Final Report for the Integration of Simulation and Naval Decision Support Tools

Prepared by:
Elizabeth Hosang

CAE Inc.
1135 Innovation Dr.
Ottawa, ON K2K 3G7

PWGSC Contract Number: W7707-145734
Technical Authority: Mark G Hazen, Defence Scientist
Contractor's Publication Date: March 2017

Contract Report
DRDC-RDDC-2017-C108
May 2017

CAE Inc.

1135 Innovation Drive
Ottawa, Ont., K2K 3G7 Canada
Tel: 613-247-0342
Fax: 613-271-0963

FINAL REPORT
FOR THE INTEGRATION OF SIMULATION AND NAVAL DECISION SUPPORT TOOLS

CONTRACT #: W7707-145734

FOR

MARK HAZEN, DEFENCE SCIENTIST / MARITIME DECISION SUPPORT, DEFENCE R&D CANADA – ATLANTIC RESEARCH CENTRE

9 Grove Street, Dartmouth, NS

31 March 2017

Document No. 5897-019 Version 01

APPROVAL SHEET

Document No. 5897-019 Version 01

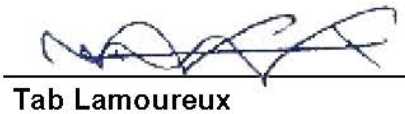
Document Name: Final Report
for the Integration of Simulation
and Naval Decision Support Tools

Primary Author

Name **Elizabeth Hosang**

Position Senior Modeling and Simulation Professional, Defence & Security, CAE Canada

Reviewer



Name **Tab Lamoureux**

Position Senior Human Factors Engineer, Defence & Security, CAE Canada

Approval

Name **Damon Gamble**

Position Project Manager, Defence & Security, CAE Canada

REVISION HISTORY

Revision	Reason for Change	Origin Date
Version 01 DRAFT A	Draft issued for review by client.	15 March 2017
Version 01 DRAFT B	Updated based on client review, submitted for re-review.	22 March 2017
Version 01	Official document issued.	31 March 2017

TABLE OF CONTENTS

LIST OF ACRONYMS AND DEFINITIONS

AIS	**AUTOMATIC IDENTIFICATION SYSTEM**
API	**APPLICATION PROGRAMMING INTERFACE**
C2SIM	**COMMAND AND CONTROL SYSTEMS – SIMULATION SYSTEMS INTEROPERATION**
C-BML	**COALITION BATTLE MANAGEMENT LANGUAGE**
CMS	**COMBAT MANAGEMENT SYSTEM**
COA	**COURSE OF ACTION**
COG	**COURSE OVER GROUND**
COP	**COMMON OPERATING PICTURE**
DRDC	**DEFENCE RESEARCH AND DEVELOPMENT CANADA**
GUI	**GRAPHICAL USER INTERFACE**
IMO	**INTERNATIONAL MARITIME ORGANIZATION**
LDM	**LOGICAL DATA MODEL**
MIO	**MARITIME INTERDICTION OPERATION**
MIP	**MULTILATERAL INTEROPERABILITY PROGRAMME**
MIW	**MARITIME INFORMATION WARFARE**
MMSI	**MARITIME MOBILE SERVICE IDENTITY**
MOOTW	**MILITARY OPERATIONS OTHER THAN WAR**
MSDL	**SCENARIO DEFINITION LANGUAGE**
MWE	**MANEUVER WARFARE EXTENSION**
NATO	**NORTH ATLANTIC TREATY ORGANIZATION**
NMEA	**NATIONAL MARINE ELECTRONICS ASSOCIATION**
PDG	**PRODUCT DEVELOPMENT GROUP**
PSG	**PRODUCT SUPPORT GROUPS**
RCN	**ROYAL CANADIAN NAVY**
ROT	**RATE OF TURN**
SISO	**SIMULATION INTEROPERABILITY STANDARDS ORGANIZATION**
SOG	**SPEED OVER GROUND**
TA	**TECHNICAL AUTHORITY**

EXECUTIVE SUMMARY

This document discusses the work done under W7707-145734 Task 10 entitled “Investigation of the Integration of Simulation and Naval Decision Support Tools”. The first work done under the task was a Literature Review of the use of Command and Control (C2) standards. The study found that the Coalition Battle Management Language (C-BML) and the Military Scenario Description Language (MSDL) have been implemented for use in a number of exercises. However, the two standards use data models that are incompatible, so the Simulation Interoperability Standards Organization (SISO) has started a Product Development Group (PDG) to create a new standard, the Command and Control Systems – Simulation Systems Interoperation (C2SIM) standard.

The Requirements Analysis document captured the use cases for the Course of Action Testbed. The use cases related to importing data were selected for the initial implementation of the C2 Gateway. Elements from the C-BML standard were selected to create the data model used to exchange data between components of the Testbed. This was done because the C2SIM standard is still under development. A second phase of development implemented the use case for exporting scenario initialization data.

The effort of mapping location report messages from GCI+ and the Automatic Identification System (AIS) was captured in a document mapping the contents of these messages into the C-BML-based data model. The OTH-GOLD standard was also mapped into the internal data model, although no code was implemented. This effort revealed issues with the use of the C-BML standard. Although the standard is meant to be unambiguous, the C-BML messages had to be carefully populated to capture all of the required data. Some of the category codes had to be extended, and others require additional Subject Matter Expertise to map between standards.

The approach taken by the C2SIM standard PDG is to create a tiny core set of entities that can serve as the basis of extensions to be developed later. The first such extension is the Maneuver Warfare Extension, which is intended to capture maneuver warfare aspects of C-BML and MSDL missing from C2SIM.

Given the state of the C2SIM it is unlikely that any C2 systems will be implemented based on the standard any time soon. There is an opportunity for Canada to participate in the development of extensions to the C2SIM related to the Maritime domain. Canada could also participate in developing an extension that represents Situational Awareness data.

Other areas of future development for the Course of Action Testbed include determining what data should be exported when multiple values are available, such as identifiers or speed data, and importing location reports in other data formats.

1 INTRODUCTION

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. 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. This document was produced for DRDC-Atlantic's Human Factors Support Standing Offer (W7711-145734) Task 10 – Investigation of the Integration of Simulation and Naval Decision Support Tools. It was produced by CAE Inc. for the Technical Authority (TA):

Mark Hazen
Defence Scientist, Maritime Decision Support
DRDC-Atlantic
6 Grove Street
Halifax, NS, B2Y 3Z7
Telephone: (902) 426-3100 x176
Fax: (902) 426-9654
mark.hazen@drdc-rddc.gc.ca

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 System), 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 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.

1.2 Objective

The aim of this work package was 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. Further, the aim of this work was to identify the requirements for a software library that would support C-BML and MSDL as the interface to other systems in a Maritime Command and Control system.

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 – Work Done:** This section reviews the work done under this task, including the literature review and requirements analysis. It provides an overview of the software developed and high level details of the issues encountered.
- **Section 4 – Gateway System Issues:** This section discusses issues encountered during implementation.
- **Section 5 – C2SIM Standard:** This section provides the status of the new C2SIM standard.
- **Section 6 – Conclusions:** This section provides a summary of the work done and the findings.
- **Section 7 – Future Areas of Investigation:** This section discusses areas of investigation that arose out of the work done under this task. It includes a section that discusses C2 Requirements for future procurements.

2 REFERENCES

2.1 Mandatory References

- W7707-145734 Statement of Work for Investigation of the Integration of Simulation and Naval Decision Support Tools
- [P16-103-0165484-001-03] 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.

2.3 Referenced Project Documents

- [5897-001] Investigation of the Integration of Simulation and Naval Decision Support Tools, CAE document 5897-001. Published as Contractor Report DRDC-RDDC-2016-C094.
- [5897-002] Requirements Analysis for the Integration of Simulation and Naval Decision Support Tools, CAE document 5897-002.
- [5897-008] C2 Gateway Software Description for the Integration of Simulation and Naval Decision Support Tools, CAE document 5897-008.
- [5897-012] Analysis Tool Data Model for the Integration of Simulation and Naval Decision Support Tools, CAE document 5897-012.
- [5897-015] C2 Gateway User Guide for the Integration of Simulation and Naval Decision Support Tools, CAE document 5897-015.

2.4 Third Party Documents

The following documents were consulted when preparing this document.

- [CBML] SISO-STD-011-2014 Standard for Coalition Battle Management Language (C-BML) Phase 1, Version 1.0, 31 October 2013, and its related schema files and related documents.
- [CBML_Guide] SISO-GUIDE-004-DRAFT Guide for Coalition Battle Management Language (C-BML) Phase 1, Version 1.0, 27 June 2016, and its related sample expressions.
- [MSDL] SISO-STD-007-2008 Standard for Military Scenario Definition Language, Reaffirmed 11 May 2015.

- [C2SIM-LDM] SISO-STD-XXX-2016 Standard for Command and Control Systems – Simulation Systems Interoperation, Version 0.9, downloaded 14 February 2017.
- [C2SIM-Initialization] SISO-STD-XXX-YYYY Standard for C2SIM Initialization. 13 November 2016.
- [C2SIM-TaskingReporting] SISO-STD-XXX-YYYY Standard for C2SIM Tasking/Reporting. 17 January 2017.
- [Hosang 2016, White Paper] Hosang, E. CAE Inc. (2016) *Representing Collected Tactical Situational Awareness Data in Military Planning Standards.* Ottawa Canada.
- [Hosang 2016, Tech Note] Hosang, E. CAE Inc. (2016) *C2SIM Recommendations for Situational Data*, Ottawa Canada.

3 WORK DONE

3.1 Literature Review

The initial work done on this task was a literature review of the standards currently being used in C2 exercises. The result was a report delivered in March 2016 [5897-001].

The C-BML was developed by the SISO to communicate a commander's intent. It defines elements that can be used to create custom schemas that are used to convey Orders, Request information, and provide Reports on the assets involved in a scenario. The standard is based on the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM), which was developed by the Multilateral Interoperability Programme (MIP) and re-uses category codes from JC3IEDM. During exercises, C-BML messages have been exchanged using centralized servers to which both C2 systems and Simulations subscribe. [5897-001]

The MSDL is used to capture data that is used to initialize a scenario. It can also be used to capture the status of a scenario at a given point, and is therefore useful for creating rollback points. It provides elements for capturing Environment, Tactical and Military Operations Other Than War (MOOTW) Graphics, Overlay data and Force Sides or hierarchy data. However, it does not have the same support for defining behaviour as C-BML. [5897-001]

A number of exercises have been held using the two standards. While they are both designed to be used in C2 exercises, they have fundamentally different data models. As a result, the SISO Product Development Group (PDG) is currently engaged in developing a new standard, the Command and Control Systems – Simulation Systems Interoperation (C2SIM) standard. Work on this standard was on going during 2016, and a draft version of the standard for balloting is still under development as of March 2017. The proposed standard will have several parts, including a Logical Data Model (LDM). More information on the state of this standard as of March 2017 is presented in paragraph 5 C2SIM Standard.

3.2 Requirements Analysis

After the Literature Review was complete, a Requirements Analysis was performed for the Analysis System that is being developed by DRDC Atlantic. A proposed architecture was identified, as is captured in the Requirements Analysis document [5897-002]. Using this architecture, a number of Use Cases were identified and used to define the requirements for the components of the Analysis System.

Key features of the architecture:

- An ActiveMQ Message Bus is used to exchange data between system components.
- A C2 Data Model Library provides the classes necessary to capture incoming data in a variety of formats and map them to the data model used internally by the Analysis System.

- A C2 Gateway acts as an interface to external simulators and systems. It transforms the external data into the data model used internally by the Analysis System by using the C2 Data Model Library.

- A Common Operating Picture (COP) database subscribes to incoming data on the Message Bus.

- A Planning Graphical User Interface (GUI) and Database subscribe to incoming data. They may also publish data for export by the C2 Gateway to other C2 systems.

Given the fact that the C2SIM standard was still under development, it was decided that C-BML will be used as the format for data exchanged over the Message Bus.

The Requirements Analysis document defines Use Cases for importing data, and starting and stopping the system. It also identifies the external data formats that will be supported (i.e., mapped into the C-BML standard for use by the Analysis System).

CAE was tasked with developing the C2 Gateway and the C2 Data Model Library.

3.3 Additional Development Work

The Requirements Analysis document discusses Use Cases for exporting data to specific external simulations, e.g. sending data to systems from which report data is received. However, this work was not included in the initial development effort due to time restrictions. In February 2017, an additional development effort was authorized. The intent of this new effort was to support the export of data that could be used to initialize a Maritime Interdiction Operation (MIO). The scope of the work to be done was defined as exporting MSDL files to capture parts of the COP, C-BML Reports to capture entity COP, and C-BML Orders to capture movement along waypoints and anticipated Red force Course of Action (COA). These requirements were not identified in the Requirements Analysis document; instead, they were established via emails and phone calls with representatives from DRDC.

3.3.1 Software Limitations

The first phase of development was restricted to defining C-BML Reports. As a result, only the C-BML classes that are required to define a Report were included in the C2 Data Model Library. With each entity and category code represented as a separate class/file, there are over one thousand files required to support the full C-BML, as defined in the third-party C-BML library that was used for the project. The inclusion of only those classes needed to support Reports was done to reduce the amount of testing required to verify the usability of the C-BML model.

During the second phase of development, support for C-BML Orders was added to the C2 Data Model Library. This brought the number of files to 284 classes.

No third-party library was found for MSDL, so instead the XSD files were used to generate classes. The MSDL specification was translated into 579 classes.

The classes are used to generate XML strings, and to parse in XML strings. While the resulting code has been tested, the sheer number of classes involved and limited hours in the project mean that there may be some combinations of classes and values that may cause errors.

4 GATEWAY SYSTEM ISSUES

The following paragraphs describe the end state of the software, including the additional development work done to support the export of MIO scenario initialization data. Due to limitations of time and availability of sample data, a subset of the capabilities and protocols identified in the Requirements Analysis document were implemented.

4.1 Software Overview

The implemented software is described in the Software Description Document [5897-008]. There are two main components to the software, the C2 Gateway and the C2 Data Model Library.

The C2 Gateway detects text files containing sensor data that are written to an input folder. It uses the C2 Data Model Library to map their contents into the internal Data Model and then publishes the resulting data on the Message Bus. A GUI was written for the C2 Gateway to support development, testing and demonstration. A simple GUI-based subscriber was written to detect the published data and display it, in order to simplify the development and demonstration of the tool.

The C2 Data Model Library consists of classes that represent:

- the external data formats GCI+ and Automatic Identification System (AIS);
- the internal data model C-BML (Reports and Orders); and
- the scenario export format MSDL.

The C2 Data Model Library also includes the classes that support mapping from GCI+/AIS to C-BML Reports.

4.2 Data Mapping Strategy

The effort of mapping of data from the GCI+ and AIS position messages into C-BML Reports was significant enough that a separate document was produced to capture the final results. The document includes the rationale for the decisions and issues encountered with the mapping. The Analysis Tool Data Model for the Integration of Simulation and Naval Decision Support Tools [5897-012] was added as a deliverable for the task.

Document [5897-012] defines the C-BML Schema used to capture incoming data. As has been noted, C-BML does not define a particular schema, but rather consists of elements that can be used to develop a schema.

The C2 Data Model Library has code to map data from GCI+ to AIS into C-BML Reports. These two message formats were selected because of the availability of both their documentation and

sample data. Documentation for the Over The Horizon GOLD (OTH-GOLD) standard was also made available to CAE, but no sample data was available. As a result, the mapping of OTH-GOLD Contact Report Messages to C-BML Reports is discussed in [5897-012], but the C2 Data Model Library does not contain any code to provide input support.

The messaging standards that were examined as part of this task have been developed at different times by different organizations for their own specific purposes. As a result, a number of issues were encountered when the mapping was developed. These issues are discussed in detail in the document. Some of them are highlighted here in the following paragraphs for reference.

4.3 Limited Support for Identifiers

Each of the message formats referenced as part of this task uses multiple identifiers for a given entity. A ship has a name. It may be issued a Maritime Mobile Service Identity (MMSI) or an International Maritime Organization (IMO) number. Most systems use some form of internal track number or other unique identification.

In addition to these, the message formats had other character-based values that could not easily be mapped to other values, such as AIS Version Number, Destination Cargo Indicator (GCI+), or OTS MSGID Suspicion Code (GCI+).

The C-BML elements were not designed to accommodate every possible identifier that could be assigned to an entity. The ObjectItemAlias element provides the ability to specify an unlimited number of alternate names or identifiers for an entity. However, the type of identifier must be labelled using a Category Code. The category code only provides six values. Each of the three input message formats examined (GCI+, AIS and OTH-GOLD) has more than six identifiers, and re-using the category codes would result in the loss of the meaning of the identifier.

To avoid loss of information, the JC3IEDM ObjectItemAliasCategoryCode was extended to ensure that the significance of each identifier could be retained within the Analysis System. The new values and their uses are discussed in the document (5897-012).

While the extension of the Category Code addresses the internal need to preserve data meaning, it makes the C-BML messages non-conforming. Therefore, when C-BML reports are created for export to a simulation system the custom Category Codes are removed and replaced with the more generic ALTNAM, or Alternate Name.

4.4 Category Code Mapping Expertise Required

Values such as Country Codes or Vessel Types are defined using an enumerated set of Category Codes. However, the mapping between Category Codes used by different messaging formats is not trivial.

C-BML defines a SurfaceVesselType which captures the attributes of a ship. The type of ship is defined by the SurfaceVesselTypeCategoryCode, which has 24 values. AIS has 99 values,

many of which are marked as “Reserved for future use”. JSON has 105 types and OTH-GOLD has 7. Mapping between these values would appear to require subject matter expertise. Since the focus of the task was to demonstrate the use of a common data model to create and publish messages on a data bus, the decision was made not to perform the mapping.

Country Codes were another Category Code where mapping was not immediately obvious. The JC3IEDM AffiliationGeopoliticalCode has 250 values, whereas AIS has 288 Country Codes and OTH-GOLD has 285. Some systems represent countries using two letters, some three, and others use numbers. The effort would have been labour intensive and may have required subject matter expertise. Since the focus of the task was to demonstrate the use of a common data model to create and publish messages on a data bus, the decision was made not to perform the mapping.

4.5 Heading vs Course vs Course Over Ground

The different message formats had different ways to capture the movement of entities. GCI+ defines Heading, Course, and Track Course Over Ground (COG). The AIS specification defines True Heading and COG. For speed, GCI+ defines Average Speed, Speed, and Track Speed Over Ground (SOG). The AIS specification defines Rate of Turn (ROT) and SOG.

All of these values were mapped into instances of the ObjectItemLocation element, but with different identifiers to distinguish between them [5897-012]. However, the COP and Planning tools will need to determine how to represent the differences between these values, and which values to export if more than one value is reported for the same entity.

4.6 Track Manipulation – Merge, Delete

GCI+ and OTH-GOLD use Tracks to identify entities of interest. During the course of analysis, the systems may determine that two tracks represent the same entity, and decide to merge the tracks. Alternately, a track may be deleted. As a result, the message formats contain special messages for managing tracks as logical entities rather than physical ones. However, C-BML is meant to convey a commander’s intent. It does not support management of entities, so it does not provide support for either merging tracks or explicitly deleting tracks.

These types of messages are mapped into C-BML using an Association report. It will be up to the other components in the Analysis System to identify these types of messages and determine how to handle them.

5 C2SIM STANDARD

5.1 New Standard

A number of exercises have been held using C-BML and MSDL. One of the common findings was that the incompatibilities of the two data models make it difficult to use the two standards together. As a result, the PDG and Product Support Groups (PSG) for C-BML and MSDL were replaced by a PDG/PSG to develop a new standard, C2SIM. A number of products are being developed:

- C2SIM-LDM – The Logical Data Model (LDM) will provide a core set of common data elements along with a standard way of adding additional elements specific to a particular domain and/or context.

- C2SIM-Initialize – This standard will supersede the MSDL v1 standard. It will support initialization data along with defining checkpoints, describing multiple courses of action or contexts in the past, present or future.

- C2SIM-TaskingReporting – This standard will supersede the C-BML v1 standard. It is meant to describe task and report assertions in operational or simulation environments. It will expand the range of tasking and Situational Awareness information relative to the C-BML v2 standard.

- C2SIM-ManeuverWarfareExtension – This document is listed in the introduction section of the LDM document, but not on the SISO website. It is meant to serve as an exemplar for other C2SIM extensions. It will “also provide for continuity with maneuver warfare aspects of MSDL and C-BML that are not included in the LDM Core but are in use in the international community.” [C2SIM-LDM].

5.2 Current Status

As part of preparing this report the following documents were downloaded 21 Feb 2017 and reviewed:

- C2SIM_LDM_StandardDocument_draft9.docx;

- C2SIM-Initialization_StandardDocument_Draft_3.docx; and

- C2SIM-TaskingReporting_StandardDocument_Draft_3.docx.

The Maneuver Warfare Extension (MWE) document was not available.

The Initialization and Tasking Reporting documents consisted mostly of introduction information and a list of definitions.

At a high level, the LDM document contains the following:

- Data Format Definitions – simple types such as formats for DateTime values, and enumerations taken from JC3IEDM, MIP Information Model (MIM), which is the replacement for JC3IEDM, and MSDL.
- Class definitions – a small set[1] of core classes representing:
  - Organizations (Echelon, MilitaryService);
  - Individual items (Entity, Materiel, Environment, Order, Report, Rule[2]);
  - Behaviour Modeling (DesiredEffectCode, ActivityCode);
  - Relationship Modeling (Affiliation, Allegiance);
  - Interaction Modeling (CommunicativeActs);
  - Time Modeling (DateTime, RelativeDateTime);
  - Current Condition Modeling (PerceivedState, TrueState, DirectionOfMovement, Orientation);
  - Location Modeling Concepts (AreaOfInterest – a rectangle, GeoCoordinateValue, GeographicFeature, RelativeLocation); and
  - Configuration Management (Version, Name, UniqueDesignation, ObjectHandle).

This set of classes is much smaller than the set of classes in previous standards. MSDL has over fifty, and C-BML Reports and Orders (Tasks) require over 100 classes, not including enumerated types. Many of the class descriptions include the standard which was the source of the class, such as JC3IEDM, MSDL or MIM.

The contents of the document are still being reviewed and amended. Version 7 of the same document included class diagrams, but these have been removed from Version 9 and replaced with comments indicating that the diagrams will be included once the model is stable. However, the basic list of classes has not changed significantly.

5.3 Implications for the Course of Action Testbed

The intent of the C2SIM LDM is that it will provide a core set of classes, and that extensions should be developed to support specific domains. The MWE will be an example of how to do

[1] The list contains the complete set of classes in the C2SIM-LDM document, broken into categories.
[2] Order, Report and Rule are included in the table of contents, but not in the actual document.

this, but the document has not yet been started. The MWE is intended to provide aspects of C-BML. It seems likely that some form of location or status report will be part of the MWE.

The classes in the core set are drawn from the existing standards, including JC3IEDM/C-BML and MSDL. It seems likely that extensions to the standard will include other classes from the existing standards. The existing standards have been widely implemented, as indicated by the number of exercises that have been conducted using them. It therefore seems likely that the concepts, if not the actual classes, will continue to be used in the extensions to the new standard. This means that a system based upon the existing standards should be able to map data into whatever extension is finally developed.

For these reasons is recommended that C-BML continue to be used internally by the Course of Action Testbed. Once a C2SIM extension is developed that includes entities analogous to location reports the C2 Data Model Library can be updated to map the C-BML reports to the new format. For the output of data, the Course of Action Testbed should continue to use C-BML and MSDL for output of data. It is recommended that the MSDL file not contain the Organization data, but that C-BML Reports be used in instead. C-BML Reports support specifying Units and Equipment, including vessel types, along with their location, in more detail than is supported by MSDL. The Object IDentification numbers OIDs assigned to the units in the C-BML reports should be used in the Force Side element of the MSDL document to link the reports.

6 CONCLUSIONS

6.1 Work Accomplished

The Literature Review revealed that the international community has performed large-scale experiments have been performed with the C-BML and MSDL standards. While there were some benefits to using the two standards, the differences between their data models provided obstacles to using them in the same exercise. These differences have resulted in a new SISO PDG, which is tasked with developing a new standard, C2SIM, to address the interoperability issues. The Literature Review document delivered by CAE was published by DRDC Atlantic as Contractor Report DRDC-RDDC-2016-C94.

A Requirements Analysis document was produced capturing the main use cases for the system. The document also identified the expected input formats.

Because the C2SIM standard is under development, C-BML was selected as the internal data model for the development of the C2 Gateway. C-BML was used in the messages exchanged between components of the Course of Analysis Testbed over the message bus. A custom C-BML schema was defined using only the elements of the C-BML standard required to capture a location report for entities. The implementation of the C2 Gateway was limited to the import of two of the expected input formats. An additional phase of development added export of data using a mix of C-BML and MSDL.

6.2 Things Learned

The mapping of location report data from existing standards into a C-BML report was complex enough that a separate document was created to record the results [5897-012]. C-BML is intended to make the commander's intent clear and unambiguous, but there are shortfalls in its representation of data. While it allows the definition of multiple identifiers for an entity, it is limited in its ability to specify a meaning for those identifiers, as noted in paragraph 4.3. Users of the schema must understand how the elements are being used to extract the data in a meaningful way, as is noted in paragraph 4.5. Category Codes differ from one standard to another. The standard is focused on commanders issuing orders, but it does not provide support for the work of analysts who may need to refine their representation of the Current Operating Picture (COP), as noted in paragraph 4.6.

The implementation of the C2 Gateway used C-BML despite the fact that the C2SIM standard was intended to supersede C-BML. It was anticipated that the C2 Gateway could be modified to use the newer standard once it was approved. However, the new standard is evolving slowly, and may not be useable for some time due to the approach taken by the SISO PDG. Canada may wish to participate in the evolution of the new standard, especially the parts of the model that affect the Maritime and Situational Awareness Domains.

7 FUTURE AREAS OF INVESTIGATION

7.1 C2 Statement of Requirements

As part of the original statement of work for this task, one of the deliverables was a C2SIM Statement of Requirements. The intent of this deliverable was to present guidelines for procuring systems with C2SIM-related capabilities, based on the assumption that the work done under this task would provide insight which could guide the procurement process. The guidelines were meant to be based on any issues encountered during the implementation of the C2 Gateway and when working with systems that supported a C2SIM type of interface. At the time the task was written it was assumed that the work to be done would integrate with an existing CGF and/or an existing C2 system. It was expected that the software developed under this task would provide an API for an existing system or extend an existing implementation

The initial investigation, done as part of the literature review, revealed that some systems had been provided a C-BML or MSDL interface for the purpose of a specific exercise. However, no commercially available systems provide such an interface. No re-usable library was found that could be leveraged for its capability. Instead of using a Computer-Generated Forces (CGF) or C2 system, the C2 Gateway development team built custom test drivers to verify that the developed code could use the Message Bus. Additionally, the team had to customize the C-BML implementation to avoid losing data. As part of the final coding effort, the team had to add code to re-process the C-BML messages to remove that customization so that the data generated will be compliant to the C-BML standard when seen by third party software.

With regards to the standards, the multinational experiments cited in the literature review have demonstrated compatibility issues with the two existing standards. These issues were deemed serious enough that a brand new standard is being developed, the C2SIM-LDM. The development started with a blank slate, and then began to incorporate elements from the two existing standards and other standards as well; specifically MIM, which is the JC3IEDM replacement, and NIEM, the National Information Exchange Model.

As of March 2017 and as discussed in Section 5, the C2SIM-LDM consists only of a handful of core concepts and is meant to be extended. The revisions being made to the document consist of formatting comments – there appears to be no on-going discussion to add entities to the data model.

The PDG has already identified that a MWE will need to be developed to capture most of the concepts in C-BML and MSDL. This extension is discussed in the introduction of the C2SIM-LDM document, but does not yet appear on the SISO web page. It will likely be a long time before the extension is developed, much less is ready for use in a fielded system. At the same time. the fact that C-BML and MSDL have been targeted for obsolescence makes it unlikely that there will be much commercial development in the next few years using these standards.

As a result of the current status of the C-BML, MSDL and C2SIM standards, CAE is unable to make any recommendations with regards to requirements for procuring specific systems.

However, there may be opportunities for Canada to contribute to the development of simulation standards going forward to ensure that the needs of the Maritime domain are properly met. The paragraphs below list other areas where more research needs to be done.

7.2 Exporting Data

The following paragraphs list a number of issues that should be addressed related to exporting data.

1. Export to other systems – The C2 Data Model Library currently only supports exporting of data in MSDL and C-BML format. These exports are meant to be the input to a scenario. The Use Cases identified in the Requirements Analysis document that have not been addressed include exporting data using other formats.

2. DRDC Atlantic needs to determine what values to use on export. the following items need to be reviewed:

    a. Identifiers – For a given ship, which values should be exported as the Ship Name and which should be exported as ObjectItemAlias values. For example, if an MMSI value is available, should it be used as the Surface Vessel name? Should it be used as the Unit name for the Unit associated with the Surface Vessel? Or should the Ship's name always be exported as the NameText of the UnitType as well as for the SurfaceVessel?

    b. Speed/course values – A number of values were mapped into the Speed and Course values in the ObjectItemLocation class when importing data, i.e. Course vs. Course Over Ground vs. Heading, Average Speed vs. Speed Over Ground vs Speed. A decision needs to be made about which values should be exported in the case where multiple values are available due to multiple sensor reports.

7.3 Category Code Mapping

As noted in paragraph 4.4, the values used to represent a surface vessel type and country codes differ between standards. Someone with appropriate Subject Matter Expertise needs to define mappings between the JC3IEDM category codes and those used by AIS/GCI+/OTH-GOLD.

7.4 Additional Import Message Formats

The Requirements Analysis document identifies a number of input formats that were not implemented due to lack of time and sample data. These include:

- OTH-Gold – a proposed mapping was developed, but not implemented;
- Link 11/16/22;

- Combat Management System (CMS) 330 Messaging;
- C-BML – Used internally, but input of this format is not currently supported;
- MSDL – Used internally, but input of this format is not currently supported;
- National Marine Electronics Association (NMEA) track; and
- APP-11 – Identified during discussions of additional work.

The C2 Data Model Library can be extended to support these additional messaging protocols by using the strategies documented in the Analysis Tool Data Model document [5897-012], including the use of the ObjectItemAlias entity for new types of identifiers and the extension of category codes as needed.

7.5 Additional Use Cases

Some of the Use Cases that were identified in the Requirements Analysis document [5997-002] were not implemented due to time. The following should be implemented as the C2 Gateway is integrated into the larger Course of Action Testbed:

1. System Control Topics Start, Stop and Shutdown need to be implemented.
2. Configuration of External Interfaces, including Create, Edit and Delete external interfaces.

7.6 Maritime Domain Extension to C2SIM

Given the design philosophy for the C2SIM standard, there is an opportunity for Canada to contribute to the new standard. The MWE is meant to provide “continuity with maneuver warfare aspects of MSDL and C-BML that are not in the LDM Core”. Some shortcomings have been identified in applying the two standards to the Maritime domain [5897-001].

Canada could participate in the development of a Maritime Extension to the C2SIM, either by creating one based on the existing standards, or by building on the MWE extension.

This work may be done in conjunction with the development of the MWE, but should not be done before that work begins. The small number of classes in the LDM means that a number of key concepts have not been defined. These concepts will need to be defined for the MWE to be able to describe concepts currently expressed in C-BML and MSDL. Some of the missing concepts include:

- Time range – Currently the LDM limits its definitions of time to DateTime and RelativeDateTime.

- Geographic Shapes – The current definition of Area of Interest is defined by a lower left and upper right corner, limiting the shape to a rectangle. The GeoCoordinateValue class defines one location, but there is no collection of locations.

- Observed Actions – The JC3IEDM has two main types of Actions: Action-Task, which is a command sent to an entity, and Action-Event, which is an observed behaviour.

7.7 Situational Awareness Extension to C2SIM

The supported input data formats represent sensor data. Some of the issues encountered when mapping these data formats into the data format used internally by the Course of Action Testbed are caused by the fact that C2 standards do not provide support for observational data. Observational data has characteristics that are not shared by planning data models, as is noted in (Hosang 2016 White Paper). Some of these features include:

- Specifying uncertainty in location data – An entity's location may be best represented using a shape such as an ellipse or a fan area.

- Multiple Identifiers – Different sensors may assign their own internal tracking numbers to the same entity. The data model therefore needs to support multiple identifiers for a single entity.

- Track Manipulation Operations – Tracks may need to be merged or deleted as the reporting sensors or intervening analysts determine that a single physical entity is represented by two or more different logical entities in the database.

- Strings longer than 100 characters – The current C2SIM-LDM defines a TextTypeVar100, which is a string of 100 characters. This may not be long enough for some identifiers. It is not long enough for any sort of analyst comment.

Canada could propose an extension to the C2SIM standard for the Situational Awareness domain. This extension would augment the other extensions with information required to capture sensor data and sensor products. A preliminary example of this type of extension is given in (Hosang 2016 Tech Note). Additional features of Situational Awareness and its reporting needs could be considered in this exercise.