C2-Simulation Interoperability for Operational Hybrid Environments

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Abstract

The NMSG has sponsored multiple Technical Activities moving toward a mature, deployable capability for interoperation of coalition command and control information systems (C2IS) with simulations. This paper reports on plans and technical approach for MSG-145, which expands C2 to simulation interoperability (C2SIM) across a broad range of military environments, collectively comprising hybrid operations.

C2SIM is expected to deliver significant operational benefits: enhanced realism and effectiveness; decreased cost and risk; and reduced preparation and response time for operational use of simulations with C2IS. Previous NMSG Technical Activities have demonstrated its technical feasibility and military utility.

The plan for MSG-145 calls for close coordination with the SISO C2SIM standardization process presented in the 2015 NMSG Symposium. The intention is to inform the standards development process based on operational evaluation, motivate system suppliers to develop compliant products, and educate the community of practice on the applicability of standards-based products. The process will end with development of a NATO Standardization Agreement (STANAG) based on the validated SISO standard.

C2SIM has been demonstrated to hold exceptional promise to support coalition operations. This paper reports on our plan and the technical approach to achieve its operational use in NATO.

1.0 INTRODUCTION

The NATO Modelling and Simulation Group (NMSG) has sponsored multiple Technical Activities moving toward a mature, deployable hybrid capability for interoperation of coalition command and control (C2) information systems (C2IS) with simulations [1]. This paper reports on plans and technical approach for MSG-145, which expands C2 to simulation interoperability (C2SIM) across a broad range of military environments, collectively comprising hybrid operations. C2SIM is expected to deliver significant operational benefits: enhanced realism and effectiveness; decreased cost and risk; and reduced preparation and response time for operational use of simulations with C2IS. Previous NMSG Technical Activities have demonstrated its technical feasibility and military utility.

The plan for MSG-145 calls for close coordination with the Simulation Interoperability Standards Organization (SISO) C2SIM standardization process presented in the 2015 NMSG Symposium. The intention is to inform the standards development process based on operational evaluation, motivate system suppliers to develop compliant products, and educate the community of practice on the applicability of standards-based products. The process will end with development of a NATO Standardization Agreement (STANAG) based on the validated SISO standard. The SISO C2SIM process described below was reported in more detail in [2].

The C2SIM work of NMSG and SISO will have real impact only if incorporated into operational C2 and simulation systems and used by military operators. The remainder of this paper therefore begins by recapping experience with C2SIM in the NMSG and SISO. It then proceeds to an exposition of MSG-145 addressing its purpose, planned technical activities, planned operational activities, and management.

2.0 HISTORY OF C2SIM IN THE NMSG

The need for C2SIM interoperation is particularly acute in coalitions. Differences among coalition partners' C2 systems make use of a single system impractical while differences in organization, equipment, and doctrine result in a situation where each national simulation system may represent only the sponsoring

nation's forces well. Since 2005 a group from the NMSG has been working toward this shared vision [2]:

> *The year is 2025, and somewhere in the vicinity of the North Atlantic a need has arisen for a military force to perform a peacekeeping mission. NATO has agreed to deploy a Multinational Brigade for this mission, and three of its member nations have agreed to provide forces. The designated military organizations promptly connect their command and control (C2) and simulation systems over a secure network and begin training together for their new, common mission. Each nation's forces are commanded by their own C2 system, which they understand well from long experience; also each nation's forces are represented in virtual engagements by their own simulation, which reflects accurately their personnel, equipment, and doctrine. As a result, the coalition force is able to prepare rapidly for its new mission, learning to deal with the unique aspects of each national force while preparing those forces to work together toward their shared mission.*

2.1 ET-016

Work on a technical solution supporting this vision began with NMSG Exploratory Team ET-016. Parties interested in C2SIM from France and the US became aware of each other's work and interests in 2005 and proposed to the Modelling and Simulation Group (MSG) that a multinational Technical Activity be considered, with the purpose of exploring use of the Battle Management Language (BML) approach for coalitions. The NMSG charted a multinational Exploratory Team (ET) to consider this possibility. France and the US were leaders in that team, which was numbered ET-016. They cooperated to provide an initial example of successful international C2SIM integration using a BML approach [3, 4]. When demonstrated for the NMSG, this example resulted in considerable enthusiasm for Coalition BML. The general architecture adopted for that work based on Web Services and shown in Figure 1. It has continued to be used for succeeding NMSG work in C2SIM. We refer to the combined C2SIM system of systems as a "Coalition."

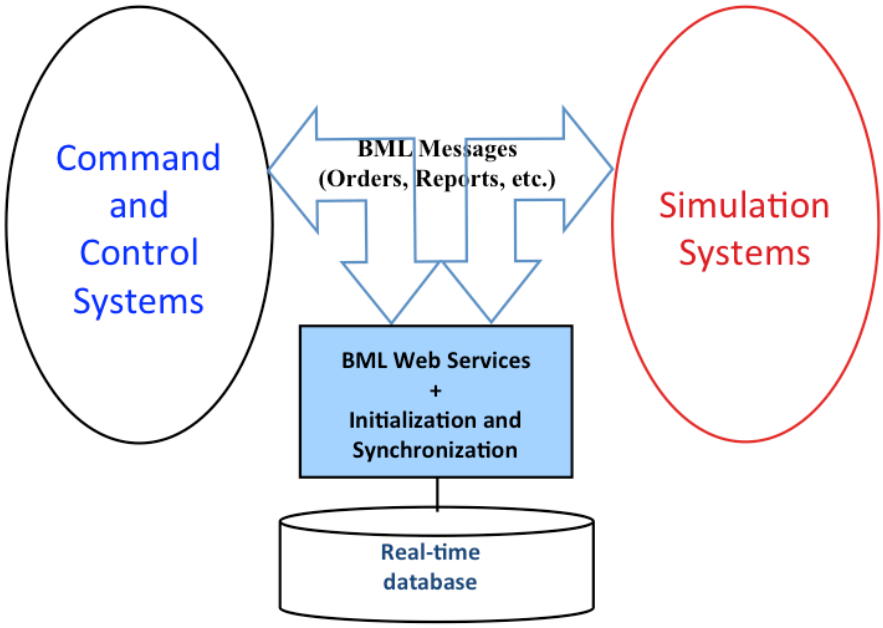

Figure 1: General Architecture for C-BML

2.2 MSG-048

With a successful France-US demonstration concluding ET-016, Coalition BML moved from an interesting idea to a challenging problem. The NMSG chartered Technical Activity 048 *Coalition Battle Management Language* for the period 2006 to 2009, to coordinate collaborative efforts of the nations and provide input to the SISO C-BML PDG (see section 3.2 below). MSG-048, organized under co-chairs from France and the USA, included national representatives from Canada, Denmark, Germany, the Netherlands, Norway, Spain, Turkey, and the United Kingdom (UK). MSG-048 work was conducted in three main areas:

1) Establish requirements for the C-BML standard;
2) Assess the usefulness and applicability of C-BML in support of coalition operations through experimentation; and
3) Educate and inform the C-BML stakeholders concerning the results and findings of the group.

This led to a primary objective: evaluating the available specification of a Coalition BML and a secondary one: assessing operational benefits to C2 and M&S communities [5]. Since a SISO C-BML specification or implementation was not available at the time the experimentation work was conducted, the MSG-048 utilized a version of BML based on contributions from participating nations, such as the Command & Control Lexical Grammar (C2LG) [6, 7] and the Joint Battle Management Language (JBML) project [8] and other related work [9, 10].

MSG-048 culminated in a one-week period of exploratory experimentation, conducted with operational military subject matter experts (SMEs) in 2009. Intensive preparation for this activity took place over the Internet, which at the time was a new way of working for most of the participants. In addition, two physical integration events were held: September in Portsmouth, UK and October in Paris, France. These events proved to be a successful risk reduction mechanism. The system-of-systems architecture used is shown in Figure 2. The experience gained in MSG-048 proved extremely useful in establishing the SISO C-BML standard and also in stimulating interest for a more extensive MSG Technical Activity.

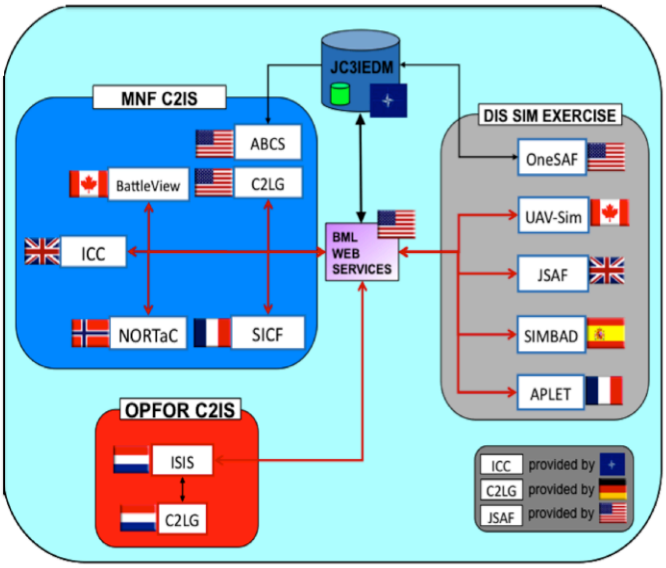

Figure 2: Architecture for MSG-048 Final Experimentation

2.3 MSG-085

Technical Activity MSG-085 *Standardization for C2-Simulation Interoperation* was held in the period 2010-2014. It was focused on assessing the operational relevance of Coalition BML while increasing its Technical Readiness Level (TRL) to a point consistent with its operational employment. France chaired and Canada was designated as co-chair. Nations participating included the original nine from MSG-048 plus Belgium and Sweden. Increased focus on operational relevance required more participation from operational military and their support staffs, which were recruited by the participating national teams.

An important finding of MSG-048 had been that, for an effective operational capability, the SISO C-BML focus on Orders, Requests and Reports need to be supplemented with another SISO standard: the Military Scenario Development Language (MSDL) [11] to provide effective initialization. Accordingly, in its first year MSG-085 members implemented MSDL in 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 and there was no "roadmap" telling how to use them together. As a result, considerable effort went into exploring alternatives before a path forward was adopted [12, 13, 14, 15].

The Final Demonstration of MSG-085 took place at Fort Leavenworth, Kansas in December, 2013. MSG-085 partnered with the US Army Mission Command Battle Laboratory, first engaging in a short integration session. The featured capability was Joint and Combined Mission Planning [16, 17]. The architecture of the demonstration system-of-systems that was assembled is shown in Figure 3. In addition to establishing the operational relevance of the approach, this demonstration showed that the technology used had achieved a greatly improved technical readiness level as shown by expeditious integration of the various systems used and also a capability for distributed operation. The MSG-85 final audience got the message "We have an exciting new capability and it works very well to improve some unmet needs of coalition C2, using interoperable simulations." MSG-085 finished its work in 2014 [18].

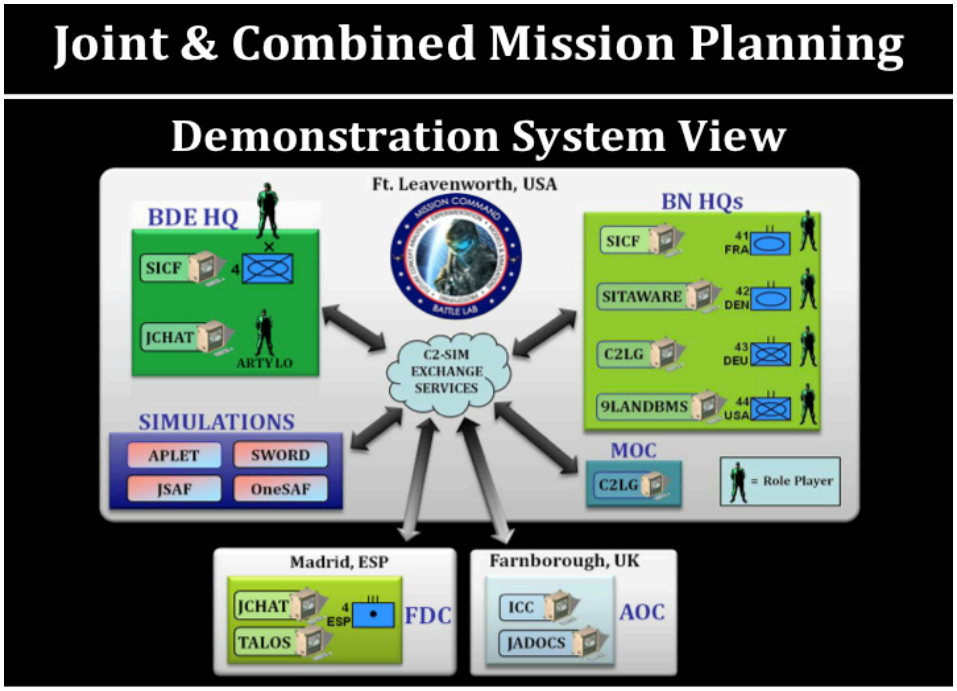

Figure 3: MSG-085 Final Demonstration System of Systems

3.0 SISO C2SIM

SISO's mission is to develop, manage, maintain, and promulgate user-driven Modeling and Simulation (M&S) standards that improve the technical quality cost efficiency of M&S implementations across the world-wide M&S community. SISO seeks to foster the open exchange of information and technologies to support the advancement and standardization of M&S-related technologies and practices. Its work is done by companies (or other organizations) and individuals volunteering their efforts. SISO Product Development Groups (PDGs) are formed as a result of approved Product Nominations (PNs) to develop or modify Balloted Products. A PDG does the work required to create the Balloted Product and resolve ballot comments. A Product Support Group (PSG) will be formed as a result of a completed product and an approved Terms of Reference to provide support to the product.

SISO's development of C2SIM standards began with parallel efforts to create the two standards described above as used by MSG-048 and MSG-085: The Military Scenario Development Language (MSDL) and the Coalition Battle Management Language (C-BML). These development efforts were loosely coupled.

3.1 MSDL

MSDL is focused on providing consistent initialization or start data for both C2 and Simulation systems participating within a Coalition. Its roots lie in the the US Army OneSAF simulation development program, whose management team was directed to give priority to development of specifications, formats, process, and tools that could be matured into industry wide standards [19]. As part of achieving this, they supported the SISO standards process that developed MSDL. Meeting their scenario development time and cost reduction goals required defining not only how to develop appropriate scenario development tools but also how to specify an interface to the scenario data that would maximize reuse across the modeling and simulation community with low introductory costs. The development was based on four principles: application independence, separation of data from code, separation of initialization from other concerns, and use of commercial and industry standards. The object standardized by MSDL is the *scenario file*, which provides a specific description of the situation and course of action at a moment in time for each element in the scenario.

The MSDL scenario file provides for initialization of nine primary data elements [11]:

Scenario ID – meta data regarding the scenario
Options – parameters to be applied across the scenario
Environment – scenario time, geographic area, weather, meteorological and oceanographic conditions
ForceSides – Sides and Forces relationships for a scenario
Organization – the organizations within a scenario
Overlays – collections of tactical graphics and associations between them military units or entities
Installation – installations as they stand at scenario start time for the forces, sides, or units.
Tactical Graphics – the tactical action-based iconic information
MOOTW Graphics – Military Operations Other Than War action-based information for a scenario

In addition to the MSDL specification, a formalized coordination process between all participants is recommended to ensure common and consistent interpretation and import of the initialization data. The formality and coordination of the initialization process depends on the size and complexity of the exercise. For a simple single simulation exercise without external connectivity to other simulations or Mission Command devices, the process can and should be defined within the simulation's documentation.

3.2 C-BML

Interest leading to SISO C-BML grew out of the US Army SIMCI Battle Management Language (BML) experiment [20]. That project sought ways to replace the natural language of battlefield C2 with an unambiguous language that can be used as input to software. The SIMCI experiment was expanded under the Extensible BML (XBML) project, supported by the previous US Defense Modeling and Simulation Office (DMSO) [21]. In the same time frame, France had demonstrated a C2SIM capability combining their SICF C2 system with their APLET simulation. Enthusiasm resulting from these projects as demonstrated by ET-016 (as described above) led to formation of a SISO Study Group on Coalition BML (C-BML) that created a Product Nomination for a C-BML standard.

The C-BML standard defines standard XML data composites for tasking (orders and requests) and reports. An explicit requirement for C-BML Phase 1 was to use the Multilateral Interoperability Programme (MIP) Joint Consultation, Command and Control Interchange Data Model (JC3IEDM) [22] as a well-defined source of vocabulary. The C-BML Phase 1 standard includes two subschemas: the "full" subschema is intended to address a very wide range of possible data representations, as broad as the complete JC3IEDM, while the "light" subschema is intended to facilitate rapid implementation of C-BML for the large majority of cases that do not need such complexity [23]. The C-BML standard and its antecedents have been the basis of investigation and application in ground, air and maritime domains [24, 25, 26].

3.3 SISO Second Generation Standard: C2SIM

MSG-085 successes in demonstrating technical and operational relevance built considerable experience that helped in completing the C-BML Phase 1 standard. However, MSG-085 also produced some clear results [18] indicating a need for more work by SISO:

- MSDL and C-BML were developed separately and are less than perfectly suited to working together; an integrated standard is needed
- C-BML Phase 1 requires extension in order to be used for the full spectrum of military operations

Because MSG-085 represented important "early adopters" of MSDL and C-BML, SISO responded to these findings attentively. MSDL and C-BML both had been intended to move forward to at least one more version. Moreover, the PDGs responsible for the two standards see significant benefit in combining their efforts in the second phase of each. They therefore proposed a new, unified effort to replace the second phase of MSDL and C-BML: a single C2SIM Product Development Group for C2-simulation interoperation, to include other systems dependent on the same information (e.g. autonomous or robotic systems).

Product Nomination for SISO C2SIM [27] defines the products as:

- C2SIM Logical Data Model (C2SIM-LDM) Standard: The logical data model that provides the logical definitions of initialization, tasking, and reporting business elements and associations referenced in the syntactic representation standards of C2SIM.
- C2SIM Initialization XML Representation (C2SIM-Initialize) Standard: The XML syntax representation for C2SIM initialization messages. Depends on C2SIM-TaskingReporting for task and report message elements.
- C2SIM Tasking and Reporting XML Representation (C2SIM-TaskingReporting) Standard: The XML syntax representation for C2SIM tasking and reporting messages.
- Guideline documents for the above.

In addition, the C2SIM PDG has decided to produce one more document: an example extension to the LDM,

for Manuever Warfare. This will both serve as an exemplar of C2SIM extensions and round out the second-generation standard to include a capability similar to that embodied in MSDL and C-BML.

4.0 MSG-145

The technical success of MSG-085 left the C2SIM community eager to pursue operationalization. A new Exploratory Team held in 2015 explored possibilities and laid plans for a new Technical Activity MSG-145, *Operationalization of Standardized C2-Simulation Capability*, which began in 2016. It is intended to build experience in deploying C2SIM with operational NATO forces and also to provide continued support of the SISO standardization process, with the intention of eventually wrapping the SISO C2SIM standard in a NATO Standardization Agreement (STANAG). Much of the information provided in this section is elaborated in the MSG-145 Program of Work [28].

4.1 Mission and Benefits

The MSG-145 Mission Statement is as follows:

> *Assess the C2SIM in development standard 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.*

The following benefits are expected to result in C2 systems using simulations, due to the work of MSG-145:

- Enhanced realism and overall effectiveness, by faster, more consistent information exchange among systems.
- Decreased cost and risk by reducing manual input (the swivel chair effect), reduced number of supporting personnel and equipment.
- Reduced preparation and response time with rapid configuration, initialization of systems and validation of scenario.

4.2 MSG-145 Summary of National Interests

Nations participating in MSG-145 have indicated a range of interests. While all nations are likely to participate in all aspects of the work to some extent, the following specific focuses have been identified.

- Applications of C2SIM in simulation for acquisition, based on a “system of systems” decision-making approach, where the goal is to select the most cost-effective mix of individual systems for development and fielding. The approach, as indicated in Figures 4 and 5, is to evaluate a proposed C2 system by integrating it into a simulated System of Systems. Focus will include Tactical Data Link applications. (France)
- Display the battlefield situation, which is calculated by a simulation system, in operational C2 systems in order to support “train as you fight”. (Germany)
- Facilitate eventual experimentation activities of the C2SIM and in particular of the extension related to the Autonomous Systems. (Italy/M&S COE)
- Contribute to the assessment of the SISO C2SIM draft standard with respect to the coverage and structure of the core LDM and the extension mechanism, focused on the C2SIM activities in Norway is currently in the Land domain, both for planning and for training. (Norway)
- Development of a C2SIM Reference Architecture and Distributed Simulation Engineering and

Execution (DSEEP) overlay. (Netherlands)

- Support development of C2SIM as a Service through liaison with MSG-136 *Modelling and Simulation as a Service* [29] (Netherlands, UK)
- Work closely with military operators to further develop C2SIM technologies, architectures and standards based on C-BML and MSDL and support moving to C2SIM from previous systems developed using C-BML and MSDL. (UK)
- Support MSG-145 organization and documentation processes, including outreach and education to the military C2 and simulation communities. (USA)
- Facilitate a continuously available distributed environment for test, evaluation, and experimentation via an Internet Virtual Private Network. This will include constructive simulations that have incorporated C2SIM and partnership with applicable Battle Labs to connect or participate in C2SIM evaluation events. (USA)

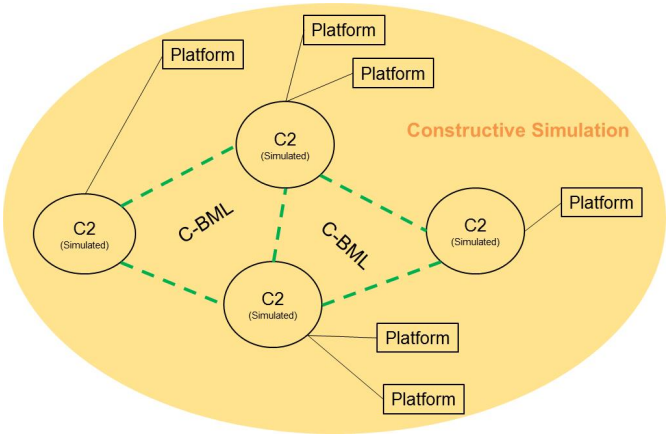

Figure 4. Simulation of System of Systems architecture

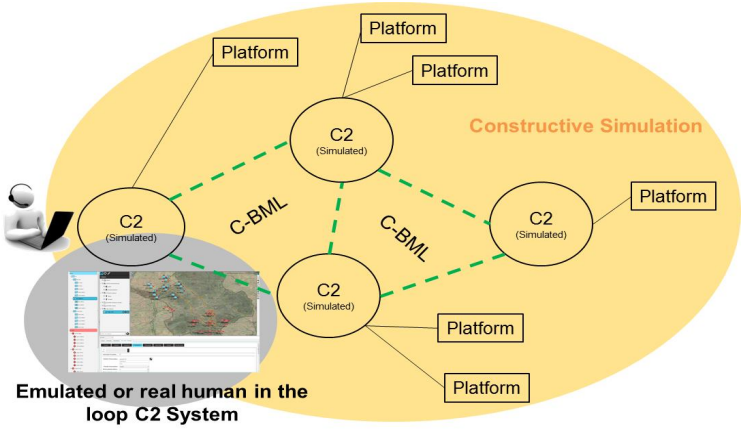

Figure 5. Integrating a virtual prototype within the simulated System of Systems architecture

5.0 MSG-145 ACTIVITIES

NATO interest in C2SIM first found expression in MSG-048, where the work was predominantly technical in nature. While operational military involvement in C2SIM grew in MSG-085 and is growing farther in MSG-145, both a strong technical component and operational activities are essential to the work.

5.1 Technical Objectives

The high-level technical objectives of MSG-145, as expressed in its Technical Activity Proposal [30], are as follows.

- Exploit C2SIM with use cases developed through an operational, conceptual and executable scenario development process by engaging the operational community.
- Develop required extensions to the C2SIM Logical Data Model Core for specific functional areas, beginning with Manoeuver Warfare equivalent to that demonstrated by MSG-085.
- Inform the standards development process and motivate suppliers to develop products by demonstrating C2SIM in operational military context.
- Educate the community of practice on C2SIM technology employment and encourage nations to use the standards by presentations at conferences such as SISO Simulation Interoperability Workshop, NATO Computer Assisted Exercise Forum, and the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC).
- Make recommendations for ”covering” the C2SIM standard with a STANAG in a manner complaint with NATO technical and operational requirements.

5.2 C2SIM Sandbox

MSG-145 is planning to develop and operate a “sandbox” testbed for C2SIM. This will be a continually available environment, available by VPN to national teams to demonstrate C2SIM. It also is expected to be useful for testing C2 and simulation systems implementing C-BML, MSDL, and (when available) the new SISO C2SIM draft standard implementation of manoeuver warfare. In addition to these functions, the C2SIM Sandbox will build experience toward a future C2SIM as a Service capability. It is envisaged that the Sandbox will serve as nucleus of a distributed testbed operated by MSG-145.

The C2SIM Sandbox will employ one or more C2 systems and commercial combat simulations, along with a server, operating in a virtual computing environment. Initially the Sandbox will support the four MSG-085 schemas, interoperating through a translating server [31]. A further goal is to add to these the new C2SIM core with Manoeuver Warfare extension, when it is defined. That would include all of the capabilities in existing MSG-085 Orders and Reports. After these functions are operational, other C2SIMS provided by MSG-145 participants and extensions such as autonomous systems can be incorporated.

The C2SIM Sandbox will have a limited GUI capability for operation via virtual desktop technology, but will not allow inspection of the C2, simulation or server code. One or more pre-packaged scenarios with recorded instructions for operation will be included to enable the C2SIM configuration to be exercised with only a minimal understanding of the software. The scenario will be user-modifiable within a limited scope via the C2 system GUI, to allow users to run alternatives and observe results.

5.3 Operational Activities

Engagement with operational military is critical for MSG-145. The most technically elegant system will be useless if it does not meet the needs of the military or is not embraced by them. The national teams of MSG-145 have been challenged to open dialog with military operators from their nations. A particularly

promising avenue for this is the US Army Mission Command Battle Laboratory, which hosted the final demonstration of MSG-085. Also outreach has been started, to some collective military training activities that represent good opportunities to obtain evaluation of C2SIM systems.

- Operational demonstration to showcase selected use cases will be organised during major simulation and C2 events such as I/ITSEC, ITEC, NATO Computer Assisted Exercise (CAX) Forum and ICCRTS or exercises such as Viking and the Coalition Warrior Interoperability Exercise (CWIX).
- Liaison has been established with NATO Allied Command Transformation (ACT), NATO Joint Warfare Centre (JWC), and the NATO Modelling and Simulation Centre of Excellence (M&S COE). Relationships with similar national centers are being sought by national teams participating in MSG-145.

The NATO future force will need to meet uncertain and hybrid nature of threats and operational environments. To this end MSG-145 is looking at a number of use cases that include:

- Cyber Warfare and Information Operations
- Autonomous Systems and Robotics
- Joint Mission Planning and Battlespace Management
- Army Mission Planning and Command Post Training
- NATO Mission Threads and Tactical Data Link.

5.4 Management

The Chair, Co-Chair, and National Leads form the management team for MSG-145. They are responsible for communication with the NMSG and Modelling and Simulation Coordination Office (MSCO) including coordinating the preparation of the following documents: (1) bi-annual briefing during the NMSG Business Meeting, (2) annual progress report and (3) the TA final report. This activity also involves coordination with the Collaboration Support Office (CSO) concerning requests for the support in the framework of the CSO Consultant and Exchange Programme and Cooperative Planning Programme.

Outreach to the community is an important function of the MSG-145 management team. In order to reach the operational stakeholder and the C2 and simulation community, the team will ensure that the results of the technical activity are reported in various conference and workshop proceedings dealing with C2 and simulation interoperability and autonomous systems such as the International Command and Control Research and technology Symposium (ICCRTS), SISO Simulation Interoperability Workshop (SIW), I/ITSEC, International Training Equipment Conference (ITEC), NATO CAX Forum, NMSG Symposium, NATO Technology for Information, Decision and Execution (TIDE) Sprint, and related national events.

MSG-145 has been organized into the following phases, which are time-phased as shown in Table 1.

- Phase 1: Development of the Programme Of Work activity
- Phase 2: C2SIM assessment, use case analysis, and extensions development
- Phase 3: Experiments to evaluate, and demonstrations to showcase, use cases
- Phase 4: Recommendation for STANAG

Table 1. MSG-145 Phase Overview

<table>
<tr><td></td><td colspan="2">2016</td><td colspan="2">2017</td><td colspan="2">2018</td><td>2019</td></tr>
<tr><td>Phase 1</td><td>POW development</td><td colspan="6"></td></tr>
<tr><td rowspan="3">Phase 2</td><td rowspan="3"></td><td rowspan="3">Standard assessment</td><td colspan="2">Use case requirements</td><td colspan="2" rowspan="3"></td></tr>
<tr><td colspan="2">C2SIM extension development</td></tr>
<tr><td colspan="2">Review STANAG process</td></tr>
<tr><td>Phase 3</td><td></td><td colspan="2">Identify target events</td><td colspan="2">Conduct experiment and demonstration</td><td></td></tr>
<tr><td rowspan="2">Phase 4</td><td colspan="4" rowspan="2"></td><td colspan="2">Final Report development</td></tr>
<tr><td colspan="2">STANAG definition support</td></tr>
<tr><td></td><td colspan="7">Communication, workshops and symposiums</td></tr>
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6.0 CONCLUSIONS

C2SIM has been demonstrated to hold exceptional promise to support coalition operations. This paper reports on our plan and the technical approach to achieve its operational use in NATO. Building on the past work or MSG-048 and MSG-085 and the technical standards activity of SISO, MSG-145 is working toward the day when coalition partners' C2IS and simulation systems will simply "plug together" to enable effective collective training, course of action analysis, and missions rehearsal. The technical readiness level achieved thus far and continuing work toward fully compatible, extensible C2SIM standards has reached a point where the next major step is operationalization. Effective engagement with military operators is essential to achieve this next step.

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