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New Directions for C2-Simulation Interoperability Standards

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ABSTRACT

C2-simulation interoperability (C2SIM) is an area where modeling and simulation (M&S) has great potential in operational planning and execution of missions. This potential has been demonstrated at a number of events by the application of evolving technical standards developed by the Simulation Interoperability Standards Organization (SISO) to support areas of system initialization, tasking and reporting. However, it has become clear that achieving that full potential requires a partnership between defense technical and operational activities and standards-making teams within SISO, so that the standards can be developed on the basis of practical usage involving a mixture of experienced national teams.

Previous SISO product development groups for C2SIM have merged, in order to produce more harmonized results and save effort where there was overlap in their activities. This paper describes, as a background, the development and characteristics of current C2SIM standards Military Scenario Development Language (MSDL) and Coalition Battle Management Language (C-BML). It then proceeds to explain the process that is developing next-generation SISO C2SIM standards while also sustaining the initial versions. SISO C2SIM standards form an essential element advancing use of simulation in support of military operations. An important complement to the SISO effort will be technology development and operational evaluation to be made by NATO Modelling and Simulation Group's Technical Activity 145 (MSG-145).

The authors are Co-Chairs of the SISO C2SIM Product Development Group and also are active in NATO MSG-145.

1. Introduction

C2-simulation interoperability (C2SIM) is an area where modeling and simulation (M&S) has great potential in operational planning and execution of missions. C2SIM coalitions assemble complex systems of systems that can be seen as a strong basis for future agile C2 solutions to coalition interoperability. This potential has been demonstrated at a number of events by the application of evolving technical standards developed by the Simulation Interoperability Standards Organization (SISO) to support in areas of system initialization, tasking and reporting. However, it has become clear that achieving that full potential requires a partnership between defense technical and operational activities and standards-making teams within SISO, so the standards can be developed on the basis of practical usage involving a mixture of experienced national teams.

Problems of military command and control (C2) are more difficult in the coalition environment, where each nation is likely to have different doctrine, equipment, and C2 information system (C2IS, also called C2 system). The difficulty is even greater where the national forces in the coalition are capable of incorporating simulations to increase the functionality of their C2IS. This paper reports on progress in developing standardized methods for military coalitions to interoperate C2 systems and simulations as a system-of-systems, resulting in improved functionality, timeliness, and cost savings. Simulations are useful as C2 system elements for course of action (COA) analysis and to stimulate training and mission rehearsal [21].

Coalitions consist of military forces from multiple nations; generally, each national force has its own C2 and simulation systems, which complicates the problem of operating as a cohesive whole. The goal of C2SIM is to enable an environment where national C2 systems can exchange information freely and each nation's military operations can be represented accurately, with each nation representing their own military operations by means of their own simulations. In developing C2SIM technology and standards, we look forward to a day when a newly-formed coalition, operating over a shared network, can "plug in" their C2 and simulation systems to the network and work together rapidly and seamlessly to train, analyze COAs, and perform mission rehearsal. As a result, the coalition will able to perform these functions as a cohesive whole and do so more rapidly and efficiently [15].

Within such a force, the C2 systems may function as a group using a C2 interoperation capability such as the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM) [11] and the simulations may function as a group using an interoperation capability such as Distributed Interactive Simulation (DIS) [9] or High Level Architecture (HLA) [8]. Alternately, it is possible for all systems to share information through the C2SIM capability, although the resulting system may have less detailed time resolution. We refer to the totality of systems interoperating under C2SIM as a *coalition*, just as a collection of simulations interoperating under the HLA is called a federation.

The remainder of this paper provides a comprehensive overview of the current state of work in C2SIM. Section 2 describes the roles of SISO and of the North Atlantic Treaty Organization Modelling and Simulation Group (NMSG), in efforts to improve and validate the interoperation capability; section 3 describes existing SISO standards in the C2SIM area; section 4 describes

the major aspects of the new standards, including the requirements-driven process being used to advance C2SIM standards; section 5 describes cooperation of SISO C2SIM with NATO MSG-145; and section 6 concludes the paper.

2. **Roles of SISO and NMSG**

NMSG has been the principal sponsor for experimental application of C2SIM, which necessarily must take place in a coalition environment. SISO has served as its partner, responsible for codifying open standards based on the results of experimentation.

2.1 C2SIM in NMSG

Initial NMSG concerns for C2SIM interoperation arose from the cost of operating modern combat simulations in a way that enables military organizations to "train as you fight" by using their operational C2 systems to interact with each other and with the simulation [3]. To do so required an extra human in the information loop in order to transfer C2 information into the simulation system and then enter situational information from the simulation into the C2 system. In a large exercise, staffing for knowledgeable people to play this role became a major expense. Automated interfaces between C2 and simulation systems, implemented in an *ad hoc*, point-to-point manner, could not be extended readily to other systems. A more generic, consistent approach to interoperability was needed; its adherents called it Battle Management Language (BML) [21]. Figure 1 shows the general service-oriented architecture that was adopted to exchange BML messages. The server provides a publish/subscribe service to its clients. Use of a server-based architecture has two advantages: it simplifies a complex development environment, since each client can be tested individually using the server; and it provides a measure of fault-tolerance, since it does not require that all members of the C2SIM system-of-systems coalition are available at all times.

The need for C2SIM is particularly compelling in military coalitions, because differences among coalition partners' C2 systems and simulations make use of a single system impractical; the national forces train to use their own C2 systems and are best represented by their own simulations. Differences in organization, equipment, and doctrine result in a situation where each national simulation system may represent only that nation's forces well. Interest in using BML for this purpose led to a four-year NATO Technical Activity *MSG-048 Coalition Battle Management Language,* led by France and the USA and included national representatives from Canada, Denmark, Germany, the Netherlands, Norway, Spain, Turkey and the United Kingdom (UK). The group developed and evaluated prototypes, working to define solutions that could be standardized by SISO as Coalition Battle Management Language (C-BML – see below). Figure 2 shows the coalition of C2 and simulations systems assembled for MSG-048 experimentation. Each box in the diagram is an independent system; the systems interoperate by passing messages, through the Web services, following an agreed schema.

Results of MSG-048 indicated that C2SIM was technically feasible [13]; this led the NMSG to charter a follow-on activity *MSG-085 Standardization for C2-Simulation Interoperation.* Figure 3 shows the software coalition assembled for MSG-085 final demonstration; again each simulation and C2 system is an independent system but now the message exchange can itself be a system of cooperating, independent Web services. The conclusion of MSG-085 was that C2SIM would be operationally beneficial [14]. As a result, the NMSG initiated in 2016 a new activity numbered MSG-145, which is aimed at operational deployment of C2SIM.

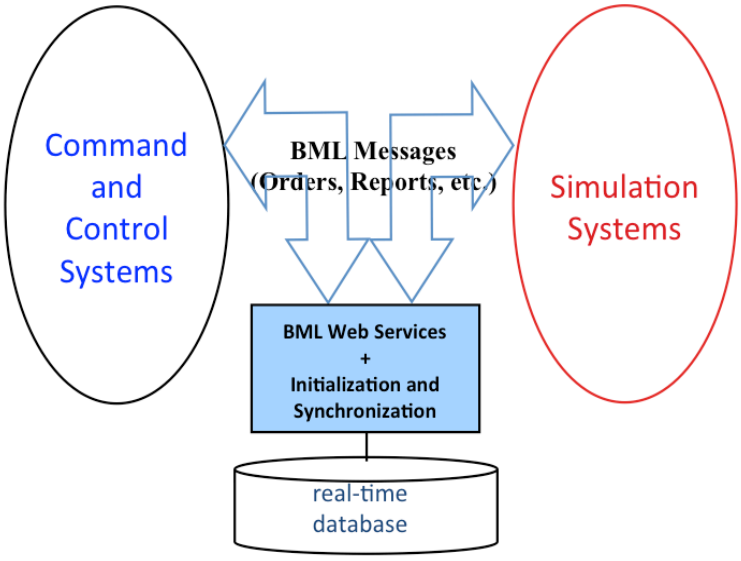

Figure 1. General Architecture for C2SIM

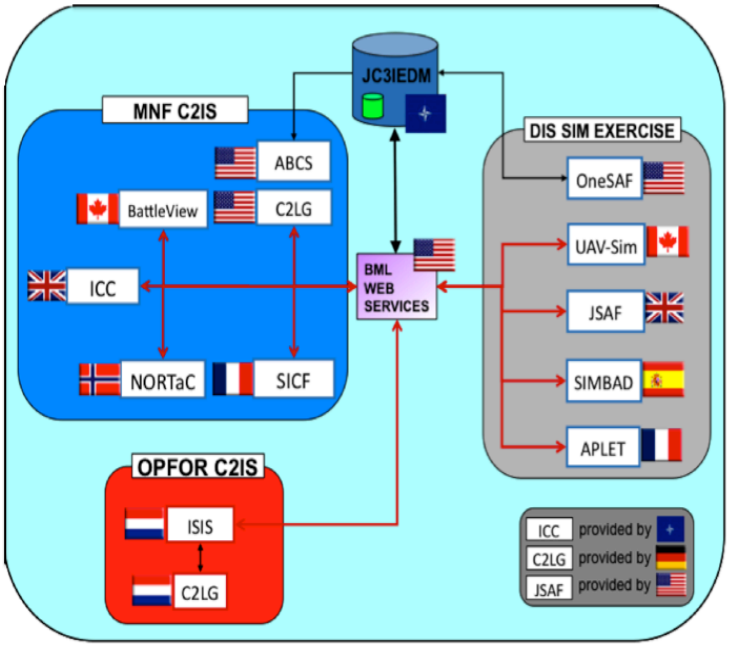

Figure 2. Architecture for MSG-048 Final Experimentation

2.2 C2SIM in SISO

SISO provides a collaborative environment for exchange of information about simulation interoperability and an organization under which standards for interoperability can be developed. A creative synergy has existed between NATO MSG activities in C2SIM and the focus of SISO on standards needed to support C2SIM [16]. For example, SISO chartered a Product Development Group (PDG) to develop a -C-BML- standard in parallel with MSG-048 [2].

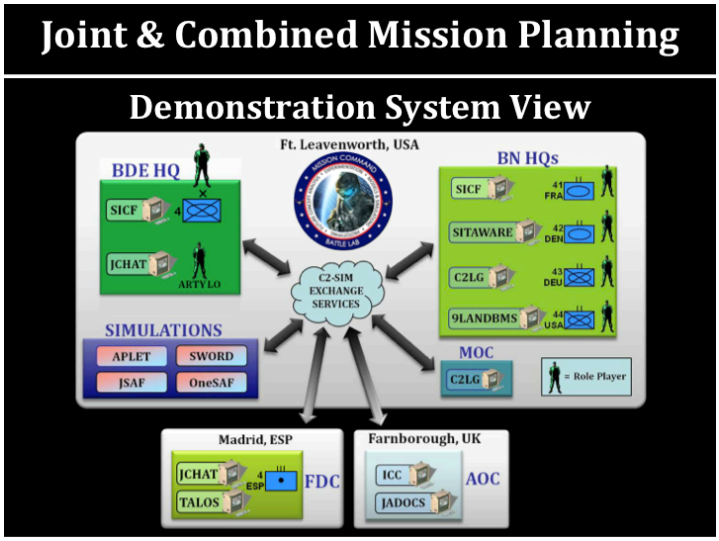

Figure 3. Architecture for MSG-085 Final Demonstration C2 and Simulation Coalition

An important finding during MSG-048 was that, for an effective operational capability, the SISO C-BML focus on orders, requests and reports must be supplemented with another SISO standard: the Military Scenario Development Language (MSDL) [18], in order to provide effective initialization of systems. Accordingly, MSG-085 began its work with adding MSDL to the simulation systems they had made BML-capable under MSG-048. This implementation was effective but it illuminated another problem: although SISO policy called for MSDL and C-BML to work together, the two were developed independently, so neither included directions for how to use them together.

The culmination of MSG-085 included a new insight: a more productive path would be to base the next generation of C2SIM standards on a logical data model (LDM), standardizing the core of that LDM and the process for extending it into new domains. Schemata needed for interoperation in various domains could then be derived from the LDM. Also, the second generation of initialization (MSDL) and tasking-reporting (C-BML) should form a single standard, based on that LDM [14]. In September 2014, SISO chartered a unified C2SIM PDG and associated Product Support Group (PSG) based on those recommendations. Its work is ongoing and is anticipated to build on experience resulting from NATO MSG-145.

3. MSDL and C-BML Standards

Current SISO standards in the C2SIM area are the MSDL [18] and C-BML [19]. Taken together, these two provide a basis for C2SIM interoperation. This section gives an overview of the two standards, which provide an intellectual basis for ongoing C2SIM standards development.

3.1 MSDL

The MSDL standard provides for initialization of the C2 and simulation systems in the coalition. In general, simulation systems require more initialization than C2 systems. The standard defines the contents of a Scenario File:

- Scenario ID – Describes meta data regarding the scenario

- Options – Describes the parameters to be applied across the scenario
- Environment – Describes scenario time, extents of the geographic area, and the weather, meteorological and oceanographic conditions
- ForceSides – Describes Sides and Forces relationships for a scenario
- Organization – Describes the organizations within a scenario
- Overlays – Describes collections of tactical graphics and associates them with a particular unit or entity owners
- Installation – Describes the installations as they stand at scenario start time for the forces, sides, or units
- Tactical Graphics – Describes the tactical action-based information
- Military Operations Other Than War (MOOTW) Graphics – Describes the MOOTW action-based information for a scenario

3.2 C-BML

C-BML is intended to support orders, reports, and requests. Its basic paradigm is to provide information as to "who-what-when-where-why." Figure 4 shows a fragment of a C-BML order, including one complete task (the whole order is significantly longer). A request would be similar to an order, however it would be sent to a party who had the option whether to comply or not; for example, a "call for fire" is a request.

Phase 1 of C-BML was intentionally coupled with the JC3IEDM standard [11]. While MSDL was derived from US Army work on the OneSAF system [21] and was ready for balloting in about two years, C-BML had a much longer development cycle that involved extensive application by MSG-048 and MSG-085 [1] and ultimately produced a standard with two major subschemata [19]. One of these, the "full" schema, was intended to support the full expressiveness of the JC3IEDM, while the "light" schema was limited to those data elements shown to be needed, by the experience of MSG-048. In practice only the "light" subschema was used in the MSG-085 demonstration described above.

4. New BML Directions in SISO C2SIM

Based on input from MSG-085, reflecting the need for harmonizing MSDL and C-BML [6] and the need for the standards to be extensible to additional domains, SISO chartered a new C2SIM PDG in 2014. The primary rationale for initiating a common C2SIM family of products is to integrate the C2SIM-Initialize and C2SIM-TaskingReporting message representations so that task and report message structures may be utilized in initialization messages.

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<cbml:Order xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation="http://www.sisostds.org/schemas/c-bml/1.0
../CBML_Phase1_March2013_DialloPullen/Schemas/cbml-1.0/cbml/cbml-example-expression-
types/1.0/cbml-example-expression-types.xsd"
 xmlns:cbml="http://www.sisostds.org/schemas/c-bml/1.0">
  <cbml:OrderIssuedWhen>20140401103600.024</cbml:OrderIssuedWhen>
  <cbml:OrderID>bb6e6082-5775-11e3-94d4-000c2975e2e5</cbml:OrderID>
  <cbml:TaskerWho>TG 401.01</cbml:TaskerWho>
  <cbml:Execution>
   <cbml:TaskersIntent>Recon enemy forces</cbml:TaskersIntent>
   <cbml:Tasks>
    <cbml:Task>
     <cbml:TaskID>1-223 Phase 1</cbml:TaskID>
     <cbml:TaskeeWhoRef><cbml:UnitRef>1-223</cbml:UnitRef></cbml:TaskeeWhoRef>
     <cbml:ActivityCode>MOVE</cbml:ActivityCode>
     <cbml:When>
      <cbml:StartWhen>
       <cbml:AbsoluteTime>
        <cbml:UnspecifiedTime>
         <cbml:StartQualifierCode>ASAP</cbml:StartQualifierCode>
        </cbml:UnspecifiedTime>
       </cbml:AbsoluteTime>
      </cbml:StartWhen>
     </cbml:When>
     <cbml:AtWhere>
      <cbml:SpecificLocation>
       <cbml:Point>
        <cbml:GDC>
         <cbml:SpecificPoint>
          <cbml:Latitude>58.587169</cbml:Latitude>
          <cbml:LatitudePrecisionCode>DEGREE</cbml:LatitudePrecisionCode>
              <cbml:Longitude>15.285854</cbml:Longitude>
         </cbml:SpecificPoint>
        </cbml:GDC>
       </cbml:Point>
      </cbml:SpecificLocation>
     </cbml:AtWhere>
     </cbml:Task>
```

Figure 4. Example XML Order Fragment

The C2SIM PDG merges the previous MSDL and C-BML groups. Additionally, the C2SIM PSG replaces the MSDL PSG and assumed maintenance MSDL and C-BML Phase 1 standards and guidance products. The functions of the PDG and PSG are distinct, but memberships are common, and administrative reporting will be as one group to consolidate administrative overhead.

4.1 PDG Organization

The C2SIM PDG consists of three groups, with overlapping membership [20]:

C2SIM-LDM will provide a logical data model, at a level independent of how the data will be communicated, including 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.

C2SIM-Initialize will supersede the MSDL version 1 standard with 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. Applications of the initialization messages include description of partial or complete start conditions for simulation execution such as events and exercises and contextual information defining the truth or belief conditions of actors in simulations. Other applications include defining simulation checkpoint (snapshots of past simulation condition for reset or rollback operation), describing multiple courses of action (COAs), or contexts in the past, present or future such as planned, preset, anticipated, objective states.

C2SIM-TaskingReporting will supersede the C-BML phase 1 standard with an XML message format for describing task and report assertions in operational or simulation environments. The new product expands the range of tasking and situational awareness information relative to the C-BML v2 standard. Task and report messages may be utilized during execution of simulations as runtime messages between real or simulated entities and as a common format for conveying information to and from tactical message formats based on the C2SIM LDM.

4.2 Standards and Guidance Products

SISO Standards and Guidance Products are produced in the formats approved by the Standards Activity Committee and will be available from website http://www.sisostds.org. Standards provide the natural language textual description of the structure and content of the standard. Guidance Products provide supporting information to understand and implement the standard. Associated machine-readable XML format/syntax files also will be published on the website. The XML-based documents will comply with SISO's XML Schema Naming and Design Rules.

Standards Products will include one document from each of the three groups described above and also a standard C2SIM Extension for Maneuver Warfare that will include that part of the essential functionality of C-BML Phase 1 falling beyond the LDM Core. The Extension also will provide a well-structured example of a C2SIM LDM Extension.

Guidance Products will include a Guideline for C2SIM-Initialize Implementation and a Guideline for C2SIM-TaskingReporting Implementation.

4.3 Requirements-Driven Process

One development of MSG-085 that is of particular importance to SISO C2SIM is the emphasis on collecting requirements in the form of use cases, to drive the design of the next generation [7]. In addition, a more formal process to derive the requirements and then generate relevant schemas was considered desirable.

MSG-085 recognized that, although both C-BML and MSDL had considered the needs from a user and systems perspective, no formal process had ever been established to ensure that either standard was requirements-driven. To consider this problem, a Requirements, Recommendations

& Schema (2RS) group was established under MSG-085. Requirements should be obtained from stakeholders, enabling the creation of a Reference Architecture. This can be based on any existing Architectural Frameworks (AF), including the DoDAF [4] and NATO AF (NAF) [12]. Ultimately, a reference implementation can be derived as illustrated in Figure 5 for a Standard Development Framework.

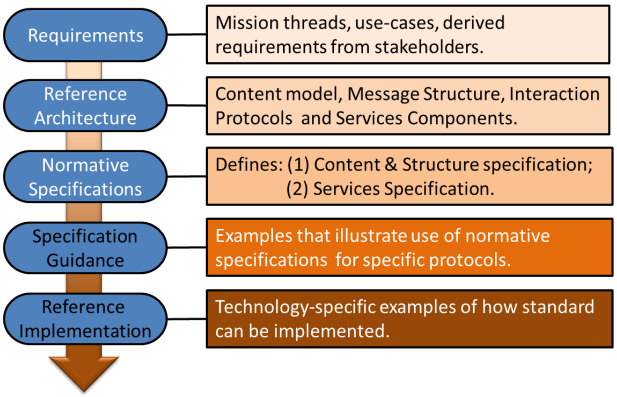

Figure 5. Standard Development Framework [7]

The 2RS group based its work on architecture principles and concepts, describing a Reference Architecture based on the Systems Engineering Body of Knowledge (SEBoK) [17]. The result of group's work was the development of a process referred to as the Scenario INitialization and Execution (SINEX) process [7], which uses a model-driven approach. The underlying principle of the approach developed in MSG-085 is that there should be a well-defined, well-documented, sustainable process that is readily available and can be easily understood by all stakeholders. Also, this process should be implemented in the form of a production chain to be made available to the community for the purposes of developing, maintaining and exploiting the standard products and extensions to core products. At the same time, the approach should be made as simple as possible and should take maximum advantage of existing products and standards. The diagram in Figure 6 illustrates the SINEX process.

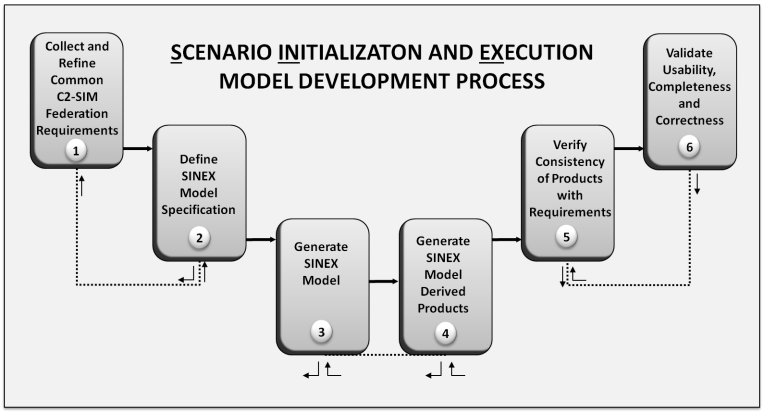

Figure 6. SINEX Model Development Process

It is expected that the SISO C2SIM PDG will follow a process similar to the SINEX process. This expectation currently is being examined further but it is consistent with the approach taken in creating a core LDM, where a number of use cases were collected, as in Step 1 of Figure 6.

5. Cooperation with NATO MSG-145

The linkage between SISO C2SIM and NMSG, always strong [5], continues under the new Technical Activity MSG-145. It is essential that proposed standards be implemented and evaluated by seasoned military subject matter experts before they are balloted for standardization. After that point, defense procurements may specify compliance with the standards, and it is entirely too late to discover that what seems like a good idea to the drafters is in fact impractical or ineffective.

In support of validating the new SISO C2SIM standard, MSG-145 plans to assess the draft, report results of the assessment in order to the C2SIM PDG to make changes, and then implement the standard under specific use cases and conduct experiments to validate it. Use cases to be considered are:

- Autonomous systems
- Cyber Warfare
- Future Mission Network mission threads
- Information Operations
- Army Mission Planning
- Joint Mission Planning and Battlespace Management
- Tactical Data Link
- Command Post Army Training

6. Conclusions

This paper has outlined the history and status of standards development for Command and Control to Simulation Interoperability in SISO, with support from NMSG. This is an ongoing effort and likely to remain so for the foreseeable future, as military coalitions and the doctrine evolve and the supporting C2 and simulation technologies mature. We conclude that standards completed today are useful and ongoing work is fruitful. The next generation SISO C2SIM standard is expected to make this important capability even more useful and enable its extension into a wide range of military operations.

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