Overview of C2 Systems – Simulation Systems Interoperation (C2SIM) Standard

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ABSTRACT

NATO Modelling and Simulation Group 211 (MSG-211) developed a Research Technical Course titled "Modelling and Simulation Standards in NATO Federated Mission Networking." The course will be presented in 2023 and 2024 in hybrid format. This Educational Notes paper presents the course content for the topic "History of Standardized C2-Simulation Interoperability (C2SIM)," one of 16 topics presented during the overall course. The paper describes the Command and Control – Simulation Systems Interoperation (C2SIM) standard. The approaches described in this paper are intended to be illustrative, not exhaustive. As the engineering community works with M&S in FMN, expanded alternatives will be identified.

1.0 INTRODUCTION

I am Dr. Mark Pullen from George Mason University (GMU), where I have retired from teaching computer science and as Director of the C4I & Cyber Center, in 2020, and maintain a working relationship with the C4I & Cyber Center. I am Co-Chair, with Kevin Galvin, of the SISO C2SIM PDG/PSG. This talk includes mention of some of the work my team at GMU has done in developing and validating C2SIM. This class provides an overview of the history of C2SIM. It is intended to give you a working understanding of the general operation of C2SIM and its top-level components.

1.1 C2SIM Vision

In this session we will look at the history of C2SIM, its development by SISO and NATO, its architecture, and how it has been tested in CWIX. We will start with the C2SIM Vision below. Please note the fact that we use "C2 system," "C2IS," and "Mission Command system" interchangeably in this course.

C2SIM VISION

We are working toward a day when the members of a coalition interconnect their networks, command and control (C2) systems, and simulations simply by turning them on and authenticating, in a standards-based environment.

The vision behind C2SIM is interoperability where partners in a coalition can use their national command and control systems, working together using C2 standards, in a system of systems with with their national simulations that could in turn be working together using M&S standards such as HLA and DIS. We use the term "Coalition" for such a system of systems because the linkage occurs at a much higher level than happens in "federated" systems such as the High Level Architecture (HLA) for M&S.

The C2SIM standard was developed by the Simulation Interoperability Standards Organization (SISO) in partnership with teams from the NATO Modelling and Simulation Group (NMSG). SISO wrote the standard; NATO nations did the technology development and evaluated it as teams, including military users. Over the past twenty years there has been a lot of partnership between NATO and SISO in C2-simulation interoperation.

1.2 C2SIM Predecessor: Battle Management Language

The concept "train as you fight" is strongly held by NATO militaries. To achieve it requires interfacing C2 and simulation systems with no human intermediary or "puckster". Originally this was done using ad-hoc interfaces. That led to experiments in DARPA and SIMCI programs to consider a more general approach, Those experiments prepared the stage for a standardized approach to interoperation. Here is a summary of early work leading to C2SIM:

- Pre-1995, various ad-hoc interfaces between C2 and simulations supporting "train as you fight" concept:
  - Motivated mostly by cost of human "puckster" interface.
- 1995 DARPA Synthetic Theater of War (STOW) sponsored:
  - Command and Control Simulation Interface Language (CCSIL).
  - Good first step but proved complex to use.
- 2003 US Army Simulation to C4I (SIMCI) sponsored Battle Management Language (BML) experiment:
  - Focus on eliminating ambiguity in task description.
  - Successful proof of principle – see Figure 1.
  - Simulated NATO MSG and SISO development.

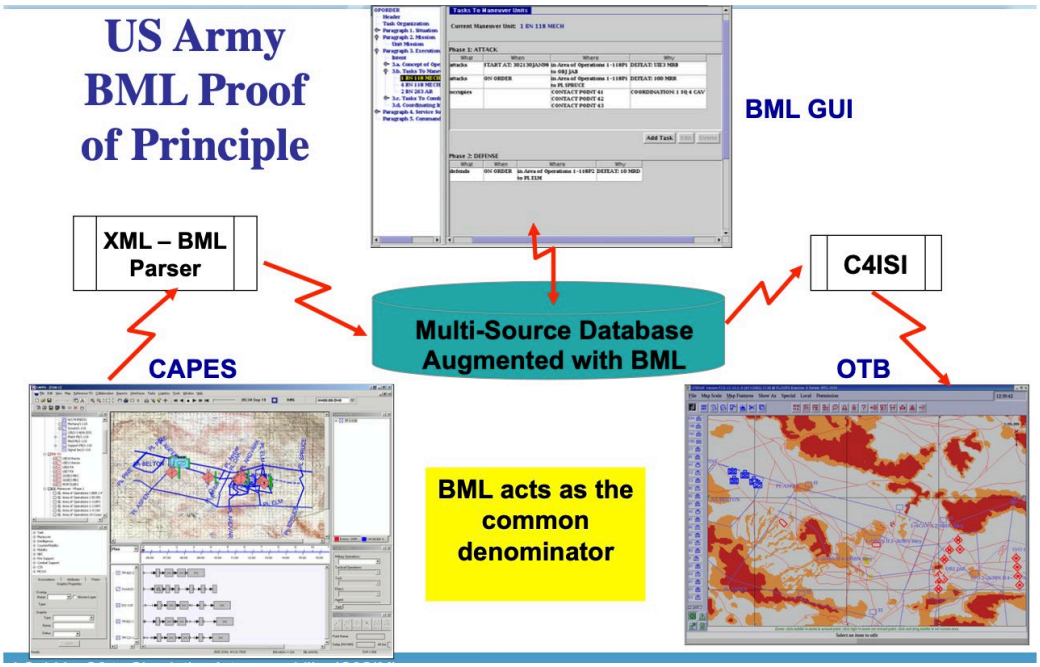

Figure 1: US Army BML Proof of Principle.

The BML Proof of Principle instigated considerable activity in NATO and SISO:

- SISO BML Study Group chartered.
- NATO ET-016 worked in parallel 2005:
  - Took unusual step of building a prototype.
  - Based on SIMCI experiment – demonstrated to NMSG at Warsaw.
- SISO started MSDL and C-BML product development 2006.
- NMSG chartered MSG-048 2006-2010:
  - *Coalition Battle Management Language.*
  - Goal: show technical feasibility was met by experimentation Manassas.
- NMSG chartered MSG-085 2011-2015 [1]:
  - *Standardization for C2-Simulation Interoperability.*
  - Goal: show military utility met in demonstration Fort Leavenworth.
- SISO formed C2SIM PDG from MSDL & C-BML in 2016.
- NMSG chartered ET-038 2016:
  - Goal: organize MSG-145 to complete C2SIM development.

1.3 Onward to C2SIM

The BML Proof of Principle raised considerable interest that eventually launched MSG-048 followed by MSG-085. Figure 2 below shows the architecture of the MSG-085 Final Demonstration, which was very well received by attendees from the military community.

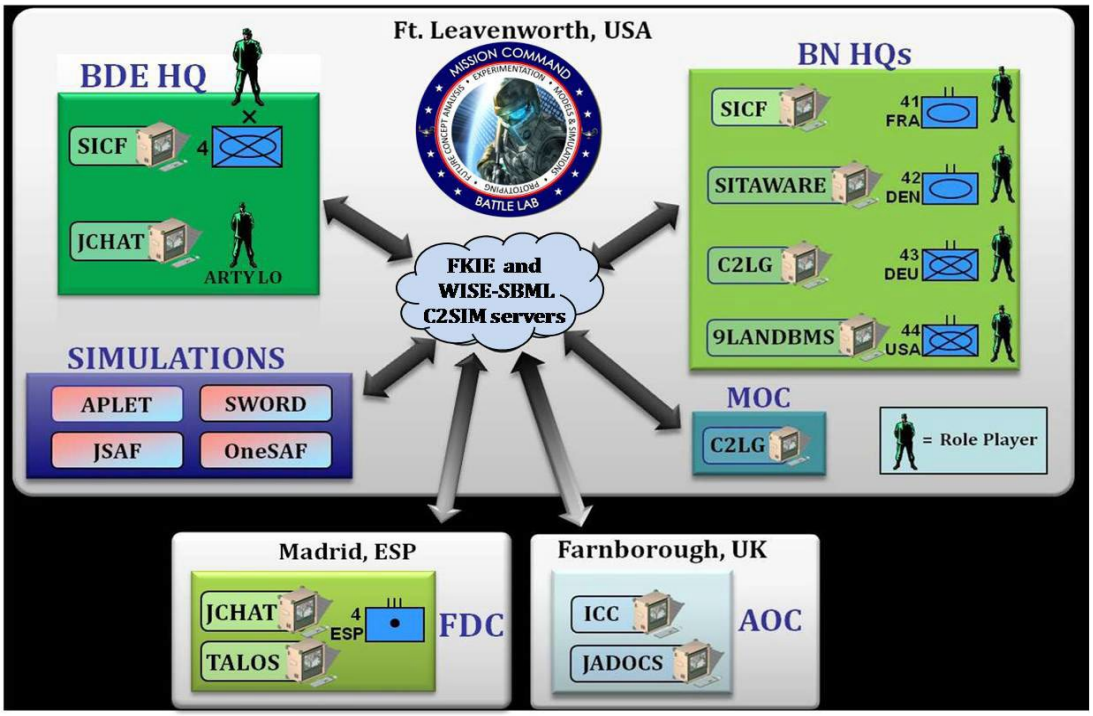

Figure 2: MSG-085 Final Demonstration Architecture.

However, it was the first major combined use of MSDL and C-BML, and as such the M&S technical concluded that while it was possible to make the two work together they should be unified for more effective implementation; also that the unified result should be made more extensible. SISO considered this input and as a result chartered the C2SIM PDG/PSG which worked with NATO MSG-145 to produce the current C2SSIM standard. So, in 2016, another NATO ET was chartered to organize a supporting effort to confirm the utility of the C2SIM standard and prepare for its operational use. This led to MSG-145 [2], which worked closely with the SISO PSG for that purpose.

The mission of MSG-145 was:

- *Assess the C2SIM standard in development and implement extensions to the unified C2SIM Logical Data Model (LDM) for specific functional areas in order to demonstrate its usability to the simulation community and support the definition of a STANAG.*

MSG-145 produced an excellent video overview of its activities, available at https://www.youtube.com/watch?v=KkfqKBzUuf8

2.0 THE C2SIM STANDARD

Figure 3 is the overview diagram from the SISO C2SIM standard. An important point here is the inclsion of Robotic and Autonomous Systems (RAS) to the big picture shown in the video. RAS was part of the original SISO BML concept because it requires the same sort of information exchange as simulations. The MiniExercise described in the video included an experimental RAS system, in simulated form. When the SISO C2SIM standard was finalized we decided to make RAS an explicit part of the big picture.

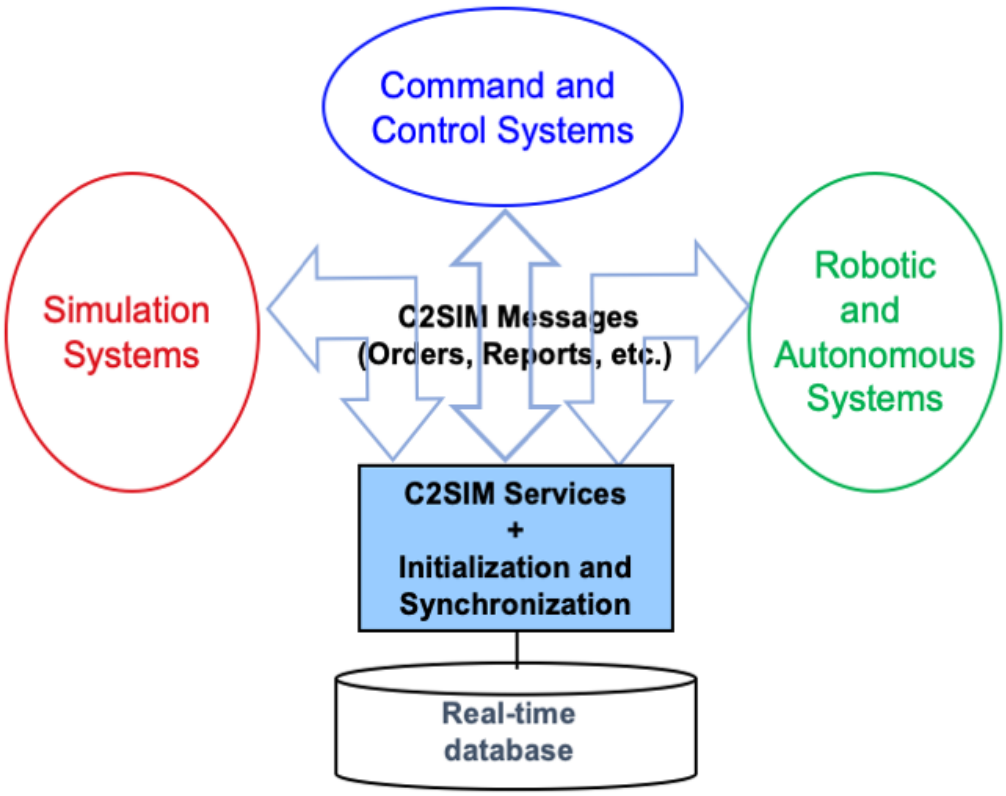

Figure 3: C2SIM General Architecture.

Important characteristics of the unified second-generation C2SIM standard:

- Built on C2SIM Core and Standard Military Extension (SMX) Ontologies.
- Provides initialization & synchronization messaging.
- Also Tasking & Reporting messaging.
- Includes extension Mechanism and Land Operations Extension.
- Further documented in Guidance document.
- All of these were accepted in SISO balloting 29 March 2020.

A big breakthrough in the C2SIM PDG was adoption of ontologies as the means of defining the C2SIM data model. SISO had said from the beginning that ontologies would have a role "someday" but it turned out the state of art in ontology made good progress while C2SIM was maturing and was ready to be used, so C2SIM was built around the concept of a Core ontology with a Standard Military Extension (SMX) that can be further extended as is done in the separate Land Operations extension (LOX). Blocks 1.5 and 2.5 will explain this further.

Adopting ontologies had many advantages that you will learn about in class 2.5, but it had the drawback that most software developers are not yet up to implementing ontologies. So, we had to come up with a way to extract from the ontology an Extensible Markup Language (XML) description that is comfortable to developers. We could not find an off-the-shelf tool to do this so Curt Blais, who will present class 1.7, created an algorithm for the standard and an Extensible Stylesheet Language Transformations (XSLT) tool implementing the algorithms. Figure 4 shows the approach.

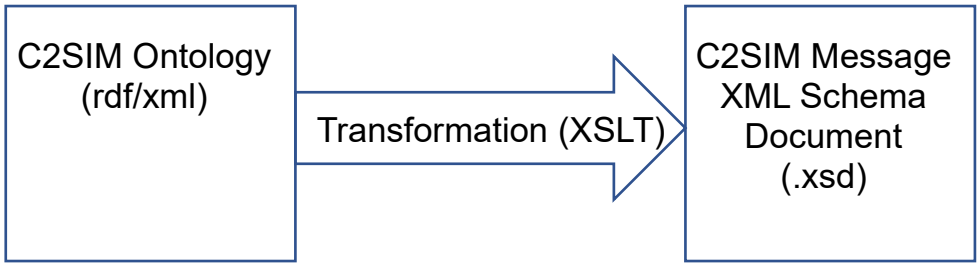

Figure 4: Ontology to XML Schema Transformation.

2.1 Role of the MIP

All of the BML and C2SIM development has adhered to a terminology base established by the Multilateral Interoperability program in the C2 model Joint Command, Consultation and Control Integrated Data Model (JC3IEDM). This avoided duplication of standards effort and promotes interoperability.

Some concern arises from the fact that C2SIM was developed by a simulation standards body and could use more C2 community involvement. This concern led us to do our testing at CWIX, which is a C2-heavy environment. But a better answer for the future is that our work with the MIP involves more than simply borrowing their JC3IEDM definitiions. We have been tracking their new version MIP 4 and have plans to build an open source MIP4 to C2SIM interface that will let *any* MIP-compliant C2 system interoperate with a C2SIM Coalition.

2.2 C2SIM in CWIX

MSG-145 did the testing part of its C2SIM validation in the NATO Coalition Warrior Interoperability eXploitation, eXperimentation, eXamination eXercise (CWIX), which has developed a strong reputation as a central place where NATO agencies and members/partner nations test information technologies for interoperability. In addition to the George Mason University (GMU) server team, various national teams created and tested C2SIM interfaces to simulations. France, Germany, Italy, Netherlands, Norway, Sweden and the UK participated along with two teams from the USA. GMU and the NATO M&S Center of Excellence (MSCOE). GMU also provided a graphic editor to submit orders and view resulting reports from simulations, which can be used as a surrogate for C2 where a real C2 system such as SitaWare is not available. Session 2.7 will provide more detail on C2SIM in CWIX.

3.0 REFERENCES

[1] NATO Science & Technology Organization Modelling & Simulation Group Technical Activity 085, "Standardisation for C2-Simulation Interoperation," 2014.

[2] NATO Science & Technology Organization Modelling & Simulation Group Technical Activity 145, "Final Report - Operationalization of Standardized C2-Simulation Interoperability," 2020.