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INVESTIGATION OF THE INTEGRATION OF SIMULATION AND NAVAL DECISION SUPPORT TOOLS:

LITERATURE REVIEW

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This report presents a literature review that was conducted to determine how widely elements of the C2SIM standard have been implemented and the extent of usability. It also presents known implementation issues and solutions. The Coalition Battle Management Language (C-BML) is used to convey taskings. The Military Scenario Description Language (MSDL) is used to capture the entities in a scenario and initialize simulations to ensure consistency between simulations and exercises. The Command and Control Systems – Simulation Systems Operation specification is meant to supersede the other two standards, but is still in development. Use of the two existing standards is complicated by the differences in their data structures, but common identifiers can be used to map messages in the two schemas to the same simulated entities. A Scripted BML server has been used to overcome differences in the implementations of the schemas as well as to distribute messages during an exercise. A number of C2 and simulation applications have been modified to read and write C-BML and MSDL documents. A number of NATO Modeling and Simulation Groups have conducted experiments using the two standards. Based on the findings of the literature review a phased approach to developing a tool for experimentation is proposed.

1 INTRODUCTION

This document was produced for the DRDC-Atlantic HF SO Task 10 – Investigation of the Integration of Simulation and Naval Decision Support Tools. This task is being done under DRDC Atlantic Human Factors Standing Offer, Task 10 Investigation of the Integration of Simulation and Naval Decision Support Tools. It was produced by CAE Inc. for the Technical Authority (TA):

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1.1 Background

The Defence Research and Development Canada (DRDC) Maritime Information Warfare (MIW) Program responds to specific guidance from the Royal Canadian Navy (RCN) to enhance command team effectiveness. This is achieved through improvements to information management techniques and the promotion of greater situational awareness (SA). The MIW Program includes projects that focus on future Naval Command and Control (C2) systems and decision support for the integration and prioritization of information within the Naval warfare domain.

DRDC is investigating the development of command planning tools that integrate with current and future combat management and command decision tools. Under projects 01DA (Next Generation Naval Command and Control Systems), 01DB (Integration of Command Decision Support), and WBE 3 (Predictive Situational Awareness), DRDC intends to demonstrate simulation based planning tools to support Naval command teams.

A fundamental requirement for these projects is the ability to assess the usefulness to command teams of various simulation-based command decision aids and that usefulness is expected to rely upon the ability to exchange data between planning tools and the combat systems.

The Simulation Interoperability Standards Organization (SISO) and North Atlantic Treaty Organization (NATO) have developed the simulation standards (Coalition Battle Management Language (C-BML) and Military Scenario Definition Language (MSDL)) to assist in this type of effort, and the standards have been implemented in a number of nations, but not recently in Canada. The two standards are currently serving as the basis of a new standard known as C2SIM.

The aim of this work package is to investigate the current status of the standards, determine their applicability to the Naval decision aid problem, create an implementation application programming interface (API), and demonstrate its use in connecting simulation based tools to a Naval command system.

1.2 Objective

The objective of this report is to present the results of the Literature Review conducted to determine the current status of the standards with regards to their maturity and the extent to which they have been implemented.

1.3 This Document

This document comprises the following sections:

Section 1 – Introduction: This section provides the background, identifies the objective, describes the high level approach, and outlines the report.

Section 2 – References: This section provides a list of the process documents related to this project.

Section 3 – Simulation Standards: This section provides an overview of the standards, their current status, and any issues associated with them.

Section 4 – Implementation of the Standards: This section provides an overview of systems that have implemented the standards.

Section 5 – Exercises: This section provides an overview of exercises that have been performed using the standards, and the findings of those exercises.

Section 6 – Conclusions and Recommendations: This section provides conclusions based on the literature review and recommendations for the next phase of the task based on the findings.

2 REFERENCES

2.1 Mandatory References

- W7707-145734 Statement of Work for Investigation of the Integration of Simulation and Naval decision Support Tools
- 5897-001 TIP Investigation of the Integration of Simulation and Naval Decision Support Tools, 08 December 2015

2.2 Guidance Documents

- [5007-001] Quality Manual, CAE document 5007-001.

3 SIMULATION STANDARDS

3.1 Overview

This section provides an overview of the standards that were studied for this report and their use.

3.2 Coalition Battle Management Language

3.2.1 Overview

The Coalition Battle Management Language (C-BML) is a standard language for expressing and exchanging plans, orders, requests, and reports across command and control (C2) systems, live, virtual and constructive (LVC) modeling and simulation (M&S) systems, and autonomous systems participating in Coalition operations. The standard describes the data model as a subset of the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM) and specifies the information exchange content and structure in the form of an eXtensible Markup Language (XML) schema [1] . The standard was developed by SISO and was validated by a number of exercises held by the NATO Modelling and Simulation Group (MSG).

The C-BML standard was developed to allow communications (data exchange) between C2 systems of different countries. It was based on the JC3IEDM, which has been superseded by the Multilateral Interoperability Programme (MIP) Information Model (MIM) [2] . JC3IEDM was ratified under NATO Standardization Agreement (STANAG) 5525. C-BML was designed to allow communications between simulation systems, as well as between Command and Control systems and simulation software.

JC3IEDM was developed with the aim of unambiguously conveying information required for planning and reporting on the operation of military organisations. It contains elements that identify troops, equipment, terrain, installations, and weather conditions. C-BML is used by C2 systems and simulations to create XML documents that may be orders, requests and reports. It defines the data structures and domain values that are used to format XML documents. The elements defined in the C-BML standard address the 5Ws of these documents: Who, What, When, Where and Why [3] [26]. It reuses some of the data structures and domain values from JC3IEDM to address the 5W topics [3].

For example, a C2 system may create an order for a simulated platoon to move to a new position to perform reconnaissance. The order defines Who (the platoon), What (move), When (the time at which the platoon should begin to move), Where (the new location), and Why (reconnaissance). The C2 system generates an XML document defining the order. This document is sent to the Computer Generated Force (CGF) that owns the platoon. The use of C-BML means that any C2 system that can produce a C-BML-formatted XML document can issue orders to any CGF that can parse a C-BML XML document.

3.2.2 Current Version

The current version of the C-BML standard is SISO-STD-011-2014 Version 1.0 (14 April 2014) [1]. C-BML was balloted in 2012 and approved as a SISO standard in 2014.

Delays in approval of the C-BML standard led to four different versions of the C-BML schema being implemented for the MSG-085 exercise by the groups that were participating in the exercise [4]. Since the standard was still developing as work on the exercise proceeded, it was determined that a method was needed to map between the different implementations. In the ramp-up to the exercise, this led to the development of the Scripted BML Server [4]. See section 4.1 Scripted BML Server for more information on the server and how it addresses the issue of multiple schema versions.

There are two dialects of C-BML. Full C-BML expresses a full implementation of JC3IEDM while C-BML-Light contains the elements most commonly used by most C2 systems and simulators [5]. C-BML-Light is based on Integrated Battle Management Language IBML, which is a collection of shared and integrated products and specifications that serve as a common foundation for the development and production of advanced C2 processes including orders, reports, and geospatial capabilities [6]. It was developed prior to MSG-048.

3.3 Military Scenario Definition Language

3.3.1 Overview

The Military Scenario Definition Language (MSDL) is an XML-based language designed to support military scenario development that provides the M&S community with a common mechanism for sharing, loading and reusing military scenarios across multiple simulation systems and exercises [1]. MSDL is used to create XML documents that define the initial state information for entities in a simulation. It provides a common mechanism for loading scenario data into the simulation systems involved in an exercise. Using a common specification allows simulations to share data, and allows the reuse of scenarios across multiple exercises [1].

In a typical exercise, an XML document formatted using MSDL is created that specifies the location and disposition of all of the simulated forces managed by each CGF [10]. This document is loaded by the CGF to initialize it prior to the exercise starting. These files may also be distributed to other software applications in the system, e.g. to the C2 systems, to populate them with information on the forces and equipment available in the simulation. These files can be reused across multiple exercises.

If an MSDL server is used in an exercise, all of the simulations may send it their initialization data in MSDL files. The server processes the files and generates one large MSDL file representing the initial state of the entities in the exercise. This file is then published to all organizations that have subscribed to the MSDL topic to ensure that all of the simulations are initialized with the same data. The MSDL server may be queried throughout the exercise by C2 systems not using the publish/subscribe service to gather initialization data or by systems joining the exercise after the MSDL data has been published to ensure that they use the same initial data [10].

MSDL files may also be used to record a snapshot of the exercise at any given point during its execution. The systems generate MSDL files that capture the current state of their forces and equipment.

3.3.2 Current Version

The current version of MSDL is SISO-STD-007-2008. It was reaffirmed 11 May 2015 [1].

3.4 C2SIM

3.4.1 Overview

In documents describing exercises using C-BML and MSDL, the combined use of these two standards is sometimes referred to as a C2SIM exercise. However, this use of the term does not represent a formal standard. There is an ongoing SISO Product Development Group (PDG) that is developing a C2SIM standard[1], but the PDG use of the term does not describe a single standard that encompasses the two existing standards. The Command and Control Systems – Simulation Systems Integration (C2SIM) [7] is a family of products being developed by SISO. The products will include SISO Standards and SISO Guidance products including:

- C2SIM-LDM – The Logical Data Model (LDM) is defined as “a core set of data elements common to most C2 and Simulation systems, combined with a standard way of adding to that core a collection of additional elements specific to a particular domain and/or context.” [7]

- C2SIM-Initialize – This standard “will supersede the MSDL v1 standard” [1]. It is an “XML message format developed with the purpose of initializing the operational environment (OE) in a wide variety of simulations and connected systems in the US-DoD and NATO-nation agencies.” [7]

- C2SIM-TaskingReporting – This standard “will supersede the C-BML v1 standard” [7]. It is an “XML message format developed with the purpose of describing task and report assertions in operational or simulation environments.” [7] The standard is being developed to maintain consistency with the “5W” principles of C-BML [2]. Some sections of the C-BML schema will be imported directly to the new standard..

- Guideline for C2SIM-Initialize Implementation – This is a guide to applying C2SIM-Initialize. [7]

- Guideline for C2SIM-TaskingReporting Implementation – This is a guide to applying C2SIM-TaskingReporting.

[1] The C2SIM PDG has also assumed responsibility for the C-BML and MSDL standards.

3.4.2 Current Version

The C2SIM standard is currently being developed by the SISO committee.

The schedule for the development of the standard is shown in Table 3-1 below [8]:

Table 3-1: Schedule

Date	Milestone
Sep 2014	C2SIM Kickoff
Dec 2014	MSDL/C-BML Convergence Agreement
Dec 2015	C2SIM-LDM Prototype Available
Jun 2016	C2SIM-Initialize and C2SIM-Tasking Reporting Prototypes Available
Dec 2016	Prototype Military Use Evaluation
Mar 2017	Drafts for Discussion
Jun 2017	Drafts for Ballot
Dec 2017	Standards and Guidelines Approval

3.4.3 Development of the Standard

The standard is being developed based on six use cases as of April 2015 [9]. The use cases are being used to define entities in the new standard. These use cases are:

- Distributed Mission Planning
  - TaskingReporting and Initialization Use Case
  - Important entities: Plan, Order, Task, 5Ws, Situation, Execution
- Call for Fire
  - TaskingReporting only
  - Important entities: Observer, Target, Tasked, Message, Action

- Simware[2] C2SIM Implementation
  - TaskingReporting only
  - Need to be able to extend Simware capabilities
- Guideline on Scenario Development (GSD) for C2SIM
  - TaskingReporting and Initialization Use Case
  - C2SIM to be aligned with GSD
  - Important entities: Unit, Geography, Rules of Engagement
- C2SIM interoperation with the National Information Exchange Model (NIEM)[3]
  - TaskingReporting and Initialization Use Case
- Simulation based joint collective training
  - TaskingReporting and Initialization Use Case
  - Important entities: Plans, Orders, Tasks, Reports

3.5 Issues

MSDL and C-BML have been used in several exercises within NATO MSG activities. During these exercises a number of issues have been identified related to problems integrating the two standards. These issues are discussed below.

3.5.1 Differences between the Standards

MSDL and C-BML were developed independently from each other, based on different specifications. As a result their XML definitions have different data structures [10] and use different symbology [11].

MSDL uses the MIL-STD-2525B/MIL-STD-2525C standard [11] to represent entities. MSDL cannot be directly mapped to the JC3IEDM, and does not have the ability to represent

[2] Simware is a platform for integration of Live, Virtual and Constructive Simulation (LVC Simulation). It is the basis for the Layered Simulation Architecture, which is a nominating standard at SISO.

[3] The NIEM is an approach to exchanging information. It defines models for data exchange between multiple government agencies. It covers a range of public health and safety information, including Intelligence, Immigration, and Biometrics. The models are defined using XML schema [37]. The C2SIM PDG has indicated that the C2SIM will be compliant with NIEM [9].

meteorological domain values [12]. C-BML uses the NATO standard APP6a Symbology [11]. It re-uses the category codes/domain values from the JC3IEDM as part of its definition [3]].

Both specifications have structures to represent graphics, including organization boundaries, obstacles, movement routes and corridors, and no-fire areas. The specifications can represent facilities and significant buildings such as hospitals, government or religious centres. Both specifications can also represent areas where hostile or terrorist actions have taken place such as an improvised explosive device (IED) attack [10].

The C-BML specification provides a full definition of all information required for tasking. It has structures and type enumerations to identify the personnel or organization that will perform the task, the actions to be carried out, the location where the task will be executed, the time when the action will be performed, and the control measures to be employed. It was designed to allow the commander to specify all of the information to answer the 5Ws of a task [10]. It is used to create both initial orders for units and subsequent orders which may be issued during the exercise [10]. The MSDL specification does not define the same set of structures. It has a placeholder for an initial tasking for specified units, but the tasking data structures are not developed in detail. MSDL also has no provision for the continuing flow of orders or reports beyond an initial tasking [10].

MSDL defines data structures for defining a Task Organization, also called an Order of Battle (ORBAT). C-BML can be used to identify a specific unit or organization, but it cannot be used to define an ORBAT [10]. C-BML does have limited support for defining organizations: it can be used to tailor organization structures if different groupings of units are required to satisfy the needs of a particular set of tasks. [31] Changes to an operation may be issued using a Fragmentary Order (FRAGO) [10].

MSDL has no full Order or Report definition. It only provides the ability to describe general categories for units and type strings for equipment, e.g. “main battle tank” for units, “M1A1 Abrams” for equipment type. During coalition exercises a wider range of unit and equipment types will be deployed [10].

3.5.2 Integration Strategies

A number of strategies have been developed to overcome the incompatibilities between the two standards.

Objects defined by MSDL have to be accessible for use when creating tasks in C-BML documents. Units introduced by MSDL must therefore be available from the database referenced by C2 systems. This is necessary so that the units can be used as either the issuers or recipients of C-BML orders [11]. The system must also understand the relationship between the units, including which units are subunits of the tasking unit so that they can be presented as possible recipients of the tasks [11].

MSDL and C-BML have different data structures, but mapping between the two is possible using the unique identifiers assigned to units and equipment [10]. The unique identifiers are assigned to units when they are created using MSDL documents, and referenced in the Orders and Reports issued using C-BML documents.

MSDL has extensibility provisions through the use of the XML schema “any” construct. The “any” construct permits an MSDL XML document to contain arbitrary XML structures from other schemas [12]. This allows the meteorological and battlespace domain values defined in the JC3IEDM schema to be included in an MSDL document [12]. MSDL is not directly mappable to JC3IEDM [12], but the “any” compositor allows fragments of JC3IEDM XML to be included in an MSDL document, including meteorological and oceanographic (METOC) information.

The “any” element can also be used to add a C-BML snippet to an MSDL document [12]. If units which are initialized by MSDL have to receive an order during initialization, the order is transformed and inserted under a specific order tag within the MSDL schema [11]. If an order deals with a unit that was not previously initialized, the XML order is enriched with a specific initialization tag within the C-BML schema to identify it as such [11].

For the MSG exercise designated MSG-085 the Reference design pattern was used for incorporating referenced files that contained additional detail and/or simulation specific information not included within the MSDL file. The importing simulation could then use the referenced data to augment the information in an MSDL file [13]. This allowed local extension files to be independently defined, used, matured and shared between simulation and Mission Command federations when appropriate [13]. MSDL Scenario files could also reference C-BML tasking documents. Similarly, C-BML Orders and Reports could refer to the Scenario File [13] [14].

As a result of these issues, a recommendation was made to develop a new standard that would supersede the C-BML and MSDL standards. The new standard should have a common data model and define schemas that could address both the tasking of entities (the role currently filled by C-BML) and initializing and capturing the state of the scenario (MSDL). The C2SIM standard is being developed to address these issues [7].

4 IMPLEMENTATION OF THE STANDARDS

As part of the MSG exercises that were held to validate simulation interoperability, a number of software applications were created or updated to work with one or more of the standards. This section describes the work done on these systems.

4.1 Scripted BML Server

The Command, Control, Communications, Computing and Intelligence (C4I) Center of Excellence at George Mason University (GMU) developed components for use with C-BML. They created a web service that serves as a repository for C-BML messages, including Orders, Reports and Requests. The messages are packaged as XML documents and stored in a relational database [15]. The default database is based on the JC3IEDM specification, but the database may be altered using scripts. The Service Manager uses a subscriber, push/pull mechanism for managing data. Orders and Reports are pushed to the database [16]. Clients subscribe to notification of data pushes. Alternately, Clients can pull BML Reports from the database instead of subscribing to notifications of data pushes.

To work with the web service GMU developed the Scripted BML Server (SBML), which is a form of middleware that is intended to allow rapid development of web services as BML evolves [15]. The SBML Server allows the database to be tailored using scripts rather than reprogramming. This makes the database more robust and facilitates faster development when changes to the protocol are needed. This was required for MSG-085, since the C-BML standard had not been finalized, which resulted in four different implementations of the C-BML standard [4]. As the objectives for the exercise evolved the C-BML implementations evolved as well during the time leading up to the exercise. Using a script to define mapping into the database facilitated adjusting to changes in the schema, and made it easier to debug the resulting database and Service Manager [16] [17] [18].

The SBML Server provides a Representational State Transfer (RESTful) interface as well as a Simple Object Access Protocol (SOAP) interface. The RESTful interface was found to provide a 15% improvement in performance versus the SOAP-based server during trials [15]. The RESTful server allows clients written in programming languages other than Java to create subscriptions to notifications of new data as long as they have access to a Hypertext Transfer Protocol (HTTP) library.

The SBML Server also integrates MSDL documents from all participants. It can then generate MSDL reports requested by exercise participants. A master controller publishes an updated MSDL document to subscribers, or non-subscribing participants can query and retrieve information.

4.1.1 WISE optimization

For the MSG-085 exercise the SBML Server was re-implemented using the Saab Widely Integrated System Environment (WISE) infrastructure. The WISE infrastructure provides a high performance and graphical editor which enables configuring and adding new schema faster than the previous approach [13]. It was determined that in an exercise, the server may need to handle one hundred XML documents being parsed and republished per second, which was a higher rate of messaging than could be handled by the previous SBML Server implementation [13].

For the exercise, multi-server operations were implemented between the existing Fraunhofer-FKIE server and the new WISE-SBML server [33]. This setup, using XML and Web Services (WS) technology, is consistent with the Network Centric Operations strategy adopted by NATO [13]. The multi-server architecture is well suited to operation in a cloud [13].

Each server implemented a back-to-back (B2B) client. The servers had a C-BML/MSDL Web service for each schema version [19]. To prevent forwarding loops, each server added its address to the message header [13].

The WISE-based WS defines a Representational State Transfer (REST) interface to accept XML inputs. It publishes one or more XML documents through a Streaming Text Oriented Messaging Protocol (STOMP) interface [19] [20]. The STOMP interface can be configured to allow filtering of messages by Topic [33]. This filtering reduces the amount of traffic being sent to subscribers. A WISE driver is required for each major information flow. The driver can be programmed in conjunction with the specifics of the application based on the XML documents. Separate handling is required for both the REST interface and the STOMP interface for publication [19].

WISE appears to SBML as an in-memory, non-persistent database [19]. It maintains copies of the messages sent to it. It also maintains a log of messages received and forwarded, so that the state of the server at any point in the exercise can be re-created by replaying the log. WISE provides a graphical editor to configure information mappings among various internal databases [19]. Elements must be maintained as changes occur to schema.

In addition to handling C-BML messages, the WISE SBML server has an MSDL server. It aggregates MSDL reports from all of the systems in a simulation [14]. It can then produce a report based on all of the received MSDL reports.

For the MSG-085 exercise the 9LandBMS WISE interface was adapted for C-BML/MSDL [19]. See section 4.11 9LandBMS (Battle Management System) for more information

The client software for the WISE Server and the replay client are available as open source [13]. Performance and stability issues found during MSG-085 were fixed before the International Training and Education Community (ITEC) demo in May 2014.

4.2 CBMS

CBMS is a collection of composable web services that can work together to support a particular federation [21]. It is implemented as a Service Oriented Architecture (SOA) with an interrupt mechanism, a filtering mechanism and a data distribution mechanism. It can support the validation, storage, search and exchange of XML-based languages, including C-BML and

MSDL. It is accessible via any commercially available web browser. It uses the Atmosphere framework to open persistent connections to clients [22].

A High Level Architecture (HLA) to CBMS mediator was created to allow exchange of data between the XML schemas used with CBMS and the HLA classes specified by a FOM. Data exchange is bi-directional [21].

The CBMS Server uses an XML Database. C-BML messages that are posted to the server are saved in the database. Messages with the XML document as the payload can be created and sent to all interested subscribers [22].

CBMS supports Namespaces, semantic validation, schema validation, filtering of data for general queries and subscription Topics, and Logging. It has a SOAP/REST interface and can be accessed using any commercial web technology. It was developed as Government open source for the Joint Coalition Warfighting (JCW) organization. Functions of JCW were taken over by US Joint Staff J7. They should be contacted for more information about the server [22].

4.3 Command and Control Infrastructure Virtual Machine (C2IVM)

Command and Control Infrastructure Virtual Machine (C2IVM) is an interoperability solution that uses SOA to support the exchange of tactical and operational messages between operational systems in a Joint Coalition environment. It supports the exchange of data between systems that utilize CBMS and HLA-compliant systems [21].

4.4 Distributed Server Considerations

There are two types of C2SIM servers that have been used as part of coalition exercises. Document servers transfer complete XML input documents intact to their output channels. They are high performance, but cannot handle multiple schemas [20]. Parsing servers, such as the WISE-SBML server, read the document and break it into individual data elements that are used to assemble output messages. These provide better support for evolving C2SIM implementations [20].

Experimentation documented in [20] concluded that the use of a star server configuration provided better performance than a mesh. A forwarding parameter is used to prevent loops by storing unique identifiers for all servers that have already seen the message [20]. The experiment used a simplified star configuration with three servers. They reproduced the results of the MSG-085 Final Demonstration with three servers in Fairfax (Virginia), Orlando (Florida), and Germany. The WISE-SBML server log showed the system of servers was operating at peak capacity of 150 reports per second [20].

The conclusion of the authors of the paper was that C2SIM has great promise, but as of the presentation of the paper at the 2015 Fall SISO Simulation Interoperability Workshop, has yet to see significant operational use [20].

4.5 BML C2 GUI

Another initiative from GMU is the BML C2 Graphic User Interface (GUI). It is patterned after the Fraunhofer-FKIE Command and Control Lexical Grammar (C2LG) GUI [23]. It reads and writes Orders and Reports. It can auto-configure to any BML schema. It provides a map/image display using MIL-STD-2525B symbols. The map can be used to select a geolocation for use in a BML file. It provides an interface for viewing and modifying the BML-XML file [23]. The interface is open source and is available from GMU [23].

4.6 VR Forces

VR-Forces by MÄK is a computer generated forces (CGF) application that has been used by the MSG group [24]. It supports the High Level Architecture (HLA) and Distributed Interactive Simulation (DIS) standards [23]. The group at GMU created an open-source capability to integrate MSDL/C-BML with VR-Forces. It was created with a Java bridging application. The Java application processes the C-BML and MSDL input. Units defined in Orders are created in VR-Forces. The move command was implemented using this interface [23]. As of Fall 2012, when [23] was presented, the ability to generate a Report had not yet been implemented.

4.7 JSAF

Joint Semi-Automated Forces (JSAF) is an entity level constructive simulation system developed by the US Department of Defense (DoD). It is an example of a Semi-automated Forces (SAF) application which is used for training as well as experimentation. It was used at MSG-085 [10].

JSAF was enhanced to add a two-way MSDL interface[4] [10]. MSDL was used to initialize the system and to perform check-pointing during the exercises.

JSAF does not provide an API for the creation and tasking of entities. An HLA-CBMS Mediator Service was developed to parse data from HLA objects and generate a CBML location report. This report is routed to the CBMS Service. The Command and Control Infrastructure Virtual Machine (C2IVM) routes JSAF RTI entity location information to the HLA-CBMS Mediator Services. [21]

JSAF also has a C-BML interface. The C-BML interface declares newly discovered units found by JSAF sensor models during the exercise. It publishes MSDL snippets to “support the representation of perceived truth in the C-BML system” [10].

Some issues were encountered during modifications that were made to the JSAF software to work with MSDL. The process of mapping MSDL units and equipment types from MIL-STD-2525C Symbol ID (SID) codes into units and entities within JSAF is an issue. The mappings had to be pre-defined between SID codes and known JSAF unit and entity compositions [10] for use during the exercise.

[4] The MSG-085 documents do not list the version of JSAF used in the exercise.

JSAF can create multi-level echelons, but the JSAF tasking process requires simpler, branch-end echelons, such as companies and platoons. This is a problem when generating MSDL documents. In MSDL sub-units inherit traits from their parents [10], so not including the parent units in the MSDL document limits the amount of information available in the MSDL document.

Different applications need to be able to ingest their own sub-sets of MSDL, which requires some degree of MSDL post-processing [10].

MSDL supports multiple force/side values. JSAF only supports four values – Friendly, Hostile, Neutral and Unknown [10]. Thus there is a risk of loss of data when importing an MSDL file into JSAF.

4.8 ICC/JADOCS

The NATO Integrated Command and Control system (ICC) and the Joint Automated Deep Operation Coordination System (JADOCS) are C2 applications used in coalition exercises, including MSG-085 [10]. Neither system could natively process C-BML or MSDL. Neither system uses a JC3IEDM database, which increases the complexity of mapping data to a C-BML report [10].

With the use of existing translator applications, ICC and JADOCS were used to display C-BML reports. Air Tasking Orders (ATOs) and Airspace Control Orders (ACOs) that were prepared in ICC were used to generate C-BML air tasks [10]. The ATO and ACO databases can be interrogated to populate C-BML orders. These orders are then published through the SBML Server.

MSDL Task Organizations (TaskOrgs) can be translated into the JADOCS Friendly Order of Battle database and vice versa [10].

4.9 NORTac

The Norwegian Tactical Command and Control Information System (NORTac-C2IS) is a C2 gateway that provides C-BML capabilities [10]. It uses a JC3IEDM compliant database. The Forsvarets Forskningsinstitutt[5] (FFI) C2-gateway provides C-BML capabilities. It exchanges C-BML documents via a SBML Server, and can extract orders and insert C-BML reports to the NORTac database. Mapping from the JC3IEDM type-structure to MSDL compliant symbol ID was complicated [10].

For the 2011 demonstration documented in [10] the FFI C2-gateway was extended with an MSDL export capability. It uses overlays to organize data internally. All data on a given overlay is exported as a single MSDL document. This interface was used to initialize JSAF with the Norwegian units [10]. As of the time of [10] only the MSDL sections forces/sides, units and equipment were supported by the gateway.

[5] The FFI is the Norwegian Defence Research Establishment.

Because the NORTac database is JC3IEDM compliant, mapping from the type structure to MSDL symbol IDs was partly implemented by using existing NORTac-C2IS mapping files and partly by using mapping rules.

4.10 OneSAF

OneSAF is an entity-level simulation developed by the US Army Modeling and Simulation Office. A number of enhancements were made to support an integrated MSDL and C-BML capability. As of Version 5.1.1 it fully complies with the MSDL standard while allowing for local extensions [10]. As of the experiment described in [10] it supports a limited set of the Full C-BML data elements and the Light C-BML data elements. Orders such as move and attack can be imported and posted to the OneSAF Mission Editor as orders to OneSAF units and/or platforms [10]. It exchanges MSDL and C-BML documents with the SBML Server [10].

4.11 9LandBMS (Battle Management System)

The 9LandBMS (Battle Management System) is an operational C2 system from Saab that supports C2 operations at all levels of echelons [39]. One of its core functions is to produce orders with a structure similar to the grammar used in C-BML [25]. It was used at NATO MSG-085.

9LandBMS and OneSAF were demonstrated interoperating with JADOCS and the JSAF system by using the WISE SBML server. JADOCS and JSAF were using the IBML09 schema from MSG-048, which is semantically consistent with C-BML but different syntactically [25].

4.12 BattleView

BattleView is the Canadian Army's C2 platform. A BML-to-BattleView gateway was prepared for Phase 3 of C-BML. The exercise validated the BML paradigm by interoperation of multiple C2 and simulation systems [26]. It converted BML Orders and Reports into the Canadian Forces Operational Database (ODB) [26]. Orders from BattleView were sent to a simulated Unmanned Aerial Vehicle (UAV) and executed with no human intervention.

4.13 HLA-FOM

For NATO MSG-106 two Federation Object Models (FOMs) were developed based on the High Level Architecture (HLA) – Evolved (HLA-E) standard, which supports modular FOMs. The high level FOM relates to C-BML functionality and defines interactions for orders, reports and requests [27]. The low level FOM encapsulates direct control of a simulated entity or unit with interactions such as “change speed” or “follow unit”. These things are not found in high-level orders [27].

This exercise highlighted the need to include federation execution and control capabilities in messages exchanged by simulations. These concepts are not supported in the SISO C-BML specification [27].

4.14 JChat

JChat is a chat service that allows the exchange of text messages. At MSG-085 a review was made of the use of C-BML to populate Openfire JChat. However, C-BML has a lot of extra text in the form of XML tags. It is not human-readable in a text-based interface [27]. C-BML messages are better displayed in an appropriate C2 interface, for example graphically on a map display, especially position reports. A C-BML subscription server was established to subscribe only to TaskStatus reports, which were sent to JChat data stream after removing the XML tags [27].

4.15 SICF

The Forces Command Information System, or le Systèm d'Information pour le Commandement des Forces (SICF) is a French C2 system developed by Thales Communications. In the experiment discussed in [11] it was enhanced to formulate MSDL and BML expressions within orders. The expressions can be automatically transformed into XML documents. Orders can be issued to units whether or not they were initialized using MSDL. If the unit was not initialized with an MSDL document a specific initialization tag is added to the C-BML document [11].

4.16 German Maritime Federation Object Model and SISO RPR FOM

Work was done for the NATO-MSG-106 exercise looking at extensions to the Real-time Platform Reference (RPR) FOM related to NATO simulation issues [28]. The German Maritime Federation Object Model (GMF) was presented at the SISO Simulation Interoperability Workshop Spring 2012. The GMF was developed for HLA 1516. The main input to this exercise was the German Navy Maritime Task List. The results of this exercise included recommendations to modify the RPR FOM. The recommendations were included in the MSG-106 final report [28]. One observation was that there is no counterpart in the RPR FOM for the METOC module [28].

4.17 VBS3

Virtual Battlespace 3 (VBS3) is a simulation system developed by Bohemia Interactive for training and mission rehearsal. VBS3 ships with VBS Gateway, which is a gateway application for VBS3 which provides interoperability using HLA or DIS protocols. [29] . Previous versions of VBS used LVC Game from Calytrix Technologies to provide HLA/DIS interoperability. LVC Game is still included with VBS3 [30].

VBSFusion is an add-on for VBS3 which provides a C++ interface that allows the modification of a VBS3 simulation and the objects within it [31]. It could be used to create a C-BML interface to VBS3.

An earlier version, VBS2, was to be integrated as part of the UK test-bed developed to support the CAGE experiments [32]. Inquiries should be made to determine whether this integration was completed.

5 VALIDATION ACTIVITIES

This section discusses some of the major activities that focussed on the use of the standards.

5.1 MSG-048

The NATO MSG-048 conducted a Technical Activity from 2006 to 2009. The final experiment was conducted in November 2009. The purpose of the TA was to assess the concept of Coalition Battle Management Language (C-BML).The MSG-048 TA included participation from Canada, Denmark, France, Germany, Great Britain, NC3A, Netherlands, Norway, Spain, Turkey and the United States [33].

This exercise was held prior to the finalization of the C-BML standard by the SISO. The findings from the exercise were provided to the PDG. Among the findings:

- The system performance for handling messages needs to be improved. Simulation reporting rates could overload C2 systems, and a mechanism for bundling reports was useful to reduce the message payload overhead.
- A C-BML management facility is useful for initialization and synchronization of the simulations.
- The variety of possible architectures for an exercise leads to varying needs for the C-BML, including the use of publish and subscribe, and subscription/filtering mechanisms.
- While C-BML could be implemented over any data model, there are advantages to using the JC3IEDM as the lower-level representation database. JC3IEDM provides C-BML with a well-developed vocabulary, and some national C2IS are based on JC3IEDM, so interfacing them to a C-BML system that has been designed to be compliant with JC3IEDM reduces the implementation effort.

Some of the recommendations from the experiment:

- C-BML should be developed to support air, e.g. ATO/ACO, and joint air-land operations, e.g. close air support. Similarly there should be investigations for extending C-BML to support maritime operations.
- C-BML should be based on C2 standards such as the JC3IEDM for acceptance by the C2 community.
- SISO MSDL should be used and evaluated as a means for initialization of simulations in the context of the MSG-085 experimentation programme.

5.2 MSG-085

5.2.1 Overview

MSG-085 built upon work done in MSG-048. The MSG-085 TA addressed problem areas and obstacles highlighted in MSG-048. It provided guidance and input for finalization of the C-BML standard and its alignment with MSDL [24]. It started January 2010 and ended January 2014. The final exercise was held at Fort Leavenworth, Kansas, 12 December 2013.

Some of the high level objectives included:

- Define the scope, and operational and technical requirements for C-BML and MSDL;
- Establish a set of reference expressions based on NATO operational procedures;
- Assess and leverage available C-BML implementations;
- Address C2 systems and simulation initialization requirements; and
- Demonstrate and communicate the operational relevance and benefits of C-BML for improving the efficiency of military operations.

5.2.2 C-BML and the Maritime Domain

One of the activities during MSG-085 was a Maritime Operations Common Interest Group (CIG). The maritime CIG evaluated the applicability of the SISO C-BML Draft Specification to maritime operations, focussed on parts of the Operational General Matter (OPGEN), and Operational Tasking Anti-Surface Warfare (OPTASK ASUW). Example orders were mapped to the SISO C-BML Draft Full Schema [24].

This exercise demonstrated that the main concepts of maritime operations could be captured in C-BML. However, it would be necessary to introduce additional attributes and domain values. This is trivial in the case of extending existing enumerations [34].

Use of Scripted BML facilitated integration, as it translated between the four different implementations of C-BML that arose out of MSG-048 due to the delays in approving the C-BML standard [4]. The setup worked with minimal integration effort [4].

5.2.3 Lessons Learned

The exercise proved the concept that C2SIM in the form of MSDL and C-BML is ready to be tested in real coalition operations [4]. The exercise concluded that the compatibility and scope of MSDL and C-BML should be expanded. Among the lessons identified was that the MSDL/C-BML specifications are sufficient for basic operations of manoeuvre warfare, but insufficient to meet the broader need of other military operations and support functions [24]

While the MSDL and C-BML specifications can be made to function together, they were not designed for this. The final report [24] calls for the creation of a unified C2SIM standard. It also identifies that a single universal C2SIM standard is not viable. It recommends that a data interoperability approach that defines an extendable common core may be preferable [24].

There is a need to work simultaneously with different versions of the interoperation standards [24]. This problem arose because the C-BML standard was not finalized in time for it to be used as a reference for all of the systems that were being augmented to use C-BML for the exercise. The federation design must account for inherent differences in time management mechanisms between simulation and C2 systems [24].

Among the results was a prototype engineering process to develop and maintain a unified C2SIM Scenario Initialization and Execution (SINEX) model [35]. SINEX provides modularity compared to typical monolithic MSDL/C-BML approaches. It uses the MIP modular sub-view approach that allows the use of a model with a smaller footprint than one that fully supports one of the existing standards [35] [24]. C2SIM interoperation must bridge simulation standards (HLA, DIS) to C2 standards (ADatP-3, Link 16, JC3IEDM).

One recommendation of the MSG-085 report was to operationalise C2SIM in its current form[6] as of the writing of [24]. National C2SIM interoperability products that implement the current C-BML and MSDL standards should be integrated and tested, and then transferred to the operational community. This would be an important step in raising the Technical Readiness Level (TRL).

5.3 MSG-141

5.3.1 Overview

MSG-141 was a Research and Technology Organization (RTO) Lecture Series delivered in Virginia USA, Farnborough UK, and Paris, France. It started January 2015 and will end December 2016. It is meant to address the combined use of C-BML and MSDL. It is expected to receive feedback on the operational utility of C-BML and MSDL and additional issues that need to be addressed to promote the use of C-BML and MSDL by industry [36].

5.3.2 Lessons Learned

It was determined that new, harmonized versions of MSDL and C-BML standards are required for effective C2SIM interoperation [64]. While the standards are sufficient for basic operations of manoeuvre warfare, they are insufficient to meet the broader need of other military operations and support functions [37].

[6] In this case, C2SIM in its “current form” refers to the use of C-BML and MSDL.

5.4 CAGE Testbed and CAGE IIIb

The Technical Cooperation Panel (TTCP) nations[7] used C-BML in the Coalition Attack Guidance Experiment (CAGE). The goals of CAGE are to develop and recommend techniques to deliver effective coalition Network Centric Warfare (NCW). These results are to be validated by appropriate experimental design and comparison of simulation and constructive modelling. CAGE I was conducted in Canada in May 2010 and all activities were co-located. All other experiments were conducted at distributed sites. CAGE II was held in 2012. CAGE IIIa was held in October 2013 and included JSAF. CAGE IIIb was held in January 2015.

To support the experiments a C2-Simulation experimentation test-bed was developed in the United Kingdom. The test-bed is persistent, agile, distributed, and scalable [16]. The test-bed includes messaging middleware to support MSDL and C-BML exchange, data logging and replay and analysis tools [32].

For CAGE IIIb C-BML software generated message formats in OTH-Gold, NATO Friend or Foe Identification (NFFI) and UK-specific messages. Messages were sent to the Canadian system, the Global C2 System-Joint (GCCS-J). Canada was responsible for preparing ACOs and daily ATOs.

One of the conclusions of the CAGE IIIb exercise was that C-BML and MSDL need extension to be of greater benefit both in in the air and maritime domains [32]. These recommended extensions were to be provided to the SISO C2SIM PDG for incorporation into the new data models.

[7] The TTCP nations: Australia, Canada, New Zealand, United Kingdom, United States of America

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The goals of the literature study were to determine the extent to which the SISO simulation interoperability standards C-BML and MSDL have been implemented, and identify issues with their implementation. The findings of the study are that support for the standards has been added to a number of existing C2 and simulation systems. These systems were extended in support of experiments that were conducted to determine the usability of the standards. To date the systems have not been extensively used in operational situations.

A number of implementation issues have been identified. The two standards are not natively compatible, and a number of strategies have been developed to overcome these issues. These strategies use existing features of the standards such as the use of unique identifiers to map references to the entities in documents created with the different standards, and the inclusion of snippets of other schemas within MSDL files.

This incompatibility between the two standards has led to the formation of a SISO PDG that is working on developing the new C2SIM standard that will supersede the C-BML and MSDL standards. While the resulting standard will presumably have a data model that is similar to the data models of the two current standards, the final XML schema will have to be different than either of the two current standards. To ensure minimal re-work, any work done to add implementations of the C-BML or MSDL standards should be done in such a way as to minimize rework when the new standard is available.

The standards were developed based on existing predecessor standards that were developed for Army use. As a result some extension is required to C-BML and MSDL in order for the standards to fully support maritime operations.

Because the standards were finalized after some of the experiments began, a number of different variations of C-BML were implemented. This required the development of strategies to translate between the different variants. One of these strategies is the use of the SBMLServer, which is capable of supporting custom interfaces to each system with which it communicates. The SBMLServer acts as a central message dispatcher, receiving orders from C2 systems and publishing them to simulation systems, and receiving reports from simulation systems and publishing them to C2 systems. This view of SBMLServer as the communications hub of a simulation exercise is shown in Figure 6-1 below.

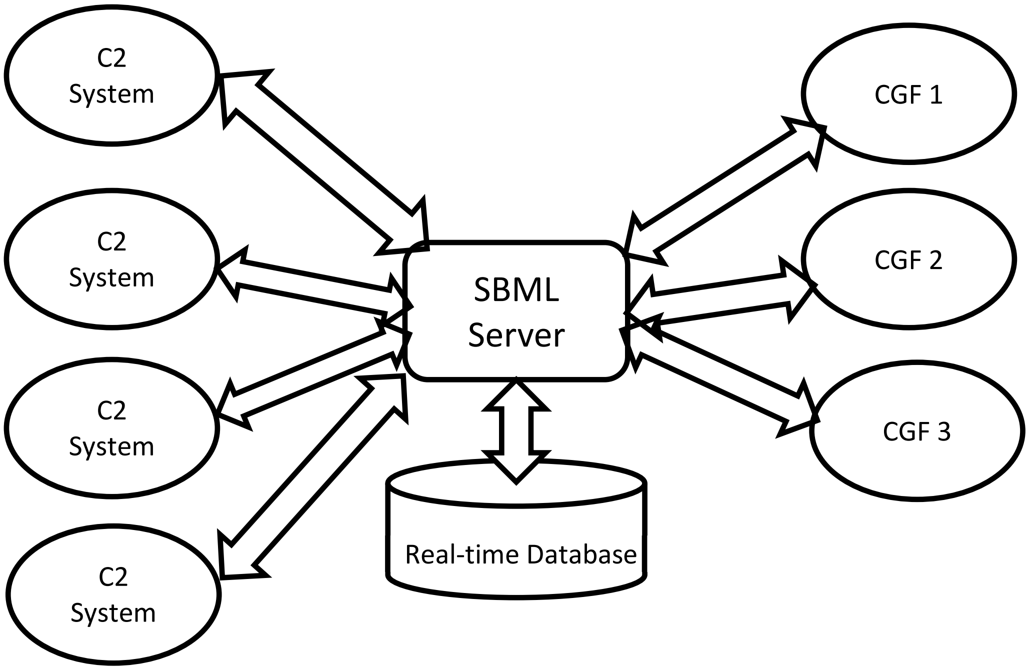

Figure 6-1: SBMLServer as Hub

6.2 Recommendations

One of the goals of the literature study is to make recommendations for the implementation of an Application Programming Interface (API) that can connect simulation based tools to a naval command system. The SBMLServer has been used in this capacity in a number of exercises. However, its use has been mostly focussed on Army and some Air resources. Maritime scenarios have only been considered as part of paper exercises, such as the one at MSG-085, and only a small set of use cases were explored. The systems that have been modified to add C-BML and MSDL interfaces are also focussed on Army and Air resources.

It is recommended that the implementation task focus on issues related to the use of C/BML and MSDL in maritime scenarios. To do this, it is recommended that a light-weight C2 application be developed with minimal overhead. This application would be developed focussing on the mapping and subscription functions required to work with other systems by use of the standards. The application itself would be a Graphical User Interface (GUI) that uses external libraries that implement all of the behaviour of the application. The features of the software are displayed in Figure 6-2 below and discussed in the following sections.

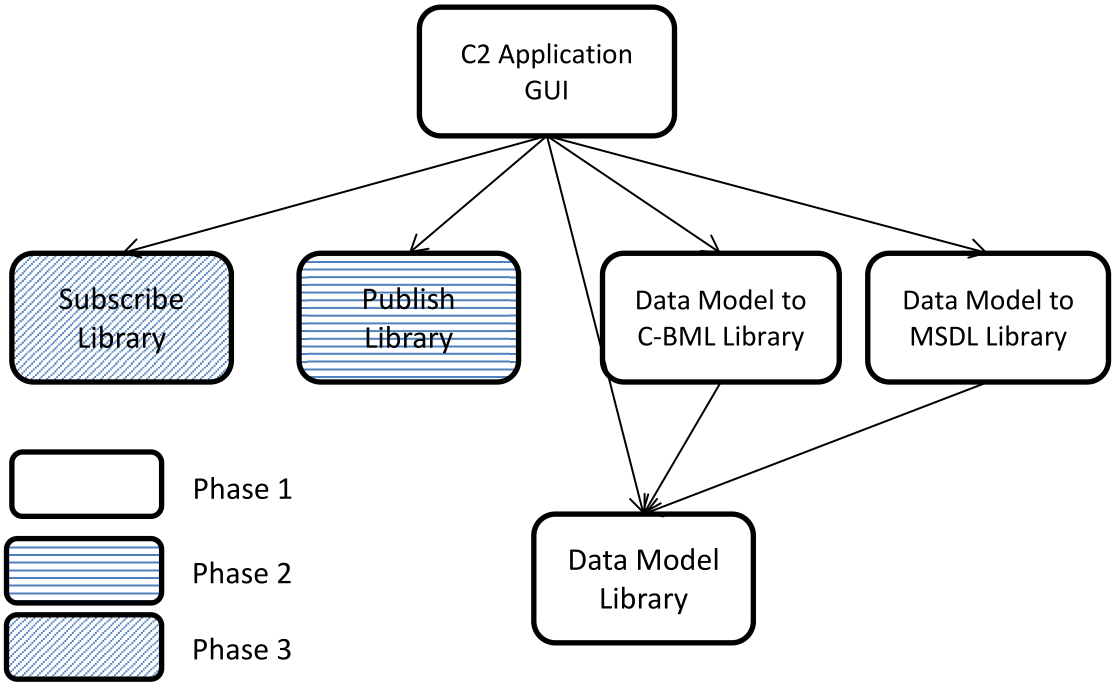

Figure 6-2: Proposed C2 Application

6.2.1 Phase 1 – Data Model Mapping and C2 Application Development

An area of possible research is to identify a set of use cases related to Maritime resources and attempt to use C-BML and MSDL to generate the appropriate messages for the use cases. This would require the following activities:

1. Identify the minimum data model required to support the scenarios. Alternately a full maritime data model could be defined, but reducing the effort on this task will allow more time to be spent on other tasks.

2. Implement the data model in code.

3. Create mappings required to create C-BML and MSDL documents from the data model. The C-BML documents generated should be orders and requests.

4. Create mappings required to read C-BML and MSDL documents and update its internal data model. The C2 application should parse C-BML reports.

5. Define a minimal C2 application that can load the data model and generate C-BML or MSDL documents on command. This may be as simple as a window with buttons to push to generate the desired documents. The interface should also provide a display to indicate the state of its internal data model implementation.

The code produced for items 2, 3, and 4 could be factored into separate libraries that could be used going forward to implement a more complete maritime data model.

6.2.2 Integration with SBMLServer

As a proof of concept the C2 application could be interfaced with the SBMLServer. The C2 application could publish orders and requests. Being able to communicate with the SBMLServer would allow the identification of issues related to participating in a larger synthetic environment.

The SBMLServer has the ability to playback a sequence of messages received, which allows the server state to be reproduced at any given point in time. This predictability would facilitate development of the subscribe capability of the C2 application.

The proposed architecture is shown in Figure 6-3 below.

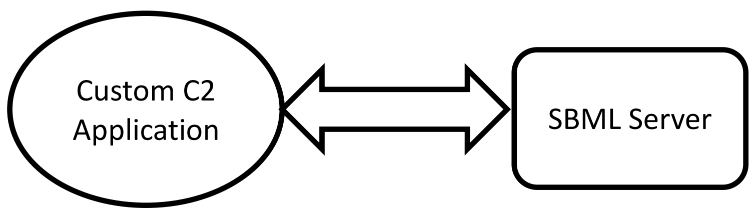

Figure 6-3: Proposed Integration with SBML

The WISE driver software is written in C++ and is available as open source [13].

6.2.3 Phase 3

Once the C2 application has the ability to publish messages to the SBMLServer, it could be used to communicate with a CGF or SAF system. The simulation system would be integrated with the SBMLServer. Preferably the simulation would be one that already has an existing C-BML/MSDL interface that could be extended or adapted as required. For example, if it is necessary to have custom XML snippets in the MSDL documents, the existing interface may need to be modified to be able to parse the information in that custom snippet.

As part of this effort the C2 application should be extended to subscribe to the SBMLServer to receive reports. If the selected simulation cannot already respond to requests it should be modified to generate reports when it receives requests. This would allow the identification of issues related to subscribing to messages from the SBMLServer.

The proposed architecture is shown in Figure 6-4 below.

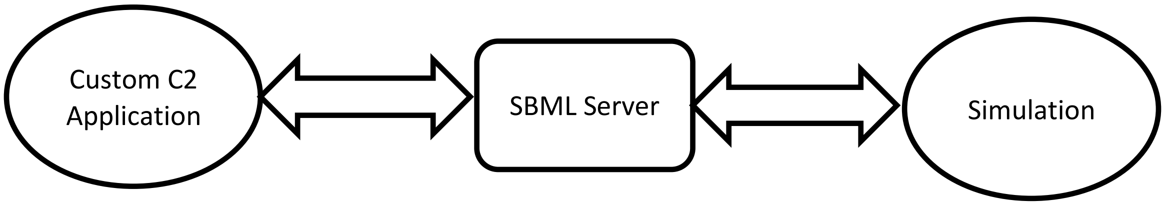

Figure 6-4: Proposed Integration with Simulation

This can be done as a separate exercise from developing the C2 application. One reason for this approach is so that development of the C2 application can proceed while the CGF is being procured. Recommended CGFs in order of preference are:

- VBS3 with VBSFusion. A C-BML interface for the previous version, VBS2, was to be developed as part of extending the test-bed developed for the CAGE IIIb exercise [32]. If possible this interface should be procured from the UK and integrated with the SBML Server. Note: Inquiries should be made as to the details of the C-BML interface capabilities to determine whether the interface serves as a good base for development. One reason use of VBS3 is recommended is that DND/DRDC has a gold license for VBS, and DRDC-Atlantic has experience in VBS.
- JSAF[8] with MSDL and C-BML interfaces.
- OneSAF with MSDL and C-BML interfaces.

6.3 Recommended Reading

This document provides a high-level overview of the status of C2SIM development. A number of papers were reviewed during is preparation. For a more in-depth overview of the topics discussed here, the following three sources are recommended for review:

1. The SISO C2SIM web-page [7] provides an overview of the work being done to unify the C-BML and MSDL standards. It has links to the status of these standards, the support documents, and the status of the Product Development Group working on the new C2SIM standard.
2. STO-TR-MSG-085 - Standardisation for C2-Simulation Interoperation [24]. This is the final report from the MSG-085 exercise. Specifically recommended are
    a. Chapter 2 Overview, which provides the background and an overview of the activities that were undertaken at the exercise,
    b. Chapter 6 Lessons Identified and Lessons Learned; and

[8] Another reason for recommending VBS3 before the SAF applications is that the SAF applications may come with export and other restrictions, which would complicate the logistics of using them.

   c. Chapter 7 Conclusions and Recommendations.

3. “Using C-BML in a persistent Coalition C2-Simulation Experimentation Environment” [32] provides an overview of research done since MSG-085.

APPENDIX A ADDITIONAL INFORMATION

A.1 Definitions and Acronyms

The following list identifies the acronyms and abbreviations used throughout this document:

Table 6-1: Acronyms

Acronym	Definition
ACO	Airspace Control Order
ATO	Air Tasking Orders
BML	Battle Management Language
C2	Command and Control
C2IS	Command and Control Information Systems
C2IVM	Command and Control Infrastructure Virtual Machine
C2LG	Command and Control Lexical Grammar
C2SIM	Command and Control Systems - Simulation Systems Interoperation
C4I	Command, Control, Communications, Computers and Intelligence.
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CAGE	Coalition Attack Guidance Experiment
C-BML	Coalition Battle Management Language
CBMS	Coalition Battle Management Services (CBMS)
CGF	Computer Generated Forces
CIG	Common Interest Group
FRAGO	Fragmentary Order
GCCS-J	Global C2 System-Joint
GMU	George Mason University
GSD	Guideline on Scenario Development
HLA	High Level Architecture
HTTP	Hypertext Transfer Protocol

IBML	Integrated Battle Management Language
ICC	Integrated Command and Control system
ICCRTS	International Command and Control Research and Technology Symposium
JADOCS	Joint Automated Deep Operation Coordination System
JC3IEDM	Joint Consultation, Command and Control Information Exchange Data Model
JCW	Joint Coalition Warfighting
JSAF	Joint Semi-Automated Force
LDM	Logical Data Model
LVC	Live, Virtual and Constructive
MIM	MIP Information Model - Successor to JC3IEDM
MIP	Multilateral Interoperability Programme
MSDL	Military Scenario Definition Language
MSG	(NATO) Modeling and Simulation Group
NATO	North Atlantic Treaty Organization
NATO MSG-085	NATO exercise 085
NFFI	NATO Friend or Foe Identification (NFFI)
NIEM	National Information Exchange Model
OE	Operational Environment
ORBAT	Order of Battle
PDG	Product Development Group
PSG	Product Support Group
REST	Representational State Transfer
SBML	Scripted BML
SICF	Systèm d'Information pour le Commandement des Forces
SINEX	Scenario INitialization and EXecution
SISO	Simulation Interoperability Standards Organization
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol

STANAG	Standardization Agreement
STOMP	Streaming Text Oriented Messaging Protocol
TIP	Technical Information Package
TTCP	The Technical Cooperation Program
UAV	Unmanned Aerial Vehicle
WISE	Widely Integrated Systems Environment
XML	Extensible Markup Language

APPENDIX B WORKS CITED

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