level that would be acceptable for the operators. As the core simulation engine (JSAF) provides only for a limited level of fidelity, we have already proposed an architecture that will serve for the implementation of a credible synthetic environment. The salient aspects of this new development are:

- Scenarios creation and management capability;
- Dynamic control of the simulation infrastructure;
- Better representation of the platforms signatures and signature propagation from the various sensor domains perspective (EO/IR, Radar, Acoustics);
- Better target acquisition models;
- And finally, the analytical capability to obtain (tactics) meaningful performance metrics from a simulation.

In conclusion, we have developed an original and effective set of technologies that support Maritime Tactics, Doctrine and Concepts in support of the Maritime Air community. The concept of assessing tactics doctrine and concepts, first on a triage workstation and secondly on a Distributed HLA-based SE, leading to thirdly, Live efforts, as required, represents a unique innovation that when coupled with a Rapid Scenario Generation capability on the front end, and an Analytical capability on the back end of the SE, effectively transforms the approach from a pretty picture to a robust Decision-making tool to be exploited across the Community of interest and the community of Practice.

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