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Design and Development of an Architecture for Demonstrating the Interplay of Emerging SISO Standards

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Keywords:

Base Object Model, Battle Management Language, Distributed Interactive Simulation, Extensible Markup Language, High Level Architecture, Interoperability, Military Scenario Definition Language, Simulation Reference Markup Language

ABSTRACT: *The Simulation Interoperability Standards Organization (SISO) focuses on facilitating simulation interoperability across government and non-government applications worldwide. A number of standards are emerging that will individually have great impact on the development and operation of simulation systems, as well as interoperation across simulation systems and command and control systems. Taken together, however, the emerging standards represent a set of capabilities and technologies which can revolutionize the simulation industry, radically improving the way we develop and deliver interoperable systems.*

In the Fall 2006 Simulation Interoperability Workshop, an architecture for demonstrating the interplay of several current and emerging SISO standards was presented. The following standards were selected for development of an initial demonstration system: (1) the Coalition Battle Management Language (C-BML) for unambiguous expression of plans and orders for live, constructive, and robotic forces; (2) the Military Scenario Definition Language (MSDL) for describing a scenarios that can be shared across multiple systems; (3) Base Object Models (BOMs) for specifying building blocks for composing larger model sets; (4) the Simulation Reference Markup Language (SRML) for platform-independent representation of executable behavior models; and (5) the Distributed Interactive Simulation Extensible Markup Language (DIS-XML) initiative for representing DIS Protocol Data Units in XML to enhance interchange of dynamic entity state and entity interactions across diverse systems in web-based network centric architectures.

This paper discusses how the framework can be used by the SISO community as a means for educating the community on emerging standards and as a platform for demonstration of new concepts and capabilities as a precursor to a new standardization effort. It describes work performed to design and develop an initial test case demonstrating the integration of these standards, including problems encountered, problem resolutions, lessons learned, and future work.

1. Introduction

The Simulation Interoperability Standards Organization (SISO) focuses on facilitating simulation interoperability across government and non-government applications worldwide. A number of standards are emerging that will individually have great impact on the development and operation of simulation systems, as well as interoperation

across simulation systems and command and control systems. Taken together, however, the emerging standards represent a set of capabilities and technologies which can revolutionize the simulation industry, radically improving the way we develop and deliver interoperable systems.

In the Fall 2006 Simulation Interoperability Workshop (SIW), an architecture for demonstrating the interplay of several current and emerging SISO standards was presented [1]. The following standards were selected for development of an initial demonstration system:

- (1) The Coalition Battle Management Language (C-BML) for unambiguous expression of plans and orders for live, constructive, and robotic forces
- (2) The Military Scenario Definition Language (MSDL) for describing a scenarios that can be shared across multiple systems
- (3) Base Object Models (BOMs) for specifying building blocks for composing larger model sets
- (4) The Simulation Reference Markup Language (SRML) for platform-independent representation of executable behavior models
- (5) The Distributed Interactive Simulation Extensible Markup Language (DIS-XML) initiative for representing DIS Protocol Data Units in XML to enhance interchange of dynamic entity state and entity interactions across diverse systems in web-based network centric architectures.

This paper describes work performed to design and develop an initial test case demonstrating the integration of these standards, including problems encountered, problem resolutions, lessons learned, and future work. The paper discusses how the framework can be used by the SISO community as a means for educating the community on emerging standards and as a platform for demonstration of new concepts and capabilities as a precursor to a new standardization effort.

2. Requirement

Several standardization activities are ongoing within the SISO community, including the following Study Groups¹:

- Common Image Generator Interface (CIGI)
- Discrete-Event Systems (DEVS) Specification
- Economics of M&S
- Generic Methodology (GM) for Verification, Validation and Accreditation (VV&A) in the M&S Domain
- HLA Performance Recommended Practice (HPRP)
- Live-Virtual-Constructive (LVC) Architecture Interoperability
- Message Passing for Simulation-based Collaborative Engineering Design (Message-Sim)
- Mode 5/Select Identification Friend or Foe (IFF)

¹ Note: Some of these are Standing Study Groups (SSGs) established to represent a specific community or national group, to mature a potential standard, or potentially to provide support to open-source software. SSGs may have an indefinite life span.

- Shareable Content Object Reference Model (SCORM) – Simulation Interface Standards
- Simulation Conceptual Modeling (SCM)
- Transfer of Control (TC)

Study Group efforts make a particular problem and proposed solution known to the SISO community in order to determine if the approach warrants transition to Product Development status. Study Groups often prepare technical papers and develop demonstrations to present the concept to the community. However, while SISO documentation for transition to Product Group status (the Product Nomination form) calls for description of prototypes developed that demonstrate the value of the proposed standard (or reasons why prototypes have not been developed), there is no requirement to demonstrate compatibility of the product with other SISO standards. The Product Nomination also has a section for describing compliance testing planned for the proposed standard. However, there is no environment maintained by SISO or the community to support compliance testing in a way that would show how the new standard integrates with existing SISO standards.

The following standards have progressed to Product Development status:

- Coalition - Battle Management Language (C-BML)
- Core Manufacturing Simulation Data (CMSD)
- Commercial Off-the-Shelf Simulation Package Interoperability (CSPI)
- Distributed Interactive Simulation (DIS) Extension
- Federation Development and Execution Process (FEDEP)
- High Level Architecture-Evolved (HLA-Evolved)
- Link 11 A/B Network Simulation Standard
- Military Scenario Definition Language (MSDL)
- Real-time Platform Reference Federation Object Model (RPR FOM)
- Simulation Reference Markup Language (SRML)
- VV&A Overlay to Federation Development

Once a proposed standard has been balloted and adopted it then transitions to community support through a Product Support Group (PSG). PSGs provide a forum for new findings and request to be made to existing standards so that if it is decided the standard needs to be reopened and updated the PSG can advocate such effort with the Standards Activity Committee (SAC), which, among other things, oversees SGs, PDGs, and PSGs.

The following standards have been approved and are now associated with a Product Support Group:

- Base Object Model (BOM) Interface Specification
- Distributed Interactive Simulation (DIS)

- Environmental Data Representation Standards (ERDS)
- Tactical Data Link (TDL)

Surprisingly, there is no composite integrated environment for demonstrating implementations of the emerging and established standards to educate the community about the new standards and to show the benefits gained for system interoperability from introduction of the standards. We believe that demonstration of the ability of an implementation of a new standard to work with other existing standards, when appropriate, should be a part of the Product Development process. Otherwise, there is no clear demonstration to the community that the standard achieves expected benefits and integrates effectively with other standards.

Clearly several of the SISO standardization efforts—for example, C-BML—are focused on interoperability of military Modeling and Simulation (M&S) systems and Command and Control (C2) systems. However, some of these standards may have application to a broader community. The opportunity to demonstrate the product in a composite environment may stimulate interest across the full SISO community, allowing others to integrate additional systems or software to investigate possible use in their domain.

To explore this idea, we selected 5 of the above standardization development areas for the purpose of planning an integrated demonstration of these technology standards. Each of the following standards addresses specific needs that have been shortcomings in M&S interoperability in the past:

- (1) The Base Object Model (BOM) standard [2] provides a way to identify piece parts of a conceptual model or simulation, which can be used as building blocks for composing larger interoperable model sets [3].
- (2) The Coalition Battle Management Language (C-BML) [4] provides a way to represent coalition battle management doctrine within a Command and Control environment to enable unambiguous expression of plans and orders for live, constructive, and robotic forces.
- (3) The Distributed Interactive Simulation Extensible Markup Language (DIS-XML) initiative [5, 6] provides a way to represent DIS Protocol Data Units in common structured way using XML to enhance interchange of dynamic entity state and entity interactions across diverse systems.
- (4) The Military Scenario Definition Language (MSDL) [7] provides a common way to describe a scenario, including initialization information, that can be shared across multiple systems.
- (5) The Simulation Reference Markup Language (SRML) [8, 9] provides a platform-independent way

to represent behavior models which can be rendered quickly and easily (at runtime) by a simulation.

The earlier paper [1] provided background information on each of these standards to help the reader understand the basic capability offered by each independent product standard and to begin to convey the potential these product standards offer collectively. Below, we briefly revisit the use case presented in that paper to act as a context for demonstrating the standards. This is followed by an overview of the initial abstract architecture for composition of prototype versions of these products. This was the starting point for work reported in the present paper. Although the earlier paper proposed a plan of action to implement the architecture for demonstration and discussion at the Spring 2007 SIW, it has not been possible to achieve the full capability initially proposed. The present paper will describe what has been accomplished, problems encountered and, where applicable, solutions applied. Finally, the paper concludes with a summary and go-forward recommendation for SISO and the M&S community.

It is also important to note that the ideas put forth in [1] were well received at the Fall 2006 SIW. SISO board members encouraged the authors to propose a Study Group (SG) effort to formalize the concepts and approach for broader community participation in the design and development of the composite demonstration architecture. However, the authors believed that such an effort would be premature if it proved difficult to create an initial capability that could be used to establish an approach and prove feasibility of the concepts. Therefore, the work toward an initial architecture is proceeding outside the formalities of the SISO process at this time. The authors, SISO leadership, and the broader community will continue to monitor progress of this effort to determine when it may be most appropriate and effective to initiate a standardization effort under the SISO guidelines and procedures.

3. Demonstration Approach

Earlier work described the interplay possible between the BOMs and SRML standards. In [9], the authors applied BOMs to process-oriented simulations, which are typically employed in the analysis and design of manufacturing, logistics, industrial, military, and business process. They investigated how several popular and emerging formalizations for describing processes relate to BOMs and how their features can be encapsulated with SRML, federated, and executed with a standardized simulator. This effort provided an example of the composition of various "Process BOMs" into an executing model and identified opportunities for SISO to impact the

process-oriented community. In [9], the authors investigated the application of BOMs and SRML in addressing the HLA Federation Development and Execution Process (FEDEP) [10], showing how using composition rather than inheritance can improve the reusability and flexibility of the interface assemblies expressed as BOMs and how the underlying code use to model the behavior of an encapsulated BOM can be accomplished using SRML.

These precursors to the current effort provided the simulation community valuable insights into the benefits of application of these emerging standards and provide a basis for the current work. Other demonstrations and development efforts involving BML, DIS-XML, and MSDL have clearly demonstrated the benefit of the other standards discussed in this paper, but have mainly been employed in isolated demonstrations to make the benefits of the particular proposed standard as apparent as possible and to establish rationale for continued standardization efforts. What has not occurred is establishment of a wide-reaching demonstration or test environment within which the mutually supporting (and possibly conflicting) capabilities of the various standards can be put on display for evaluation and education by and for the SISO community at large.

3.1 Use Case

The notional use case selected for the initial demonstration is planning and executing a mission involving the employment of autonomous robotic forces. Plan execution occurs in a simulation to allow the decision-maker to evaluate the mission, possibly providing insights leading to re-planning. Employment of robotic systems is of particular interest since such forces need to be directed either by detailed scripted orders, much like the encoded behaviors of constructive forces in simulation systems, or by declarative mission orders providing high-level goals to be achieved, allowing the robots to perform their own low-level planning to achieve the goal, much like how orders to live human forces are given (at each level of command, a certain degree of autonomy and initiative is allowed) [11]. Orders provided in the simulated or virtual environment can readily be directed to real robots to carry out the same operation. The distinction between live and simulated robotic forces is blurred since precisely the same orders are given to both, and each class of robots will use its implemented control mechanisms (according to the architecture of the individual robotic system) to carry out the assigned orders. Using a situation involving robotic forces for the demonstration removes the need to involve live human forces, which would overly complicate the demonstration architecture and execution. Finally, numerous simulation

test beds for robotic simulations exist for the purpose of testing and rehearsing robot missions and decision-making before employing those systems in a live mission. Specifically, the Naval Postgraduate School, Monterey, California has developed a simulation test bed for Autonomous Unmanned Vehicles (AUV) that includes implementation of an Autonomous Vehicle Command Language (AVCL) and already incorporates DIS-XML communications of simulated object state information. Refer to [11] for discussion of AVCL and its implications for the C-BML specification relative to command and control of robotic forces.

The scenario of interest is Anti-Terrorism/Force Protection (AT/FP) of a harbor, where one or more unmanned surface vehicles (USVs), unmanned air vehicles (UAVs), unmanned undersea vehicles (UUVs), and unmanned ground vehicles (UGVs) have the mission of creating a layered defense by patrolling a protected area and alerting response teams (also unmanned, for purposes of this scenario) when a suspect or hostile intruder is detected. Such a scenario has clear implications to military planners as well as cross-over into the public Homeland Security arena. Again, the fundamental purpose of this architecture is to show the community how the standards can be employed in the future and what benefits will accrue, particularly from synergistic effects that may occur when multiple standards are employed together.

3.2 Architecture

In order to address the proposed use case, the contribution of each of the selected standards needs to be described and any required interactions across the standards need to be identified. Conceptually, the selected standards offer the following capabilities in the context of this scenario:

- (1) BOM – conceptual modeling of each of the entities to be represented (robotic platforms) and specification of interactions (patterns of interplay) among the entities;
- (2) C-BML – specification of the orders given to each of the robotic platforms, either as scripted behaviors or goal-directed tasks (see [11])
- (3) DIS-XML -- runtime state updates that can be used for visualization of the scenario, logging of state changes, and entity messaging;
- (4) MSDL – description of all initialization data regarding the locale, forces, force structures, environment, control measures and other information to preserve the scenario set-up for re-use; and
- (5) SRML – representation of entity behaviors and dynamic execution of actions and interactions of the entities.

A significant commonality across these selected standards is the use of XML to structure and pass information. An interesting aspect of the development of the demonstration architecture will be seeing how much of the interplay across these standards can be performed using common XML tools and techniques, such as the Extensible Stylesheet Language for Transformations (XSLT) to transform information across representations.

Figure 1 provides an abstract view of the proposed demonstration architecture, suggesting the roles and interactions across the standards indicated above (entities in the Operational category represent the various types of autonomous vehicles identified above in section 3.1).

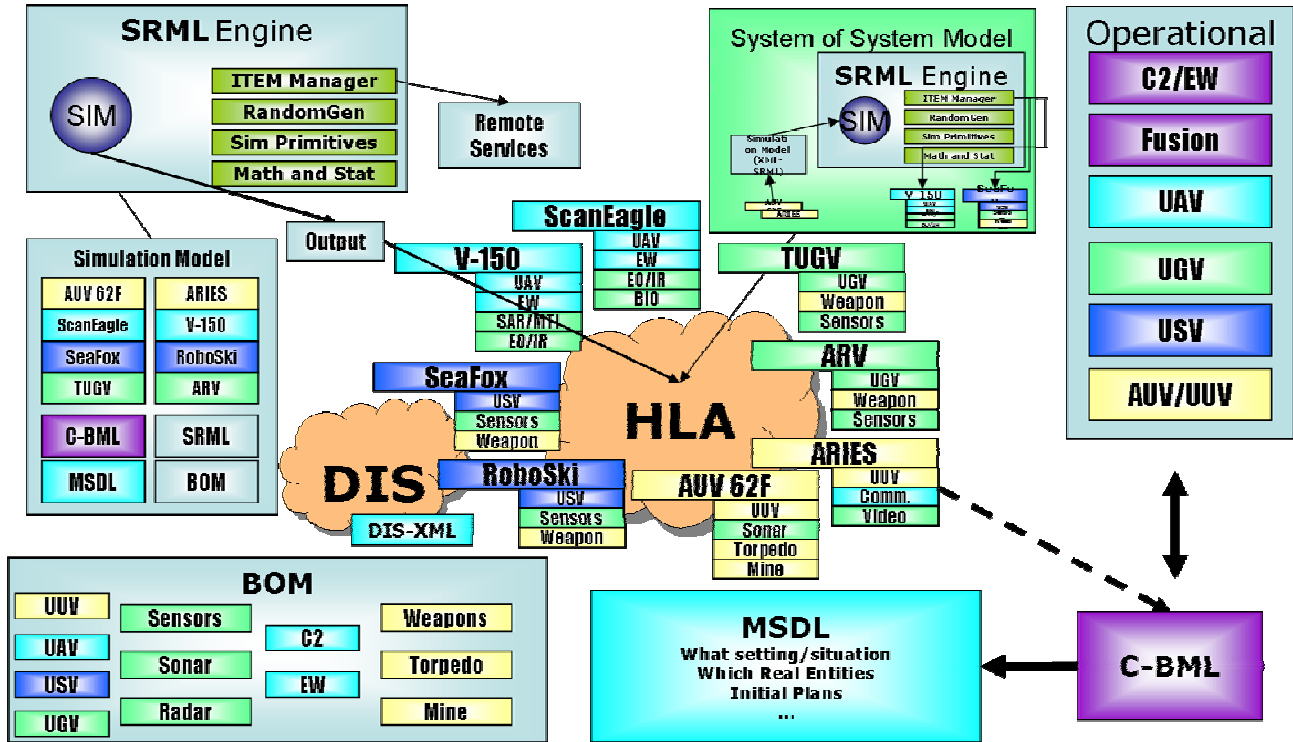


Figure 1. Abstract Demonstration Architecture.

4. Progress towards a 2007 Demonstration

The goal of the activity proposed in the Fall 2006 SIW was to provide a demonstration of the selected standards, working in an integrated fashion in the context of the proposed use case, for the Spring 2007 SIW. In the following, we list the planned tasks and describe the status of the each task at the time of the writing of this paper.

4.1 Technical Kick-off

The authors met by teleconference in October 2006 following the Fall SIW to plan and coordinate development activities. Areas of responsibility were assigned to each of the participating organizations (principal points of contact are identified in parentheses): NPS (Curtis Blais) – DIS-XML code base; Simventions (Paul Gustavson) – BOM development; Boeing (Steve

Reichenthal) – simulation specification using SRML; Saab (Per Gustavsson) – MSDL scenario description and C-BML expression of plans and orders.

4.2 Scenario Development

The team worked on design of the scenario details regarding types and quantities of autonomous vehicles to be represented, what behaviors they will have and how they will be controlled (scripted or goal-driven). Initial development of an MSDL description of the scenario was completed. The team identified candidate workbenches, platforms, tools etc. to be used. A primary component will be the NPS AUV Workbench open source software providing physics-based AUV modeling and visualization of vehicle behavior and sensors in all mission phases. The 3D models are defined in the Extensible 3D Graphics (X3D) ISO standard for 3D on the Web [12]. The virtual environment facilitates control algorithm development,

control constant testing, mission generation and rehearsal, and replay of completed missions in a benign laboratory environment. The software includes automated generation of mission specifications in AVCL and supports mission scripting and vehicle-to-vehicle, vehicle-to-agent, and vehicle-to-human communications (DIS-XML). XML mission specifications can be converted into various text-based AUV command languages using XSLT. An XML-based Tactical Chat capability provides an open-source communications protocol among remote vehicles and individual operators, either in the virtual or real worlds.

4.3 BOM and C-BML Development

Work is in progress to develop supporting conceptual models and class structures (BOM) to be represented in the implementation space, which will be supported using DIS-XML. For C-BML expressions of the plans and orders to be given and executed by the autonomous vehicles, the team is mapping the AVCL to current grammar expressions for BML as described in [13], although the team is also monitoring current Joint BML project activities (employing Web services and the Joint Command, Control, and Consultation Information Exchange Data Model) for possible integration into the demonstration architecture.

4.4 Simulation Development and Integration

According to the demonstration development plan, SRML was going to be used to provide an implementation-independent expression of the simulation. However, just prior to and during the Fall 2006 SIW, questions were raised regarding intellectual property (IP) rights to the SRML specification and potential impact on future systems that may be implemented in compliance with that specification. Boeing has provided statements to SISO releasing IP rights. These will be reviewed by the SISO Standards Activity Committee (SAC) and Executive Committee for final resolution. Until resolved, the SAC has recommended suspension of SRML drafting activities.

While waiting for resolution of this issue, the team moved forward with a similar simulation specification language available as open source from the NPS Modeling, Virtual Environments, and Simulation (MOVES) Institute. NPS has developed an open source Java Application Program Interface (API) for developing discrete event simulations called Simkit [14] and an open source visual tool for developing discrete event simulations called Viskit [15]. Viskit enables developers to design simulations using event graph notation [16, 17] in a graphical user interface. The tool stores the event graph design in an XML representation, and auto-generates a Java implementation of the event graph using the Simkit API for execution of

the simulation model. It has been speculated that the Viskit XML representation of event graphs can be translated to the SRML representation (and vice versa, showing semantic equivalence) using XSLT, but no one has yet attempted to perform this transformation, to our knowledge. Work is in progress to refine BOM patterns of interplay and state machine descriptions in coordination with Viskit description of same. This is expected to yield event graph representations of autonomous vehicle behaviors similar to those currently in the NPS code base for Anti-Terrorism/Force Protection scenarios developed for the Naval Facilities Engineering Service Center. The NPS AUV Workbench is being used as a virtual environment for execution of the planned mission (as if by a live vehicle). Interactions between the Viskit simulation and the AUV Workbench use DIS-XML.

When SRML IP issues are resolved and the specification standardization process moves forward, it will become advantageous for tools such as Viskit to add capabilities to import SRML files for manipulation in the tool and to export models in SRML format for interchange with other tools/products employing the standard.

4.5 Final Integration and Demonstration

Due to the above delays, it is not yet certain that the team will successfully complete preparations to conduct a demonstration at the Spring 2007 SIW. At this stage, it may be more reasonable to target the Fall 2007 SIW for this capability. Either way, the status of ongoing development activities will be reported in the Spring 2007 SIW and the team will describe plans for follow-on efforts.

5. Integration Lessons Learned

The major objective of the previously stated demonstration discussed in section 3 and 4 is to ultimately report on the integration lessons we have experienced in this effort. At this stage, those lessons are still being gathered, but we look forward to sharing our experiences at the Spring SIW, and anticipate that those findings will be provided in an update of this paper following the Spring SIW.

6. Summary

As identified in this paper, there are many SISO standardization efforts that have been researched and developed. Each independently provides a unique capability for simulation interoperability. The true success of these standards, however, is in how well they are able to work together. The aim of this paper and planned demonstration has been to show how the

standards can work together for greater benefit than when they are employed individually.

The proposed demonstration architecture exhibits the capabilities of the BOM, C-BML, DIS-XML, MSDL, and, in lieu of SRML, a similar XML-based representation of a simulation. We invite other PDGs to consider how they can participate in continuing and future demonstration development as we look to update and evolve this effort.

To date, coordination of this effort has been challenging, particularly considering that most efforts supporting SISO are performed on a volunteer basis, but we feel the near and long-term benefits to the community will be significant if the initial effort can be completed.

Beyond this initial demonstration, we recommend that SISO consider the concept of establishing a standing demonstration test bed, perhaps as extension of the work to be demonstrated for the Spring 2007 Workshop, that can be used by Product Development Groups to demonstrate how emerging standards fit into the Big Picture; specifically how each standard can complement the other and how they collectively address major interoperability issues. We believe that this goal will greatly benefit the M&S user community, which is represented by SISO, by offering more opportunities for education and familiarization in the capabilities of emerging standards, and in providing an environment for development and testing of supporting tools, techniques, and methodologies.

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Acknowledgements

We thank the Defense Modeling and Simulation Office (DMSO) for sponsoring the BOM development effort intended to bring forth an increase in composability within the distributed simulation communities. We also express gratitude to SMART-lab² for the sponsoring of Swedish participation in simulation interoperability standardization development.

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² SMART-lab is a Swedish Defence Materiel Administration facility with an environment installed for analysis and development of the total Swedish defence.