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Coalition Battle Management Language (C-BML) Study Group Final Report

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Executive Summary

Interoperability across Modeling and Simulation (M&S) and Command and Control (C2) systems continues to be a significant problem for today's warfighters. M&S is well-established in military training, but it can be a valuable asset for planning and mission rehearsal if M&S and C2 systems were able to exchange information, plans, and orders more effectively. To better support the warfighter with M&S based capabilities, an open standards-based framework is needed that establishes operational and technical coherence between C2 and M&S systems.

System developers, integrators, and users have expended considerable effort over the past 20 years to provide interoperability between C2 and M&S systems. This has often been motivated by the need to reduce the costs associated with inputting data into simulations that supported C2 training. The development of digitized C2 systems and the opportunity to utilize M&S tools for Course of Action Analysis and Mission Rehearsal, as well as emerging work on robotic forces, increase the requirement for interoperability across these systems. The move to net-centric, network-enabled operations creates new opportunities and context within which M&S capability must support the warfighter. Furthermore, military operations are no longer conducted by single services and a single national force. Operations are increasingly joint down to the tactical level and likely to be conducted within a coalition or alliance such as the North Atlantic Treaty Organization (NATO). This leads to a requirement for multinational interoperability and the development of standards for inter-system information exchange.

In September 2004, the Simulation Interoperability Standards Organization (SISO) Standards Activity Committee (SAC) approved the establishment of a Study Group (SG) on Coalition Battle Management Language (C-BML). A Terms of Reference agreement provided a statement of work for the C-BML SG, identifying the following tasks:

- The study group shall conduct a paper survey identifying as many international contributions applicable to the C-BML effort as possible.
- The study group shall develop a plan of how these identified efforts can contribute to a common C-BML standard and a standard framework.
- The study group shall formulate a set of recommendations on how to proceed toward a C-BML Product Development Group (PDG).

The proposed C-BML standard is the foundation of a framework that can provide an objective capability to enable automatic and rapid unambiguous tasking and reporting between C2 and M&S Systems. Products resulting from establishment and execution of the above tasks include, but are not limited to:

- A literature survey summarizing the results of the first task.
- A final report, summarizing the results of the above tasks, to be delivered during the Fall 2005 Simulation Interoperability Workshop (SIW).

Throughout the life of the C-BML SG there have been 9 meetings (including telephone conferences). C-BML meetings were conducted at SIWs in the fall of 2004, the spring of 2005, as well as at Euro-SIW in June, 2005. In addition, a dedicated C-BML meeting was held at the Virginia Modeling, Analysis, and Simulation Center (VMASC) on March 7-9, 2005, that brought together 35 international experts. Five universities and 6 nations participated. Participants presented information on related projects and were tasked to provide project summaries of relevance to C-BML (see Section 2 of this report). A second dedicated meeting for C-BML was held at George Mason University (GMU) to finalize the Study Group Report. There are currently over 100 participants representing 11 nations in the C-BML SG.

In parallel to C-BML SG activities, the NATO Modeling and Simulation Group (MSG) established a 12-month Exploratory Team 016 (ET-16) on C-BML. The team held its first meeting in Paris in February 2005 with 7 nations represented. It endorsed the requirement for a C-BML and has proposed that a 3-year Technical Activity Program be established. Their recommendations will be submitted to a meeting of the NATO MSG in October 2005 in Poland. This group anticipates using a C-BML standard developed by SISO.[1]

Also in parallel to C-BML SG activities, following the Spring 2005 SIW in San Diego, the SAC approved establishment of a SG to examine the requirement for a Military Simulation Definition Language (MSDL). It is a separate but related activity to C-BML. Its primary purpose is to provide initialization to simulation systems independent from the simulation and scenario generation tools. The Co-chair of the C-BML SG was elected the Vice-chair of the MSDL SG to ensure there was no duplication of effort. Close collaboration between both study groups has identified areas of commonality and differences. In brief, C-BML is focused on C2/M&S data interchange and MSDL is focused on simulation initialization.

A major finding of the C-BML SG is that the first version of a C-BML standard should use the de facto international standard Command and Control Information Exchange Data Model (C2IEDM) as the basis for the standard development. This aligns with research already conducted by various organizations in several nations and as recommended for C2 to M&S interoperability at NATO M&S Conference MSG-022 (October, 2003) and more recently by the US Army M&S Executive Council (July, 2005).

The C-BML SG makes the following recommendations to the SISO SAC:

- We recommend that SISO accept the Product Nomination.

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[1] While this statement was true when the report was submitted, several activities took place since this happened. The SISO C-BML Study Group results were indeed presented to the NATO MSG during their meeting in Poland in October 2005. The NATO Task Group MSG-048 on "Coalition Battle Management Language" was established under French and U.S. co-chairmanship. This group will closely collaborate with the SISO C-BML Product Development Group.

- We recommend that SISO establish a PDG in order to develop a C-BML standard.
- We recommend that SISO initiate a phased approach to the development of the standard.
- We recommend that the C-BML PDG be separate from a proposed MSDL PDG.
- We recommend that the C-BML PDG closely collaborate with a MSDL PDG where there are areas of common interest, such as the development of a military tasking grammar.
- We recommend that the C-BML PDG maintain engagement with C2 community to ensure joint ownership and development of the standard.

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1 Introduction

The Simulation Interoperability Standards Organization (SISO) is responsible for the identification of applicable standards to support distributed simulation in all simulation domains and to develop standards in case no available standards are applicable to fulfill the community's interoperability needs. These objectives are achieved by:

- Conducting Simulation Interoperability Workshops (SIWs) that:
  - Identify requirements and respective interoperability gaps.
  - Exemplify solution possibility in prototypes.
  - Demonstrate applicability of standards.
- Evaluating interoperability domains in depth in Study Groups (SG) that:
  - Conduct surveys of the related domains.
  - Develop plans on how to reach consensus.
  - Identify potential solutions.
- Preparing standards in Product Development Groups (PDGs).

A review of technical papers at SISO, Command and Control Research and Technology Symposium (CCRTS), other forums, as well as military customer requirements, discloses a continuing need for improvement in the capability of Command and Control (C2) and Modeling and Simulation (M&S) systems to interoperate. This has often been motivated by the need to reduce the costs associated with inputting data into simulations that supported C2 training. The development of digitized C2 systems and the opportunity to utilize M&S tools for Course of Action Analysis (COAA) and Mission Rehearsal, as well as emerging work on robotic forces, has created an increased requirement for interoperability across these systems. In addition, the move to net-centric and network-enabled operations creates new opportunities and context within which M&S must support the warfighter. Military operations are no longer conducted by single services and a single national force. Rather, they are increasingly joint down to the tactical level and likely to be conducted within a coalition or alliance such as the North Atlantic Treaty Organization (NATO). This leads to a requirement for multinational interoperability and the development of standards for inter-system information exchange.

In September 2004, the Simulation Interoperability Standards Organization (SISO) Standards Activity Committee (SAC) approved the establishment of a Study Group (SG) on Coalition Battle Management Language (C-BML). The C-BML SG was formed under the following premise:

> *In order to improve simulation interoperability and better support the military user with M&S-based capabilities an open standards-based framework is needed that establishes operational and*

> *technical coherence among C2 and M&S systems. The objective capability will enable automatic and rapid unambiguous initialization and control of one by the other.*

The foundation for such a capability is a Battle Management Language (BML), a concept that has been discussed during several SISO workshops and prototyped in a technology demonstration. BML is not a new concept, having its genesis in the 1990's in Eagle BML and the Command and Control Simulation Interface Language (CCSIL) from the Synthetic Theatre of War (STOW) program. In the international C2 community there is a history of complementary efforts to achieve country and system-independent technical and semantic standards for conveying information relevant to C2.

The objective capability can only be realized through standards that define technical and operational coherence between C2 and M&S systems. *Technical coherence* is relatively straightforward given the variety of technologies that exist today to engineer distributed integrated systems, such as the Common Object Request Broker Agent (CORBA), Web Services, and Extensible Mark-up Language (XML). *Operational coherence* is the fundamental difficulty to achieving the objective capability. It requires that a precise and unambiguous set of concepts, semantics, and business rules be established as the basis for communications and control between C2 and M&S systems. Previous simulation standards, such as the High Level Architecture (HLA), have had similar objectives in the simulation-to-simulation area. *Today, the semantic misalignment between M&S standards and C2 standards form a barrier to achieving the desired objective capability. A BML must derive directly from the C2 view of operations*.

During the Spring SIW 2004, a meeting of subject matter experts decided that there was considerable merit in taking the BML initiatives that had been carried out in the US Army and developing a Coalition BML. As a result a statement of work was drafted and submitted to the SISO SAC.

The Terms of Reference (TOR) for the C-BML SG listed the following tasks:

- The study group shall conduct a paper survey identifying as many international contributions applicable to the C-BML effort as possible.
- The study group shall develop a plan of how these identified efforts can contribute to a common C-BML standard and a standard framework.
- The study group shall formulate a set of recommendations on how to proceed toward a C-BML Product Development Group (PDG).

The TOR stated that the products resulting from the establishment and execution of these tasks shall include, but are not limited to:

- A literature survey summarizing the results of the first task.
- A final report, to be delivered during the SIW Fall 2005, which summarizes the results of the second and third tasks.

The Command, Control, Communication, Computers, and Intelligence (C4I) Forum is sponsoring this SG. In addition to its SISO membership, the SG collaborates with other organizations with potential interest in this work, in particular the North Atlantic Treaty Organization (NATO) Modeling and Simulation Group (MSG) and the CCRTS.

The C-BML SG formally began work at the Fall 2004 SIW. It submitted an interim report at the 2005 Spring SIW, and completed work with submission of this final report to the Executive Committee (EXCOM), SAC, and Conference Committee (CC) at the Fall 2005 SIW. In addition to electronic collaboration facilitated by use of the SISO web site, interim meetings were held in conjunction with other M&S-related conferences during the 12-month tenure of the SG.

1.1 Battle Management Language

A BML must provide an unambiguous language for conveying orders and commands to live, simulated, and robotic forces. A BML prototype initiative was started in 1999 by the US Army Modeling and Simulation Office (AMSO), now part of the Battle Command, Simulation, and Experimentation (BCSE) directorate. A BML must formalize concepts such as the “Who, What, When, Where, Why” (5W’s) information needed to command and control forces. These constructs must be understood by C2 systems, simulations, and autonomous robots.

These principles have led researchers to describe three “views” or perspectives on BML (Tolk & Blais 2005):

- BML Doctrine View: Every term within the language must be unambiguously defined and must be rooted in military doctrine. BML should not implement a single service doctrine, but allow different doctrinal viewpoints of services or nations to be defined. This is conveyed in BML by a glossary of terms and definitions.
- BML Representation View: The representation structures and relates the terms defined in the doctrine in a way that they result in the description of executable missions and tasks (where a mission is defined as a sequence of tasks that must be executed in an orchestrated manner). Relevant representations can include conceptual, logical or physical data models or fully formalized ontologies[2].
- BML Protocols View: Protocols standardize the way the description of the executable tasks and assigned executing military means is transported from the BML implementation to the target system (C2, simulation, or robot). In the emerging net-centric operational environment, Web-based

[2] An ontology is described in (Tolk & Blais 2005) as a formal specification that “concisely and unambiguously defines concepts such that anyone interested in the specified domain can consistently understand the concept’s meaning and its suitable use.” Discussion of a C2 Ontology for BML is provided in Appendix C.

standards and grid standards offer candidate protocols. In particular, the use of XML to describe information exchange requirements is considered fundamental since it is the currently accepted standard for data description across battle command (BC), simulation, and robotic systems.

Figure 1 summarizes the three BML views. It should be clear that BML is a concept that can have numerous realizations across the three views.

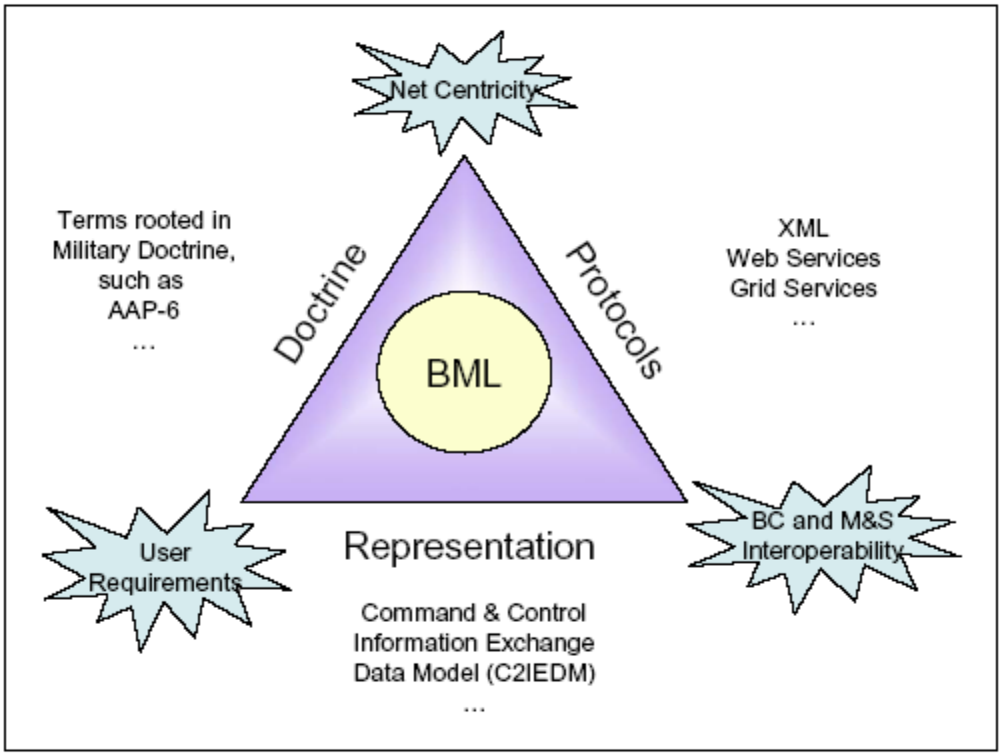

Figure 1. BML Views: Doctrine, Representation, and Protocols.

1.1.1 BML – Doctrine View

Every term used within BML must be unambiguously defined and must be rooted in doctrine. In other words, *the doctrine view must be a glossary* comprising each term and its unambiguous definition as well as the source of this definition.

The glossary must be aligned with other SISO efforts to create a standard dictionary for use within M&S solutions; e.g., the Real-time Platform Reference (RPR) Federation Object Model (FOM) definitions of the FOM/Simulation Object Model (SOM) lexicon and respective C2 efforts such as the Command and Control Information Exchange Data Model (C2IEDM)[3]. Furthermore, the glossary must be aligned with the manuals and handbooks used to describe doctrines for

[3] Each attribute in the C2IEDM has a mandatory field providing the meaning of the attribute and a pointer to the source of the definition. This can be compared to the FOM Lexicon specified in the HLA standard.

the warfighter. A starting point should be NATO and ABCA[4] publications supported by the relevant national publications. The Multilateral Interoperability Programme (MIP) C2IEDM provides this type of doctrinal pedigree.

A misperception often surfacing in discussions is that the doctrine view implements only a single doctrine. This is not the case. The view provides unambiguous definition of a doctrine, but allows different doctrinal viewpoints of services or nations to be defined. The BML doctrine view – once it is standardized – helps to describe different doctrines in a common form. Therefore, it actually will help show different partner viewpoints regarding doctrine.

Groundbreaking work performed for the US Army is documented in the reports referenced in detail in (Sudnikovich, et. al., 2004) and (Carey, et. al., 2001). Setting up a C2 ontology is not a trivial task and should not be underestimated. Work performed to date provides a basis for recommendations on a standard and shows methods and procedures to be followed by future C-BML developers. No generally accepted technical approach is yet established. Preliminary discussions are exploring the question concerning to what extent ontological layers will be necessary to express doctrine. The SG is convinced that we will need a phased development approach to extend an initial standard from the a glossary approach to a more semantically rich ontology approach, but there is no solution accepted by all target domains of C-BML that is applicable today.

1.1.2 BML – Representation View

The representation view structures and relates the terms defined in the doctrinal view in such a way that they result in the description of *executable missions and tasks*. A mission is defined by a sequence of tasks that must be executed in an orchestrated manner. The representation must not only allow description of the various tasks but also composition and orchestration of these tasks into missions. Furthermore, the representation must comprise military means, which can be real units or platforms, or simulated entities. Being able to cope with causalities and temporal relationships in terms used by the warfighter is required and connects the representation view to the doctrine view.

The US prototype development for BML currently uses the C2IEDM as the underlying data model. The evolving MIP data model will serve as the foundational basis for representing C-BML. To the degree that the C-BML work identifies tasks and missions outside the current scope of C2IEDM, the C-BML working group will recommend that change proposals be forwarded to the MIP by

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[4] ABCA is a standardization program initiated in 1947 after close cooperation of the allies in World War II. The program initially involved America, Britain and Canada, with Australia joining the program in 1964. New Zealand was granted observer status in 1965. Today, the focus of the Program is on interoperability, defined as: "*the ability of Alliance Forces, and when appropriate, forces of Partner and other Nations, to train, exercise and operate effectively together in the execution of assigned missions and tasks*."

member nations. Extensions to the C2IEDM to support the M&S community needs will be treated in the same fashion.

Furthermore, emerging commercial standards activities such as the Object Management Group's (OMG) Shared Operational Picture Exchange Services (SOPES) may also contribute to C-BML as this work is expected to leverage the MIP work into industry and international standards for expressing and sharing information in support of coordinated operations.

There are several expert opinions concerning the applicability of data models to cope with ontological challenges. Additional ideas and future model-driven solutions need to be evaluated. One possibility is the use of Artificial Intelligence approaches, such as the Knowledge Interchange Format (KIF), to support the structuring process by (semi-) automatic tools. Linguistic approaches and methods used for knowledge sharing between intelligent software agents would also seem to be valuable.

1.1.3 BML – Protocols View

In order to communicate necessary initialization data into BML and the resulting executable missions and tasks from the BML to the executing system, communication protocols are needed. The protocol view standardizes the way the description of the executable tasks and assigned executing military means is transported from the BML implementation to the target system, be it a C2 device, a simulation system, or a robot.

The use of XML to describe the information exchange requirements is fundamental, as XML is the only standard for data description accepted by the C2 community, the simulation community, and the robotic community. The Extensible BML (XBML) project (and follow-on efforts) used Hypertext Transfer Protocol (HTTP)-based Web services as the means for communications across distributed applications (Hieb, et. al., 2004a) (Hieb, et. al., 2004b). Based on results in ongoing work of the Extensible M&S Framework (XMSF) Profiles SG, as well as other interested experts in the domain of application of Web services within computer grids, solutions that are more general may be needed in the international domain, which further point to XML. Many have expressed concern that the size of XML files will over-burden already limited bandwidth supporting military operations. These concerns have being addressed through activities such as the World Wide Web Consortium (W3C) XML Binary Characterization Working Group[5] and technical initiatives such as the Naval Postgraduate School's XML Schema-based Binary Compression (XSBC) algorithm (Norbraten, 2004) that is demonstrating the ability to further reduce the size of transmitted XML files compared to standard text compression techniques[6].

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[5] See http://www.w3.org/XML/Binary

[6] Such techniques are being explored for tactical messaging. XSBC was employed in tests by NATO in July 2005 for compressing XML messages encoding Link-16 standard message formats.

Grid services[7] are one example for alternative future research. Although they follow the same principles for data exchange and invocation, these services allow more alternatives within applicable protocols for web communication.

Based on ongoing prototyping efforts, the PDG should analyze advantages and disadvantages of alternatives and point to connected efforts within the community. It is anticipated that XML will be the initial foundation for the protocol view, as XML is the only standard accepted by all three target domains as the necessary component schema on which the export schema can be based.

1.1.4 Operational Need and Expected Benefits[8]

Operational Need

Today's operational C2 processes suffer from the use of non-standard, ambiguous language, both written and verbal, as well as a lack of precision in terms and definitions. These deficiencies undermine a commander's efforts to achieve unity of effort and simplicity. Interoperability is also problematic, due primarily to shortcomings in language translation between C2 systems and computer simulations used for training, course of action (COA) analysis, and mission rehearsal. The use of non-standard, ambiguous language and the lack of precision in terms and definitions are problems that exist apart from any technical implementation in current C2 systems. The de facto common, joint language that exists today in the form of joint and service doctrinal publications cannot ensure unity of effort because of the wide range of definitions of key terms. (Carey, et. al., 2001)

Analysis of training results from the Army¹s Battle Command Training Program (BCTP) at Fort Leavenworth, Kansas, reveals chronic misuse of doctrinal terms and graphics. (Kleiner, et. al., 1998) Despite positive trends in this area in recent years, doctrinal terms are still used incorrectly, or mixed with other terms, unnecessary adjectives, and adverbs in such a way as to confuse the intended meaning, resulting in the need for added clarification later in the exercise. As an example of needless language in C2 processes, an examination of an actual commander's intent statement from a Corps operations order demonstrated the ability to reduce the verbiage from a fairly straightforward 417 words, to a far leaner 214 words, without losing the essence of the commander's purpose, method, or end state. As B. H. Liddell Hart observed, "the fog of war is bad enough without it being thickened by obscured phrasing; battles may be lost by lack of lucidity as well as by lack of tenacity" (Vego, 2004). The way doctrinal

[7] Grid services combine the power of grid computing with Web services to facilitate rapid integration in an environment that simplifies support of demanding computational and database access. (Pullen, et al, Using Web Services to Integrate Heterogeneous Simulations in a Grid Environment, *Journal on Future Generation Computer Systems*, Volume 21 pp. 97-106, 2005)

[8] The material in this section is excerpted and adapted from (Lambert, 2005), by the author's permission.

language is used today contributes to complexity rather than simplicity. The number of separate orders generated within an Army corps in a major operation typically exceeds 1100 (Sudnikovich, et. al., 2004). The length of a corps order usually exceeds 400 pages, much of which is redundant, complex, or unclear information (Kleiner, et. al. 1998). This is not to suggest that current language alone is responsible for this type of complexity. Yet, considering this volume of information in combination with the large number of definitions for doctrinal terms, the ability to achieve unity of effort becomes doubtful without strenuous effort. Therefore, despite the progress made in Operation Iraqi Freedom towards jointness, the lack of a common, joint language remains deeply rooted in disparate service cultures and numerous "communities of interest" within those cultures. (DoD, 2003)

Operational Benefit

From the discussion thus far, one may conclude that in order to foster unity of effort, enhance simplicity, and improve interoperability between and among C2 systems and simulations, the combatant commander requires both immediate and long-term improvements to the common, joint doctrinal language. The resultant language must meet two fundamental requirements: the language must be unambiguous and it must be readable by both humans and machines. The refinement and modification of existing doctrinal language to meet these two requirements will yield a number of important benefits.

<u>Faster, Improved Military Decision Making Process (MDMP)</u>. Implementation of a more formalized joint language may reduce or even eliminate the use of non-standard terms and ambiguous language, contributing to efficiency in human-human, human-machine, and machine-machine communication. At the same time, an increase in the precision of terms and definitions contributes to improved reliability of communication and better decisions. The improved clarity inherent in such a language reduces chances for misinterpretation and therefore improves both simplicity and unity of effort. As a result, a common, joint language has the potential to significantly enhance the MDMP.

<u>Greater Interoperability and Jointness</u>. A common, joint language may greatly enhance inter-service and coalition interoperability, the importance of which is difficult to overemphasize. As DoD policy states, "Interoperability within and among United States forces and U.S. coalition partners is a key goal that must be addressed satisfactorily for all Defense systems so that [DoD] has the ability to conduct joint and combined operations successfully." (DoD, 2001) Without interoperability, DoD will not realize its network-centric vision. Improved joint interoperability will result from joint and service languages built into logically centralized databases, dynamically linked to their respective doctrinal sources.

<u>Improved Fidelity of Simulations</u>. Increased precision in the meaning of C2 terms results in entity behaviors (i.e., units, weapons, platforms, etc.) that more realistically model the real-world. The increased realism of simulated COAs and mission rehearsals contributes to greater combat effectiveness with lower risk. In addition, C2 applications that use a refined joint language can check the doctrinal

consistency of situations used to start simulations for decision support, and provide doctrinal analysis of COAs developed from simulation runs in a real-world situation, thus reducing the risk of inadvertent departures from approved doctrine. (Tolk, et. al., 2004a)

Elimination of "Human-in-the-Loop" C2-to-Simulation Interface. Use of a common, joint language will diminish or even eliminate simulation input errors that can degrade simulation fidelity. At the same time, eliminating errors in the C2-to-simulation interface will enable quicker analysis of COAs, thus making more time available for subordinate planning and mission rehearsal. The fact that the improved joint language remains readable to humans also helps to reduce the chance for errors in automated systems.

Full Exploitation of Technical Advantages. The United States continues to enjoy a considerable qualitative advantage in C2 systems versus potential adversaries. (JCS, 2004) Without a formal joint language, however, the "free text" problem will undermine future efforts to improve the utility, efficiency, and effectiveness of operational C2. This represents a classic case in the information technology world of automating a bad process; diminished benefits are the only guaranteed result. Pursuit of a common, joint language solution now will greatly reduce the risks associated with future requirements to precisely communicate C2 information to increasingly automated systems, including weapons platforms, sensors, and robots. A common, joint language also reduces the risks associated with the increasing need for C2-to-simulation integration in support of COA analysis and mission rehearsal.

Support for Adaptive Planning (AP). This recent DoD initiative represents a significant departure from the contingency planning process employed throughout the Cold War and still in use today. The AP approach will integrate C2 planning processes with the DoD net-centric environment and link disparate databases to allow improved access to information. These changes will support faster, better planning. (DoD, 2005) However, linking databases is only useful when each uses the same conceptual model. In addition, the AP initiative aims to exploit all the benefits of net-centricity. As a result, the AP process will rely heavily on the collaborative decision-making tools envisioned for use in the net-centric environment. A common, joint language will enable these collaborative capabilities and will improve the combatant commander's AP processes, resulting in faster production of higher quality plans.

1.1.5 Identification of Risks in Use of C-BML

The principle risk in the C-BML standards approach is that the C2IEDM will not be adopted within national C2 systems, but rather these systems will continue to use unique data representations. If there is not a common C2 standard, then another approach to defining an initial representation will need to be determined. However, work performed in later phases of C-BML development will still be a contribution, as they will take advantage of the emerging standards for specifying ontologies.

1.2 C-BML Study Group Terms of Reference

As introduced earlier, the statement of work for the C-BML SG identifies the following tasks:

- Conduct a **Paper Survey** identifying as many international contributions applicable to the C-BML effort as possible.
- Develop a **Plan** of how these identified can contribute to a common C-BML standard and to a standard framework.
- Formulate a set of **Recommendations** on how to proceed toward a C-BML Product Development Group.

This document contains the products of the SG efforts across these three tasks.

1.3 C-BML Study Group Meetings

The following meetings were held during the course of the C-BML Study Group's chartered term:

- Initial SG Meeting at Fall 2004 SIW - September 2004
- Meeting at the 2004 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) - December 2004
- Face-to-Face Meeting at the Virginia Modeling, Analysis, and Simulation Center (VMASC) – 7-9 March 2005
- SG Meeting at Spring 2005 SIW – 7 April 2005
- SG Interim Telecom – 4 May 2005
- SG Prep for Euro-SIW Telecon – 22 June 2005
- SG Meeting at 05 Euro-SIW - 30 June 2005
- SG Report Meeting at George Mason University (GMU) - 2-3 August 2005
- SG Interim Telecom – 4 August 2005

The following meetings are expected to be held prior to concluding the Study Group:

- SG Interim Telecom – 9 September 2005
- Final SG Meeting at Fall 05 SIW – 22 September 2005

A kick-off meeting was held in the Fall of 2004 to present the Study Group to SISO and establish the initial membership and work plan. During this meeting, it was decided to have a first interim meeting during I/ITSEC in December 2004 in Orlando, Florida. This meeting was held in collaboration with a NATO pre-kickoff-meeting on the same topic. During the NATO MSG meeting in October 2004 in Koblenz, Germany, the group decided to set up an expert team to evaluate the applicability of BML ideas for the alliance in the form of an Exploratory Team 016 (ET-016). The official kick-off for this activity took place in February 2005 in Paris, France.

As the time for discussions and presentations during the official SIW meetings is always limited, and because the meeting in Orlando during I/ITSEC showed a tremendous international interest in BML, it was decided that another face-to-face meeting would be conducted in March 2005 at the Old Dominion University (ODU) VMASC to give potential contributors the opportunity to present related work and allow time for discussion of ideas. This meeting focused on the survey task of identifying possible international contributions applicable to the C-BML effort.

The VMASC face-to-face meeting was held between 7-9 March, 2005. The meeting was chaired by Major Kevin Galvin and hosted by Dr. Andreas Tolk. It brought together 35 international experts. Five universities (Carnegie Mellon University, George Mason University, Naval Postgraduate School, Old Dominion University, and the University of Texas) participated in the event and six nations were represented (Canada, France, Germany, Sweden, UK, and USA). An overview of the meeting is provided in Appendix A.

The C-BML SG conducted an open meeting on 7 April 2005 during the Spring 2005 SIW in San Diego, California. With the formation of a related but separate SG for Military Scenario Definition Language (MSDL) for automated initialization of C2 and simulation systems, a close working relationship has been established with the Co-chair (Maj Galvin) being Vice-chair of the MSDL SG. Other activities at the Spring SIW included a C2IEDM tutorial and presentation of relevant papers (05S-SIW-007, 018, 019, 055, 068, 140, and 154).

A meeting was held at Euro-SIW in Toulouse, France to work on the SG Report. This meeting was conducted in coordination with the MSDL SG, where most of the MSDL SG officers attended the C-BML SG meeting, and most of the C-BML SG officers attended the MSDL SG meeting.

A working group meeting was held at GMU on August 2-3 to finalize the Study Group Report. This meeting was also coordinated with the MSDL SG, who met at GMU on 3 August immediately following the C-BML SG meeting. Substantial coordination between the two study groups occurred.

1.4 Document Organization

This document is structured into 4 main sections. Section 1 provides an introduction to the SG objectives, an overview of BML, and a summary of SG activities. Section 2 identifies related work in the international M&S and C2 interoperability community relevant to C-BML objectives. Section 3 lays out a phased plan of action for development of the C-BML standard. Section 4 summarizes recommendations from the C-BML SG. Section 5 lists the references cited in this report. Section 6 acknowledges those participants who provided particular inputs to this report or were otherwise influential in the activities of the C-BML SG. Appendixes provide supporting materials, including a summary of the March VMASC meeting (Appendix A), considerations for ontology work supporting the C-BML standardization effort (Appendix B), a list of C-BML participants (Appendix C), a glossary of acronyms used in the report

(Appendix D), and an extended bibliography of references relevant to the C-BML effort (Appendix E).

2 Related Work

Attendees to the March 2005 SG meeting (Appendix A) were asked to respond to a survey to describe their current work with C-BML or their interest in future C-BML standards in relation to their current projects. The following is a summary of information received from the respondents as well as other ongoing projects considered relevant to the C-BML effort. The organization identified in the project title is the organization that provided the project input.

2.1 ABACUS Architecture (Raytheon, USA)

Problem Statement

Raytheon has been tasked with developing a 'rebaselined' Advanced Battlefield Computer Simulations (ABACUS) architecture for the next generation Command and Staff Trainer (CAST) for the UK Ministry of Defence (MoD). ABACUS is the current legacy training system, a broad coverage aggregate-level simulation, which has been interfaced to the BOWMAN C2 system[9] over the past year. However, due to limitations in both systems' interfacing capabilities, the current interoperability is restrictive and limited. The next generation architecture must be much more robust and flexible with HLA capability, as well as easily adapted to additional C2 components, such as the Battlefield Information System Applications (BISA), planned to be introduced in parallel with future BOWMAN upgrades over the next several years.

Solution Proposed

In a report already delivered to the MoD, Raytheon has proposed a revised ABACUS system based on a service-oriented architecture (SOA). The system uses the C2IEDM schema as a baseline for its simulation database, and will incorporate a C2IEDM-based object model to help ensure interoperability with C2 systems. Raytheon expects to build on and re-use existing design work already available (e.g. US Army Simulation to C4I Interoperability (SIMCI) C4I/M&S Reference Object Model (CROM) efforts) in order to further reduce design risk and effort. The architecture also includes an external interface management layer which will provide adapters for translation of required simulation data into appropriate information exchange formats for data transfers with external systems, including those required for High Level Architecture (HLA)-capable simulations, BISAs, and related C2 systems.

C-BML Relevance

The C-BML is seen as a natural and cohesive extension needed for the proposed ABACUS Rebaseline architecture. By participating in the C-BML working group and the BML standards development, Raytheon expects to gain experience

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[9] BOWMAN is the UK program that provides a digitized radio for the British Army in order to facilitate secure voice and passage of data.

needed for incorporating BML capabilities into the interface adapter design for the revised system, thus providing ‘out of the box’ interoperability not based only on a recognized standards work, but also on a composable and extensible framework which will help guarantee information exchange compatibility with future C2 systems. The timing for the planned BML standards development along with the Rebaseline architecture schedule are seen as complementary and achievable over the next several years.

2.2 Aide a la Planification d’Engagement Tactique (APLET) (DGA/EADS, France)

Problem Statement

Aide a la Planification d’Engagement Tactique (APLET) is a French Ministry of Defence Research and Technology program which aims to investigate the capabilities offered by M&S for its use in an exiting French Brigade level C2 system, SICF (Système d’Information et de Commandement des Forces), for COAA purposes. APLET explores the technical issues of C2 and M&S coupling and will provide recommendations for interface specifications and data models to overcome the gap between current M&S and legacy C2. (Khimeche & de Champs, 2003) (Khimeche & de Champs, 2004) (Khimeche & de Champs, 2005)

One of APLET’s technical challenges is dealing with the definition and design of its simulation data model which has to be consistent with the SICF data representation. APLET’s approach is to identify a C2 data model that can be re-used and improved to build the APLET data model.

Solution Proposed

This led to the conclusion that the C2IEDM was the most suitable data model to address APLET requirements, for the following reasons:

- C2IEDM is a recent and very complete model (good coverage of the land forces’ requirements)
- Most of APLET’s data can be represented with the C2IEDM data model
- C2IEDM is the current convergence point of the C2 international community and is supported from an operational point of view
- SICF is based on the Army Tactical Command Control and Information System (ATCCIS) C2IEDM version 5, also designated Generic Hub version 5 (GH5)

However, simulation needs many more parameters and attributes than C2. Specific requirements are introduced by several models for simulation purposes. For example, physical behaviour which comprises speed characteristics, probability of hit, probability of kill, and detection probability are not represented in C2IEDM. Moreover, a simulation needs to manage several values of selected parameters. For example, a military unit has several “values” for its status: status imported from the C2 system, status modified by simulation operators to initialize the simulation, and the set of values during simulation execution.

Being out of the scope of C2 systems, such objects, attributes, and parameters are not within the frame of C2IEDM. They are managed internally by simulations and are not transmitted to C2 systems. Thus, APLET's lessons learned will provide Change Proposals for submission to the MIP Data Modeling Working Group (DMWG) in order to enhance and improve C2IEDM.

In conclusion, APLET's data model is being designed as an extension of C2IEDM. This approach facilitates the mapping of APLET's data model with C2IEDM and gives APLET a "natural" interoperability with C2 systems (like SICF) based on C2IEDM.

C-BML Relevance

In the scope of the C2-simulation interoperability studies, APLET converged towards an architecture similar to the US Extensible BML (XBML) prototype, with the definition of an "APLET BML" XML schema consistent with the C2IEDM. Further, the motivation is to make this "APLET BML" format available to the SISO C-BML SG, as a contribution to the standardization effort. On the other hand, APLET will evolve to take into account efforts of the C-BML SG, and to make the APLET's BML compliant with C-BML format defined by the C-BML SG and future PDG. This effort will be conducted in the context of the upcoming NATO MSG-48 on C-BML experimentations. The objective is to promote BML within NATO and enable operational use of a NATO BML standard.

2.3 Army C4ISR and Simulation Initialization System (ARL/UT, USA)

Problem Statement

C4ISR systems have evolved to support full Network-Centric Warfare (NCW)[10] to provide commanders and their staffs with a complete and accurate Common Operational Picture (COP) of the battle space in near real-time. M&S systems have also evolved to support large federations of hundreds of workstations and servers exchanging information between many disparate simulation systems linked to many disparate service-specific and Joint C2 systems to provide a Joint National Training Capability (JNTC).

The first essential step in establishing and maintaining a complete and accurate COP is to initialize systems from a common set of complete, accurate, and synchronized data. The production of Army network-centric system architectures and C2 and simulation initialization data products for real-world operations and training exercises is time intensive, expensive, and error prone. The legacy initialization process is complex, de-centralized, sequential, and primarily manual, which yields data inconsistencies between C2 systems and simulations. Current force alert-train-deploy timelines require initialization data products to be generated and synchronized in a number of days. The current process requires a number of weeks or months. The scope of this problem will continue to grow as

[10] US terminology to describe its vision for digitized operations conducted over a Global Information Grid.

more digital C2 systems are fielded across the US Army, as new systems, such as Future Combat System (FCS)[11], are developed and fielded, and as these systems interoperate with joint service and coalition systems.

Solution Proposed

To begin to meet these challenges, a collaborative effort among the Central Technical Support Facility (CTSF), Army Program Executive Office for Command, Control, and Communications Tactical (PEO C3T), the Defense Modeling and Simulation Office (DMSO), and the Army Simulation-to-C2 Interoperability (SIMCI) Overarching Integrated Product Team (OIPT) has developed the Army C4ISR and Simulation Initialization System (ACSIS). The CTSF, at Fort Hood, Texas, is responsible for producing and integrating data products to initialize digital C2 systems for units equipped with the Army Battle Command System (ABCS), including the Force XXI Battle Command Brigade and Below (FBCB2) and Blue Force Tracking (BFT) systems. Applied Research Labs at the University of Texas in Austin (ARL/UT) is providing technical expertise to both the PEO C3T and the simulation community in the development of ACSIS.

The basic concept of ACSIS is to rapidly generate initialization data products, with automated tools, for both the C2 (ABCS) systems and a federation of simulation systems. The PEO C3T objective is to reduce the C2 data production time from months to some period of time closer to 96 hours.

Currently ACSIS outputs ABCS network and simulation initialization data products in a number of different target system-specific formats and standard XML Data Interchange Formats (DIFs) based on the C2IEDM and the MSDL. ACSIS does the appropriate translations of data element syntax and naming convention required by the target system and formats the initialization data in the appropriate native format that the target system can directly ingest or import. However, now that data element and format standards, such as the C2IEDM, Enterprise-wide Identifiers (e.g., Global Force Management EwIDs), and the MSDL are beginning to be adopted by both the C2 and the simulation communities, fewer data element mappings and translations will be required.

C-BML Relevance

BML provides a standard (semantics and syntax), unambiguous, automated means to exchange individual data elements, representing battle management products, among C2 systems and simulations. C-BML will allow all the partners of a coalition to share battle management products across the battle space. C2 systems and simulations need to be initialized and synchronized with data contained in these tactical battle management products.

[11] FCS is a US Army program to develop a number of platforms that will support the NCW concept.

2.4 Base Object Model (BOM) PDG (SimVentions, USA)

Problem Statement

The principal need within the C2 community is the ability to exchange information in a relevant, consistent, and meaningful manner. The difficulty, however, is in building and integrating systems, simulations, and other assets to be interoperable. Typically, these systems must conform to common agreed-upon message interfaces. It is desirable for C2, simulation, robotic, and other system interfaces to be represented at the subsystem or component level. This would provide the basis for a composable infrastructure allowing interfaces (and their subsystems and components) to be composable, mappable, and integratable. This infrastructure must also support the ability for representing the decomposition of complex systems in a modular form to facilitate understanding.

Solution Proposed

The BOM PDG has developed a set of products within SISO (SISO 2005a, 2005b) useful for representing reusable components of simulations and simulation environments, and understanding complex systems in a modular form. A BOM is defined as a “piece part of a conceptual model composed of a group of interrelated elements, which can be used as a building block in the development and extension of a federation, individual federate, FOM or SOM” (Gustavson, et. al. 2005). BOMs are designed for enabling composability, providing extensibility, facilitating interoperability, improving manageability, and encouraging understandability.

A BOM solution provides consistency to the layout and processing of data exchanged between various systems, increasing the dependability of the system results. A BOM solution can offer a reference standard to be used in exchanging the data and how the data is to be processed.

C-BML Relevance

BOM provides a mechanism for describing/defining individual interfaces of a C4I capability in the context of HLA using XML. As such, BOMs can be used as an exchange mechanism between a C4I system and simulation allowing a developer to focus on the representation of an “interface” rather than on an “implementation.” This separation of interface from implementation allows C2 and M&S domains to be more easily bridged.

With respect to C-BML, the Pattern Actions / State Machines of a BOM can correlate with the executable tasks, orders, and commands driven by C-BML. Elements of the C2IEDM, which C-BML intends to leverage for C2 information modeling, can be represented within a BOM. Specifically, the BOM can be used to help capture conceptual model elements reflected in BML/C2IEDM as a reference. Additionally, the BOM provides mappings of these conceptual model elements to an HLA-based interface. As a result, BOMs can be loosely coupled and assembled to represent C4I/simulation environments helping enable an SOA approach for M&S and C4I environments.

2.5 C2 Ontology (VMASC/ODU, Norfolk, Virginia, USA)

Problem Statement

The modern C2 data (i.e., C2 systems and their data models) world is very complex. Today's information technology environment contains not just systems, but systems of systems. These systems are required to interoperate with other systems from within the same service (Army, Navy, Air Force), the same nation, and across national boundaries. This interoperability comes at an extreme cost – namely the tedious design and redesign of system to system interchange mechanisms. And those mechanisms often are the cause of misinterpreted or misunderstood data by the receiving system. It is believed that this problem, while complex, is solvable by modern information technology solutions.

Solution Proposed

If the ontological meaning of the data of these different systems can be understood, and if there is a sufficiently complete referential data model for translating to and from these different ontologies, then the interoperability of systems will not only become easier to perform (through the mechanism of a well designed referential data model), but also the data exchanged will be consumable with a higher degree of assured validity by the target system. The contribution of research work to this system is three-fold: (1) to define what is meant by an ontology, in particular an ontology of a referential data model and its intended use; (2) to propose a method for evaluating a referential data model and its use rules against that definition; (3) to apply that method against the C2IEDM and evaluate the resultant findings.

C-BML Relevance

This work is relevant to the C-BML group since the resultant findings will identify how an ontological process can leverage the C2IEDM. The C2IEDM ontology will be evaluated to see if it is sufficiently rigorous to be the foundation of future C2 ontologies. In addition, this ontology will be used to evaluate the completeness of the C2IEDM as the basis for the inter-system, inter-service, and inter-national data exchange envisioned by the C-BML project.

2.6 EXPLAIN Project (North Side, Inc., Canada)

Problem Statement

The EXPLAIN project is focused on semantic understanding of factual English texts. There is no requirement that such texts be limited to "controlled English." A first application of EXPLAIN is semantic processing of military scenarios in English and the generation of a formal, ontology-anchored encoding of such texts.

EXPLAIN produces a formal, ontology-anchored encoding of Natural Language texts that can be post-processed for several purposes:

- Using English for Operational Planning (OPLAN), situation reporting, and issuing orders will provide more efficient and effective interaction of live forces with live, constructive, and robotic forces. The translation of English texts into a formal representation enables ontology-based interoperability solutions. Once C2IEDM has been represented using a sound ontology, a user will be able to interface with C2IEDM systems easier than using complex menus, by directly entering English orders and OPLANs.

- Extraction from text of the information required to simulate what is described in the text (actors, objects, attributes, events, locations, times, modus operandi) will enable rapid scenario generation.
- Displaying the meaning of the text visually on a map (forces, affiliation, attributes, movement, sensor and weapon activation, etc.) will enable rapid situational awareness.

Very rapid scenario specification will improve mission effectiveness. Currently, the behavior of military simulations is specified programmatically, or quasi-programmatically, by selecting functions from a library through a GUI. As a result, preparation for a complex military operation or exercise is today a matter of several months. With Natural Language specification, it becomes feasible to specify scenarios much faster and as a result, to consider many more tradeoffs, resulting in more effective missions. The ability to specify scenarios much faster and, as a result, to consider many more tradeoffs results in more effective missions. The ability to specify scenarios in English will enable end-users, including officers in the field, to evaluate COA directly. Effectively, EXPLAIN will enable deploying and using simulation in the field.

Solution Proposed

In order for C-BML to achieve its goal of being an unambiguous language, it (and C2IEDM) must be based on sound ontological grounds. Development of a C2 domain Ontology will need to be based on an Upper Ontology which axiomatizes basic concepts such as Abstract and Physical Objects, Class and Sub-Class, Relations, sub-Relations, Attributes, and so on. It is well accepted in the Ontological Engineering community that such work is necessary to be able to automatically check the integrity of any particular domain Ontology (such as a C2 Ontology). Recognizing the importance of generic Upper Ontologies for Ontological Engineering, the Institute of Electrical and Electronics Engineers (IEEE) is attempting to define a generic Upper Ontology to lay the basis for any future Domain ontology (IEEE, 2005). We believe that following this sound Ontological Engineering approach will prove very beneficial for both BML and C2IEDM.

C-BML Relevance

The ability to encode English in a formal, ontology-anchored representation means that a user will be able to express himself/herself in English, and obtain an automatic translation into BML. This opens the way to using English for operational planning, simulation, and command of robotic forces, which in turn will lead to increased acceptance of BML by operational users.

2.7 Formal Tasking Language Grammar (Mitre, USA)

Problem Statement

At present it is difficult to determine and ensure computational feasibility, consistency, overlap, and coverage between the tasking languages that are part of MSDL and BML because both MSDL and the Army BML lack a common formally defined tasking language grammar.

Solution Proposed

The US Army BML effort originated based on a need to provide US Army commanders with an unambiguous language to command and control forces and equipment conducting military operations and to provide for situational awareness and a shared, common operational picture. An important part of the US Army BML is a tasking language telling subordinate forces what actions to take.

MSDL is being designed as a simulation independent scenario definition language allowing scenario reuse among simulations supporting the MSDL format (Franceschini, et. al., 2004). Keeping the MSDL free of simulation specific references and information, and using an open and available data interchange format, are of primary importance in the development and evolution of MSDL. As with BML an important part of the MSDL is a tasking language telling subordinate forces what actions to take during execution of the simulation.

Ideally, a common tasking language supported by both MSDL and BML would allow BML generated orders to be saved in MSDL format and imported into simulations as part of the simulation scenario generation process. At present it is difficult to determine and ensure consistency, overlap, and coverage between the tasking languages that are part of MSDL and BML because both MSDL and the US Army BML lack a common formally defined tasking language grammar.

Currently, the Military Scenario Development Environment (MSDE) and US Army BML developers are generating a common, single, formal tasking language grammar that can be implemented in an XML-based format (MSDL) and supported within the C2IEDM (BML) implementation. The resulting implementations will allow BML generated tasks to be imported via MSDL into simulations leveraging the MSDL technology.

C-BML Relevance

This effort directly and positively impacts the C-BML community by providing a formal unambiguous grammar definition that can be shared among and used to unify the Armed Forces, Coalition, and other BML efforts.

2.8 Geospatial BML (US Army Engineer Research and Development Center, USA)

Problem Statement

Terrain and weather information is perhaps the only truly ubiquitous information relevant to all aspects of C2 and M&S. Consequently, terrain and weather information generation would greatly benefit from, and contribute to, a common approach to BML development and extension. Efforts to reach a common terrain/environment model have heretofore focused mainly at the data level. The US Army Engineer Research and Development Center (ERDC) invests in numerous projects in the areas of Battle Space Environments and Military Engineering, investigating information technology and knowledge representation in these areas, as well as their role and application in both M&S and C2 domains. One ongoing project in the area of M&S and C2 interoperability is Common Maneuver Networks for Embedded Training, Mission Planning, and Mission Rehearsal. This project uses Battlefield Terrain Reasoning and Awareness (BTRA) products and One Semi-Automated Forces (SAF) Objective System (OOS) as platforms for proof-of-principle development and demonstration.

Solution Proposed

ERDC is developing automated decision support services that apply tactical terrain behavior and activity models to terrain and dynamic environment data. The approach taken is to derive a maneuver ontology from maneuver related tasks found in the US Army Universal Task List (AUTL), US FM 3-0 "Operations", FM 3-90 "Tactics", and other relevant sources. The resulting information and knowledge products aid planning, preparation and execution of tactical missions and operations. ERDC seeks to represent terrain and dynamic environment abstractions through a rich set of discrete objects (spatial and temporal) and relationships to tactical entities and tasks. Instances of these objects and relationships can then be extracted from the current and future large terrain and dynamic environment datasets and databases – essentially reducing large terrain data sets to their tactical essence and expressing the reduction in an ontology for interoperability at the conceptual level. On this base, ERDC is building tactically relevant decision aids that can be used by commanders, staff, subordinates or software services for C2 and M&S. The tactical patterns that are represented in the decision aids are registered to and modulated by terrain and dynamic environment and can be used as building blocks for lower echelon implementation of commander's intent in a like battle space context. A concrete example of this approach is a maneuver ontology mapped to the local schemas of both SAF and C2 platforms, entities, and tasks. Interoperability is demonstrated by exporting planned routes and maneuver networks from the C2 platform into the maneuver conceptual schema. From there, routes and networks will be imported into the M&S platform.

The advantages of this broad abstraction and representation of the battle space context are numerous:

- **Consistent with current state-of-the-art** in representation of other tactical entities and relationships.
- **All-inclusive framework for planning** and manipulating targets, terrain, activities, plans, sensing, shooting, moving, etc.
- **Interactive visualization and integration of COA** by human users, including rapid exploration of "what-if" scenarios and plan modification

leading to deep understanding of the interaction of tactical operations and terrain and dynamic environment context.

- **Facilitates communication between humans and software systems** by representation of tactical pattern entities and context in a common language.
- **Network-friendly representation of all entities and relationships**, including terrain and dynamic environment, in relatively lightweight databases and structures that reduce bandwidth and storage and processing requirements at nodes.
- **Enables application of state-of-the-art algorithms** for feasible option generation and search, dynamic tracking and synchronization, and efficient task sequencing and scheduling.

C-BML Relevance

While not a current focus of the C-BML SG, expression of the current situation and the COP is an essential and inevitable exercise for building C-BML. Commander's intent and taskings for subordinate echelons are formulated based on a given battle space context – COP and the current situation. Planning for execution without benefit of a consistent terrain context will introduce ambiguity in C-BML not present in current planning.

A critical requirement to achieve the ultimate goal of the Center is an extension of BML, designated here as the Geospatial BML (GeoBML), that maps the tactical task-based representations of the BML to the geospatial and temporal requirements of and enablers for the tactical activities. Traditional linear combat operations and central planning within a tactical operations center allowed commanders, staffs, and subordinates to communicate mission intent and tactical concepts around a map or sand table in a visual and iterative process. Future force operations will require distributed planning and execution. The shared understanding and communication of the geospatial and temporal aspect of plans and course-of-action in a distributed environment require that terrain and dynamic environmental context be explicitly represented for distribution and visualization in a net-centric force. Current and future ERDC programs are developing explicit tactical terrain ontologies to enable this process, but these information structures need to be organized and sequenced to support the implementation and elaboration of mission command in a distributed battle space. Selected ERDC programs and BML developers can work together toward the development of a GeoBML to ensure a consistent semantic language for ubiquitous application of terrain and dynamic environment context enabling and supporting mission command in the net-centric future force.

2.9 Identification of C-BML Need (Ericsson, Sweden)

Problem Statement

This summary covers four different, but related topics that address the need for a C-BML: (1) Planning for Joint operations; (2) Operational Joint Command Support; (3) Assessment of a Commander's Intent; (4) Opponent's Intent.

Solution Proposed

Planning for Joint Operations. The need for joint operations also implies the necessity for joint planning. In order to utilize units of soldiers or units from various service branches and nations, it must be possible to express a commander's intent unambiguously. The assumption is that there exist doctrines/workflows that can be expressed in a way that facilitates machine readability and allows the exchange of information/data between coalition forces during simulated operations. The solution is to create a planning tool where commanders from various service branches and nations are able to work in collaboration simultaneously with their own views and representations.

Operational Joint Command Support. In a Joint Command, the mission context is constantly changing, since deployed units need to interact with other units from other branches or nations. Each branch/nation has a command language and representations, which are often unique for them. The variety creates difficulties in describing a commander's intent usable across the various services/nations. The mission context is changing in such a way that more joint operations are required along joint doctrine that needs to be expressed in machine-readable format. The solution is to enable a commander's intent to be translated/understood unambiguously by other commanders regardless of national and service branch affiliation. This must be done in a way that keeps the different commanders familiar with their own taxonomy, representations, specialized systems, and other capabilities unique to their C2 environment.

Assessment of Commander's Intent. When acting in the constantly changing operational context, the ability to adapt to a new operational picture is essential. Training is performed weeks/days/hours prior to the mission but the commander might have to adapt to completely new ways of conducting operations. In order to avoid having old behavior influencing the commander or being constrained by group thinking, some type of real-time assessment is necessary during the operations. Furthermore, it entails the use of another nation's service branch commander intentions during training of units/individuals using their own doctrinal procedures. One of the key assumptions is that there exists an information fusion capability to align sensor data towards a commander's intentions. The solution is to use information fusion methods/algorithms to ascertain the commander's intent for current missions and how it connects with intentions at higher levels. Then it is possible to assess if the goal will be met.

Opponent's Intent. If the own force commander's intentions are expressed, used in planning, and available for assessment, then the opponent's intentions may also be described using the same ontology/taxonomy. Thereby, a decision support system can identify the opponent's intent and use the own force commander's intent construct to apply appropriate countermeasures. An assumption for this topic is that there is a way to describe commander intent that applies not only to the taxonomy of today, but also to a future state.

C-BML Relevance

Planning for Joint Operations. The relevance for a C-BML is the ability for the user to represent intent in own nation/service representations (National BML) that can be mapped/translated to a C-BML and used in C2 or simulation systems.

Operational Joint Command Support. As above, with addition of the ability for commanders from different nations/services to share each other's intentions in their own command and control systems.

Assessment of Commander's Intent. As above, with addition of the ability to map the current progress of an operation against current status reports and warnings.

Opponent's Intent. The relevance to C-BML is that without a common language it is a much harder task to represent an opposing commander's intentions.

For the ideas/solutions presented above some work has been done, some work is in progress and some is planned:

- The work within LedsystM[12] is one source for a C-BML methodology and an example of building doctrinal representations.
- Swedish Defence Material Administration vision and practical work in the field.
- The Swedish Armed Forces (SweAF) Ground Combat Model is an existing BML for ground forces and might be used as a case study for alignment towards C-BML.
- Work within Swedish industry (Ericsson and others) to build efficient decision support systems for commanders.
- Information Fusion research project at University of Skövde.

2.10 IMASE Scenario Generation Tool (US Army Threat System Management Office, USA)

Problem Statement

The Intelligence Modeling and Simulation for Evaluation (IMASE) Scenario Generation Tool (ISGT) has the requirement to support the rapid generation of Operational Test threat scenarios for system testing of US Army Intelligence and Electronic Warfare (IEW) systems. The scenarios are executed using M&S to generate a synthetic environment in which to immerse the IEW System Under Test (SUT). The current M&S environment is provided by Tactical Simulation Operational Test (TACSIM-OT), but is limited to stimulating the All Source

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[12] Swedish C2 system

Analysis System (ASAS). TACSIM-OT is being replaced by the IMASE SoS. The IMASE system will leverage the experience and success of TACSIM-OT to extend M&S support to IEW Sensor Systems and other IEW processing systems.

Solution Proposed

Currently, ISGT has entered one of the last phases of development. Its current capabilities include multiple client/server machines using Microsoft Structured Query Language (SQL), import of intelligence data using the Unit Order of Battle Data Access Tool (UOB DAT, v8.1), scenario data import/export using ISGT XML schema, and export of scenario data using the MSDL schema. Other capabilities include a data driven database and HLA runtime data import using the Modeling Architecture for Technology and Research Experimentation (MATREX) FOM v0.5 rev3.

C-BML Relevance

Army Test and Evaluation Command (ATEC) Headquarters has a task to examine the integration of ISGT, BML, ACSIS, and the C3 Driver. Currently ISGT has been able to export scenario data to other M&S systems, such as OOS using MSDL v3.1.0 Block C build 21. In terms of BML specifically, ISGT may be able to use BML to link to other M&S and C2 systems, provided that they also know how to manipulate BML. Being able to speak BML will provide ISGT with the same type of capability as the import and export of scenario data via the ISGT XML schema, but at a much more global level. ISGT would be able to export scenario data using BML to populate scenarios for M&S and C2 systems that understand BML, and would be able to populate a new scenario by importing BML scenario data generated by M&S and C2 systems.

2.11 Multilateral Interoperability Programme (MIP) (DMSO, USA)

Problem Statement

The nature and composition of a force structure to meet military requirements will be specific to the operational requirements to achieve a general and flexible military capability. An assured capability for interoperability of information is essential. The successful execution of fast moving operations needs an accelerated decision-action cycle, increased tempo of operations, and the ability to conduct operations within combined joint formations. Commanders require timely and accurate information. Also, supporting C2 systems need to pass information within and across national and language boundaries. Moreover, tactical C2 information must be provided to the operational and strategic levels of command including other governmental departments. Additionally, forces must interact with non-governmental organizations, including international aid organizations.

Solution Proposed

The aim of the Multilateral Interoperability Programme (MIP) is to achieve international interoperability of Command and Control Information Systems (C2IS) at all levels from corps to battalion, or lowest appropriate level, in order to support multinational (including NATO), combined and joint operations and the advancement of digitization in the international arena. The MIP specification is a managed interface between C2 information systems. When incorporated into a system it enables interoperability of information with any other system that also incorporates the specification. Battle space data is transferred as information. The meaning and context of the information is preserved across national and system boundaries precisely and without any ambiguity.

The core of the MIP solution is the C2IEDM. It is a product of the analysis of a wide spectrum of allied information exchange requirements. It models the information that combined joint component commanders need to exchange. The MIP common interface consists of the C2IEDM and various formally specified information exchange mechanisms (IEM).

The MIP programme is a voluntary and independent activity by the participating nations and organizations. The nations and HQs that are active in the MIP programme are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, Turkey, United Kingdom, United States, Regional Headquarters Allied Forces North Europe (RHQ AFNORTH) and Allied Command Transformation (ACT).

C-BML Relevance

C-BML will leverage the C2IEDM logical data model as a basis for XML namespace semantics, grammars (nouns, verbs, adjectives) and ontology work. The C-BML effort will provide C2 feedback to the MIP data model development efforts.

2.12 NATO Modeling and Simulation Coalition BML Exploratory Team (ET-016) (DMSO, USA)

Problem Statement

Within the NATO M&S community it is recognized that in order to improve simulation interoperability and better support the warfighter with M&S-based capabilities an open framework is needed to establish coherence between C2 and M&S systems. The desired capability will provide automatic and rapid unambiguous initialization and control of one by the other.

Solution Proposed

To accomplish this goal, a multinational Exploratory Team (ET-016) was established in September 2004 under the NATO MSG to explore the conceptual and semantic alignment of C2, M&S, and robotics systems. ET-016 will report its recommendations in October 2005. It is expected that the NATO MSG will charter a three-year follow-on C-BML Technical Activity (TA) effort. The NATO MSG TA will work with the integrated SISO C-BML and MSDL SG and PDG efforts to evaluate the evolving SISO standard.

C-BML Relevance

ET-016 and the future NATO MSG TA offer a NATO context for assessing the integrated SISO C-BML and MSDL SG and PDG efforts. The proposed Technical Activity will constitute a primary initial multinational user community providing SISO with feedback regarding the maturity and completeness of the evolving integrated C2/M&S standards.

2.13 Shared Operational Picture Exchange Services (DMSO, USA)

Problem Statement

The objective of the Object Management Group (OMG) Shared Operational Picture Exchange Services (SOPES) initiative is to enhance the ability of first responders, government, military and civilian organizations to develop and sustain a complete, timely, and accurate awareness of the operational situation.

Solution Proposed

The solution includes both an Information Exchange Data Model (IEDM) and an Information Exchange Mechanism (IEM):

- Information Exchange Data Model (RFP C4I-2004-06-13)
- Trusted Information Exchange Mechanism (RFP C4I-2004-06-28)
- Information Exchange Policy Management
- Logging and Auditing for Information Exchange Environments
- Unified Modeling Language (UML) Profiles for Trusted Information Exchange

The shared information environment envisioned by the SOPES initiative is categorized by services and/or capabilities supporting a broad cross-section of organizations, including First Responders (e.g., Police, Fire Department and Emergency Medical Personnel), Government Agencies (Federal, Provincial/State and Municipal), Non-Government Organizations (NGOs), Private Volunteer Organizations (PVOs), para-military and security agencies, and the military (Land, Maritime, Air, and Space).

C-BML Relevance

The SOPES IEDM specifications are largely met by the MIP Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM), the successor standard to the C2IEDM. OMG considers the JC3IEDM as the leading candidate for the IEDM. The SOPES IEM will specify a general protocol for the exchange of SOPES information that can be realized in any number of specific communications technologies. Thus, SOPES provides a future industry standard for the exchange of plans and orders that can be exploited by C-BML implementers.

2.14 SINCE (Atlantic Consulting Services, USA)

Problem Statement

The Simulation to Command and Control (C2) Information System Connectivity Experiments (SINCE) program was initiated to investigate interoperability issues by conducting multinational C2 experiments supported by C2 and M&S systems designed to address the transformation of collaborative planning and interoperable execution in a coalition environment. This is a US-German Army Bilateral Collaborative Project.

Proposed Solution

A key technical feature that was implemented and demonstrated in the program was the use of a common XML schema to represent the various C2 products that embody information exchange requirements (IERs). C2 products included a mix of messages represented by friendly position reports (PositionRpt) observations of enemy units (called SPOT reports), operational orders (OPORDs), fragmentary orders (FRAGOs), operational plans (OPLANs), and warning orders (WARNOs). The common schema for SINCE Experiment 1a (SINCEx1a) was developed as a W3C XML schema that enabled all instances of information exchange to be checked for being well-formed as well as for being valid. This common schema was used to generate all instances of IER in all phases of SINCEx1a. Publish and subscribe (P&S) mechanisms were also a major feature implemented for both C2 systems as well as for M&S systems and for their cross coupling. The C2 system exchanged Java objects within the framework of the Java Message System (JMS) topics and the M&S systems exchanged RPR data within the framework of the HLA (RPR FOM). This enabled a highly flexible and upgradeable filtering mechanism for information that needed to take place to appropriately support collaboration and interoperability as well as for stimulating the exchange via combat simulations. Filtering is possible based upon classification, source, content, time and location as basic criteria. SINCEx1a was limited to unclassified coalition data. To facilitate collaboration between current and future allies with disparate means for collaboration, we've found it both necessary and convenient to provide Web services that include a Web C2 Portal (WebC2P) via a standard browser that enables the sharing of coalition domain items such as the user-definable coalition COP initialization and updates and the coalition plans and orders. We have also initiated the representation of the architecture of this experimentation environment in UML and identified key use cases and issues for each of the four phases essential for network-centric C2 system of systems (SoS) integration: inter-connection, inter-federation, inter-collaboration, and inter-operation. The initial US Army BML prototype software was leveraged to reduce the operator requirement for the OneSAF Testbed Baseline (OTB) simulation and to initiate analysis of BML as a common language for interchange of mission and task information.

C-BML relevance

SINCE provides a repeatable baseline from which to grow a test bed environment suitable for supporting a broad range of coalition C2 technical and operational experimentation activities directed at defining, developing, evaluating, and demonstrating improved, collaborative coalition force command and control while operating in highly dynamic and mobile military operational environments.

In addition, the SINCE experimentation environment provides a repeatable baseline to demonstrate and evaluate interoperability between multinational C2 systems stimulated as a direct result of events generated in real-time by the M&S systems. This is key to driving and evolving a combat situation represented by a user definable/common operational picture (UDOP/COP) that provides context to these experiments from a technical as well as an operational perspective.

The results of SINCEx1a should prove to be invaluable not only to future SINCE experiments but to support other related efforts. Initial experimental results obtained from. SINCEx1a is a significant step towards developing and establishing a comprehensive international Research and Development (R&D) program to support transformation to Future Force and transition to MIP. Use of UML to design the experimental architecture has proven invaluable. The use of XML to provide a common coalition domain model facilitated integration and bridging between disparate data models. By leveraging existing C2 prototypes for planning and execution monitoring and coupling them to existing M&S systems to provide a dynamic operational environment we are able to provide valuable feedback for enhancements. The SINCE experimentation environment will provide a stable baseline for experimentation, analysis, and evolution of Coalition BML concepts and capabilities.

2.15 SOKRATES (FGAN-FKIE, Germany)

Problem Statement

In Germany, FGAN-FKIE developed a prototype for automatic report analysis, the SOKRATES system. This system takes reports written in natural language as input, parses the information in the report, inserts the analyzed content into a data base, and displays the information on a map.

Solution Proposed

In a first step, the reports are transformed into a formal representation by means of information extraction (Hecking, 2003) (Hecking, 2004). The formal representation used is an XML version of a feature-value structure, the standard representation format used by unification-based processing systems in the field of computer linguistics (Shieber, 1986) (Bresnan, 2001). In a second step, these representations are augmented semantically by ontological processes (Schade, 2004) (Schade & Frey, 2004). Lastly, during the post-processing step, the results are visualized within a common operational picture as well as inserted into an underlying C2IEDM data base.

C-BML Relevance

The formal representation and ontology component used in the SOKRATES are grounded on the C2IEDM. The taxonomy as well as attributes, their values and their value restrictions are taken from there. Thus, the formal representation is quite similar to C-BML. The main difference lies in action framing. C-BML uses a fixed frame system (the 5Ws). In contrast, the formal representation of SOKRATES is “lexical driven.” The frame system used in a specific statement is determined by the type of the respective action; e.g., if the statement is about a rest-action there will be a location-slot like C-BML's "WHERE", but if it is about a move-action there will be four kinds of "WHERE-slots", namely one for source, one for destination, one for path, and one for direction. In addition, SOKRATES also adds complexity by allowing whole statements as arguments of its "intention-slot" which mirrors C-BML's "WHY". The pros and cons of these differences as compared to C-BML need to be identified and assessed.

2.16 Task Analysis Leading to BML Vocabulary (AcuSoft, USA)

Problem Statement

How can the requirements of an order/task be identified in a common way across the doctrine of the coalition? Key considerations include:

- Independent of the doctrine of each coalition member, there are common terms of when, where, and why. Each of these "terms" is represented differently in the natural language within the doctrine of each coalition member.
- Given common terms exist, these terms provide a common computational language across all doctrine.
- The syntax, grammar, and vocabulary cannot be identified without a detailed understanding of the targeted ontology that is represented in doctrine.
- The "context" of the language changes when an order applies to a smart (human warrior) versus a dumb (synthetic force or autonomous robot with limited decision-making capability) unit.
- The information should be derived from the explicit language of the task.

In other words, the analysis must assume the doctrine is correct and is not subject to interpretation. If the task is incorrect, then the task must be corrected first. The analyst must not take expert liberties in the analysis. If liberties are taken, the language is no longer traceable and will not pass the Verification, Validation and Accreditation (VV&A) activities.

Solution Proposed

The following activities need to be conducted:

- Perform a task analysis to identify the information that is provided with, or in context to, the specific order/task.
- Identify the information required, and information that results from situational understanding. Information providing situational understanding is a required input for "dumb" actors/units.
- Identify methods of specifying *why* in context to these terms. For example, of all the task input terms, the one representing a firm constraint in context to the mission is the "why".

- All the terms identified from the task must be placed in the context of both the language and the doctrine; in other words it must be both human readable and computational.

A conceptual basis and structure for this work is provided by the Mission to Means Framework (MMF) (Hieb & Kearly, 2004).

C-BML Relevance

This effort will provide a methodology for specifying language requirements based on the tasks to be communicated. This applies to real (smart) units as well as robotic and simulated units to address terms required as input with the order to provide constraints or requirements. For dumb units additional information representing situational understanding needs to be communicated as well.

2.17 UK Research into BML (QinetiQ, UK)

Problem Statement

QinetiQ was tasked by the UK MoD under the Research Package "Training for Combat Readiness" to assess the utility of BML (Carlton, et. al., 2005) as an enabling technology to support interoperability within the context of the proposed Interoperability Coherence Framework (ICF).[13] If the maximum benefits of C2 capabilities are to be realized, then C2 information must be passed in an unambiguous manner between C2 nodes and between C2 capabilities (including those of other UK services and other nations).

Furthermore, to enable the concept of "train as you fight" for mission rehearsal and COAA, it is vital that C2 capabilities can unambiguously communicate with Collective Training, mission rehearsal, and decision support systems to pass C2 information in both directions.

This requires an unambiguous structured language, rooted in doctrine, with the necessary protocols to enable communication.

Solution Proposed

The work discussed here was an assessment of the utility of a BML, so no solution was proposed. In summary, it was found that it was technically possible to represent a large fraction of a UK Brigade OPORD in an existing (US) BML format, which in turn was based on a slightly enhanced version of C2IEDM (Haines & Galvin, 2005).

Although BML is less mature than C2IEDM, and is not used by operational systems, further examination is considered valuable because BML provides one

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[13] Research in the UK has indicated that no one architectural approach will solve the integration problem and recommends that an Integration Coherence Framework (ICF) be developed to provide guiding principles for when and where particular architectural approaches such as the US DoDAF/UK MoDAF, HLA, or XMSF should be applied. A secondary challenge is to recognize when there is no suitably mature off-the-shelf approach in a particular area in order to identify the need for refinement of an existing approach or development of a new one.

of the most promising existing approaches to the translation of complex operational orders into tasking for simulated forces. It can therefore potentially reduce training support staff workloads during exercise set-up and execution. It can also provide a basis for creating a common “tasking language” that accepts orders from C4I systems in a consistent way, and then translates them into formats required by a given training system. It is also important to ensure that the BML approach is consistent with UK doctrine and procedures.

BML may in fact be useful to future operational systems to support their own requirements for storing and exchanging information in support of orders. Operational acceptance of a UK BML can be facilitated by ensuring that the UK BML is based on an existing operational format such as C2IEDM.

C-BML Relevance

As a result of the assessment a number of recommendations were made that are considered relevant to the development of a C-BML standard:

- The MoD should continue to actively support the NATO C-BML research and participate in planned demonstrations to ensure C-BML can support UK requirements for interoperability.
- The MoD should participate in SISO activities to develop a C-BML standard to ensure UK needs are included.
- The MoD should develop a UK national BML to fully meet UK requirements for interoperability which can be mapped to any emerging NATO BML/C-BML standard.
- The MoD should build a capability to demonstrate the utility of a UK BML to stakeholders to reduce the risks associated with developing a UK BML and to support NATO C-BML research. The capability should demonstrate the utility of BML within the proposed ICF and must show that it is an enabler for international C2/C2 interoperability and C2/Collective Training interoperability. The demonstration must show how:
    - BML can be generated from a C2 system.
    - BML can be read, interpreted and used by a simulation.
    - A simulation can generate BML.
    - A C2 system can read, interpret, and use BML generated by a simulation or another C2 system.

2.18 XML-based Tactical Language Research (Naval Postgraduate School, USA)

Problem Statement

The Naval Postgraduate School (NPS) is conducting research in a number of programs related to employment of M&S and Web-based technologies in tactical systems. A key area of work is information representation in the various systems and mechanisms for efficient and effective information interchange across systems. Representative efforts include:

- Undersea Warfare (USW) XML Working Group: employment of XML data formats and messaging within tactical systems.
- Global Information Grid (GIG) M&S Community of Interest Focus Groups: metadata, data mediation, and services supporting M&S on the GIG.
- Autonomous Unmanned Vehicle (AUV) Workbench: including Autonomous Vehicle Control Language (AVCL) as a representative BML for robotic forces.
- Common Maneuver Networks (CMN) and Mobility COP (M-COP): developing common data representations to facilitate exchange of maneuver network data among M&S and C2 systems and to form a basis for definition of a Mobility COP, including contribution to formalization of a GeoBML to describe the operational battle space.
- XMSF: continued development of exemplar projects and community education to define a composable set of standards, profiles and recommended practices for web-based military modeling and simulation leveraging the extensive commercial investment in web-based technologies.
- Model-based Communication Networks: creating producer/consumer data semantics for task-driven information exchange to achieve *Valued Information at the Right Time* (VIRT).
- Naval BML: extending current Army and Air Force centric BML approaches to represent Naval plans and orders.
- Joint Tactical Integrated Data System (JTIDS): NATO project developing XML encodings of Link-16 messages and application of binary XML compression schemes for tactical data links.
- Coalition Secure Management and Operating System (COSMOS) Advanced Concept Technical Demonstration (ACTD): applying C2IEDM for core data representations in a coalition information processing network.

Solution Proposed

Broad technical interoperability is enabled by open standards, XML-based markup languages, Internet technologies, and cross-platform Web services supporting diverse distributed M&S simulation applications. The XMSF project is providing the technical basis for transformational interoperability via XML data and messaging interchange, profiles, and recommended practices for Web-based M&S. Specification and formalization of strong semantics is a fundamentally difficult area that has seen much research progress in recent years as part of the W3C's Semantic Web and other initiatives. The first requirement in the area of ontologies is to define and approve complementary taxonomies that can be applied across multiple application domains. This will allow for consistent classification of data and services via precise vocabularies. A subsequent requirement is to establish consensual common meaning. It does not suffice for there to be agreed-upon meaning within a group, but to be truly useful, there needs to be a mechanism for defining the equivalence of terms across groups (ontology mapping). This will allow for both extensibility and for interoperability. The Defense Advanced Research Project Agency (DARPA) Agent Markup Language (DAML) project has established an ontology repository for common service representations. In practice, the NATO-developed C2IEDM is being exploited for tactical operations. It is particularly interesting to consider the implications of standard semantics like C2IEDM that help to establish commonalities between services and coalition partners. Development of effective ontologies for military operations orders (which contain tactical versions of the "who, what, when, where and how" of an operation) is a strategically important application area deserving dedicated further work. NPS is addressing this need through a number of projects and example applications (identified above).

C-BML Relevance

A key requirement of all these efforts is a well-defined language for representing the commander's intent and conveying orders to operational forces, be they live, constructive, or robotic. If successful, the C-BML will provide the basis for unambiguous expressions upon which autonomous agents and automated decision-support systems can provide effective support to warfighters across ever-more important joint and coalition operations.

2.19 Core C-BML References

Over the past decade there have been a number of initiatives to create a common language for interactions between Battle Command systems and M&S systems. Listed below are several key publications that support the need for, as well as the initial concept and feasibility analysis of, a Battle Management Language Standard. The initial references are to the Command and Control Simulation Interface Language (CCSIL) initiative. Interestingly, the first papers predate both the HLA and the establishment of SISO. After CCSIL the SISO C4I Track sponsored a Study Group to develop recommendations for C4I to Simulation Interoperability. This Study Group produced a report that both surveyed common approaches and made recommendations. After the Study Group report, several initiatives were started in parallel in different countries concerning Battle Management Language. These and other references (if not cited explicitly elsewhere in this document) are included in an extended bibliography provided in Appendix F.

1994

Dahmann, J. S., Salisbury, M., Booker, L. B. and Seidel, D. W., "Command Forces: An Extension of DIS Virtual Simulation," MITRE Informal Report, Twelfth Workshop on Standards for the Interoperability of Defense Simulations, 1995. (http://ms.ie.org/cfor/ diswg9409/diswg9409.pdf)

This is the first paper that mentions the future development of CCSIL and how this standard would be used in the DARPA Synthetic Theater of War (STOW) 97 Program.

1995

Salisbury, M., “Command and Control Simulation Interface Language (CCSIL): Status Update,” MITRE Informal Report, Twelfth Workshop on Standards for the Interoperability of Defense Simulations, 1995. (http://ms.ie.org/cfor/diswg9503/diswg9503.pdf)

Groundbreaking work on structuring an Army Operations Order. From the document:

> ***“Why Is This Difficult?***
>
> *People often ask why the existing standard message sets used by the military services are not sufficient for this task … In most cases, the standard message sets rely heavily on free text fields where a human can input natural language to convey the essence of the order or situation. … The current state of natural language interpretation software is not sufficient to support our requirements. The current set of CCSIL messages focuses on providing highly structured, yet flexible formats for the types of information normally conveyed using natural language.”*

1996

Hartzog, S. M., Salisbury, M. R., "Command Forces (CFOR) Program Status Report," *Proceedings of the Sixth Conference on Computer Generated Forces and Behavioral Representation*, Orlando, Florida, July 1996.

A look at the different CCSIL messages developed for the Army, Navy, Air Force and Marine Corps.

1997

MITRE, DARPA STOW ACTD version of the CCSIL documentation.
(http://ms.ie.org/cfor/)

The complete documentation for the CCSIL Specification. Highlights are the representation of the US Army’s Operation Order and the Air Force’s Air Tasking Order.

Hieb, M. R., Cosby, M., Griggs, L., McKenzie, F., Tiernan, T., and Zeswitz, S., “MRCI: Transcending Barriers between Live Systems and Simulations,” Paper 97S-SIW-197, Simulation Interoperability Standards Organization, Spring 1997 Simulation Interoperability Workshop.

MRCI was a general C4I interface developed as part of STOW 97. MRCI used CCSIL as the simulation standard for Command and Control messages and translated between CCSIL and common C4I message formats (such as USMTF or OTH-Gold). This provided a proof of concept that it is possible to create unambiguous messages representing complex orders for simulations.

Layman, G. E., Conover, J., Kunkel, P., and Robins, D., “JMCIS/GCCS Interoperability with External Simulations,” Paper 97S-SIW-132, Simulation Interoperability Standards Organization, Spring 1997 Simulation Interoperability Workshop.

A paper describing the Command and Control Architecture for STOW 97, placing the use of CCSIL in context.

Lightner, M., Schanduaa, J., Cutts, D., and Zeswitz, S., "The High Level Architecture Command and Control Experiment – Lessons Learned in Designing an Extended Federation," Paper 98S-SIW-93, Simulation Interoperability Standards Organization, Spring 1998 Simulation Interoperability Workshop.

An analytical evaluation of the MRCI Interface, again placing the use of CCSIL in context.

1998

Carr, F. H. and Hieb, M. R., "Issues and Requirements for Future C4ISR and M&S Interoperability," 7th Conference on Computer Generated Forces and Behavioral Representation, 1998.

This paper developed a "Technical Reference Model" for C4I to Simulation Information Exchange. Exchange of Order information is explicitly called out as one of the main Information Exchange areas in the model.

Hieb, M. R., and Staver, M. J., "The Army's Approach to Modeling and Simulation Standards for C4I Interfaces," Paper 98F-SIW-259, Simulation Interoperability Standards Organization, Fall 1998 Simulation Interoperability Workshop.

This paper puts the exchange of C2 information in the context of a Standards Development program.

Kleiner, M. S., Carey, S. A., and Beach, J., "Communicating Mission-Type Orders to Virtual Commanders," *Proceedings of the 1998 Winter Simulation Conference*, December 1998.

An innovative look at expressing commander's intent in a structured format. This was the basis for the future US Army Battle Management Language work.

1999

Paola, A. R., and Ressler, R. L., "Stimulating the Army Tactical Command and Control System Using the Run Time Manager: Concepts and Implications," Paper 98S-SIW-162 Simulation Interoperability Standards Organization, Spring 1999 Simulation Interoperability Workshop.

Describes how the Run Time Manager C4I to Simulation interface used CCSIL Fire Support Messages to communicate to C4I devices.

Ressler, R., Hieb, M. R., and Sudnikovich, W., "M&S/C4ISR Conceptual Reference Model," Paper 99F-SIW-060, Simulation Interoperability Standards Organization, Fall 1999 Simulation Interoperability Workshop.

Further development of the C4I to Simulation Technical Reference Model and identification of the need for standards in the area of expressing C2 Orders.

2000

Timian, D. H., Hieb, M. R., Lacetera, J., Tolk, A., Wertman, C., and Brandt, K., "Report Out of the C4I Study Group," Paper 00F-SIW-005, Simulation Interoperability Standards Organization, Fall 2000 Simulation Interoperability Workshop.

From the report:

> ***"Orders** are a type of interaction that convey C2 information. Translation of this class of information has been extremely difficult to achieve with current interfaces. Presently, C4ISR systems do not support the generation and maintenance of this C2 information in a uniform manner."*

2001

Carey, S., Kleiner, M., Hieb, M. R. and Brown, R., "Standardizing Battle Management Language – A Vital Move Towards the Army Transformation," Paper 01F-SIW-067, Simulation Interoperability Standards Organization, Fall 2001 Simulation Interoperability Workshop.

This paper laid out the key concepts and principles for development of an Army Battle Management Language as described in this Study Group report. The idea of using the emerging C4I standard databases to disambiguate orders was developed in this paper.

Ogren, J., and Fraka, M., "EAGLE Combat Model Battle Management Language (BML)," Powerpoint presentation, BML Symposium at Fort Leavenworth, KS, 25 April 2001.

Eagle was a very complete constructive Ground Combat simulation. It used a very well constructed form of BML in its internal architecture.

2002

Carey, S., Kleiner, M., Hieb, M. R. and Brown, R., "Standardizing Battle Management Language – Facilitating Coalition Interoperability," Paper 02E-SIW-005, Simulation Interoperability Standards Organization, 2002 European Simulation Interoperability Workshop, London, England.

Extension of the BML concept described in Fall 2001 SIW paper 01F-SIW-067 to Joint and Coalition Operations.

2003

Khimeche , L., and de Champs, P., "Courses of Action Analysis and C4I-Simulation Interoperability," Paper 03F-SIW-028, Simulation Interoperability Standards Organization, Fall 2003 Simulation Interoperability Workshop.

Innovative work on using C2IEDM for exchanging C2 information between Simulations and C2 Systems.

Tolk, A. and Pullen, M., "Ideas for a Common Framework for Military M&S and C3I Systems," Paper 03E-SIW-032, Simulation Interoperability Standards Organization, 2003 Euro Simulation Interoperability Workshop.

Proposes BML as a common Operational Model for both C2 and Simulation Systems in Future C2 Architectures.

Sprinkle, R. B., Heystek, D. and Lovelady, S. D., “Common Scenario Generation for Army M&S and C4ISR Systems,” Paper 03S-SIW-103, Simulation Interoperability Standards Organization, Spring 2003 Simulation Interoperability Workshop.

Paper pointing out applicability of BML for Scenario Generation.

2004

Hieb, M. R., Sudnikovich, W., Tolk, A., and Pullen, J. M., “Developing Battle Management Language into a Web Service,” Paper 04S-SIW-113, Simulation Interoperability Standards Organization, Spring 2004 Simulation Interoperability Workshop, Crystal City, VA.

Paper that describes how the US Army’s BML Proof of Principle demo was standardized (by using the C2IEDM) and made extensible (through XMSF protocols).

Hieb, M. R., and Kearly, J., “A Methodology for Doctrine in Modeling and Simulation: Battle Management Language (BML) and the Mission to Means Framework (MMF),” Paper 04F-SIW-110, Simulation Interoperability Standards Organization, Fall 2004 Simulation Interoperability Workshop.

Paper relating where BML fits in the Mission to Means Framework.

Khimeche, L., and de Champs, P., “M&S in Decision Support for Courses of Action Analysis, APLET,” 04F-SIW-006, Simulation Interoperability Standards Organization, Fall 2004 Simulation Interoperability Workshop.

Recommendation to standardize on C2IEDM for implementation of C-BML and discussion of BML in the context of a COAA system.

Mayk, I., and Klose, D., “Experimenting with C2 Applications and Federated Infrastructures for Integrated Full-Spectrum Operational Environments in Support of Collaborative Planning and Interoperable Execution," Proceedings of the 2004 Command and Control Research and Technology Symposium (CCRTS), San Diego, CA, June 15–17, 2004.

Description of the US-German Collaborative Program SINCE which has done extensive development of their own BML using the 5 Ws and adding “Which” and “How.”

Sudnikovich, W., Hieb, M. R., Kleiner, M. and Brown, R., “Developing the Army's Battle Management Language Prototype Environment,” Paper 04S-SIW-115, Simulation Interoperability Standards Organization, Spring 2004 Simulation Interoperability Workshop, Crystal City, VA.

Paper describing the US Army’s BML Proof of Principle demonstration, focusing on representing US Brigade/Battalion/Company Operations orders.

Tolk, A., Hieb, M. R., Galvin, K., and Khimeche, L., “Coalition Battle Management Language,” Paper 04F-SIW-103, Simulation Interoperability Standards Organization, Fall 2004 Simulation Interoperability Workshop, Orlando, FL, September.

Proposal for development of a BML for Coalition activities.

Tolk, A., Hieb, M. R., Galvin, K., and Khimeche, L., “Merging National Battle Management Language Initiatives for NATO Projects,” Paper 12 in Proceedings of the RTA/MSG Conference on “M&S to address NATO’s new and existing Military Requirements,” RTO-MP-123, Koblenz, Germany, October 2004.

Proposal to NATO to form a C-BML Technical Activity.

Turnitsa, C., Kovurri, S., Tolk, A., DeMasi, L., Dobbs, V., Sudnikovich, W., “Lessons Learned from C2IEDM Mappings Within XBML,” Paper 04F-SIW-111, Simulation Interoperability Standards Organization, Fall 2004 Simulation Interoperability Workshop, Orlando, FL, September.

Technical report on using the Coalition data model, the C2IEDM, to represent BML.

2005

DeMasi, L., Dobbs, V. S., Ritchie, A. and Sudnikovich, W. P., “Implementing Battle Management Language: A Case Study Using the Command and Control Information Exchange Data Model and C4I-M&S Reference Object Model,” Paper 05S-SIW-068, Simulation Interoperability Standards Organization, Spring 2005 Simulation Interoperability Workshop, San Diego, CA, April.

Work in structuring BML in the C2IEDM using the 5 Ws.

Garcia, J., “Technical and Operational Constraints for Web Based M&S Services for the Global Information Grid,” Paper 05S-SIW-011, Simulation Interoperability Standards Organization, Spring 2005 Simulation Interoperability Workshop, San Diego, CA, April.

Describes BML as a technical enabler for the GIG.

Khimeche , L., and de Champs, P., “APLET's Courses of Action Modeling : A Contribution to CBML,” Paper 05S-SIW-018, Simulation Interoperability Standards Organization, Spring 2005 Simulation Interoperability Workshop, San Diego, CA, April.

Description of French use of a BML and recommendations when supporting a Course of Action Analysis system.

Perme, D., Tolk, A., Sudnikovich, W. P., Pullen, J. M., and Hieb, M. R., “Integrating Air and Ground Operations within a Common Battle Management Language,” Paper 05S-SIW-154, Simulation Interoperability Standards Organization, Spring 2005 Simulation Interoperability Workshop, San Diego, CA, April.

Paper that shows how the XBML prototype can be extended to the Air Domain from the Ground Domain by reusing the 5Ws and C2IEDM implementation.

Roberts, J. D., and Sudnikovich, W. P., "Achieving Higher Levels of Interoperability Between M&S and C2 Systems Through Application of BML to the SINCE Program," Paper 05S-SIW-055, Simulation Interoperability Standards Organization, Spring 2005 Simulation Interoperability Workshop, San Diego, CA, April.

Detailed explanation of how BML affects simulation behaviors from a US-German Collaboration.

Tolk, A., and Blais, C., "Taxonomies, Ontologies, and Battle Management Languages – Recommendations for the Coalition BML Study Group," Paper 05S-SIW-007, Simulation Interoperability Standards Organization, Spring 2005 Simulation Interoperability Workshop, San Diego, CA, April.

Paper giving specific recommendations for C-BML development within SISO.

Tolk, A., Diallo, S., Dupigny, K., Sun, B. and Turnitsa, C., "Web Services based on the C2IEDM – Data Mediation and Data Storage," Paper 05S-SIW-019, Simulation Interoperability Standards Organization, Spring 2005 Simulation Interoperability Workshop, San Diego, CA, April.

Paper detailing how the XBML work can be standardized further in the area of prototols with C2IEDM Web Services.

Tolk, A. and Winters, L., "The Integration of Modeling and Simulation with Joint Command and Control on the Global Information Grid", Paper 05S-SIW-148, Simulation Interoperability Standards Organization, Spring Simulation Interoperability Workshop, San Diego, CA, April.

BML is used as a key component in a use case of "COAA on the GIG".

3 Products and Plan for Developing a C-BML Standard

3.1 Phased Approach

The C-BML SG recommends the development of standard products as well as accompanying guidance products. The development will be conducted in close cooperation and collaboration with the standardization efforts of the MSDL PDG. Furthermore, the Base Object Model (BOM) PDG products will be evaluated and considered for use.

Standards for C-BML will be produced in phases resulting in incremental versions that provide increasing capability. For all phases and versions, the SG recommends using C2IEDM and its successors (i.e., JC3IEDM) as a basis for C-BML reference implementations and standards. Each version of the C-BML standard will have:

- A Data Model
- An Information Exchange content and structure specification
- An Information Exchange Mechanism specification
- Guidelines

The SG agreed that a guideline product, which explains C-BML use and provides practical examples, must accompany every standard product version. Furthermore, every version extending or replacing an earlier version will describe a migration procedure.

The SG proposes that the C-BML Standard evolve over time through three phases:

- <u>Version I (April 2006-2007)</u>: In Version 1.0 specify a sufficient data model to unambiguously define a set of military orders using C2IEDM as a starting point and extending as necessary so that they can be interpreted by C2, M&S and Robotic systems. The C-BML Standard will describe a data model in a subset of C2IEDM, an Information Exchange, content and structure specification in the form of an XML schema and an Information Exchange mechanism specification embedded into a WSDL document. This standard, including recommended guidelines, will be finalized in April 2007. An initial version of the C-BML XML schema will be evaluated by the parallel NATO MSG-048 effort (see Section 2.12).
- <u>Version II (April 2006-2008)</u>: In Version 2.0 of the C-BML Standard will introduce a grammar (syntax, semantics, and vocabulary) as part of the Information Exchange, content and structure specification. The objective is to formalize the definition of tasks such that they are rigorous, well documented, and parse-able. The grammar will be extended to accommodate "reports" after a tasking grammar is defined. The need for a grammar for tasking and reporting is seen as a common requirement for both the C-BML and MSDL efforts and this could be conducted by

establishing a joint C-BML/MSDL Tiger team for this task. The standardization effort will include recommended guidelines applicable to C-BML and MSDL to be finalized in April 2008.

- Version III (April 2006 – April 2010): Version 3.0 of the C-BML Standard will include development of a battle management ontology to enable conceptual interoperability. The standardization effort, including recommended guidelines, is envisioned to last at least until April 2010. While the SG realizes the potential of ontology-based solutions it is also recognized that current approaches require additional research and agreement on processes outside of SISO to achieve applicable solutions.

Although the phased approach outlined above is considered the best mechanism to deliver each version of the C-BML Standard, the SG recognizes that underlying research is not constrained by this schedule and will take place from the outset of establishing the PDG. For this reason, the above start dates for each phase are the same. The SG recommends initial establishment of all three subgroups within the C-BML PDG in order to begin research in support of each phase in parallel.

3.2 Other Considerations

While the C2IEDM is considered the best information hub currently available, it will potentially need extensions to meet the requirements of the M&S community. Studies described in (Franceschini, et. al., 2004) (Tolk, et. al., 2004a) (Tolk, et. al., 2004b) show that the resolution needs of simulation systems are not met in all areas. This requires members of the PDG to identify the necessary extensions by the Phase 1 subgroup in coordination with the MIP.

While XML enables separation of data definition and data content, it does not ensure that data exchanged is interpreted correctly by the receiving system. Other standards may be needed to ensure correct application. The SG must evaluate such standards for future extensions to core data models such as C2IEDM.

Phase 2 work activities may need to include analysis of the representation of multi-national tasks using C2IEDM constructs (e.g., when the US talks about "Gain/Maintain Control of Land Areas," forces in Canada, Australia and UK use the phrase "Dominate Key Terrain"). While the tasking grammar is intended to be general and designed to describe classes of tasks, missions, and operations, there may need to be additional work to standardize usage within the MIP. Of note, analysts in Australia have constructed a preliminary mapping of task lists based on country-specific lists from Australia, Canada, UK, and US (as a tool to develop ASJETS).

The phased approach is consistent with previously published recommendations (Tolk & Blais, 2005):

(1) XML, C2IEDM, and the glossary of used terms as the initial set of standards for C-BML.

(2) Establishment of subgroups addressing the challenges of extending the C2IEDM, establishing a C-BML ontology, and evaluating additional standards applicable to all three C-BML domains of C2 devices, M&S systems, and robotic systems.

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4 Recommendations

The C-BML Study Group makes the following recommendations:

- *We recommend that SISO accept the Product Nomination.* Through a literature search and a survey of related projects, the C-BML SG has demonstrated that there is a recognized need and consensus across the international C2 and M&S communities for a standardized Coalition battle management language.
- *We recommend that SISO establish a PDG in order to develop a C-BML standard.* The C-BML SG has gathered a group of subject matter experts across numerous services and nations who are willing to work on and assist the standardization effort. A draft Product Nomination is provided in Appendix B of this report as a starting point for moving the standardization process forward.
- *We recommend that SISO initiate a phased approach to development of the standard.* An incremental development approach best serves the C2 and M&S communities by making initial and evolving products available for experimentation and employment as early as possible. Technical feedback from community use of the standard will also help focus the PDG on implementation of the standard as well as documentation of the standard.
- *We recommend that the C-BML PDG be separate from a proposed MSDL PDG.* The C-BML standard will focus on C2/M&S data interchange; the MSDL standard will focus on C2 and simulation system initialization.
- *We recommend that the C-BML PDG closely collaborate with a MSDL PDG where there are areas of common interest, such as the development of a military tasking grammar.* A cooperative relationship with the MSDL SG was established during the SG effort, with several participants actively engaged in both efforts. These efforts will continue to ensure full compatibility across the two standardization efforts working toward complementary capabilities.
- *We recommend that the C-BML PDG maintain engagement with C2 community to ensure joint ownership and development of the standard.* The ultimate value of the standard is its ability to improve warfighting capabilities through more effective C2 and simulation system interoperability, in addition to effective employment of emerging robotic systems within the overall battle space.

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Appendix A – Overview of the March 2005 C-BML Study Group Meeting

The Coalition Battle Management (C-BML) Study Group (SG) met at the Virginia Modeling Analysis and Simulation center (VMASC) of Old Dominion University (ODU), Norfolk, Virginia, USA., on March 7-9, 2005. The meeting was chaired by Major Kevin Galvin, QinetiQ and hosted by Dr. Andreas Tolk, ODU/VMASC. Scott Hanson represented the Standards Activity Committee (SAC) of Simulation Interoperability Standards Organization (SISO). This face-to-face meeting brought 35 international experts together. Five universities (Carnegie Mellon University, George Mason University (GMU), Naval Postgraduate School (NPS), ODU, and the University of Texas) participated in the event; represented nations were Canada, France, Germany, Sweden, United Kingdom, and United States of America. The full report of the meeting is provided in (Tolk, 2005).

This meeting was primarily targeted to contribute to the survey task specified in the SG Terms of Reference, to identify additional groups that were interested in the C-BML work, and to continue the discussion of alternative views for a common C-BML standard/standard framework. To this end, 15 presentations were given and discussed. The variety and breadth of presentations demonstrated that numerous schools and agencies across several countries are exploring interoperability issues relevant to the C-BML study.

Besides the SISO experts and members of the study group, invitations were sent to other subject matter experts, in particular the authors of the soon to be published special issue of the *Journal on Transactions on Simulations, Society for Modeling and Simulation* (SCS), on “Military Simulation Systems and Command and Control Systems Interoperability.” Another aspect was consensus based work of the Multilateral Interoperability Programme (MIP) and the Command and Control Information Exchange Data Model (C2IEDM) – both identified as potential contributions to broader M&S-to-C2 solutions in previous North Atlantic Treaty Organisation (NATO) and SISO conferences.

During the first day, all participants presented their organization and their interest in C-BML issues. Among the topics of common interest were the C2IEDM and additional standards, in particular the US Department of Defense (DoD) Interface Standard MIL-STD-2525B. Furthermore, the specification of terrain was a common topic, raising issues concerning the relation of C-BML with Synthetic Environment Data Representation and Interchange Specification (SEDRIS) and emerging ideas, such as the Geospatial Mark-up Language (GML).

The German Information Technology (IT) Office declared interest in the meeting, but was not able to send an attendee. Nonetheless, they committed to send information on related German efforts (see the Simulation to Command and Control (C2) Information System Connectivity Experiments (SINCE) program description in Section 2 of this SG final report).

All presentations are published on the Face-to-Face Minutes website: http://www.vmasc.odu.edu/coalitionbml/cobml overview.html

Following overviews of the SG and BML, Bill Sudnikovich gave an overview on the current US work on BML. The presentation identified several current research domains, such as the necessity to extend the C2IEDM in order to cope with all information exchange requests based on national concern issues; the challenge of coping with matching the eligibility of similar units for given tasks; how to handle the requirement to add tasks from other types of units or even to add a new task (as often observed during peace and stability operations); using ontological layers for cross-checking assets and their capabilities versus tasks; and more.

The second day was used for presentations on related topics which must be evaluated by the SG to determine relevance to C-BML. Presentation topics included: C2SR/Simulation Technical Reference Model (C2SR/Sim TRM); C2IEDM as a core C2 Ontology; NATO Exploratory Team 016 (ET-016) efforts and Aide a la Planification d'Engagement Tactique (APLET); Army C4ISR Simulation and Initialization System (ACSIS); Military Scenario Definition Language (MSDL), Military Scenario Development Environment (MSDE) and a common tasking language for C-BML and MSDL; Swedish Armed Forces interests in C-BML to promote interoperability; NPS initiatives with C2IEDM and robotic control languages; Engineer Research and Development Center (ERDC) initiatives in semantic interoperability for sharing Common Maneuver Networks (CMN) and defining a Mobility Common Operational Picture (COP); Geospatial BML (GeoBML); Intelligence Modeling and Simulation for Evaluation (IMASE) Scenario Generation Tool (ISGT).

Presentations on the third day were given by invited experts in domains that will shape the BML discussion on the mid and long term – general integration frameworks on the industrial scale such as the one used by Northrop Grumman; the application of natural language parsers; and the requirements of intelligent software agents as developed by Carnegie Mellon University.

In summary, these presentations provided a good basis to initiate discussion on the scope of C-BML. While the second day presentations identified additional domains to be covered (in particular a closer look at terrain and it constraints), the third day presentations challenged the study group with more fundamental questions regarding the support of all levels of interoperability and broad applicability in future infrastructures.

All participants of the workshop were asked to prepare a half page to a one page summary on their topic focusing on three points:

- Problem statement: What is the problem to be solved by their approach?
- Solution statement: What are the assumptions and constraints are made and what is the resulting solution?

- Relevance statement: How is this solution relevant to the C-BML efforts? All contributions should keep in mind that we are in particular interested in standards applicable in the coalition domain, which means national standards and solutions are only of limited interest.

Information received after the meeting addressing these questions is provided in Section 2 of this final report.

It was determined that three tasks have to be accomplished for completion of the SG effort; namely:

- **Assess Currently Ongoing Efforts:** This would seem to be the easiest of the three tasks and as a result of the creation of the SG it has provided a focus for others to inform us of their efforts in developing a C-BML. What seems to be common is the use of Extensible Mark-up Language (XML) and C2IEDM, and there are other efforts that have the same aims such as the MSDL but with a different focus. There is also a growing recognition, as various nations embark on the Digitization trail, that we have to add structure to the BML that we use today if we want to use simulation to stimulate operational C2 systems, or in the Military Decision Making Process (MDMP) for Course of Action Analysis (COAA) and Mission Rehearsal (MR). Recognising the need is one thing but providing adequate funding at a time when many of our countries are engaged in military operations throughout the world is a challenge.
- **Evaluate a Standard Framework:** Developing a standard framework is perhaps the more challenging aspect of the study. What is a "Standard Framework" or do we mean a "Framework of Standards"? A pure C2 BML is only part of the framework of C2 to M&S interoperability. Others include terrain and other geospatial data, and scenario generation. Both of them need a BML and vice-versa. What is a BML standard? When we define a language, do we define grammar and a dictionary or do we need other formalisms? The 5W format is the first step in developing a standard, but what is needed in addition?
- **Recommend Steps to Form a C-BML PDG:** Should be able to identify a set of applicable standards such as XML, Web Services (SOAP, XML Schemas, etc), Data Models (C2IEDM?), and so on. Identify in addition Research & Development (R&D) areas such as Ontologies, Task Language Grammars, etc. Need to recommend PDG activities.

The first discussion point was if the protocol view is necessary in the context of a C-BML specification. The definition of this view was first published in the paper (Tolk, et. al., 2004a). Three views were postulated as necessary to describe BML:

(1) A Doctrine View – BML must be aligned to doctrine;

(2) A Representation View – BML must model these aspects in a way that can be interpreted and processed by the underlying heterogeneous information technology systems of the coalition;

(3) A Protocol View – BML must specify the underlying protocols for transferring BML information between participating systems.

These views are specified in more detail in the paper referenced.

The necessity to identify an underlying protocol in the specification of BML, was discussed during the meeting. The main argument for a protocol view is that a common protocol is the basis of interoperability. If the user can choose between different protocols, additional mappings are necessary and may result in ambiguous results. A common protocol can insure technical and syntactic interoperability and – when using a common reference data model – even semantic interoperability. C2IEDM, XML, and web services seem to be a preferred and widely accepted representation for the initial phase and are extensible enough to suit other needs than those currently specified.

The main argument against a protocol view is that the protocol limits users of BML too much. Some may prefer to use their own protocols and standards, such as High Level Architecture (HLA) Object Model Template (OMT) or C2-related standards – and may not want to migrate towards XML and web services. With the result that in the protocol view of making the specification more complicated than necessary. In summary, BML should allow any protocol to be used; it might have an example implementation in web services, but must be able to evolve as technology evolves.

Both sides have valid arguments and it will be part of the discussion during the next SIW meetings to establish a consensus for the SG.

Without doubt, the main first step of BML must be a specification for executable tasks, as this is the core piece of battle management: producing orders and tasks that are understood and can be equally executed by soldiers, simulated forces, and robots. The initial BML core is based on the 5Ws concept, which focuses on identifying the organizations, what actions they can perform, where and when they do it, and “why” in free text, sometimes in context containers, sometimes in additional tables. It was discussed if we already know what content and what aspects of that content are needed for BML purposes (missions, orders and C2), or how to consume an operations order in an unambiguous manner. The US BML work started with the Army and tried to extend to the Air Force (with some difficulty) and Navy (to be started), and is also moving to Coalition operations. To be successful, these examples are desirable and necessary to gain an understanding of the problem, but we need to define a reproducible and understandable method and supporting tools to be successful with a general solution. We want to make business rules understandable by applications so they can be used by the applications, and these must be part of BML as well. Furthermore, representation and communication of the Commander’s intent is really the desired end state, not the process to achieve it in BML. Determining if this is sufficient must be part of more research, as well as discussions with the operational users of a BML.

The meeting obtained consensus that in the near term to retain focus on unambiguous communications between live and constructive forces, and robotic systems; unambiguous C2/Sim communications resulting in executable orders. This discussion is directly connected to the next discussion issue. Do we want to define BML now, or do we already anticipate a standard that is designed to be improved gradually in several phases?

The meeting also reached consensus that a phased approach is necessary. What these phases will be and what the sub-objectives of these phases will be must be discussed during forthcoming meetings. A flexible implementation similar to the Overarching Integrated Product Team (OIPT) model as used by the US Army Simulation to C2 Interoperability (SIMCI) group may be a way to go under the umbrella of SISO.

The following discussion points were captured by the report writers and are not part of the main four discussion points; however, they are too important to be ignored.

- The BML-MSDL integration is critical to ensure close coordination between BML and MSDL. MSDL, as a standard, needs to be divorced from OneSAF.
- We have to accept that we cannot do everything at once so need to prioritize – suggest 5W construct is a good starting point but recognize that we will need 6W+H some time in the future particularly in commanding robotic forces. Should also realize that the ‘Why’ (Commander’s Intent) remains for the present “free text”.
- GeoBML is an important piece of the jigsaw puzzle as ultimately is Natural Language scripting.
- BML and by extension C2IEDM are used in a variety of activities that deal with different parts of the battle space at different resolutions.
- BML should be able to support the 6W+H in order to make it simulation compatible (no matter what kind of simulation).
- C2IEDM in its current version (and future – Joint Consultation, Command and Control Information Data Model (JC3IEDM)) should remain the interchange Data Model, because it is designed with that purpose in mind (more than sixteen nations have participated in the effort). It is not complete but it is encompassing enough to be representative.
- Participants of the C-BML SG should be aware that BML is a composition of ontologies (model of different views of the battle space) not a language in the computer science point of view. It provides the necessary vocabulary for C2, but the associations and combinations (methods and

functions) that lend meaning to a vocabulary have to be implemented as client interfaces.

- A standard mapping process from any data model to BML should be designed and approved by the SG members. Similarly a standard approach to mapping to the C2IEDM model should be presented. By standardizing these approaches, we mean that the data engineering process should be followed explicitly.
- Service Oriented Architectures (SOA) should be the preferred implementation method for interoperable systems. Web services are one of the implementations of SOA; however, they are not *the* SOA. This gives BML the potential to be integrated within the Global Information Grid (GIG) without having to make changes to its architecture. It also keeps BML within the framework of new technologies such as the semantic web project currently under way (a standard will be approved soon by the World Wide Web Consortium (W3C). Once again it is important that participants understand that SOA does not mean web services, SOAP and XML.
- The natural language ideas while important for ease of use should not affect the data models (BML or C2IEDM) but rather add another level of abstraction. Therefore special care should be taken that: (a) BML and/or C2IEDM support the language, view and resolution level provided by the commander using natural language; (b) the data derived from the natural language level should be consistent with not only the true intent expressed by the commander but also the structure of BML for C2 orders.
- Natural language processors should go through a meticulous internal Verification, Validation and assessment (VV&A) before they can be accepted as a safe way to issue C2 orders. In addition GeoBML and other uses of the BML are part of the data engineering process.
- Should there be other nations involved? The XBML effort will be presented in Australia at SIMTECT. Also, there may be interest from Korea and Singapore.
- We need more participation from Air Force and Navy (and Marine Corps), also more Joint support. We hope to get input from NATO ET-016 and others.

Overall, the meeting was a success. It could have been improved by having the presentations a little bit earlier to prepare discussions and group them more efficiently, but the objectives of the workshop were reached.

All information has been made available to the C-BML SG via the SISO reflector and via a VMASC supported website:
http://www.vmasc.odu.edu/coalitionbml/cobml_overview.html

Appendix B – Consideration of an Ontology for C-BML

B-1 Introduction

The term "ontology" has become a buzzword in recent years working its way from computer science to the M&S community through numerous papers and presentations. The C-BML SG believes that methods and technology related to work being done under the name of Ontology studies will be invaluable in defining some of the more difficult concepts required for conceptual interoperability. As it currently exists, the work (both within the M&S community as well as the world of computer science) is in its infancy and needs further understanding and refinement. In spite of this, there are some questions in the area of semantic interoperability (and higher levels of interoperability) that seemingly can be addressed by a method that makes available the ontological definition of data elements, relationships to other elements, and rules for their use.

B-2 Definitions

The area of ontology studies, and related methods and technologies, introduce a number of terms that we believe should be defined:

- Ontology – this is easily defined as "a specification of a domain's conceptualization"[14]. There are a number of other definitions available, but most of them seem to be reducible to this simple statement. In essence, it means that all of the conceptualizations of a domain (in our case, the data model that represents that domain) should be explicitly and unambiguously defined.
- Conceptual Interoperability – this is defined as interoperability between systems where some level of conceptual understanding is reached concerning the data that is interchanged. Note that this is beyond the level of technical interoperability. Conceptual understanding is seen as a means to attain system-to-system composability. At its higher levels, conceptual interoperability will require the definition of data based on a domain's formal ontology in order to be semantically explicit[15].
- Central Referential Data Model (CRDM) – we believe that one of the mechanisms (or techniques) that can be employed to enable semantic (and higher) inter-operability is the concept of the CRDM. This is accomplished by having a mediation technique for data that maps the data from a system-specific view to a view that is common to the central referential data model. If the data elements of the CRDM are defined via a formal ontology, then semantic understanding is possible.

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[14] Tom Gruber, "A Translation Approach to Portable Ontology Specifications"; available online at http://ksl-web.stanford.edu/KSL_Abstracts/KSL-92-71.html; 1993

[15] Charles Turnitsa, "Extending the Levels of Conceptual Interoperability Model," *Proceedings of the Summer Computer Simulation Conference*, Philadelphia, 2005

B-3 Development

The earliest work in this area, of particular interest to the C-BML study group, has been conducted at VMASC. Researchers there are investigating the C2IEDM and its ability to stand as the basis for a formal ontology in the domain of C2. Reports on this work have been presented at 2005 Euro SIW and 2005 Fall SIW. Further work is needed and is part of a planned research agenda.

This early work has been concerned with the definition of what a formal ontology is and what it means for the world of M&S interoperability. This is being applied first to the C2IEDM, but the next stage of the work will be to apply this method to other data models to determine if any other data models can serve as a central referential data model. Possible outcomes are: (1) there is currently a model that fulfills all our needs, but we consider this unlikely; (2) it may be too complex of a demand to have a data model that can serve as a central referential data model, but this, too, is considered unlikely; and (3) there is currently a data model that can satisfy the majority of the criteria based on the working definition, but that will need some support before it can be called complete. This third case is considered the most likely outcome.

B-4 Goals

There are several important goals in the area of ontology related work. These include:

- Determination of sufficiency, or rather, to determine how much granularity of definition within a formal ontology or how many layers of refinement of resolution must exist within a formal ontology.
- Identification of a C2 domain ontology. This includes finalizing the definition of what a formal ontology (for M&S interoperability) must include, as well as a method for evaluating the soundness of a data model to satisfy that definition (based on sufficiency as defined above).
- Defining the needs and applicability of techniques to enable ontological descriptions to be used within systems supporting interoperability.

B-5 Applicability

The goals of the ontology work are to produce methods and techniques that will assist in the application of semantic understanding to the data being interchanged. It is not completely clear what these methods and techniques will be, as of yet, which is why further study is required in this area.

B-6 Guidance from the Community

There have already been several very good, although early, exchanges of dialog occurring within the C-BML community regarding ontology-based work. The salient points of those conversations are captured here:

1. To envision the applicability of ontology (and related techniques and methods) there have been several requests for use cases describing how

the artifacts produced out of ontological studies could be of benefit to the overall project. We leave this to the PDG to appoint and direct.

2. As the standards derived from the C-BML PDG will not be related to a predetermined list of applications, the C2 ontology will need to be based on an Upper Ontology that axiomatizes basic concepts such as Abstract and Physical Objects, Class and Subclass, Relations, Attributes, and so on. Such work is needed to be able to automatically check Ontology integrity. Another standards body, the Institute of Electrical and Electronics Engineers (IEEE), is defining a generic Standard Upper Ontology (SUO) to lay the basis for any future Domain ontology (IEEE, 2005). Guidance for such a formal ontology can be gained from the work being produced by the Suggested Upper Merged Ontology (SUMO) group (Anderson & Peterson, 2001).
3. The existence of an addressable upper level ontology, made available via formal ontology techniques and derived artifacts, will allow for domain experts to have a common, authoritative language for addressing issues related to data interchange and interoperability. It will also provide the basis to verify through formal methods that C-BML is an unambiguous language for C2, maintaining internal consistency and integrity.
4. To enable verification of the Ontology by formal tools (commonly called *reasoners*), it will be necessary to express the Ontology formally using a logic programming language. At the time of this writing, two candidates are gaining popularity: the Knowledge Interchange Format (KIF), which is a candidate for an American National Standards Institute (ANSI) standard, and the Web Ontology Language (OWL Full), sponsored by the W3C. These languages are roughly equivalent in terms of their expressiveness.

These advisements are the result of discussions occurring among Curtis Blais, Rob Whitman, Chuck Turnitsa, and Eugene Joseph (to whom the C-BML ontology community already owes a debt of thanks for the guidance he has given). The C-BML members are eager to continue research into this emerging area of study as C-BML moves from SG to PDG status.

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Appendix D – Glossary of Acronyms and Abbreviations

ABACUS	Advanced Battlefield Computer Simulations
ABCS	Army Battle Command System
ACSIS	Army C4ISR Simulation and Initialization System
ACTD	Advanced Concept Technology Demonstration
AMSO	Army Modeling and Simulation Office
ANSI	American National Standards Institute
APLET	Aide a la Planification d'Engagement Tactique
ARL/UT	Applied Research Laboratory, University of Texas
ASAS	All-Source Analysis System
ASJETS	Australian Joint Essential Tasks
ATCCIS	Army Tactical Command Control and Information System
ATEC	Army Test and Evaluation Command
AUTL	Army Universal Task List
AUV	Autonomous Unmanned Vehicle
AVCL	Autonomous Vehicle Control Language
BC	Battle Command
BCSE	Battle Command, Simulation, and Experimentation
BCTP	Battle Command Training Program
BFT	Blue Force Tracking
BISA	Battlefield Information System Applications
BML	Battle Management Language
BTRA	Battlefield Terrain Reasoning and Awareness
C2	Command and Control
C2IEDM	Command and Control Information Exchange Data Model
C2IS	Command and Control Information Systems
C3	Command, Control, and Communications
C3T	Command, Control, and Communications Tactical
C4I	Command, Control, Communications, Computers, and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance

CAST	Command and Staff Training
C-BML	Coalition Battle Management Language
CC	Conference Committee
CCRTS	Command and Control Research and Technology Symposium
CCSIL	Command and Control Simulation Interface Language
CCTT	Close Combat Tactical Trainer
CMN	Common Maneuver Networks
COA	Course of Action
COAA	Course of Action Analysis
COP	Common Operational Picture
CORBA	Common Object Request Broker Agent
COSMOS	Coalition Secure Management and Operations System
CRDM	Central Referential Data Model
CROM	C4I/M&S Reference Object Model
CTSF	Central Technical Support Facility
DAML	DARPA Agent Markup Language
DARPA	Defense Advanced Research Projects Agency
DIF	Data Interchange Format
DMSO	Defense Modeling and Simulation Office
DMWG	Data Modeling Working Group
DoD	Department of Defense
ERDC	Engineer Research and Development Center
ET	Exploratory Team
EwID	Enterprise-wide Identifier
EXCOM	Executive Committee
FBCB2	Force XXI Battle Command Brigade and Below
FCS	Future Combat Systems
FGAN-FKIE	German Research Institute for Communications, Information Processing, and Ergonomics
FM	Field Manual
FOM	Federation Object Model
FRAGO	Fragmentary Order

GeoBML	Geospatial Battle Management Language
GH	Generic Hub
GIG	Global Information Grid
GML	Geospatial Markup Language
GMU	George Mason University
HLA	High Level Architecture
HTTP	Hypertext Transfer Protocol
ICF	Interoperability Coherence Framework
IEDM	Information Exchange Data Model
IEEE	Institute of Electrical and Electronics Engineers
IEM	Information Exchange Mechanism
IER	Information Exchange Requirements
IEW	Intelligence and Electronic Warfare
I/ITSEC	Interservice/Industry Training, Simulation, and Education Conference
IMASE	Intelligence Modeling and Simulation for Evaluation
ISGT	IMASE Scenario Generation Tool
IT	Information Technology
JC3IEDM	Joint Consultation Command and Control Information Exchange Data Model
JCDM	Joint Common Data Model
JCS	Joint Chiefs of Staff
JMS	Java Message System
JNTC	Joint National Training Center
JRD3S	Joint Rapid Distributed Database Development System
KIF	Knowledge Interchange Format
LVC	Live-Virtual-Constructive
M&S	Modeling and Simulation
MATREX	Modeling Architecture for Technology and Research Experimentation
M-COP	Mobility Common Operational Picture
MDMP	Military Decision-Making Process
MIP	Multilateral Interoperability Programme

MMF	Mission-to-Means Framework
MOD	Ministry of Defence
MOVES	Modeling, Virtual Environments, and Simulation
MR	Mission Rehearsal
MRCI	Modular Reconfigurable C4I Interface
MSDB	Multi-Source Data Base
MSDE	Military Scenario Development Environment
MSDL	Military Scenario Definition Language
MSG	Modeling and Simulation Group
NATO	North Atlantic Treaty Organization
NCW	Network-Centric Warfare
NPS	Naval Postgraduate School
NUWC	Naval Undersea Warfare Center
ODU	Old Dominion University
OIPT	Overarching Integrated Product Team
OMG	Object Management Group
OOS	OneSAF Objective System
OPLAN	Operational Plan
OPORD	Operational Order
OTB	OneSAF Test Bed
OTH	Over-the-Horizon
OWL	Web Ontology Language
P&S	Publish and Subscribe
PDG	Product Development Group
PEO	Program Executive Office
R&D	Research and Development
RHQ AFNORTH	Regional Headquarters Allied Forces North Europe
RPR	Real-time Platform Reference
SAC	Standards Activity Committee
SAF	Semi-Automated Forces
SCS	Society for Computer Simulation

SEDRIS	Synthetic Environment Data Representation and Interchange Specification
SEDTEP	Synthetic Environment Development Tools Evaluation Project
SG	Study Group
SICF	Système d'Information et de Commandement des Forces
SIMCI	Simulation to C2 Interoperability
SINCE	Simulation to C2 Information System Connectivity Experiments
SINCEx1a	SINCE Experiment 1a
SISO	Simulation Interoperability Standards Organization
SIW	Simulation Interoperability Workshop
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SOM	Simulation Object Model
SOPES	Shared Operational Picture Exchange Services
SoS	System of Systems
SQL	Structured Query Language
STOW	Synthetic Theater of War
SU	Situational Understanding
SUO	Standard Upper Ontology
SUMO	Suggested Upper Merged Ontology
SUT	System Under Test
SweAF	Swedish Armed Forces
TACSIM-OT	Tactical Simulation - Operational Test
TA	Technical Activity
TAP	Technical Activity Program
TOR	Terms of Reference
UDOP	User-Defined Operational Picture
UK	United Kingdom
UML	Unified Modeling Language
UOB DAT	Unit Order of Battle Data Access Tool
US	United States

USMTF	US Message Text Format
USW	Undersea Warfare
VIRT	Valued Information at the Right Time
VMASC	Virginia Modeling, Analysis, and Simulation Center
VV&A	Verification, Validation, and Accreditation
WARNO	Warning Order
WebC2P	Web C2 Portal
WSDL	Web Services Description Language
W3C	World Wide Web Consortium
W6H	Who, What, When, Where, Why, Which and How (Project SINCE BML construct)
XBML	Extensible Battle Management Language
XML	Extensible Markup Language
XMSF	Extensible Modeling and Simulation Framework
XSBC	XML Schema-based Binary Compression
5W	Who, What, When, Where, Why (Original US Army BML construct)

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