Coalition C2-Simulation History and Status

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Abstract

In December 2013, the MSG-085 Technical Activity presented a demonstration featuring military operational use of command and control (C2) systems interoperating with combat simulations. The demonstration was hosted by the Mission Command Battle Laboratory (MCBL) at Fort Leavenworth, Kansas, and featured six national (non-US) C2 systems and five national simulations, supported by servers from two different nations, linked into a single system of systems and operated by personnel from nine *nations, including two Internet locations. Standards used were the Military Scenario Definition Language (MSDL) Coalition Battle Management Language (C-BML), along with elements of the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM).*

The Call for Papers of this conference addresses "M&S Solutions to be applied within the entire NATO Framework, including best practices, standardization, interoperability, and other activities with the aim of expanding the efficient use of M&S within the Alliance." The MSG-085 Technical Activity made significant contributions in each of these areas.

This paper traces a successful history of C2-simulation (C2SIM) interoperation over the past decade, beginning with early experiments and culminating in the demonstration at Fort Leavenworth. The methodology and supporting technology were developed through three phases, roughly corresponding to concept development, proof of principle, and proof of concept, each facilitated by an energetic team from the NMSG. The factors leading to success are outlined.

The paper culminates with an extended summary of the operational aspects of the final demonstration, which showed how C2SIM can support commanders and staff assessments of the feasibility of selected courses of action, planning of branches and sequels, rehearsing the resultant order, and enhancing collaboration, planning, and preparation within a command structure of units. The operational focus of the demonstration was joint and combined mission planning, operating in a breakthrough parallel, collaborative mode across brigade and battalion echelons of a multinational coalition force. Military subject matter experts (SMEs) provided by the MCBL played roles of brigade and battalion commanders and contributed a critique of the operational employment that was highly positive and also offered avenues for future improvement.

1.0 INTRODUCTION

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 supported 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. The national C2 and simulation systems all interoperate, sharing orders, requests, and reports, so that all systems share relevant information. 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.

The above vignette, taken from [1], represents the vision of an international group of warfighters and technologists who have spent the past decade pursuing the technology of Coalition Battle Management Language (C-BML) and its operational relevance. The supporting technology provides the ability to exchange command and control (C2) and situational awareness information in a seamless, transparent form without building custom interfaces among various C2 and simulation systems. Significant advances have been achieved in this area; for example, in December 2013, the MSG-085 Technical Activity presented a demonstration featuring military operational use of C2 systems interoperating with combat simulations (collectively known as C2SIM). The demonstration was hosted by the Mission Command Battle Laboratory (MCBL) at Fort Leavenworth, Kansas, and featured six national (non-US) C2 systems and five national simulations, supported by servers from two different nations, linked into a single system of systems and operated by personnel from nine nations, including two Internet locations. This paper describes development of C2SIM over the last decade; it is based on references [1], [2] and [3], which provide greater detail.

Section 2 of this paper describes the organizations that have worked to advance C2SIM: the NATO Modelling and Simulation Group (MSG) and Simulation Interoperability Standards Organization (SISO). Section 3 recaps the history of C2SIM in NATO, starting with its national roots and culminating with MSG-085. Section 4 describes the operational validation of C2SIM that was part of the MSG-085 Final Demonstration.

2.0 ORGANIZATIONAL CONTEXT: NATO MSG and SISO

The work described below was undertaken by participants in NATO Modelling and Simulation Technical Activities and has included developing and validating SISO standards.

2.1 NATO MSG

The NATO Modelling and Simulation Group (MSG) charters technical activities conducted by groups from nations that are members or NATO or Partners for Peace to improve understanding and utility of technology involving modelling and simulation. Technical feasibility of coalition BML was demonstrated by NATO MSG-048 in a Technical Activity conducted 2006-2009. References [4 - 11] describe the C2SIM environment developed for NATO Technical Activity MSG-048, *Coalition Battle Management Language*. This activity included six national C2 systems, five national simulations, and two supporting software systems, a scale of interoperation not previously attempted. References [12, 13] describe developmental work for NATO Technical Activity MSG-085, *Standardization for C2-Simulation Interoperation,* leading to an experimental operational environment where multiple national C2 and simulation systems can interoperate using MSDL and C-BML (see Figure 1).

The follow-on Technical Activity, MSG-085, was chartered to demonstrate and facilitate the operational utility of MSDL and C-BML in military coalitions, and also to assess the operational relevance of MSDL and C-BML while enhancing the technical readiness level of their available implementations. MSG-085 had its initial organizing meetings in 2010, resulting in an Operational Subgroup (OSG) that defined validation experiments and a Technical Subgroup (TSG) that assembled required C2 and simulation systems and necessary infrastructure.

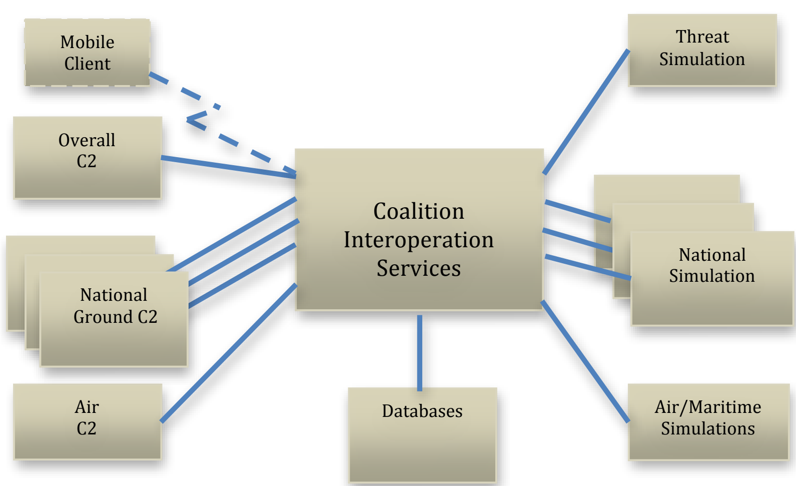

Figure 1: C2-Sim Coalition Services Architecture

2.2 SISO MSDL and C-BML

SISO has a two-part standards effort supporting BML. The Military Scenario Definition Language (MSDL) standard [14] was approved in 2008. It is intended to reduce scenario development time and cost by enabling creation of a separable simulation-independent military scenario format, focusing on real-world military scenario aspects, using the industry standard data model definition eXtensible Markup Language (XML) as input to initialize C2 and simulation systems. The Coalition BML (C-BML) standard [15] provides the tasking and reporting aspects of C2-Sim. It was balloted in 2012 and approved as a SISO standard in 2014. Several recent studies and implementations have addressed effective combination of MSDL and C-BML [16 - 19]. Informing the standardization process have been multiple projects under various US DoD sponsors and an ongoing sequence of experimental BML configurations that were developed and demonstrated by the members of NATO MSG-048 and MSG-085. The experience gained in these activities has proved critical to shaping the MSDL and C-BML standards and implementing infrastructure, such as the translation service described in this paper, and also in demonstrating the potential applicability of BML. The C-BML approach has generally followed the Lexical Grammar approach introduced by Schade and Hieb [20, 21]. Informing the standardization process have been multiple projects under various US DoD sponsors and an ongoing sequence of experimental BML configurations developed and demonstrated by the members of NATO MSG-048 and MSG-085 as described in the references.

3.0 HISTORY OF C2SIM IN NATO

With introduction of modern combat simulations in the 1980's came a new capability: military organizations can "train as you fight" by using their operational C2 systems to interact with each other and with the simulation [22]. However, interaction with the simulation required an extra human in the loop: a supporting "puckster" who transfers C2 information into the simulation system and also enters situational information from the simulation into the C2 system. In a large exercise, staffing for this role became a major expense. Furthermore, if the "puckster" was not knowledgeable in this role and diligent in transferring information, then the operation of the exercise became degraded. Therefore, automated interfaces between C2 and simulation systems were sought and in some cases implemented. However, such interfaces were implemented in an *ad hoc*, point-to-point manner and could not be extended readily to other systems.

Beyond the domain of training, the ability to couple C2 and simulation systems presented an intriguing new possibility: that simulation support of planning and preparation phases of ongoing military operations, providing course of action analysis and mission rehearsal capabilities. These C2SIM capabilities also were implemented experimentally but also were strictly *ad hoc*, point-to-point and could not be extended readily to other C2 or simulation systems. Clearly, the C2SIM area was ready for development of a more generic, consistent approach to interoperability.

3.1 SIMCI BML Experiment 2003

The first, important step toward a general approach to C2SIM interoperation was taken by the United States (US) Army Simulation to Mission Command Interoperability (SIMCI) program, using the approach shown in Figure 2 (which is still in use today for C2SIM) [22]. The emphasis of this effort, which also survives as a fundamental principle in C-BML, was to remove ambiguity at the C2SIM interface by replacing the free text of military orders and reports with a standardized vocabulary. An experimental interface was built using the approach:

- Build in the vocabulary contained in US Army FM 101-5-1 (September 2004), Operational Terms and Graphics and BML-1 as data tables.

- Incorporate a corresponding doctrinal base into the US Department of Defense (DoD) Joint Common Data Base (JCDB).
- Build in the syntax and semantics defined by the US Army Universal Task List (AUTL), the Army Training and Evaluation Program (ARTEP) Mission Training Plans (MTP) and the other related field manuals. Doing this allowed specific items to be aligned with echelon and type unit as relationships in the data tables.
- Create data-oriented messages that eliminate or reduce the free text currently in use.

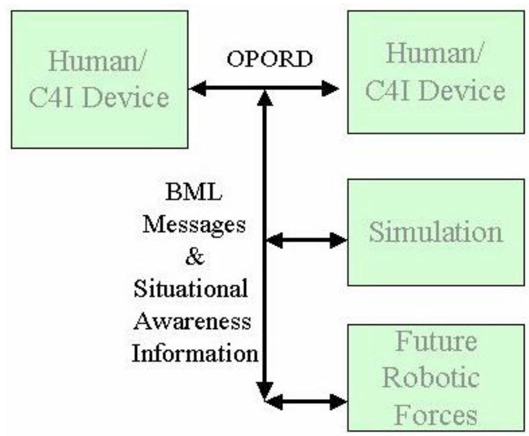

Figure 2: Scope of SIMCI Experimental BML in 2003

3.2 Extensible Modeling and Simulation Prototype

Starting in 2004, the US Defense Modeling and Simulation Office (DMSO) supported a broad effort aimed at use of emerging Web technology for interoperation of simulations: the Extensible Modeling and Simulation Framework (XMSF). An important part of XMSF was re-implementation of the SIMCI BML prototype using Web Service technologies [23]. The resulting prototype was migrated in 2005 to a database aligned with the Command and Control Information Exchange Data Model (C2IEDM) that later became the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM) under auspices of the Multilateral Interoperability Program (MIP), closely aligned with C2 in NATO.

3.3 Early C2SIM in France: Interoperation of APLET and SICF

In parallel with growing C2SIM interest in the US, other nations were considering the problem. In 2004, the *Direction générale de l'armement* (DGA) of France moved from consideration to action by interfacing the C2 *Système d'Information pour le Commandement des Forces* (SICF) to the simulation system *Aide à la Planification d'Engagement Tactique terrestre* (APLET).

APLET is a French Ministry of Defense (MoD) Research and Technology (R&T) program which aims to analyze simulation concepts of use in order to facilitate and improve Course of Action Analysis performed at Brigade or Division Headquarters fitted with the C2 system named SICF. In addition, APLET addresses the technical issues of C2 – simulation coupling.

APLET's main objectives are:

- Automate the Military Decision-Making Process for Course of Action Analysis;

- Foresee capabilities and added value given by simulation in case of close integration with C2 systems and as an example with SICF;
- Explore and solve C2-simulation interoperability issues and propose recommendations to bridge the gap between those systems;
- Define the most suitable simulation granularity allowing Courses of Action Analysis (COAA) in a limited time;
- Propose mechanisms to automatically produce Operation Orders from a selected Course of Action.

3.4 NATO MSG Exploratory Team 016 (2005)

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. Parties interested in C2SIM from France and the US became aware of each other's work and interests in 2005 and proposed to the NATO Modelling and Simulation Group (MSG) that a multinational Technical Activity be organized with the purpose of exploring use of the BML approach for coalitions. The MSG charted a multinational Exploratory Team (ET) to consider this possibility. France and the US were leaders in that team, which was numbered ET-016, and cooperated to provide an initial example of successful international C2SIM integration using a BML approach [24]. When demonstrated for the MSG, this example resulted in considerable enthusiasm for Coalition BML.

3.5 SISO BML Study Group

The Simulation Interoperability Standards Organization (SISO) provides a collaborative environment for exchange of information about simulation interoperability and an organization under which standards for interoperability can be developed. Various interested parties, including several ET-016 participants, formed a SISO Study Group to consider the possibility of developing a Coalition BML standard. After due deliberation, in 2005 that group produced a report [25] recommending that SISO charter a Product Development Group (PDG) for that purpose.

3.6 Proof of Principle: NATO MSG-048 (2006-2009)

With the successful France-US demonstration concluding ET-016, Coalition BML moved from an interesting idea to a challenging problem. France and the US were joined by other NATO nations, as described below. The NATO MSG chartered Technical Activity 048 *Coalition Battle Management Language* to coordinate collaborative efforts of the nations and provide input to the SISO C-BML PDG. This section provides a synopsis of the activities of MSG-048.

MSG-048 was organized under co-chairs from France and the US and included national representatives from Canada, Denmark, Germany, the Netherlands, Norway, Spain, Turkey, the United Kingdom (UK), and the US. Meetings rotated among most of these nations, at a rate of about four meetings per year. The final meeting of each year was associated with the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) in Orlando, Florida, where a demonstration was presented in the NATO MSG booth, representing the current state of C-BML at the time.

The Technical Activity Proposal for MSG-048 stated: "An open framework is needed to establish coherence between Command & Control (C2) and Modelling & Simulation (M&S) type systems in order to provide automatic and rapid unambiguous initialisation and control of one by the other. To accomplish this, C2 and M&S concepts must be linked in an effective and open manner defining new, system-independent, community standards and protocols."

This charge 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. 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) [20] and the Joint Battle Management Language (JBML) project [8 - 10]. This led MSG-048 to work that 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.

3.6.1 Technologies: C2, Simulation, and Supporting Software

The general architecture for Coalition BML followed by MSG-048 is shown in Figure 3. It presumes that all interaction among participating C2 and simulation systems takes place by exchange of messages through a server, implemented using Web Service technology. This architecture has two major advantages:

- Simplifies a complex development environment, since each client can be tested individually using the server.
- Provides a measure of fault-tolerance since it does not require that all members of the C2SIM system-of-systems coalition are constantly available.

The components used by MSG-048 will be described in terms of their role in the architecture of Figure 3: C2 Systems, Simulation Systems, and Server. Each system required a BML interface, consistent with the Web service schema used.

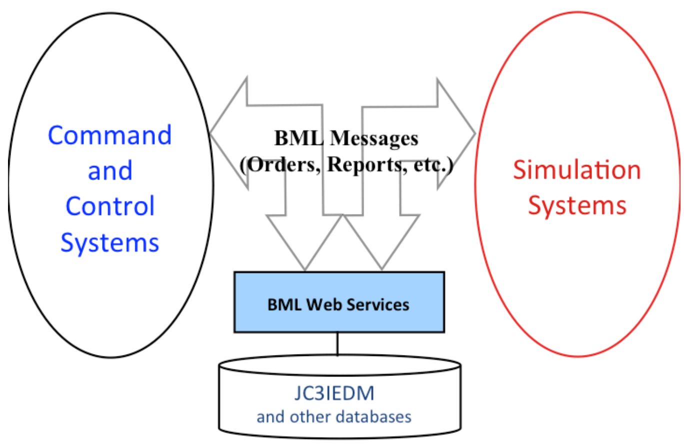

Figure 3: General Architecture for C-BML

C2 Systems:

- Battle View (Canada), used with a Predator Unmanned Arial Vehicle (UAV) for tactical air reconnaissance and fire support
- SICF (France) an actual fielded workstation
- ISIS (Netherlands), used as opposing force C2 system
- NORTaC-C2IS (Norway), designed for tactical army operations
- ICC (UK) Integrated Command and Control system that was developed by NATO for air operations
- ABCS (US), interfaced using JC3IEDM to its partner simulation system OneSAF (see below)

Simulation Systems:

- UAV-SIM (Canada), combined UAV agents with a system simulation
- APLET (France), mentioned previously in conjunction with ET-016
- SIMBAD (Spain), a constructive simulator intended for battalion-level task force training with minimal human operation
- JSAF (UK), a system originally developed by the US Joint Forces Command, used to represent air elements but capable of representing ground forces at need
- OneSAF (US), US Army standard simulation for collective training

Supporting Software:

- C2LG-GUI (Germany), a specialized interface that facilitates creation and editing of BML documents encoded in XML and submitting them to a server; this also proved valuable as an intermediate element, accepting partial BML from a C2 system that did not have enough information to complete the Order, inserting the missing information, and submitting the Order to the server.
- Scripted BML (SBML) server (US), open source software from George Mason University (GMU) C4I Center; the design of this server evolved over the duration of MSG-048, starting from a server where the parsing of the order was completely specified in Java code and emerging as a rapid prototyping tool that is configured by a script. The specifics of the Integrated BML (IBML) schema used at the end of MSG-048's work had evolved considerably from the initial version, but SBML was able to accommodate the changes rapidly.

3.6.2 MSG-048 and SISO C-BML

In parallel with MSG-048 investigations, the SISO C-BML PDG undertook to define a standard. This did not go as smoothly as the work of the NATO TA did. While there was progress in drafting and adopting a standard, the overall process was slower than most stakeholders found satisfactory. The standards effort went on past the end of MSG-048; at one point, the leadership of the PDG found it necessary to publish an analysis of the reasons for delay [26]. Eventually the process did produce results, as described below. In the interim, MSG-048 worked with a schema that had been developed in the US, in conjunction with an effort to increase the geospatial relevance of C-BML [27].

3.6.3 MSG-048 Final Experimentation

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 4.

A scenario, called "Operation Troy," was built by the SMEs that participated in MSG-048. These SMEs acted as the Brigade Staff that sent out the order to their subordinates. The exercise area was the Caspian Sea region used in earlier demonstrations. This allowed reuse of components that were prepared in 2007 and 2008. The Multinational Brigade consists of French and Norwegian battalions and a US reconnaissance element, with UK air component and a Canadian UAV company. The Mission given to the Brigade was to maneuver rapidly from an attack position along Phase Line Denver to seize objectives LION and TIGER, destroy Enemy forces in zone, and secure objectives along the international border to enable establishment of Caspian Federation (CF) regional military stability. Figure 5 displays a French Course of action.

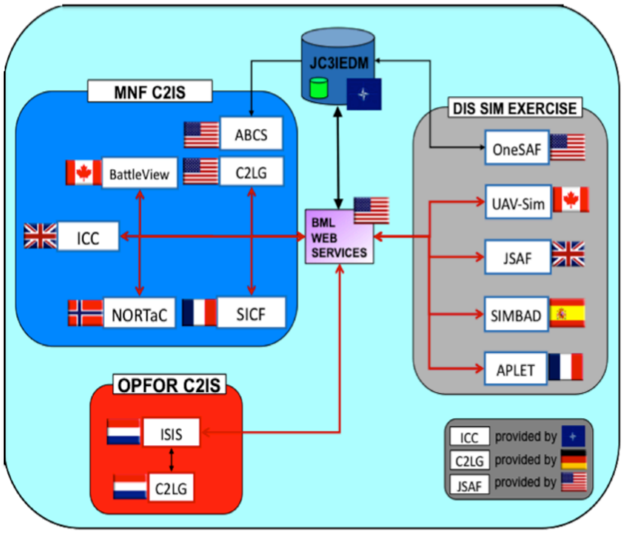

Figure 4: Architecture for MSG-048 Final Experimentation

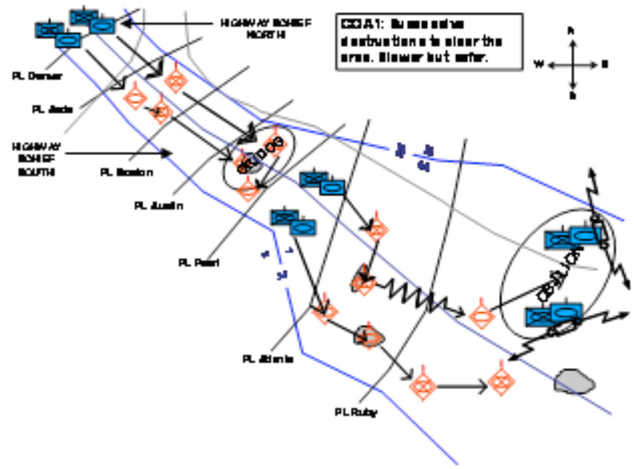

Figure 5: French Course of Action

Each of the two battalions (French and Norwegian) was assigned its own area of operation. The French had the area with objective Lion and the Norwegians had the area with objective Tiger. The US reconnaissance squadron went ahead of the other two battalions to report on the enemy. Further tactical reconnaissance and fire support was provided by a UAV under Canadian command.

By the end of the experimentation period interoperability was achieved, many of the experimentation goals were met, and much was learned about how BML would need to be supported in MSG-085. Considering the complexity of the system of systems assembled (as reflected in the variety of subsystems described above) and that an entirely new paradigm was implemented, the fact that the MSG-048 final experimentation ended with all subsystems demonstrating interoperation was a significant accomplishment. As a "proof of principle," the process followed was basically successful and showed that the technologies used, and the overall BML concept, would provide a sound basis for future work. This was confirmed by the participating SMEs, who were not part of the MSG-048 development team and therefore were able to view the results objectively [28]. Evidence that others also were convinced can be seen in the fact that MSG-048 received the NATO Scientific Achievement Award in 2013.

3.7 Proof of Concept: NATO MSG-085 (2010-2014)

As MSG-048 was preparing for its final experimentation, the NATO MSG considered a charter for a follow-on Technical Activity. It was clear even before the experimentation that Coalition BML was a very promising approach, so a new charter was approved with no hesitation. The new Technical Activity 085 was named "Standardization for C2-Simulation Interoperation" and focused on assessing the operational relevance of Coalition BML while increasing its Technical Readiness Level (TRL) to a point consistent with its operational employment. Consistent with this charter, MSG-085 has been, to a large extent, a process of maturing the technical and operational basis for coalition use of standardized C2SIM.

MSG-085 began in 2010. France and Canada were designated as co-chairs. Nations participating included the original nine from MSG-048 plus Belgium and Sweden, with interest also expressed by Italy and Australia. (In NATO context, Australia and Sweden are Partner Countries but not committed to its collective security; the Partner Countries are welcome in MSG-085 and many other NATO activities.) With increased focus on operational relevance came more participation from operational military and their support staffs. To use this new talent effectively, MSG-085 divided participants into an Operational SubGroup (OSG) and Technical SubGroup (TSG). The OSG developed methods for validation of operational relevance while the TSG continued the MSG-048 tradition of collaborative technology development, increasingly conducted via the Internet. In 2012, this organization was enriched by an orthogonal division into Common Interest Groups (CIGs) for Autonomous/Air Operations, Land Operations, Maritime Operations, Joint Mission Planning, and MSDL/C-BML Infrastructure (see below) [29 - 31].

An important finding of 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) [14] to provide effective initialization. Accordingly, in its first year MSG-085 pressed its members to implement 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 [16 - 18] before a path forward was adopted [19].

3.7.1 MSG-085 and SISO standards

Late in 2012, the SISO C-BML PDG completed balloting of the Phase 1 C-BML standard, including 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. Final editing of the C-BML Phase 1 document took place late in 2013; official standardization occurred in 2014, a long-anticipated event.

However, this result came so late that some MSG-085 member nations had not converted to C-BML from the IBML schema used in MSG-048, and in the absence of a C-BML standard other member nations had enhanced IBML and some others had adopted the enhanced version. Thus, there were four different schemas that might be used in the MSG-085 final demonstration, and there was not adequate time and resources to converge on a single schema. The resolution to this problem will be described in the section below on Server Technology Advances.

3.7.2 Early Simulation Implementation of SISO MSDL and C-BML

The first US simulation using the both the light and full schema definitions within the Phase 1 C-BML standard in conjunction with the MSDL standard was the US Army's OneSAF simulation toolkit. This was accomplished as part of its web-enabled evolution that enabled OneSAF's ability to support a right-sized integration with Mission Command (MC) systems in support of training, experimentation, mission planning, and mission rehearsal. Commercial web and standards-based technologies; current development trends; and lessons learned from past efforts including the Defense Advanced Research Projects Agency's (DARPA) Deep Green project, as well as the NATO MSG-048 and MSG-085 efforts drove OneSAF's evolutionary design. This new flexible, web-enabled, design resulted in OneSAF's ability to provide the necessary building blocks to implement significant new automated simulation support for critical military operational capabilities including:

- Mission Planning and Rehearsal;
- Automated Course of Action Analysis/Wargaming;
- Deployed Command Staff Training and After Action Review; and
- Commanders Critical Information Requirements (CCIR) Identification and Tracking.

There are a number of OneSAF development efforts that are now using these new building blocks to provide an integrated simulation capability within the Mission Command computing environments.

OneSAF's evolution is in direct response to lessons received from active participation within the DARPA Deep Green program; a number of US Simulation and Mission Command Interoperability (SIMCI) projects; and the NATO MSG-048 and MSG-085 projects. From participation in these projects the key Government and MITRE engineers on the OneSAF team identified and derived a number of critical requirements for simulations to support embedded Mission Command applications across a range of Mission Planning/Mission Rehearsal; training; testing; and experimentation. The required simulation services derived from active participation in these projects included:

- fully automated behaviors that are initiated based on command level orders,
- faster than real-time execution to support the timelines associated with mission planning cycles,
- setup, execution, and control transparent to the operational user,
- ability to base the simulation start point on Mission Command data,
- user selectable branch points and optimization criteria,
- command selectable reporting and running estimates,
- comparison of plans with actual execution,
- easy separation and identification of simulation and real-world data,
- opposing force initialization and behavior representations, and
- broad range of warfighting functional area representations.

The team then began implementing capabilities supporting these requirements. While not all of these services are completely functional within OneSAF, their initial limited existence allowed for prototyping integrated end-to-end mission planning and mission rehearsal operational capabilities. As such, OneSAF proved very useful in supporting the MSG-085 activity. Through participation in MSG-085 a number of additional insights regarding multi-national C2 coalition simulation were identified and include:

- Applying SISO standards for simulation initialization (MSDL) and for order, report, and request transmission (C-BML) reduce development and integration costs when operating in a single nation or coalition mission planning/rehearsal execution.
- Common supporting web-enabled infrastructure for publish and subscribe, persistence, bridging, and merging of initialization and order and report service eases cross coalition-based integration.
- Defining specific coalition initialization and order, report, and request agreements reduce development, integration, and rework costs when developing and executing mission planning activities within a federation environment.
- Loose coupling of coalition resources is necessary to allow multi-nation simulation with MC/C2 applications.
- Web-enabled access to simulation and MC and C4I systems is necessary to allow distributed access to mission planning/mission rehearsal assets.

A number of US projects currently are underway, extending OneSAF's foundational building blocks to extend and more fully support integrated simulation services within the Mission Command computing environment.

3.7.3 Server Technology Advances

While progress continued on all parts of the C2SIM system of systems as MSG-085 progressed, for C2 and simulation systems other than OneSAF it was incremental, without significant breakthroughs. However, in the area of servers, significant advances occurred.

Document-based Server: The SBMLServer used in MSG-048 worked by parsing every BML transaction into a JC3IEDM database. While powerful and flexible, this was slow. The Virginia Modeling and Simulation Center (VMASC) of Old Dominion University, in support of the US Joint Forces Command, implemented the CBMS server approach, which does minimal parsing and serves each transaction as a single document. This allows much higher performance [32].

MSDL Server: In order for various members of a coalition to interoperate the C2SIM systems, they need to assemble a single, consistent MSDL Scenario file. The SBMLServer was extended to automate this process and then serve the resulting MSDL file as part of the initialization process. The CBMS server, while it does not automate merging the MSDL Scenarios, also is capable of serving the combined MSDL Scenario.

Translating Server: The original server developer, GMU, focused on the problem of multiple schemas that was fragmenting MSG-085 operations, taking advantage of the fact that the SBMLServer parses all BML transaction and reassembles them for publication. Since the four possible schemas were largely equivalent semantically, they arranged for SBMLServer to reconstitute the parsed document in any of the four representations, acting as a translating server [12].

Web-based System-of-Systems Coordination: The envisioned mode for future use of C2SIM is distributed, not requiring the participating organizations to come together physically. As MSG-048 experienced strongly in its final experimentation, this requires an effective means of synchronizing operation of the various participating systems. GMU has developed a capability, based on normal webpage technology, to coordinate first the initialization and then the operation of a C2SIM coalition [33].

Commercially-based Server: While the translating SBMLServer offered a potential way to interoperate the multiple schema versions used by MSG-085 nations, its performance would not support a meaningful coalition in that mode. Happily, the Saab Corporation, a Swedish company, had offered MSG-085 access to its Widely-Integrated Systems Environment (WISE), which offered a high-performance way to implement SBMLServer. Saab further chose to provide limited support to GMU to enable transition of SBMLServer from open source Java that works with JBoss to open source C++ that works with WISE. The resulting WISE-SBML server has more than 10X performance over the original and is on a path to future commercial support. Saab also made available a BML-enabled version of its battalion-level C2 system 9LandBMS [12] for use by MSG-085; it was used as a surrogate US system because security issues precluded use of the US C2 system that has been developed for use with OneSAF.

Linked Servers: Ultimately it will be necessary to combine the power of multiple servers in support of larger coalitions. MSG-085 determined that it had a near-term need for such a capability, to interoperate the US/UK OneSAF/JSAF/ICC/9LandBMS coalition (using C-BML Light and IBML schemas) with the France/Germany coalition (using enhanced IBML schema). The France/Germany coalition used a hybrid server, developed by Fraunhofer-FKIE, based on the original open-source SBMLServer. GMU and Fraunhofer-FKIE collaborated to develop a capability to link their servers, using a “back to back client” in the middle [13]. Figure 6 shows the linked server architecture.

3.7.4 MSG-085 Final Demonstration

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 there to engage in a short integration session. The featured capability was Joint and Combined Mission Planning. The architecture of the demonstration system-of-systems that was assembled is shown in Figure 7.

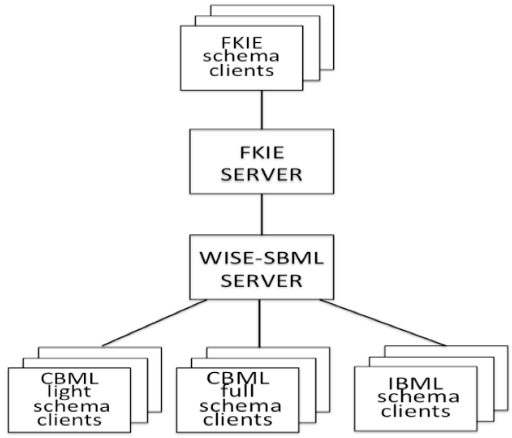

Figure 6: Linked Server Architecture

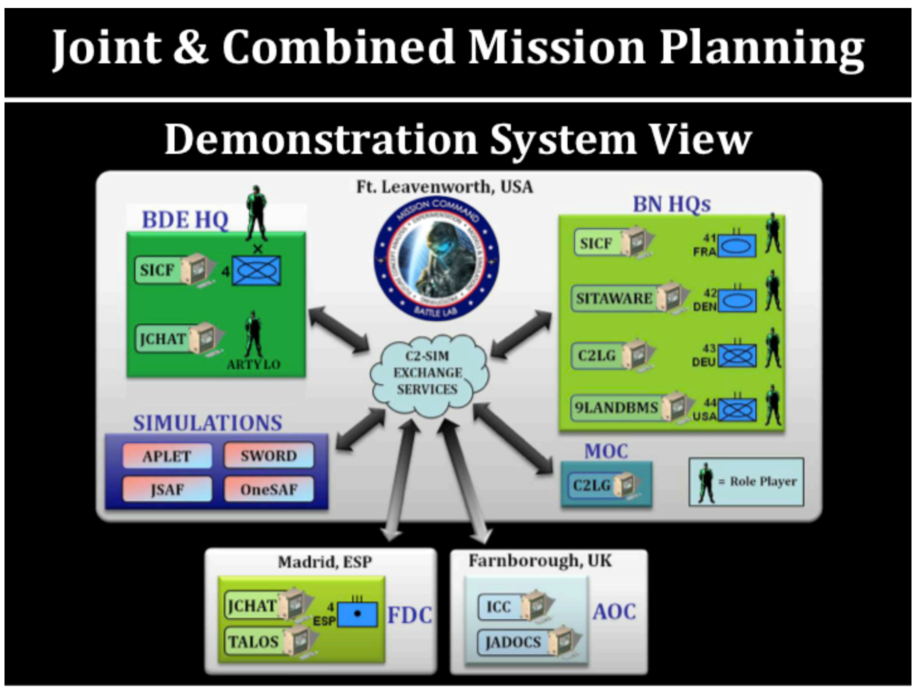

Figure 7: MSG-085 Final Demonstration System of Systems

While the complexity of the MSG-048 and MSG-085 final events is roughly similar, there were some striking differences:

- *Network sophistication*: The MSG-085 network included two remote participants and operated with two linked servers and three schemata (C-BML Full, while available on the WISE-SBML server, was not used by any of the systems). This models the sort of operation expected in operational BML use.
- *Setup process*: The MSG-048 setup was somewhat chaotic, with some of its capabilities becoming usable only on the last day of experimentation. By contrast the MSG-085 systems came together smoothly. There were a few problems but mostly they "just worked".

- *Audience impression*: The MSG-048 final audience got the message "We have an exciting new capability. It's not working very well yet but it has great potential for the future." In contrast, 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."

In short, where MSG-048 succeeded in proving the principle that C2SIM could be used effectively in coalition operations, MSG-085 succeeded in a harder goal: proving the concept that C2SIM in the form of MSDL and C-BML is ready to be tested in real coalition operations. The next section addresses that question.

4.0 OPERATIONAL VALIDATION IN THE MSG-085 FINAL DEMONSTRATION

Command and control (C2) systems are co-located within a facility to assist the commander of a military organization in establishing and maintaining situational awareness/situation understanding (SA/SU). The systems provide the information for the commander and staff to consider in determining the optimum course of action to accomplish his or her given mission. All militaries have a well-defined process for considering the different methods and various courses of action that could be used to accomplish a mission and then issue orders to their units to do so. Currently, such course of action development and analysis is a linear, sequential, resource intensive, human endeavor that the military unit's staff completes for the commander. The staff presents the courses of action and their analysis to the commander for a decision, who then directs the production of an order to execute the approved plan.

The C2 of military operations always has been a key target for technology advancement. The development of automated digital C2 systems has occurred rapidly in relative terms along with a change in focus of our method of communications away from human to human towards these systems [3]. Advances in the interoperation of simulation and C2 systems, along with an emphasis on collaboration between echelons, allow the commander and staff to leverage simulations during course of action development and analysis, to improve collaboration with subordinate unit commanders and staffs. Additionally, it is almost impossible to imagine a situation in the future when a single US military service or a single country's military forces will be unilaterally employed. Because future military operations, and a significant amount of training, will be Joint and Combined/Coalition in nature, our capability for information exchange must engage all aspects of a future military operations in a multi-service or multinational environment. This anticipated environment has driven the development of Coalition Battle Management Language (C-BML) and the Military Scenario Definition Language (MSDL). C-BML will support communication of C2 information in a format that can be read, parsed, interpreted and acted upon by "intelligent agent" software. MSDL grew out of a desire to reduce scenario development time and cost and then be able to use the resulting scenario across multiple simulations running within a federated environment or as independent simulations. These two technologies underpin the efforts of the NMSG-085 and the ensuing operational demonstration.

4.1 Operational Focus of MSG-085

MSG-085 successfully completed initial experiments and demonstrations toward coalition C2SIM interoperability at Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) in December 2011 with three unique architectures and scenario vignettes (Recon, Ground Maneuver, Logistics) with a coalition federation of C2 devices and simulations being rapidly initialized with common scenario data, and synchronized for execution using the evolving SISO standards. These initial experiments verified that the technology was capable of meeting MSG-085 objectives and that input from an operational perspective was needed.

To show the operational relevance of using simulation to support planning of military operations, a location known for operational experiments was approached to host the event: The United States Army Mission

Command Battle Lab (MCBL) at Fort Leavenworth, Kansas, USA. The MCBL agreed to provide a venue and planners with military experience to act as role players/subject matter experts during the event because of the value and impact of the MSG-085 from the US perspective [3]:

- Supports standards.
- Provides venue to evolve, deploy & demonstrate key M&S standards.
- Supports coalition operations.
- Enhances interoperability for coalition Training, Mission Rehearsal and COA.
- Supports US Army simulation (OneSAF) reuse.
- Improves and extends OneSAF (and tools) into MC, Training, and international communities.
- Supports Army integration with Joint Projects for enhanced return on investment (ROI).

4.1.1 Operational Benefits in MSG-085 Final Demonstration

The primary purpose of information is to allow commanders and their staffs at all levels to make better and faster decisions. The key to this is the ability to collect, fuse, and disseminate accurate, timely, and relevant information with much greater rapidity to achieve a common and shared understanding among the participating commanders and staffs [5]. To this end, technology is providing more and more information. C2 systems are designed to support operational information and allow the commander to visualize better the battlefield. Simulations are able to portray the potential outcomes of decisions before they are executed in the real world. Using information from the C2 and simulation domains in a common environment provides the commander and staff a robust tool to support collaboration and decision making, to address not only the operation at hand, but also the implications of concurrent and sequential operations. One great challenge to getting simulations used in the C2 decision-making process is making it acceptable to the military user. If the operational community does not accept the concept and use it, the software will only take up space on a computer. To make it acceptable to the “field” users, it must have the comfortable look and feel of what they are using now. Where major changes are incorporated, the user must realize the benefits either through saving time or adding clarity [34]. The remainder of this subsection addresses key points for introducing simulation support to the planning of military operations.

4.1.1.1 Benefits of introducing simulation to operational headquarters

Military operations are complex and hard for the human mind to portray precisely. Computers, however, are capable of portraying large number of entities engaged in operations accurately without bias. The MSDL and C-BML technologies provide a simple way to access simulation functionality from the command post C2 system and allow the command and staff a visual representation to support decision-making.

4.1.1.2 Simulation for training versus support to operational planning

Traditionally simulation has been used to support training. For this purpose the actions of the hostile parties and enemy has been played by the RED cell which operates independently from the main training audience. For planning purposes however the hostile parties and enemy should be controlled by the planning group that is responsible for its own plan. Manual wargaming is an activity where G-3 planners initiated actions, G-2 planners reacted to that action and finally G-3 planners initiated counter-actions. When using simulations to support planning, the same action-reaction-counteraction process is needed within the planning group.

4.1.1.3 Synchronization matrix delivered as a shared service between command posts

The synchronization (sync) matrix is a common product from the Military Decision Making Process (MDMP) and often serves as the foundation of the operations order (OPORD). Prior to digital communications, each command post developed its own sync matrix and published to subordinates. Now, collaboration between unit commanders and staffs has improved the sync matrix development process and using simulation has the potential to improve this process yet again.

4.1.1.4 Rehearsal support

Simulations provide an environment to support rehearsal in a similar manner as they support training. When used in an operational context, the simulation records the actions of units and outcomes of engagements. These capabilities allow the commander and staff to adjust the plan and then "re-fight" it to consider results of the changes.

4.2 Conduct of the Operational Demonstration

The primary purpose of the event was to demonstrate the operational relevance of C2 system-simulation interoperation in support of multi-level, multi-domain and coalition military enterprise activities such as coalition mission planning and mission rehearsal. The secondary goal was to demonstrate that NATO Comprehensive Operational Planning Directive (COPD) activities can be conducted in a distributed manner and more quickly than is currently possible. Benefits of this approach to a commander are:

- Conducting an integrated planning process
- Increasing the number of subordinates aware about the future plan
- Improved understanding at multiple levels
- Early identification of risks associated with operations
- Higher quality plan that maximizes planning time at lower echelons

The demonstration featured six national non-US C2 systems and five national simulations, supported by servers from two different nations, linked into a single system of systems. Standards used were C-BML and MSDL, along with elements of the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM). Personnel and systems from nine nations (23 people) participated at Leavenworth while personnel from the United Kingdom and Spain participated from their home locations via Internet links. In order to meet US Army security guidelines, the commercial C2 system 9LandBMS was used as a surrogate C2 system for SMEs playing US command and staff roles.

As described in [36] and [37], the context of the demonstration is the US Army Military Decision Making Process (MDMP) with a focus on course of action (COA) development, analysis (wargame), and comparison. The operational scenario focused was:

> *As a result of a broken ceasefire agreement in BOGALAND, a NATO Response Force (NRF) has been activated and will conduct combined and joint operations in order to separate the parties and reinstate adherence to the peace agreement. The 4th Multi-National Brigade (4 MNB) is tasked to defeat the aggressor and restore a safe and secure environment and therefore must perform operational planning.*

The demonstration used a mission planning cycle consistent with the NATO COPD (Figure 8) and used C2-simulation linkages to facilitate collaborative planning between the role players as brigade and battalion commanders.

The demonstration was comprised of three vignettes, which were conducted in parallel, collaboratively across brigade and battalion echelons of a multi-national coalition force:

1. Initial COA Development: the brigade informs the battalion commanders of the initial COA and sends it to the simulation for execution. Based on the simulation results, the brigade refines the COA, which is communicated to the battalions who then generate their orders to subordinate companies and in turn send them to simulations for execution.

2. COA Refinement: simulation results were used by the battalions to substantiate further refinements of the support requests.

3. Mission Synchronization: the brigade performs final adjustments to the orders that are communicated to the battalions for the purposes of mission synchronization.

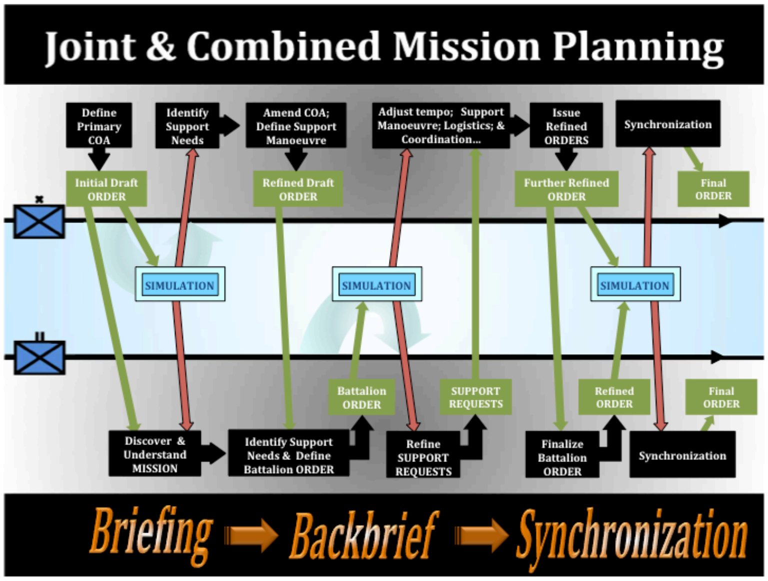

Figure 8: NATO COPD as applied in MSG-085 Final Demonstration

As each demonstration/vignette was executed, the planners from the US Army MCBL participated as commanders at the brigade and battalion level. Assessments, pro and con, were recorded and shared for each iteration (see [3] for details). During all iterations, the demonstration quickly revealed the necessity for a shared and common sync matrix. First the planning groups experienced the need for coordinating their own operation. Phases and steps were based on the Brigade plan but were further refined by the Battalion planners. These changes and amendments were then shared to the other command posts. For example, changes to phase lines and fire coordination lines were fully coordinated across all planners and echelons. Additionally, the planners realized they needed to coordinate the timeline and speed for the actual simulation itself. The simulation systems had the functionality to monitor elapsed time even when the simulation was advanced or ran faster than true time. This allowed planners to run several different force or organizational arrangements to accomplish the mission.

The demonstration was well attended by US and international military and supporting civilian personnel, who offered mainly positive comment and also recommendations to improve operational utility, for example the need to resolve security issues before deployment.

4.3 Outcomes of the Operational Demonstration

Demonstrated joint and combined mission planning, operating in a breakthrough parallel, collaborative mode across brigade and battalion echelons of a multi-national coalition force.

Military planners provided by the MCBL played the roles of brigade and battalion commanders and contributed a critique of the operational employment that was highly positive and also offered avenues for future improvement.

Demonstrated significant potential cost and time savings associated with the use of C2-simulation interoperability technologies for command post training.

Demonstrated strong potential for improving the COA development process through increased collaboration among Brigade and Battalion commanders using C2-simulation interoperation.

Set the stage for NATO to move toward employing C2SIM interoperation in Coalition Warfighting capabilities.

5.0 CONCLUSIONS

This paper has reviewed the inception and steady progress of C2-simulation (C2SIM) interoperability as a standardized capability that can improve the decision-making and training in coalition military operations. Starting with an exciting concept, the community involved in C-BML, both in NATO and SISO, has made continued progress toward the goal that, in the not too distant future, military coalitions will be able to come together and benefit from interoperating C2 and simulations across all nations participating.

While commendable progress has been made toward the vision motivating the vignette that began this paper, much remains to be accomplished. The feasibility of C2SIM was demonstrated by MSG-048 and the utility of C2SIM has been demonstrated by MSG-085. What remains is to engage the operational military community in the various NATO nations and provide them compelling evidence, in the form of well-supported training events, that C2SIM should be an integral part of NATO and national C2 systems.

Initial results work with the operational community in the MSG-085 Final Demonstration augur well: a representative multinational Coalition demonstrated the potential for positive outcomes when C2SIM interoperability is used for planning a military operation. The result clearly indicates the likelihood of increased technological capabilities in C2 and simulation systems in Coalition military operations is seen as part of the prospective solution set for conducting collaborative military planning.

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