Technical Evaluation Report

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ABSTRACT

The NATO Modelling and Simulation Group (NMSG) branch of the NATO Science and Technology Organization (STO) held the NMSG-119 Workshop on Command and Control to Simulation (C2-SIM) Interoperability in Orlando Florida on December 5th 2012. Approximately 60 persons attended the workshop with representation from 4 continents covering 20 NATO, NATO Partnership for Peace (PfP) and other nations. Participation was balanced with about 25% active military officers, 25% government, 10% from academia and 40% representing industry. The workshop included two main parts; the first part was comprised of theoretical and technical briefings on command and control (C2) to simulation interoperability while the second part included a series of C2-SIM interoperability demonstrations involving real C2 and simulation systems.

The C2-SIM interoperability standards that were considered during the workshop included the Coalition Battle Management Language (C-BML) and the Military Scenario Definition Language (MSDL). Following the demonstrations a short discussion period took place to highlight some of the workshop findings and seek feedback from the workshop participants.

1.0 INTRODUCTION

Simulation systems now are an integral part of many military enterprise activities such as training, planning and experimentation. To support these activities, it is necessary that C2 and simulation systems share information. To facilitate the seamless exchange of military information such as orders, reports and requests one can define a C2-Simulation (C2-SIM) federation of systems. The end goal is not only to share information, but rather to specify a common, standardized approach that also supports the acquisition and evolution of the systems comprising the C2-SIM federation and to do so in a repeatable, cost-effective manner. Therefore standardization is critical to ensuring that the key benefits of C2-SIM interoperability can be achieved and repeated.

The concept for a Battle Management Language (BML) as a means to automate the execution of military operations by simulated forces in the conduct of military enterprise activities was introduced over a decade ago[1]. The original work defined a model as the basis for standardized machine to machine language for use by intelligent software agents to execute military functions and also to interface with the human controller. This work also defined the five key factors: *Who*, *What*, *When*, *Where* and *Why* (*aka* the five Ws) that allow simulated units to: analyze their situation; project the end state of an operation; determine a course of action; and execute a course of action.

[1] H.Argo, E.Brennan, M.Collins, K.Gipson, C.Lindstrom, S.MacKinnon,"Level 1 Model for Battle Management Language (BML-1)", 1999

Several years later[2], it was suggested that requirements for C2-SIM interoperability were similar to requirements for interfacing C2 systems with *robotic forces* or *autonomous systems* (AS). Therefore, BML was considered as an interoperability enabler for C2-AS interoperability as well. Another important conclusion of this work was that the use of a formal language to minimize the use of *free-text* elements that cannot be processed easily by simulations also could support C2-C2 interoperability not only across services, but also in a multinational/coalition environment. However it was recognized at this time that the formal BML, as an automated system output, should support formats adapted to intended audiences that include both intelligent software agents and humans.

In 2004, the Simulation Interoperability Standards Organization (SISO) initiated a study group to explore the need for a Coalition Battle Management Language (C-BML) that culminated, two years later, in a final report recommending that a Product Development Group (PDG) be formed for the creation of a C-BML standard[3]. A major finding of this report was that the initial C-BML standard should use the Multilateral Interoperability Programme (MIP) C2 Information Exchange Data Model (C2IEDM), predecessor to the Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM), as the underlying data model for the C-BML vocabulary. Finally, another important recommendation from the study group was that the C-BML product be developed using a phased approach. The C-BML PDG developed an approach based on three phases, each phase having the following focus areas: Phase 1 – vocabulary; Phase 2 – grammar; and Phase 3 – ontology.

The phase 1 C-BML product is soon to be released as an official SISO standard and the phase 2 C-BML drafting activity already has commenced. In parallel, the Military Scenario Definition Language (MSDL) standard also has been developed by SISO, for the initialization of simulation systems. The combined used of these complementary standards has been the focus of recent experimentation activities within the NATO Modelling and Simulation Group NMSG-085 Technical Activity: *Standardization for C2-Simulation Interoperation*, kicked-off in 2010. The main objectives of this activity are to:

- Clarify and complement existing C-BML and MSDL requirements;
- Propose a set of C-BML orders and reports to serve as a common reference set;
- Assess and leverage available C-BML implementations;
- Address C2 and simulation initialization requirements; and
- Demonstrate the operational relevance and benefits of the approaches considered.

1.1 Workshop Overview

The MSG branch of the NATO Science and Technology Organization (STO) held the NMSG-119 Workshop on Command and Control to Simulation (C2-SIM) Interoperation in Orlando Florida on December 5th 2012, (see Figure 1). Approximately 60 persons attended the workshop with representation from 4 continents covering 20 NATO, NATO Partnership for Peace (PfP) and other nations. Participation was balanced with about 25% active military officers, 25% government, 10% from academia and 40% representing industry. The workshop included two main parts, with the first part being comprised of theoretical and technical briefings while the second part included a series of C2-simulation demonstrations involving real C2 and simulation systems.

[2] S.Carey, M.Kleiner, M.Hieb, R.Brown,"Standardizing Battle Management Language – Facilitating Coalition Interoperability", 2002
[3] "Coalition Battle Management Study Group Final Report", SISO-REF-016-20060V1.0, July 2006

The C2-SIM interoperability standards that were considered during the workshop included the C-BML and MSDL. Following the demonstrations a short discussion period took place to highlight some of the workshop findings and seek feedback from the workshop participants.

1.2 Workshop Objectives

The objectives of the workshop were:

- to inform the community concerning the recent lessons learned in the area of C2-SIM interoperability;
- to hold a C2-SIM interoperability tutorial concerning the use of C-BML and MSDL;
- to present and complement current national expectations and requirements for the C-BML and MSDL standards;
- to provide a status to the community concerning the development of the C-BML and MSDL standards; and
- to present a set of use-cases that illustrate the applicability of C-BML and MSDL for the conduct of military enterprise activities (e.g. force readiness, support to operations, concept development & experimentation).

The workshop was held during the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) in order to facilitate participation from the government and industry sectors that are interested in learning more about the benefits of C2-SIM interoperability technologies applied to areas such as the preparation and execution of training exercises, for decision support applications as well as joint and multinational experimentation.

1.2.1 Time, Date and Meeting Place

The workshop has been scheduled from 08:30-12:00 pm on December 5th 2012, which coincides with day three of the four-day I/ITSEC[4] 2012 event that took place in Orlando Florida at the Orange County Convention Center from December 3rd through December 6th.

The workshop took place in a meeting room during the I/ITSEC event in order to facilitate participation from government, industry and the research community that are present at I/ITSEC, that has a focus on military training and education.

1.2.2 Workshop Programme

The workshop programme is shown in Table 1. Following an introductory presentation by the chairing nation (France), the first part of the workshop was comprised of three technical presentations. The second part of the workshop involved domain-specific demonstrations with actual C2 systems followed by a short discussion period.

[4] Interservice/Industry Training, Simulation and Education Conference

Table 1 - MSG-119 C2-Simulation Interoperability Workshop Programme

C2-Simulation Interoperability Workshop Programme		
08:30-08:45	Welcome and Introductory Presentation	Mr. Lionel Khimeche, DGA (FRA)
Session 1: Standards & Infrastructure		
08:45-09:10	Coalition Battle Management Language (C-BML)	Dr.Saikou Diallo, VMASC (USA)
09:10-09:35	Military Scenario Definition Language (MSDL)	Dr. Rob Wittman, MITRE – (USA)
09:35-10:00	C2-Sim Communication Infrastructures	Dr. Mark Pullen, GMU C4I Center (USA)
Session 2: Military Applications & Demonstrations		
10:15-10:45	Land Operations Demonstration	Maj. Desmond Liberg, NLD Armed Forces (NLD)
10:45-11:15	BML-Enabled Air Operations	Dr. Fawzi Hassaine, DRDC (CAN) Dr. Kevin Heffner, PEGASUS R&T (CAN)
11:15-11:45	OneSAF Land/Air Reconnaissance Demonstration	Dr. Rob Wittman, MITRE – (USA)
11:45-12:00	Discussion & Wrap-up	Dr. Kevin Heffner, PEGASUS R&T (CAN)

2.0 SUMMARY OF PRESENTATIONS

2.1 Opening remarks and Introductory Presentation: Mr. Lionel Khimeche, French MoD

The workshop was opened by Mr. Lionel Khimeche, the Workshop Chairman, who provided an introductory presentation that described the overall context for the workshop. In particular, the military requirements for C2-SIM interoperation were identified for two key areas: 1) Command Post Force Readiness; and 2) Support to Operations.

The benefits of C2-SIM interoperability were clearly articulated around three themes: 1) enhanced realism and overall effectiveness; 2) decreased cost and operator workload; and 3) reduced preparation time and response time. Enhanced realism is made possible since additional details easily can be communicated to the simulation thus increasing the realism of the synthetic environment, which can add value and possibly increase the effectiveness of the military enterprise activity. Furthermore, the simulation communicates directly with the C2IS and therefore allows C2IS operators to interact with their systems during training events using the same interface as in actual operations, as per the “Train-As-You-Fight” paradigm. This presentation concluded with a transition to the first part of the programme agenda dealing with C2-SIM interoperability standards. Although C2-SIM interoperability can lead to the benefits described above, the *standardization* of C2-SIM interoperability is paramount to ensuring that these benefits indeed are achieved in the form of reduced acquisition, maintenance and integration costs.

2.2 C-BML Overview: Dr. Saikou Diallo, Virginia Modeling Analysis and Simulation Center

Following Mr. Khimeche, Dr. Saikou Diallo presented an overview of C-BML, currently being developed by SISO. C-BML is an international, open standard for the unambiguous expression of plans, orders, requests and reports for the exchange of military information among C2IS, simulation systems and autonomous or robotic systems. C-BML is intended to support multinational and coalition operations but also should support lower-echelon tactical operations. Although primarily intended for C2-SIM information exchanges, C-BML also has been considered for C2-to-C2 information exchanges. This however traditionally has been the object of other interoperability standards such as those promulgated by the MIP, such as the JC3IEDM.

The presentation also highlighted the strong interest from the NATO nations, as witnessed by the presence of 13 nations participating in the NATO MSG-085 Technical Activity working in the area of standardization for C2-SIM interoperation. From a technical perspective, this briefing indicated the consequences of not standardizing C2-SIM interoperability would be the propagation of proprietary interfaces that would result in significant development, maintenance and integration costs. Another point that was made was that beyond these costs, the C-BML standard is an enabler to multinational and coalition training and experimentation activities. This advantage is due, in part to the fact that the SISO C-BML product nomination included the C-BML Study Group recommendations to use the MIP JC3IEDM as the underlying data model for C-BML.

The C-BML Product Development Group (PDG) has outlined a 3 phase development approach for C-BML with subsequent focus on: 1) vocabulary derived from the JC3IEDM; 2) a formal grammar and 3) an ontology. The C-BML standard includes specifications for: 1) a data model; 2) an information exchange content and structure specification; 3) an information exchange mechanism specification; and 4) guidelines. C-BML is intended to be a formal language that specifies expressions comprised of constituents of the type Who, What, Where, When, and Why also referred to as the 5Ws. These constituent 5Ws are composed of C-BML vocabulary elements and are combined to form expressions as dictated by the set of production rules, also referred to as the grammar. The first phase of the SISO C-BML development activity has come to an end with the Phase 1 C-BML standard nearing the end of the balloting process. The Phase 2 C-BML development already has commenced and is working on developing the grammar, a message framework and an initial C-BML ontology product.

2.3 MSDL Overview: Dr. Rob Wittman, MITRE Corporation

Dr. Rob Wittman then presented a briefing on MSDL that also addressed the need for convergence between the MSDL and C-BML standards. MSDL initially was developed as a simulation standard for the definition of military scenarios to be used for the purposes of initializing simulation systems. MSDL version 1.0 was balloted and approved by SISO in October of 2008. In recent years, preliminary experimentation has been performed using MSDL for the initialization of C2 systems. MSDL version 2.0, currently under development by SISO, now is considering enlarging the scope of MSDL to include C2IS initialization. MSDL is intended for scenario initialization while C-BML is intended for scenario execution. However, the C-BML tasks and reports must reference entities that are defined using MSDL. Currently, MSDL uses both the MIP JC3IEDM and US DoD Joint Symbology standard MIL-STD 2525B to define data elements whereas C-BML uses only the MIP JC3IEDM. MSDL and C-BML currently are specified using XML Schema Description (XSD) documents. In the future, other representations could be considered, such as the High Level Architecture (HLA) Federation Object Model (FOM) or JavaScript Object Notation (JSON).

2.4 C2-SIM Communication Infrastructures: Dr. Mark Pullen, GMU C4I Center

The first part of the workshop concluded with a presentation by Dr. Mark Pullen entitled C2-Simulation Communications Infrastructure. The presentation illustrated how C-BML standard could be implemented using WSDL or RESTful Web Services (WS) for exchanging messages among C2IS and simulation systems.

This approach has been used by the NATO MSG-048 Technical Activity during their final experimentation event in 2009 using the open-source Scripted BML (SBML) server. SBML allowed for connecting five simulations with 7 C2IS during a coalition training experiment. The messaging infrastructure includes a central server that connects to a JC3IEDM database and thus also supports C2-C2 interoperability.

Server functionality includes WS transaction-based information POST or PUSH while also supporting topic-based subscriptions as per Publish and Subscribe technologies. Additional server functionalities include logging and replaying of messages in the original sequence using the original time intervals. The briefing also mentioned other C-BML messaging capabilities that have been developed such as: the Coalition Battle Management Services (CBMS) developed for the US Joint and Coalition Warfighting (JCW); the "FKIE Server" – based on SBML and developed by the Fraunhofer Institute; and the WISE-version of the SBML server developed by Saab. The SBML server software is publicly available and includes monitoring software and a graphical user interface that can be used to edit C-BML or MSDL documents and also can serve as a "surrogate" C2 system.

3.0 SUMMARY OF DEMONSTRATIONS

3.1 Land Operations Demonstration

The first demonstration presented a Battalion Command Post training use-case that highlighted several advantages to employing C2-SIM interoperability technologies, including virtually eliminating the need for swivel-chair simulation operators in the Response Cells (RC) of the Lower Controller (LOCON) and the Higher Controller (HICON). Based on the Bogaland terrain and scenario from the Viking 2011 exercise, the demonstration illustrated the execution of a three-phase operation to take control of an airport that is under enemy control. The demonstration was based on a realistic and seamless exchange of military messages between superior and subordinate commanders, some of which were simulated commanders. These exchanges included: orders (with order acknowledgement); artillery call-for-fire requests and subsequent messages; Unmanned Air Vehicle (UAV) tasking; intelligence reports; and logistic and situation reports. The simulations executed the orders in a realistic and timely fashion, but when an intentional error was introduced into an order created by a C2IS operator commanding a simulated force, the simulated commander replied to his (human) superior with an acknowledgement reply message indicating that he was unable to execute the order. The simulation behaviour included the reason for the (negative) acknowledgement reply as part of the acknowledgement reply message. Within the machine message, the "reason" is represented as a free-text field and is required so that it can be displayed to the human C2IS operator, as per the training requirements and consistent with current operational systems. Once the (human) error was corrected, the simulation then was able to successfully execute the order and the operation was able to proceed. This also is consistent with the initial projected use of BML (as described in section 1.0) by both machines (e.g. C2/simulation systems) and by human operators (e.g. Battalion C2IS operator).

This demonstration also highlighted the additional C2-SIM interoperability benefit of increased realism, as demonstrated through the incorporation of logistics information in the scenario. Initial equipment and supply quantities first were specified as part of the scenario initialization process using operationally representative means, such as the NATO Stock Number (NSN) reference. Then, during scenario execution, information such as quantities was updated through the use of appropriate operational messages, such as: Logistic Report (LOGREP); and Situation Report on human resources (SITEFF).The demonstration gave an overview of a Battalion Command Post training capability that encompassed significant levels of detail covering several domains (e.g. Intelligence, Logistics, and Fires Support) and was based on requirements derived directly from real operational messages.

One of the conclusions of this work was that in order to maximize the usability and achieve greater benefits of the C2-SIM interoperability technologies, C2-SIM interoperability standards products such as XML schemata should be derived from operational requirements. Another conclusion of this work was that although these XML schemata are necessary to perform the development and integration tasks, it is important that they be part of a larger reproducible process that includes traceability back to the operational and technical requirements and therefore can support the need for evolution over time. It also was concluded that the C2-SIM interoperability process include a federation agreement.

3.2 Air Operations Demonstration

The second demonstration presented C2-SIM interoperability capabilities that have been developed to support the air component scenario initialization and scenario execution in the context of multinational training and Joint Fires Support experimentation. The capability that was developed was based on a detailed analysis of operational information flows including air tasking and airspace control messages. One of the underlying assumptions for this work was that the operational C2IS could not be modified and therefore operational messages, such as the Air Tasking Order (ATO) and the Airspace Control Order (ACO) were taken as inputs in US Message Text Format (USMTF) and NATO APP-11(C) formats. Thus the ATO and ACO were translated into C2-SIM interoperability formats (i.e. C-BML) using translators that subsequently could share air tasking and airspace control information with the rest of the C2-SIM federation.

The execution of air missions by the simulation included preplanned, on-call and immediate missions5 involving simulated air assets that could be controlled by a combination of live, virtual and constructive actors. Preplanned missions such as Air Interdiction (AI) generally can be simulated in a highly automated manner whereas the execution of support missions such as Close Air Support (CAS) requires coordination between the aircraft and the supported unit (i.e. the Forward Air Controller (FAC)), who may be human or simulated. Finally, immediate missions cannot be planned for in advance and result in dynamic tasking that refers to missions that arise to meet evolving battlespace requirements. For example, an aircraft performing an ISR task may report the position of a High-Value Target (HVT) and subsequently may be re-tasked to engage the target.

The first benefit that was illustrated was that of using the initial existing ATO and ACO to initialize the simulated blue forces air component. Feeding the ATO and ACO as defined by the air C2IS directly to the C2-SIM federation allowed for rapidly specifying the initial aircraft types, locations, missions and relating them to pre-defined Airspace Control Means (ACM) as specified in the ACO without the need for a simulation operator or other human-in-the-loop. This represents a significant cost-reduction compared to the manual process currently employed and also allows for accelerating significantly the scenario development and refinement process. The use of technologies such as C-BML was shown to support all three types of missions. In particular, C-BML has been used effectively for the execution of preplanned missions by simulated assets while maintaining the flexibility to include human actors, as required, to meet training and/or experimentation goals, depending on the target audience. This reinforces the point that C2-SIM interoperability technologies support the Live Virtual Constructive (LVC) training paradigm.

[5] See for example, http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf

The demonstration emphasized the use of actual operational messages as issued by real C2IS. This facilitated the integration of air C2IS as part of the C2-SIM federation. However, current air operations messages include, in some instances, free-text fields for important coordination purposes. Similar to the previous demonstration, the need to transport free-text must be addressed by C2-SIM interoperability standardization efforts. A short video was shown that demonstrated how an ATO and ACO generated by an unmodified NATO-wide Integrated Command and Control (ICC) air C2IS was sent to a web service that translated the ATO and ACO into C-BML and then communicated it to the Joint Semi-Automated Forces (JSAF) simulation. JSAF then was able to represent the various ACMs in a 2D map view. When subsequent aircraft were initiated and flew their missions as per the ATO, the aircraft behaviour respected the ACM, including ACO updates thus demonstrating the ability of the simulations to adapt to changes in the operational environment as reflected in the tactical operational messages.

3.3 Air-Land Operations Demonstration

The Air-Land Operations demonstration presented a C2-SIM technical infrastructure that could support mission planning, training and mission rehearsal activities. The infrastructure provides functionality for the exchange of MSDL and C-BML messages using primarily the Scripted BML (SBML) server developed by George Mason University and includes capabilities for communicating orders and tasks from an operational Land Forces C2IS for execution by simulations and also for disseminating reports, generated primarily by simulations, as inputs for shared situation awareness (SA). The vignette that was shown was based on the Bogaland scenario and focused on a land forces reconnaissance mission that involved an armoured unit response of land forces with close air support (CAS) from fast-jet and UAV assets and the use of rotary-wing aircraft for troop insertion.

The Swedish 9LAND Battle Management System (BMS) was used to construct orders that then were translated into C-BML and communicated to the simulations using the MSDL/C-BML infrastructure. The WISE Connectivity framework, developed by Saab, was used to connect to the SBML server to the 9LAND BMS. The Environment Systems Research Institute (ESRI) provided a tool capable of representing tracks based on C-BML reports and thus was used to provide SA.

OneSAF was used as the primary simulation, but the simulation federation was extended to include JSAF that simulated the air component. Similar to the previous demonstration (see 0), a C-BML air tasking capability co-developed by the UK Defence Science and Technology Laboratory (DSTL) and Defence Research and Development Canada (DRDC) was utilized. The JSAF simulation running remotely in the UK, was able to receive air tasking initially generated using the NATO ICC Air C2IS. The tasking was communicated to JSAF over internet using a web service to connect to the SBML MSDL/C-BML messaging infrastructure.

The demonstration highlighted the usefulness of a dedicated C2-SIM federation toolset for military scenario definition and execution. Initial task organizations were defined and shared across systems to form a common military scenario in MSDL format and a mission editor allowed for the generation of C-BML orders for subsequent publication and execution by simulations. The demonstration also confirmed the increasing maturity and technical readiness of C2-SIM interoperability technologies as attested to by the relative ease in defining and sharing military scenarios over a wide range of C2IS and simulation systems. Furthermore, little or no modifications were required to existing C2IS so that they could be integrated as part of the C2-SIM federation. This last point is particularly significant as the next steps in adapting C2-SIM interoperability technologies likely will include technology insertion plans that will be simplified greatly if existing C2IS easily can be integrated into future C2-SIM federations.

4.0 DISCUSSION

The main concern of C2-SIM interoperability is to enable the automation of military information flows across C2 and simulation systems to support military enterprise activities, while satisfying information assurance requirements such as: availability, integrity, security, storage etc. The goal of standardizing C2-SIM interoperability is to facilitate the specification, development, deployment and evolution of system of systems comprising a C2-SIM federation such that stakeholders may reap the full benefits of C2-SIM interoperability in the form of reduced cost, reduce preparation times, increased realism and increased effectiveness. As demonstrated during this workshop, it is becoming increasingly obvious that C2-SIM interoperability technologies will help to achieve these benefits. The focus now has shifted to determining how the standardization of C2-SIM interoperability can be established in a timely manner while supporting requirements for a variety of military activities representing a diversified set of stakeholders.

The following sections highlight some of the issues that will need to be addressed as C2-SIM interoperability moves forward down the road of standardization and as C2-SIM interoperability technologies move from laboratories to operational environments.

4.1 Sustaining and Disruptive Application of C2-SIM Interoperability Technologies

The use of C2-SIM interoperability technologies can be associated with both evolutionary and revolutionary changes in how armed forces operate and interoperate. For example, one vision of using C-BML to its full potential clearly represents a disruptive change6 with respect to the role of the commander in the decision-making process; future subordinate commanders may play in increased role in the planning cycle of their superiors. However, this is consistent with NATO's Comprehensive Operational Planning Directive7 (COPD) that calls for a more iterative approach to planning and thus provides the opportunity for increased input from subordinate commanders as part of the planning process. Also, in the future, unmanned systems likely will receive and execute increasingly complex tasks directly from C2 systems with less and less human intervention and/or monitoring. However, in the short-term, there are many practical issues (e.g. technical, legal, social, organizational) that first must be addressed and therefore the final decision-making responsibility will remain squarely with the human commander and human operator, at least in the near future.

Therefore, before considering requirements, standardization or technology insertion plans, it is useful first to consider whether the C2-SIM interoperability technology is intended to support a sustaining capability or as a support a new concept of operation that could be considered as a disruptive change? Is the C2-SIM interoperability technology being introduced to improve the operational procedures and capabilities that currently are in place or to define new procedures and new capabilities?

The answer to the question undoubtedly is "all of the above". Thus it is important to track requirements in a systematic manner such that successful short-term (sustaining) and long-term (disruptive) use of C2-SIM interoperability technologies can be assured, and more importantly coordinated. The prioritization of requirements depends on stakeholder involvement likely will vary from nation to nation but, clearly, it is a requirements management task to differentiate and track the various needs associated with short-term and long-term requirements.

[6] http://oieg-1.4.pergu.eu/OIEG-Specification-v1.4.1.pdf

[7] http://info.publicintelligence.net/NATO-COPD.pdf

4.2 The Benefits of a Staged Approach to C2-SIM Interoperability Capabilities Development

In the current challenging financial times, there are advantages to adopting a pragmatic approach where the proven benefits from short-term investments in C2-SIM interoperability may be incentives or even pre-conditions to investing in longer-term capability development of a more disruptive nature. Also, presenting short-term (sustaining) and long-term (disruptive) use of C2-SIM interoperability technologies side-by-side may contribute to a misleading message to active military commanders and other stakeholders that the introduction of such technologies will necessarily require new operational procedures and even a paradigm shift from centralized to de-centralized command. This is not the case.

In the short-term, the role of the commander should not change as C2-SIM technologies support the military enterprise activities as they are defined today, or with little change. C2-SIM interoperability technologies first must bring benefits to the way that military forces operate today, namely with the commander-in-the-loop, operating as usual. Furthermore, to ease the introduction of new C2-SIM interoperability technologies, effort should be made to minimize the impact on existing C2IS. After successfully introducing C2-SIM interoperability benefits into existing military enterprise activities, it will be easier to suggest modifications to existing operational systems and possibly propose changes to operating procedures.

Ultimately, decisions regarding capabilities development are made by the sponsors and are out of the technical scope of this workshop. But beyond capability development and acquisition strategies, it is imperative that a clear distinction be made between C2-SIM interoperability technologies that are ready for operational employment to support today's operational requirements and those that may support future concepts of operation such as self-synchronization and highly automated decision support systems.

4.3 C2-SIM Interoperability Requirements

Designing and implementing C2-SIM interoperability solutions has been done for quite some time. However, this has proven expensive and generally it takes a lot of time to develop these solutions. Also, often they still require human interactors, thus further increasing cost. One of the main focuses of current C2-SIM interoperability community is to specify and develop C2-SIM federations in a cost-effective manner, and this requires standardization. Government representatives from the defence acquisition community need a standard that they can specify as part of Request For Proposal (RFP) processes that guarantee current and future interoperability of C2-SIM federations of systems. For this reason, standardized languages for C2-SIM interoperability, such as MSDL and C-BML, are an integral part of the C2-SIM interoperability landscape.

This includes the ability to define a C2-SIM federation in much the same way that an HLA federation can be defined today. This could be accomplished using the SISO Distributed Simulation Engineering and Execution Process (DSEEP) that defines a seven-step iterative process that includes involvement from the end-user/sponsor, the federation environment manager and the development/integration team. The process starts with the definition of the federation objectives and includes federation analysis and design, development, integration and testing, execution and post-execution analysis and evaluation of results. It is within the context of such a process, that requirements for C2-SIM interoperability should be defined. But before considering C2-SIM interoperability requirements, consistent with a systems engineering approach, it is important to define the "System Boundaries".

4.3.1 C2-SIM Federation Users and System Boundaries

The C2-SIM federation can be considered as the "system" and consistent with the DSEEP approach, the following "actors" interact with the system: the federation end-user; federation developer; and the federation manager. Depending on the military activity, the C2-SIM federation may require more or less interactions with human actors during scenario execution. For command post training, the actors include the "target audience" which are humans that interact directly with the C2-SIM federation. On the other hand, in the case of a Decision-Support System (DSS), the C2-SIM federation may require a simpler human-machine interface since the federation may be (partially) embedded or otherwise transparent to the DSS user.

An important distinction also should be made when considering federation developers. These actors must implement two sets of requirements originating from both the C2-SIM interoperability standards and also requirements that are specific to a particular C2-SIM federation. Therefore, when defining C2-SIM interoperability standards it is important to distinguish between C2-SIM Federation requirements and C2-SIM Interoperability Standard requirements.

Ultimately, the standard will be used to define aspects of the interfaces and behaviours of systems comprising the C2-SIM federation. In fact, all of the requirements in the standard should be traceable to C2-SIM federation end-user and operational requirements or quality factors. But the opposite does not hold; many C2-SIM federation requirements should not be included as part of the standard as they may be specific to the federation.

One of the challenges in developing and maintaining C2-SIM interoperability standards is to define a set of sufficient and necessary requirements for the standard(s) that allow federation developers enough freedom to implement federation requirements while imposing enough constraints to reap the benefits of C2-SIM interoperability standardization.

4.3.2 Sustaining Engineering Requirements

Sustaining Engineering8 refers to technical activities that reduce the total cost or improve the readiness of existing systems. In order to support subsequent prioritization, it is necessary to establish a set of C2-SIM interoperability requirements associated sustaining engineering activities for military activities that can be distinguished from those requirements addressing future capabilities. For example, although automation increasingly is being introduced as part of military information systems and other equipment (e.g. aircraft), current military operations rely heavily on the use of free-text fields as a part of operational messages. This is consistent with the fact that humans generally still are the intended recipients of operational messages, even if more and more information is being processed by machine-based information systems and made available to the human in a form that facilitates the access, interpretation, storage and other manipulation of information.

Therefore, as an example, if today's C2-SIM interoperability solutions are to support today's military enterprise activities, then the ability to communicate free-text as part of current operational procedures must not be diminished. Furthermore, if a human interactor is part of the target audience, all efforts should be made to reproduce the same operational environment that the warfighter will encounter during operations – as per the train-as-you-fight paradigm. Clearly, it is difficult to develop machine parsers that can effectively interpret unstructured free-text fields that were intended for human consumption. However, free-text fields can be passed through machine languages in much the same way that images or annotations are displayed. In the future, perhaps Natural Language Processing (NLP) will provide additional options for parsing free-text and then including them as part of digitized machine-to-machine information flows (see section 4.4).

[8] http://www.aviation.dla.mil/ExternalWeb/UserWeb/AviationEngineering/Engineering/Sustainment/whatissustainingengineering.asp

The Sustaining Engineering requirements should focus on making today's military business processes more efficient, and if possible more effective. For example, when considering CP training, significant savings can be associated with reducing or eliminating swivel-chair simulator operators without sacrificing operational relevance or realism.

4.3.3 Future Simulation Requirements

Arguably, the area where simulation is most mature is that of training, where is used to provide a realistic synthetic environment that provides appropriate and realistic cues for the human training audience and properly stimulates the operational systems. With the advent of C2-SIM interoperability technologies, the use of simulation systems as part of operational systems of systems likely will increase over time. However, currently, military simulations often are limited by the behaviours of models for which their current use was not anticipated. For example, military synthetic environments are composed of Computer Generated Forces (CGF) that may include automated or semi-automated forces (SAF). If they are to be integrated as part of automated capabilities, simulation models will need to evolve in order to support increasingly automated mission execution and reporting. Also, the complexity of the models may need to evolve in order to provide the required level of fidelity.

With respect to mission planning, simulations do not provide the outcome of a military scenario; they provide a possible outcome that can help commanders to consider aspects that otherwise may not have identified. Over time, if they are to be relied on as part of DSS, simulation capabilities will need to improve and provide increasingly realistic outputs, but care should be taken not to expect simulations to provide 100% accurate predictions of military engagements. Even as model behaviours are extended and improved, it is important to note that simulation systems provide an answer to a specific question and not the answer to all questions. For this answer to be useful and usable by the human end-user and decision-maker, additional complementary information will required as part of simulation results such as: Measures of Performance (MOP); Measures of Effectiveness (MOE); simulation limitations; scenario assumptions etc. Simulation is one form of war-gaming that in the past has occurred in a sandbox using sticks, stones and other simple objects. Tomorrow's wargaming will rely increasingly on simulations, but the ultimate usefulness of simulation as a wargaming tool will depend, to a large extent, on the ability of the commander to successfully integrate the simulation results as part of the military decision making process while taking into account all of the simulation caveats. Therefore, in addition to providing more complex and realistic model behaviours, there is an onus on simulation manufacturers to ensure that simulation results can be provided in a form that is consistent with the end-users military enterprise activities and related processes.

4.3.4 Future Capabilities Development

Structured data for military scenario initialization (i.e. MSDL) and formal languages for military information exchanges during scenario execution (i.e. C-BML) support the automation of business processes and associated activities, including military enterprise activities considered during this workshop.

The development of future capabilities also will contribute to C2-SIM interoperability requirements. Concepts such as self-synchronization and Integrated Dynamic Command and Control[9] (IDC2) will require a level of information sharing that will include non-hierarchal and highly automated information flows. As described in section 4.1, C2-SIM interoperability technologies may play an important role in defining the new operational procedures associated with such future operational capabilities.

[9] http://www.dodccrp.org/events/13th_iccrts_2008/presentations/111.pdf

Although the focus of the workshop was on C2-SIM interoperability, simulation systems are similar in many ways to autonomous systems (AS) or robotic systems. For this reason, it is no coincidence that the original Battle Language Management concepts included both C2-SIM and C2-AS interoperability components and that the demonstrations that took place during the workshop all included tasking of autonomous systems. Autonomous systems, by definition are capable of decision-making, thus allowing them to act autonomously. Therefore, BML-type languages must provide the information required as inputs to AS decision-making in a form that is consistent with machine-to-machine communication and machine processing. The formalism of the BML family of languages, such as the Command and Control Lexical Grammar[10] (C2LG), is consistent with both C2-SIM and C2-AS interoperability requirements and has been used successfully for the tasking of simulation systems and robotic systems11. Similar work in this area has suggested the use of a BML-enabled approach to diminish other interoperability gaps to decrease UAV operator workloads and thereby contribute to increasing the effectiveness of autonomous system based capabilities12.

Both autonomous systems and some simulation systems rely on intelligent software agents that perform specific functions on behalf of the system and a formal language is required to effectively communicate with these agents. Part of the intelligence of software agents resides in the knowledge base to which they have access, such as an ontology that captures common, shared definitions and meaning and other domain-specific information. Future C2-SIM interoperability capabilities therefore will rely on knowledge bases and ontologies to successfully interpret and act upon the information contained, for example, in C-BML messages. Therefore, in the future, the development of a C-BML ontology will become increasingly important as C2-SIM interoperability capabilities are implemented using agent-based approaches, as already is the case in several recent research initiatives taking place concurrently in several NATO nations.

4.4 Natural Language Processing

Although the digitization of information has been an integral part of modern military force transformations, much of military communications still rely on voice communication and chat applications such as mIRC. These means of communication involve natural language constructs such as free-text. The guiding assumption within the C2-SIM interoperability community is that parsing free-text is to be avoided since such parsers are difficult to develop and the results of such parsing cannot always be guaranteed. However, Natural Language Processing (NLP) technologies, in time, may provide a bridge for some of the free-text interoperability gaps. There are obvious benefits to adding a NLP capability to a C2-SIM federation that then could translate free-text originating from operational voice and chat communications systems into a digitized form that then could be communicated across a C2-SIM federation.

Within NATO13 there is an activity to develop NLP-based capabilities that focus on identifying information constituents (Who, What, Where, When and How) similar to those comprising C-BML from sources such as chat and on-line news. The current focus of this work is on NLP applications often involving human users, such as: document retrieval; question-answering; information extraction; text; mining; automatic metadata generation; cross-language retrieval and document summarization.

[10] http//:www.bastianhaarmann.de/download/c2lg_specification.pdf

[11] T. Remmersman, U. Schade, "Secruing Area with Robots under BML Control", Springer Link, Communications in Computer and Information Science, Vol 318, 2012, pp 526-529

[12] K.Heffner, F. Hassaine, "Towards Intelligent Operator Interfaces in Support of Autonomous UVS Operations",16th International Command and Control Research and Technology Symposium, June 2011

[13] Private communication with Dr Dave Allen, NATO Communications and Information Agency

With the development of a C-BML ontology, including national/domain community extensions, NLP techniques could be applied to the parsing of some military messages, such as the so-called "9-liner" messages, and thus increase the level of automation of certain military information flows in support of training, experimentation and other military activities. In some instances, parsing specific elements of otherwise structured messages also could prove useful, such as the free-text Amplification information associated with air tasks in an ATO. Perhaps in the medium-term, automated NLP parsing followed by human verification could be a possible solution that could reduce human resource requirements of an otherwise largely manual process.

4.5 Considerations for C2-SIM Interoperability Standardization

The first demonstration concluded with a recommendation concerning the need for a C2-SIM interoperability standard development process that is: well-understood, reproducible and that allows for traceability to requirements and also tracking of changes over time. This section addresses some characteristics for such a process.

As often is the case with technical standards, three types of stakeholders are involved as part of the C2-SIM interoperability standardization process: end-users, representatives from the research community and industry. End-users provide operational requirements, the research community ensures that an appropriate theoretical foundation for the standard is laid, and industry offers best practices, prototypes, reference implementations and technological solutions to be considered during the standard development process.

Interoperability standards are products and therefore establishing a clear validated set of requirements is important. But, in fact, requirements are subject to change, and interoperability solutions must be developed in such a way that they can evolve to meet changing operational needs14. The rigour of a systems engineering approach to interoperability standards development is required to ensure that stakeholder expectations are well-captured, well-documented and tracked, but this must be combined with an agile development methodology such that new requirements can be injected into a well-defined, well-documented, well-understood process that rapidly can produce the C2-SIM interoperability standards, including specifications, guidelines, XML schemas and other derived products.

C2IS and simulation systems developed today often must conform to several interoperability standards. The combined use of these standards when developing new interoperability standards has several advantages15. The SISO C-BML Phase 1 and MSDL Version 1.0 standards currently utilize elements from the MIP JC3IEDM C2 interoperability standard, which was cited several times during the workshop as an interoperability enabler. Therefore C2-SIM interoperability standard development processes should be able to react not only to changing requirements but also to future evolutions of the MIP JC3IEDM while maintaining a balance such that C2-SIM interoperability standards are not too tightly coupled or dependent on other standards.

5.0 CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

The first part of the workshop was comprised of technical briefings and presentations that provided an overview of the state of the art in C2-SIM interoperability in terms of the currently available standards and the first

[14] http://ftp.rta.nato.int/public/PubFullText/RTO/MP/RTO-MP-IST-101///MP-IST-101-08.doc

[15] K. Gupton, C. Blais, K. Heffner, "Management of C2 data standards with modular OWL ontologies", International Journal of Intelligent Defence Support Systems (IJIDSS), Vol. 4, No. 3, 2011.

implementations of these standards as MSDL and C-BML messaging infrastructures. These presentations highlighted the SISO MSDL and C-BML Product Development Group activities, the status of the standards and the relationship between these activities and the MIP JC3IEDM C2 interoperability solution.

The second part of the workshop provided concrete demonstrations of C2-SIM interoperability technologies in support of military enterprise activities that covered the land, air and joint air-land domains and included multinational components. The capabilities that were demonstrated were based on the standards and messaging infrastructures presented in the first part of the workshop. The demonstrations highlighted the increased maturity of C-BML, MSDL and combined C-BML/MSDL and clearly illustrated several key benefits such as: 1) several-fold decrease in the time and resources required to prepare military scenarios for multinational training events and experimentation events; 2) vast reduction in required resources (i.e. number of swivel-chair operators) during scenario execution; and 3) increased realism in the operational training environment and experimentation environments.

C2-SIM interoperability technologies can enable both sustaining and disruptive changes. Yet, it is important to distinguish between the two, and to keep in mind that the former should not impact current operational procedures while the latter necessarily involves introducing major differences in the way in which military forces operate and interoperate. It may be worth considering the advantages of first achieving sustaining engineering benefits before trying to convince stakeholders to engage in disruptive technology change initiatives. This also can be viewed as short-term and long-term use of C2-SIM interoperability technologies. It is imperative that short-term enhancements and improvements to existing operational capabilities (e.g. operational command post training) introduced via emerging C2-SIM interoperability technologies do not result in reduced functionality compared to previous capabilities or require excessive investment for integrating legacy systems as part of C2-SIM federations. As an example: If a CP training federation requires that a C2IS display free-text information (as per the operational system) as part of a (negative) acknowledgement message, then the standards should support and even facilitate this functionality. Moreover, if possible, legacy C2IS should not require modification in order to benefit from C2-SIM interoperability technologies.

It now is possible for C2IS to communicate orders and requests to simulations but simulation models do not always have behaviours to execute tasks in a sufficiently automated and/or realistic manner. Therefore, in the future more complex simulation behaviours will be required to support some use-cases, particularly in the case of task execution involving coordination among units. Similarly, legacy C2IS employ gateways and adapters to interoperate with a C2-SIM federation but there are benefits for future C2IS to be designed with native, built-in standardized C2-SIM interfaces that should greatly simplify integration and testing activities.

Longer-term use-cases of C2-SIM interoperability technologies likely will involve more highly automated information flows in operational contexts for which procedures and capabilities generally are yet to be fully defined, tested or validated and therefore require additional research. Several of these important research activities referenced in this report already are underway and have contributed to shaping future C2-SIM interoperability requirements. However, care should be taken when communicating with stakeholders so that it is clear whether a sustaining or disruptive change is being proposed or considered and also when managing the associated stakeholder requirements and expectations.

C2-SIM interoperability technologies have evolved greatly in recent years but significant work remains. Concerning the standards, it already is recognized by the C2-SIM interoperability community and discussed during the workshop, that it is necessary to align and/or merge the existing standards for military scenario initialization (MSDL) and scenario execution (C-BML) in order to facilitate and optimize their combined use. Also highlighted during the workshop was the importance of ensuring that operational requirements and operationally realistic information flows be utilized as the basis for the development of standards and derived products such as XML schemas. Finally, with increasing use of C2-SIM interoperability standards by the community a process and methodology are required in order to guarantee the evolution of the standards over time and to maintain traceability of stakeholder requirements while ensuring a quick response time to new requirements.

5.2 Recommendations

This workshop has provided convincing demonstrations concerning the benefits of utilizing a standardized C2-SIM interoperability approach in support of military enterprise activities. Other NATO MSG technical activities such as previous workshops (i.e. MSG-079) and current technical group activities such as MSG-085, continue to provide guidance and valuable feedback that can be used to ensure that C2-SIM interoperability technologies such as MSDL and C-BML transition from advanced research projects to operationally relevant interoperability solutions with technical readiness and maturity levels consistent with operational employment by stakeholders.

The remaining questions and issues now deal with what is required to finalize the current standardization efforts and identifying what is required to accelerate the availability of these technologies to the community. Toward this goal, the following recommendations are provided:

- Distinguish between short-term (sustaining) and long-term (disruptive) capabilities when considering requirements for C2-SIM interoperability standards and also when communicating with stakeholders and others concerning the potential benefits and use of these standards and related technologies.
- Establish a comprehensive set of requirements to serve as the primary inputs for C2-SIM interoperability standards development; these requirements should be derived from operational needs and grounded in actual military operational procedures.
- Put into place an agile, requirements-based C2-SIM interoperability standards development process that defines a well-understood, well-documented methodology for producing specifications and derived standards products. The process should be sufficiently automated such that changing or additional requirements easily can be integrated and transformed into a revised set of products while maintaining traceability between the products and the requirements. This process could be based on the Enterprise Architecture approach described in Lang, Gerz, Meyer and Sim[14] that leverages the NATO Architectural Framework[16] (NAF).
- Define a C2-SIM DSEEP Overlay that covers all phases of C2-SIM federation development and relates these activities to the C2-SIM interoperability standards.
- Concerning the C2-SIM interoperability standards (C-BML, MSDL):
  - Beyond operational and derived requirements, C-BML and MSDL standards products' quality factors such as *understandibility*, *usability* and *maintainability* should be improved to facilitate communication and subsequent adoption by the community.
  - C-BML/MSDL should be represented as a combined, conceptual model (e.g. using the Unified Modeling Language (UML)) that can be used to represent the C2-SIM interoperability domain entities and relationships that are the object of standardization and to communicate them in various forms that are understandable by all stakeholders. This will facilitate subsequent analysis and changes to the standards while providing the foundation for a C2-SIM Ontology that will be required for medium- and long-term C2-SIM interoperability research activities.
  - MSDL and C-BML should be merged into one standard covering both scenario initialization and scenario execution, consistent with a DSEEP C2-SIM federation approach.

[16] NATO Architecture Framework Version 3, 2007

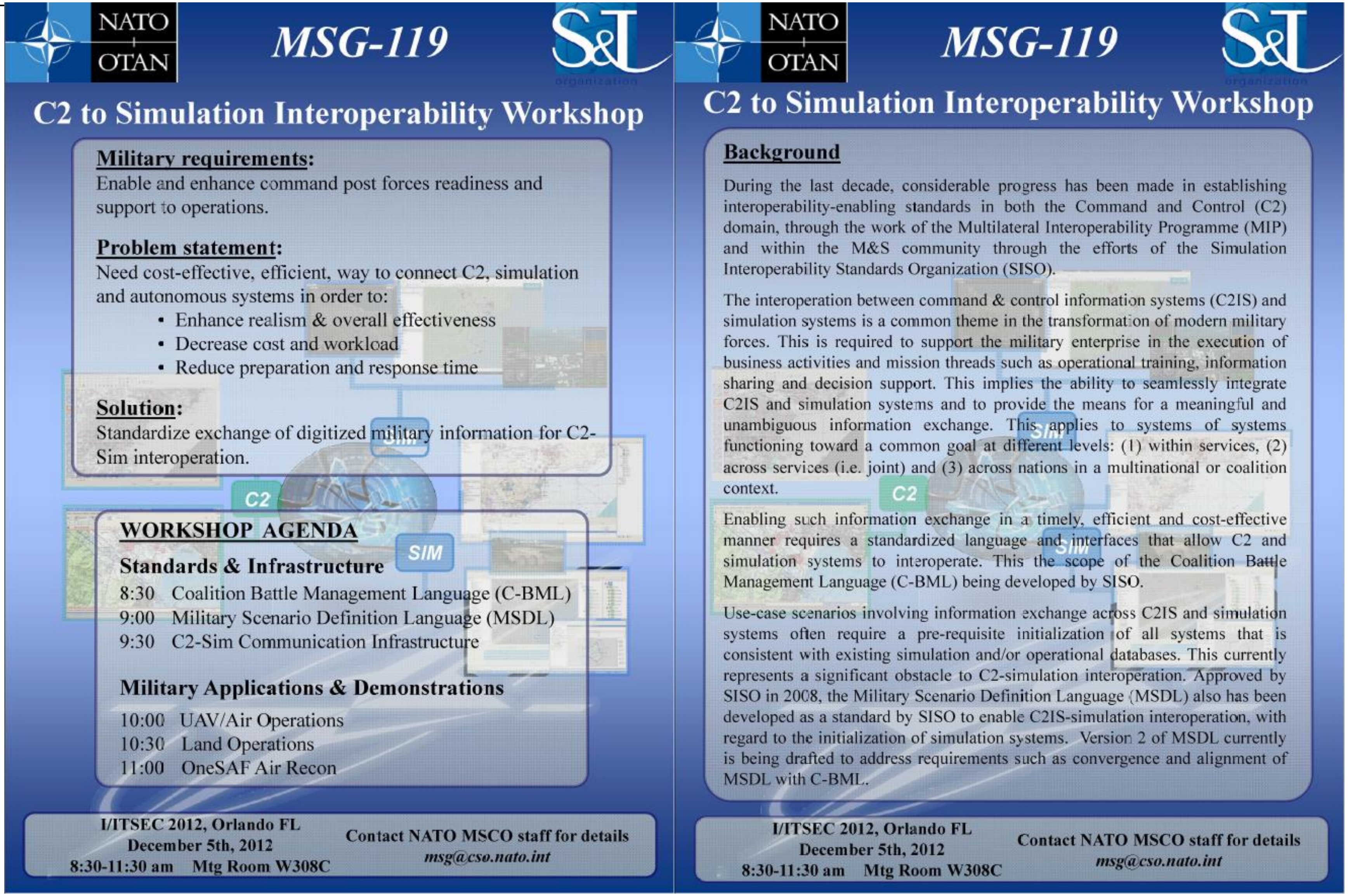

Figure 1-MSG-119 C2-Simulation Interoperability Workshop Flyer