NATO Modelling & Simulation Group (NMSG) Workshop MSG-138

"Command and Control (C2) to Simulation Interoperability"

Technical Evaluation Report

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1.0 INTRODUCTION

Command and Control (C2) and Simulation (C2SIM) interoperation is required to support military activities such as Force Readiness; Support to Operations; and Capabilities Development. However, different manufacture's and/or nations use proprietary interfaces that cost time and money to develop and maintain. In most cases there is also a need for human intervention in scenario definition, initialization, and execution. The interfacing between the systems is often conducted by manual translation of information into instructions that the simulation can process.

Therefore standards for defining exchange of military information between C2SIM systems can lead to significant cost-reduction, greatly facility systems integration and provide better quality (e.g. robustness, determinism, less human and manual intervention) in the C2SIM systems support to military activities. The benefits of standardizing C2SIM interoperation include: reduced scenario preparation time; increased realism; overall effectiveness; capability to easier connect systems that not originally was supposed to interconnect; and a reduced cost and workload in all phases.

The key enabling technologies for C2SIM interoperation that have been identified are Coalition Battle Management Language (C-BML) (SISO-STD-011-2014) and Military Scenario Definition Language (MSDL) (SISOSTD-007-2008) developed by Simulation Interoperability Standards Organisation (SISO). The C-BML is an unambiguous language that is intended to be used to command and control forces and systems in the conduct of military enterprise activities. The intention with MSDL is to permit scenario development by enabling creation of a separable simulation independent military scenario format, focusing on real-world military scenario aspects.

The NATO Modelling and Simulation Group (MSG) of the NATO Coordination and Support Office (CSO) have supported several technical activities related to C2SIM interoperation in recent years such as MSG ET-016, MSG-048 and MSG-085.

- The MSG ET-016 (2004-2005) investigated and demonstrated the feasibility of a C2IEDM based Battle Management Language (BML) using web services between national C2IS and Modelling and Simulation (M&S) type systems. The ET-016 provided insights of limitations in current standards that were addressed in the follow on activity MSG-048;
- The MSG-048 (RTO-TR-MSG-048) (2006-2010) Technical Activity explored the technical feasibility of a BML as a component of an open framework to link C2 and M&S or robotic systems in a NATO context;

- MSG-085 (2011– 2014) was a follow up activity to MSG-048 technical activity and investigated the combined use of C-BML and MSDL mainly under experimentation activities in order to increase the maturity level and reach a higher Technical Readiness Level (TRL) of related technologies to a level consistent with operational employment.

1.1 Workshop Overview

The aim of the workshop is to share national experiences, MSG-085 results and lessons learned and to provide recommendations for the common use of C-BML and MSDL standards in the perspective of operational employment. In addition, the workshop may help to understand best practices, barriers to further exploration and to identify ways these might be overcome.

1.2 Workshop Objectives

The objectives of the workshop were:

- To inform the community concerning the lessons learned in the area of C2-Simulation interoperability;
- 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;
- To show highlights if the various experimentation and demonstration events;
- To receive feedback from the operational community concerning their expectations for C2-simulation interoperability technologies for the conduct of military enterprise activities (e.g. force readiness, support to operations, concept development & experimentation).

1.3 Workshop Program

The workshop was held 22nd October 2014, Founders Hall, George mason University, Arlington VA between 0830 and 1700, the following table present the briefings held together with the associated section number.

Table T-1: Workshop Program.

Section	Topic
2.1	Overview of C-BML and MSDL standards development (USA/Dr. Robert Wittman)
2.2	History of C2SIM NATO Activities (FRA/Lionel Khimeche)
2.3	Leavenworth Demonstration Operational Impact (NOR/LtCol Hyndoy)
2.4	Leavenworth Demonstration Technical Impact (DEU/Thomas Remmersmann)
2.5	Foundational Infrastructure (USA/DR. Mark Pullen)
2.6	C-BML Maritime (NOR/Ole Mevassvik)

2.7	VBS2, C-BML FOM &MSDL (GBR/Kevin Galvin)
2.8	Mission Commands Embedded Simulation System Services (USA/Amit Kapadia/Robert Wittman)
2.9	Brainstorming and wrap-up (SWE/Dr. Per M. Gustavsson / USA/Dr. Robert Wittman)

1.4 Technical Report Outline

Introduction (Section 1) describes the background and rational for the workshop. In Section 2 a summary of the briefings are presented and eliciting the key-messages. In Section 3 the summary and recommendations are presented.

2.0 SUMMARY OF BRIEFINGS

The briefings outline is first presented followed by the key-messages from the briefing and then each major section of the briefing is summarized, as an addition some references to publications are added for further reading.

2.1 Overview of C-BML and MSDL standards development (USA/Dr. Robert Wittman)

The overview of MSDL (SISO-STD-007-2009) and of C-BML (SISO-STD-011-2014) started with an overall problem scope followed by the respective standards and core components. Then a presentation of the newly effort of standardization of C2SIM was presented regarding long-term objective and initial focus together with the officers[1]. The next part of the presentation presented thoughts on how to converge MSDL and C-BML into C2SIM and suggestions of methods, process and tools.

2.1.1 Key Messages

In short the key message is that both MSDL and C-BML are based on formalized formatted instance documents (e.g. XML[2], XSD[3]). At initialization time MSDL already has a mechanism to reference C-BML documents. C-BML can access MSDL elements (both at initialization and execution) through Universal Unique Identifiers (UUID[4]). There is a need to resolve the redundancy in C-BML regarding full and light schemas. MSDL and C-BML need to leverage common enumeration standards such as JC3IEDM[5], NATO APP-6 (A-C)[6] and US MIL-STD-2525 (B-C)[7]. C-BML has a complex structure that needs to be more feasible to use. MSDL and C-BML is specified as XML schemas – other technologies worth considering such as FOM[8]/ Modular FOM [9]components, JSON[10].

[1] Co-Chairs Mark Pullen (USA-GMU) and Kevin Galvin (GBR-Thales), Vice-Chairs Saikou Diallo (USA-VMASC), Rob Wittman (USA-MITRE) and Kevin Gupton (USA-ARL-UT)

[2] XML – Extensible Markup Language http://www.w3.org/XML/

[3] XSD - XML Schema Definition Language http://www.w3.org/TR/xmlschema11-1/

[4] UUID – Universal Unique Identifier http://www.ietf.org/rfc/rfc4122.txt

[5] JC3IEDM – Joint Consultation Command & Control Information Exchange Data Model - https://mipsite.lsec.dnd.ca/

[6] APP-6 – Allied Procedural Publication 6C (implements STANAG 2019) http://armawiki.zumorc.de/files/NATO/APP-6(C).pdf

[7] MIL-STD-2525C Common War fighting Symbology http://armawiki.zumorc.de/files/US/ms2525c.pdf

[8] FOM – Federation Object Model

The MSG-085 Common Interest Group SINEX has provided insights in how the Scenario Initialization and EXecution Imitative (SINEX) have been used in MSG-085 activities and how it could be used in the future. SINEX is an engineering process to develop and maintaining a unified C2-Simulation interoperability. For C2SIM, SINEX would provide automated generation of derived standard products from a common data model (e.g. XML, OWL, HLA-FOM); and the ability to capture, validate and track stakeholder/ operation requirements and derived technical requirements. SINEX builds upon Model Driven Architecture (MDA) to create a holistic UML model. The basis for the holistic model is the Multinational Interoperability Program (MIP)[11] Interoperability Model (MIM) and entailing a variety export formats (e.g. XML, JSON, and HLA FOM). Uses Model Driven Architecture to create a holistic Unified Modeling language (UML) model. With the core concept of maintain a model, but generate schemas (i.e. products). The process defines scope and managing requirements; verifies that technical specifications have been followed; and validating that the derived products meets stakeholders' expectations. The process follows system-engineering process of requirements. Specification, model, generate derived products verify products towards requirements and finally validate usability, completeness and correctness.

2.2 History of C2SIM NATO Activities (FRA/Lionel Khimeche)

The NATO C2SIM activities conducted between 2004 and 2014 have provided insights and development of C2SIM interoperation on both technical and operational levels. In short the feasibility were showcased in MSG ET-16 (2004-2005), MSG-048 (2006-2010) was a proof of principle and MSG-085 provided a proof of concept (2011-2014). Each of the activities objectives, achievements and conclusion were presented. In the end of the presentation a proposal for future C2SIM activates were presented focusing on C2SIM operationalization.

2.2.1 Key Messages

The key message is that the previous NATO activities have moved the C2 to simulation interoperation from Feasibility (ET-016), via proof of principle (MSG-048) to proof of concept (MSG-085) and have had significantly impact on the C-BML and MSDL standardization activities.

The C2SIM interoperation needs to be made ease of use for both military and industrial stakeholders.

Therefore the suggested next step is to establish an Exploratory Team (ET) and Lecture Series (LS). The ET proposal is the operationalization C2SIM and by the three activities: 1) developing, experimentation and provide a set of tools to ease common use of the MSDL (SISO-STD-007-2008) and C-BML (SISO-STD-011-2014) standards; 2) Prepare the next generation of C2SIM by developing a C2SIM advanced grammar, business rules, production rules, unified C2SIM logical data model, define a process to generate derived products and continue to capture the national, domain specific and stakeholders requirements; and 3) Specify, develop and assess a reference communication infrastructure by defining a set of reference C2SIM services. The LS are to provide an overview of C-BML and MSDL for military commanders and Industry Leaders and provide detailed technical information of C-BML and MSDL and the C2-Simulation program for military/industry technical staff. The content in the LS are for the leadership amongst issues for example an overview of Military Enterprise Activities, presenting the Operational Relevance and Utility, and the capabilities of C-BML and MSDL illustrated by use cases. For the technical focused LS the content are exemplified by detailed technical information; update on C-BML and MSDL standardization; and introduction to C-BML Distributed Simulation Engineering and Execution Process (DSEEP) and C-BML Federated Object Module.

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[9] Modular FOM -

[10] JSON -

[11] Multinational Interoperability Program (MIP)

ET-016: The ET-016 activity objectives was to demonstrate the feasibility of a C2IEDM based interface standard using web services between national Command and Control Information System (C2IS) and Modeling and Simulation systems and to show limitations of current standards that were needed to be addressed by the following on activity MSG-048. Further the ET-016 was also to build experience to help structure the Technical Activity MSG.048.

The demonstration architecture consisted of that CAPES (a French C2IS system) developed a Course of Action (COA) that was sent to a BML Web server (i.e. a set of BML services upon an extended C2IEDM database). The JSAF and APLET simulation systems pulled COAs from the BML Web Server and executed them. The APLET also were used to define COAs. In 2005 the ET-016 showcased a joint scenario of a brigade consisting of a US and a French Battalion and the interaction between brigade and battalion by a request from the French battalion to move the brigades boundary. The brigade sends out new boundaries to both battalions and each battalion defines its COA and sends it to the shared C2IEDM Database.

From the ET-016 it was evident that the limitations of current standards did not permit easy use of simulation with C2 systems. The participating systems had internal as well as external limitations. Internal in that for example the APLET was not able to automatically execute with C2IEDM data. This since the simulation system did not have a full representation of C2IEDM objects and attributes and did not have models of US forces. JSAF could only simulate US Forces against an opposing force. The ET-016 identified the need for a Business Model for the sharing of a common understanding and C2IEDM improvements to provide automatic simulation execution.

MSG-048: The MSG-048 continued where ET-16 ended by expanding the scope to show the usefulness of the M&S-C2 interoperability and capability it can offer to coalition forces such as control of robotic forces, rapid COA analysis and Mission Rehearsals. The objectives for MSG-048 was to: 1) provide support to the development of a NATO representation of digitalized command and control information that is understood by military personnel, simulated and in future, robotic forces; 2) enable improved situation awareness and common operational picture through structured plans, reports and returns; 3) support the SISO standardization of a C-BML; and 4) Assess operational benefits to C2 and M&S communities.

The program of work consisted of 1) substantiation for a NATO C-BML by gathering military needs, technical requirements, and deciding Design, Goals, Priorities and Scope; 2) Design for a NATO C-BML Demonstration consisting of reference implementation, development of experiments and scenario roadmap, identifying national candidate systems; 3) Implementation of C-BML interfaces by development of tested capability and the alignment of data produced and consumed by the participating systems; 4) C-BML experimentation and Education by integration of systems, perform experimentation , release open source C-BML reference tested and conduct C-BML symposium.

The achievements of MSG-048 were a series of opportunities to share knowledge, experience and advertise the TA work. Technical demonstrations where conducted at I/ITSEC 2007, 2008 and 2009. During the activity more than 20 academic publications has been published at SISO, ICCRTS, and NMSG conferences. The publications have and are still cited and form a body of knowledge in the M&S to C2 interoperation domain. Operational assessment was performed in experimentation involving military Subject Matter Experts (SME) (e.g. 2009), demonstrating the efficiency of C-BML with multiple C2 and simulation systems. During the TA the end users requirements of Measure of Effectiveness and Measure of Performance where collected and incorporated in the work. In 2010 a NATO MSG symposium/workshop was conducted.

The main experiments made was to show simulated units can be commanded directly from C2 (2007 experiment with 8 systems from 5 nations), Generation of Automated situation reports from simulation and air operation (2008 experiment with 8 systems from 6 nations), and in 2009 with an experiment that used the same base architecture, systems and configurations for show how planning, mission rehearsal and training could benefit from the use of C2SIM interoperation.

The MSG-048 provided he insights that C-BML has demonstrated much promise as an enabler for interoperability between C2 systems and simulations; MSG-048 have proven technical feasibility and military relevance; and that work is still required to bring C-BML closer to operational deployment – especially the standardization of C-BML. The MSG-048 also won the NATO Scientific Achievement Award 2013.

MSG-085: The C2 – Simulation Interoperation (MSG-085) objectives was to assess the operational relevance of C-BML while contributing to the C2-Simulation standardization and assist in increasing the TRL of C-BML technology to a level consistent with operational employment by stakeholders.

The main for tasks in MSG-085 was to clarify and complement existing C-BML and MSDL requirement including C2 and simulation initialization; Propose a set of C-BML orders and reports to serve as a common reference set; 3) Assess and leverage available C-BML implementations (e.g. C2 systems, Simulation system, integration tools, adapters, middleware, servers); and 4) demonstrate the operational relevance and benefits of the technical and methodological approaches considered in the MSG-085.

The work plan consisted of three phases and later also an extension. The first phase was the establishment of the program of work. The phase two (2011-2012) focused on requirement analysis and was divided in to Operational Concept Development (OCD) for planning, OCD for Training and Technical requirements and specifications. The demonstration experimentation and evaluation schedule (20111-2014) consisted of 7 main demonstration events at ITEC and I/ITSEC and two Workshops and two symposiums were held. The final demonstration was held at Fort Leavenworth in 2014, and a dozen of publications were published at SISO SIW, ICCRTS and NMSG conferences.

The MSG-085 final demonstration demonstrated the potential for positive outcomes through operational employment based on improved technology readiness level (i.e. TRL6: Technology system/subsystem model or prototype demonstration in a relevant environment)

The MSG-085 Lessons identified and learned are that there are: 1) variability of C2SIM Interoperation Requirements because requirements vary across services, nations and also depend on themes and focus areas of specific training, mission rehearsal or experimentation events. 2) There is a need of a Combined Standard for scenario definition, initialization and execution since the MSDL/C-BML specifications are sufficient for basic operations of maneuverer warfare, but insufficient to meet the broader need of other military operations and support functions. It is also impractical to create a single massive schema since the complexity will be too large. The SISO MSDL and C-BML specifications can be made to function together but there is a need for new, harmonized versions are required for effective C2SIM interoperation; 3) Need for Management process that Formally Manage Standard Products that maintain logical data model and generate derived products so that stakeholders requirements can be collected, managed and effectively traced to the derived standard products; 4) A reference C2SIM infrastructure should be defined to facilitate C2SIM federation design that allows combining Various Versions of MSDL/C-BML to work simultaneously with various versions of C2SIM interoperation standards.

The conclusion and recommendation (also mentioned in Key message) are to 1) Operationalize MSDL and C-BML standards by engaging the industry and increase the trial use of C2SIM interoperability technologies to include more stakeholders; 2) Educate a broader community o C2SIM technology employment by develop lecture series; 3) Advance C2SIM interoperability by require a funded technical activity to develop and validate the technical approach before it is a codified standard; 4) Support next generation of c2SIM interoperability Standards Development by supporting the new SISO C2SIM standardization as a candidate for a NATO STANAG.

2.3 Leavenworth Demonstration Operational Impact (NOR/LtCol Hyndoy)

The MSG-085 final demonstration was conducted at Fort Leavenworth in 2014. The purpose of the demonstration at Leavenworth was to show how to use C2-Simulation interoperation technologies to facilitate collaborative distributed planning. The presentation focused on the operational side and the impact on military doctrine the C2SIM interoperation can provide, but also that the systems must evolve for practical use and the long-term operational impact.

2.3.1 Key Messages

With C2SIM interoperation there is a possible doctrinal impact. Distributed Command post structure is possible because of the collaboration tools and the C2SIM interoperation. The planning cycle can be modified to be more cyclic and repetitive, emphasized branch planning, provide support to decision support matrix. Further it is possible to allow for *Synthetic tactics* that provides tactical tips (e.g. analysis and simulation) and accumulate plans and orders from operational missions and training. There is also a need to consider if it is Planning or commanding that is in focus for the commanders' and staff.

The recommendations from the demonstration are that there is a need to develop a Synchronization Matrix tool. In order to fully use the potential it is needed to implement After Action Review tools. The current and future C2 systems need to define roadmaps for adoption. It is essential that operational users be involved in the development and implementation.

The demonstration goal was to show that C2-Simulation interoperability could contribute to increased collaboration among Brigade and Battalion commanders during COA development.

The demonstration used the Military Decision Making Process (MDMP) step three to five: COA Development, COA analysis (War game) and COA comparison.

The final demonstration of Fort Leavenworth was to show that c2-simulation interoperability could contribute to increased collaboration between brigade and battalion commanders, and their staffs, during COA development. The demonstration consisted of three parts to showcase joint and combined mission planning where parallel COA development is performed between brigade HQ and battalions HQs. Demo1 (Briefing): Brigade Head Quarter (HQ) Define primary COA in a draft order that is assessed by simulation and sent to subordinates that display the mission execution with simulation in their C2 systems Demo 2 (Back brief): The Battalion develops COA that are assed with simulation and sent back to the brigade that display the mission execution. Demo 3 (Synchronization): Brigade refines the Brigade order and the battalions refine their COAs and add Air support to the simulation. The battalion and brigade display mission execution. The demonstration consisted of C2 several systems (e.g. SICF (France), SIR (France), Sitaware (Denmark), 9LandBMS (USA and Sweden), TALOS (Spain), JCHAT (Spain), ICC (UK), JADOCS (UK), C2LG GUI (Germany)) and Simulation system (e.g. OneSAF (US), JSAF (UK), APLET (France), Sword (France and Denmark), VR-Forces (Netherlands and Spain), and three communication infrastructures provided by GMU/SAAB, FKIE and DGA.

The positive result was visualization of Brigade graphics; Collaborative modification of plan, initial stages of synchronization matrix was supported. The control of the simulation needed some improvement. From Demo2 the positive feedback was that the control of simulation speed was better, Battalion commanders were able to better understand the brigade plan, express their requirements to the brigade and modify plans with immediate coordination with other battalions and brigade across the coalition. Need for improvement of battalion commander ability to synchronize support for their plans. Demo3 lessons learned was that with a shared common operational picture (COP) allowed for cooperation, battalion commanders interactively exchanged information with their brigade commanders and adapted their plans in coordination with Brigade planners, using simulation gave opportunity to question why things might not happen as planned, and brigade commander visualized the battalion commanders' sectors with a focus on high priority events. From demo3 the improvement identified was to accurate portrayal of war fighting function for better analysis and the perception of enemy engagement and combat power in c2 and simulation systems.

The utilization of technology requires improvement of the C2 systems and simulation systems. C2 systems usually only handle the own ORBAT, it is necessary that both the RED and BLUE ORBAT can be developed in the own C2 in order to assess the own COA in simulations. There is a need for a synchronization matrix tool.

There is a need for an After Action Analysis capability to assess metrics and statistics but also provide tactical tips (e.g. analytic software like chess computer) and provide tacticians judgment (e.g. why did RED do so well? what is the RED doctrine? what makes the BLUE plan good?). With such capability the methods and doctrine can be further developed (e.g. what is more important to have? A perfect plan or the ability to adapt?).

Operational benefits besides the already presented are that the quality of plans are increased, Manning savings since less can do more, time saving since the planning is distributed and collaborative, the team is not only the own HQ but the subordinate and superiors.

Training can be made distributed allowing for centralized Center of Excellence. The automation and interoperation provides an increased ability to master tactical understanding and to master planning process, together with an added ease of teaching.

2.4 Leavenworth Demonstration Technical Impact (DEU/Thomas Remmersmann)

The MSG-085 final demonstration was conducted at Fort Leavenworth in 2014. The purpose of the demonstration at Leavenworth was to show how to use C2-Simulation interoperation technologies to facilitate collaborative distributed planning. The presentation by Remmersmann focused on the technical implementations and included a live demonstration at the workshop.

2.4.1 Key Messages

During the development of C-BML different dialects of BML have been developed and used in ET-016, MSG-048, MSG-085, within the SISO standardization effort (C-BML become a standard in September 2014) and in national and international projects. In these projects different connection mechanism has been used. Therefore the infrastructure constituted of two servers linked together.

The reason for the linked servers is to bridge dialects and interfacing mechanisms but also to connect servers based on two different paradigms. The FKIE Server was developed due to that the original GMU SBML server was rigid to configure since it required that each data message checked towards the schema. The FKIE server relaxed those requirements and therefore provided a quicker implantation when changes in the schemas were made and also provided a higher transaction Speed. With the Saab/GMU WISE/SBML a schema change only requires a graphical editing and the speed of transaction has increased tenfold. The Saab/GMU Wise/SBML server requires that the "data" is following the implemented standard whereas FKIE-sever stores the XML data without checking that the data is conformant to the schema specification. The former is more rigid and changes to schemas need to be configured and in the later no changes is needed.

In the demonstration the FKIE Server was used by Germany, Spain, France, and Denmark and the Saab/GMU WISE/SBML server was used by UK, US, and Sweden.

The servers used in the Leavenworth demonstration provided the necessary interoperability for the demonstration. From the lessons learned the complexity similar to MSG-048 but with some major differences. The MSG-085 network sophistication with two linked servers, three schemata and two participating sites over Internet showed that the infrastructures were able to handle the complexity, the setup process just worked in MSG-085 as opposed to mSG-048 that was chaotic. The audience impression was that the MSG-085 demonstration worked very well.

The demonstration showed proof to that the concept that C2SIM in the form of MSDL and C-BML is ready to be tested in real coalition operations. C2SIM concept has made steady progress over the last decade. Both NATO and SISO have continued progress toward the day when military coalitions will be able to "plug in" their C2 and simulation systems to interoperate.

However there is a need to further engage the operational military community as users and to expand the compatibility and scope of MSDL and C-BML.

2.5 Foundational Infrastructure (USA/DR. Mark Pullen)

In order to exchange data between C2 systems and simulation systems there is need for an infrastructure. The presentation goes through the work performed within the MSG-085 and its predecessors as well as the standardization of C-BML and MSDL. The presentation goes through Servers, GUIs to support BML documents and status and monitoring controls.

2.5.1 Key Messages

MSDL and C-BML standards have been developed by the SISO and the most effective input has come from actual use in MSG-048 and MSG-085. MSDL and C-BML have merged into SISO C2SIM group working on a common view on MSDL and C-ML together with a limited core data model with procedures to extend it rapidly to new domains such as cyber, logistics, medical etc.

C2SIM interoperability technology has enabled significant improvements in the ability to create a "plug and play" capability. With continued work in MSG-085 follow-on it the expected result is operational capability. However operational input is needed to develop effective standards.

An example of an interconnected C2SIM infrastructure consists of C2 systems, simulation systems, servers, support GUIs and status monitoring and control.

C2SIM Server

BML is an unambiguous language to: Command and Control Live and simulated forces conducting military operations, and provide for situational awareness and a shared common operational picture. BML do so by a shared semantic between C2 and M&S via a Common Tasking Language, i.e. BML. The shared semantics then incorporates Orders, Reports, and Scenarios etc. and are exchanged by a technical infrastructure. The infrastructure services used in the MSG-085 are based on Web Services. Web Services is a generalization of servers that provide webpages in the Internet. The core is stateless transactions where and the two methods of Get/Pull and Post/Push for XML documents. Generally a web service can be seen as a Remote Procedure Call (RPC) using the Simple Object Access protocol (SOAP) and could also be seen as a way to share and fetch XML documents that could use Representational State Transfer (REST) protocol. The REST method is more efficient and is therefore used more frequently in implantations. In order to provide all systems with the messages each system can poll for new data, which introduce unnecessary network traffic. Another approach is to use a Publish/Subscribe method called Streaming Text Oriented messaging Protocol (STOMP) that allows system to subscribe to topics of interest. The STOMP server copies each message to the subscribing systems. XML is a generalization of the Hypertext Markup Language (HTML) that is used for webpages. Information is expressed between tags that are defined by a schema (e.g. XML Schema (XMS)).

The server (could be more than one) is responsible for services such as startup synchronization, initialization, exchange, repository and logging. In order to connect a C2 system it needs to be able to connect to the server and exchange XML documents (e.g. orders and reports). Either the C2 system needs to be native compliant with the infrastructure, or having an interface module that follows the agreed schema, or that there is an external module that communicate on the operational interface (e.g. gateway). The C2 system also needs to be able to make use of the subscribed data (e.g. reports) by presenting them within the C2 system (e.g. providing Situation Awareness). It is also important to identify when running in simulated or operational mode. That the C2 support start and stop of simulated operations. A simulation system needs to accept orders and produce reports. To enable interoperation the simulation needs to have an native interface, interface module or external (e.g. gateway) to send status changes as reports, the ability to subscribe to orders distributed by the server and translate the orders into actions within the simulator. Also the simulation needs to be able to be started stopped from coalition control.

Primary server functions are Accept Push/Post of XML documents and store the C-BML orders and reports together with MSDL scenario files; Accept subscription by topic (e.g. all general status reports); and Publish documents to subscribers as they arrive and also respond to Get/Pull from the subscribers.

Additional server functions are Namespace support allowing tag-names from different sources to work safely together; Schema validation which is the function were the server confirms that each received document conforms to the agreed schema to use. With this function the identification of incompatibilities between systems can be found.

A server may also need to provide Logging and replay functions. Then the server needs to store every message with timestamps and that the server is capable of recreate the original sequence of order and Reports at original time intervals. Within MSG-085 the need for Bridged servers was identified due to location, use of web service interfaces and geographic locations.

Another function a server needs is Schema translation since developing organizations are reluctant to change their interface each time a new schema is developed. Meaning that C2 systems and simulation system interface different (but mostly equivalent) schemas. The function in the server is that the server parses the XML document according to the appropriate schema and produces an output conforming to different designated schemas.

For an MSDL server all MSDL inputs from participating systems need to be aggregated. Also to consider is that C2 and simulation systems do have different initialization requirements. Therefore a consolidated MSDL file is needed for consistency. A MSDL server can aggregate them automatically and a change on any system is reflected to all participating systems.

The server in used today are: Coalition battle Management Server (CBMS) developed by VMASC for JCW; FKIE Server developed by Fraunhofer for German Bundeswehr; and Saab/GMU WISE/SBML server that is re-engineered from GMU Scripted BML (SBML) Server on Saab's WISE high-performance platform (a description of the two servers used in Leavenworth demonstration is presented below)

Saab/GMU SBML Server

The WISE/SBML Server provides Namespaces, Schema validation, Filtering data for subscription topics, Logging and replay, Bridging, Over ten times the performance of original SBML, Schema translation, Multithreading, REST input, STOMP output, aggregating and serving MSDL.

The Scripted BML Server (SBML) The George Mason University C4I Center, under management of US Army PM OneSAF and in close cooperation with MITRE and QinetiQ personnel, has developed a set of services that provide infrastructure to support implementation of MSDL/C-BML in MSG-085 C2 and simulation systems. The top-level architecture of a C2-simulation coalition using these services is shown in Figure 1. These implementations are available at http://c4i.gmu.edu/OpenBML as open source software.

Experience to date in development of BML indicates that the language will continue to grow and change. This is likely to be true of both the BML itself and of the underlying database representation used to implement the scripted server capability. However, it also has become clear that some aspects of BML middleware are likely to remain the same for a considerable time: namely, the XML input structure and the need for a repository server to store a representation of BML in a well-structured relational database, accessed via the Structured Query Language (SQL). This implies an opportunity for a re-usable system component: a scripted server that can convert between a relational database and XML documents based on a set of mapping files and XML Schema files. The scripted server introduced in [19] and now named "SBMLServer," accepts *push* and *pull* transactions (BML/MSDL XML documents) and processes them according to a script (or mapping file, also written in XML). While the scripted approach may have lower performance when compared to hard-coded implementations, it has several advantages:

- New BML constructs can be implemented and tested rapidly;
- Changes to the data model that underlies the database can be implemented and tested rapidly;
- The ability to change the service rapidly reduces cost and facilitates prototyping;
- The script provides a concise definition of BML-to-data model mappings that facilitates review and interchange needed for collaboration and standardization.

Since its initial use in NATO MSG-048 [18], SBMLServer has been enhanced considerably by:

- Supporting XML namespaces: XML tag-names can be qualified by addition of a "namespace" prefix. This allows tag-names from different sources to work together safely;
- Schema validation: the server confirms that each document received conforms to the schema, which identifies a likely source of incompatibilities, at the cost of slowing the service;
- Filtering data to restrict delivery based on user-defined criteria: SBML supports dynamic definition of Publish/Subscribe Topics;
- Logging/replay: the server writes a file showing every transaction it receives, with time stamps. The server is then capable of replaying this file to recreate the original sequence of Orders and Reports at original time intervals;
- Multithreading: server throughput can be improved by processing multiple messages in parallel;
- RESTful Web service interface: initially, SBMLServer supported only the traditional Web service protocol SOAP, which is intended to support remote procedure calls. However, the need in BML is for transfer of documents, which can be achieved more efficiently via Representational State Transfer (REST) protocol, reducing overhead and facilitating C++ implementation. MSG-085 has adopted the RESTful approach;
- Aggregating MSDL inputs: see section 5 below;
- Schema translation: because SBMLServer parses the BML input documents and stores their XML elements in a database, it is possible to generate a version of the document translated to comply with a different, semantically similar schema.

FKIE BML Server

The FKIE Server was developed as an alternative to the SBMLServer with the focus on allowing a simple, fast exchange of BML while keeping flexibility to change the schema. The FKIE Server uses the same web interfaces as the SBML Server to be able to exchange the servers while using the same clients. Incoming messages are distributed over the messaging service and are stored in the file system for later requests. The XML of the messages is neither changed nor validated by the server. However, for some messages types the server does a search for predefined strings to extract order, report or request IDs. This makes the server fast and allows changing the schema from one experiment to another without also changing the server. This allowed fast development of new schemata and schema extensions.

Currently, the FKIE Server supports IBML, SISO Phase 1 and the CIG Land Ops schema [15]. Since there is no converting done by the server, all clients must agree upon one of the mentioned schemata at the start of a session or experiment. In addition to BML message exchange, the FKIE server supports MSDL for scenario initialization. Messaging services JMS and STOMP currently are supported, while SOAP and a RESTful interface are offered for Web services.

For the CIG Land Ops experiment, the SOAP and the JMS interface of the FKIE Server were used together with the CIG Land Ops schema. For the experiment, we used the following systems C2-Systems: SITAWARE (Denmark), SIR (FRANCE), TALOS (SPAIN) and C2LG GUI (Surrogate, Germany) and simulation systems: SWORD (France/Denmark), APLET (France) and VR-Forces (Netherlands/Spain).

BML GUI

A BML GUI is very useful to have to generate and inspect BML documents. Functions needed are creating of Order, Reports, request etc. and the mechanism to send it to the server. The GUI also needs the ability to accept and display Order, Report etc. from clients or servers and the ability to edit Order, Reports, request etc. The G I can be seen as a limited/surrogate C2 system used for experimentation. The two used BML GUIs (C2LG GUI by Fraunhofer FKIE and BML C2 GUI Open source by GMU) provides the capabilities to Edit a C-BML or MSDL document, merging MSDL documents, serialization of document, grammar validation, schema validation, auto-configuration to schema, request documents, push documents, subscribe to server topics, retrieving latest reports, C2 capability, displaying maps with standard overlays (e.g. 2525B symbology), geolocation entry to documents from maps.

Status Monitoring and Control

Lessons learned from MSG-048 it is impractical to coordinate multiple interoperating C2 and simulation systems with only spoken communication. Solution a coordination webpage that shows possible states of each coalition system, master controller provides coordination guidance; inputs can come from webpage interface or a web service client.

2.6 C-BML in Maritime Operations (NOR/Ole Mevassvik)

In MSG-085 the Maritime Operations Common Interest Group (CIG) performed an initial assessment of C-BML for maritime operations and showcased the FFI maritime CAX demonstrator. From the work conducted the C-BML structure proved to be sufficient to be used in the maritime domain. However there are several domain values that need to be added as well as task verbs that need to be identified and incorporated into C-BML. From the limited demonstration both C-BML and MSDL proved successful. The greatest challenge is to develop models of doctrine and tactics capable of interpreting high-level (maritime) tasks.

2.6.1 Key Messages

The MSG-085 Maritime Common Interest Group has been to initial asses C-BML for maritime operations. The focus in the work has been on Anti-Surface Warfare (ASuW) in order to develop Information Exchange Requirements (IER). Map the IERs to the C-BML full schema and prepare and conduct a limited demonstration. The participating nations in the work have been Belgium, Canada, Germany, Norway and Turkey and US.

With a scenario-based modeling approach an example set of operational messages in accordance with a naval operational scenario was developed. An initial set of prioritized IERs was developed based on message templates in APP-11(C) (i.e. NATO Message Catalogue" such as Operational general matters (OPGEN) and Operational Tasking Anti-Surface Warfare (OPTASK ASuW). Then a mapping of IERs to C-BML expressions/elements and constructed a maritime tasking grammar based on Command and Control Lexical grammar (C2LG). C-BML expressions/improvements are Naval task organization and initial location of units; control features; force dispositions and formations; and a set of ASuW tasks.

Naval tasking is characterized (according to OPGEN and OPTASK ASuW) is that maritime platforms may perform many simulations tasks and roles in several warfare areas during an operation. Maritime plans are less specific compared to an Air tasking Order (ATO) and Army Operations Order. In C-BML 100 of the 400 task values originates from the maritime domain.

Control features are geographical element associated with one or more tasks (e.g. patrol area or route). The meaning and purpose of a control feature is implied by the task. A simple approach using a general-purpose geographic position is that points, lines, areas and volumes represent geometry without any semantics. Control features, with semantic meaning, are assigned geometry (e.g. WaitingArea, Waypoint).

The purpose of the limited demonstration is to minimize exercise staff, and improve prove availability, simulate high-level maritime tasks, automatic initialization form a single data source, and interface with trainee systems (real equipment). The architecture of the system consists of an Exercise staff tool that is connected to a multi-agent system that in turn communicates with a Computer Generated Force (CGF) tool, a C2 system (NORCCIS) and a Naval strike missile path planner. The Exercise staff tool is the operator interface that controls the multi-agent system. The multi-agent system handles planning, tactics and procedures and the simulation system (i.e. CGF) directs movement, sensors and weapons.

In the work a low-level BML has been developed (in cooperation with TNO) that connects between the multi-agent system and the CGF. The information exchanged is CGF tasks, routes, areas and reports. The information is sent over HLA. The interchange between the operators to the multi-agent-system is conducted by C-BML tasks and reports using JSON over web sockets. MSDL is inserted into the operational GUI.

2.7 Using the C-BML FOM and MSDL with VBS2 (GBR/Kevin Galvin)

NATO education & Training Network (NETN) is a project initiated by NATO to establish a distributed and networked education and training capability. The NATO MSG 106 is a follow on to MSG-068 and ET.025 (2006). The Defense Science and Technology Laboratory (Dstl) awarded QinetiQ with a research contract to support aC2SIM (October 2012). One task was to investigate the feasibility to use NETN, Low-Level Coalition Battle Management (LBML), and Federated Object Model (FOM) together with VBS2.

2.7.1 Key Messages

The overall outcome form the work is that there are some issues with C-BML and the C-BML FOM. The C-BML FOM uses multiple string types. This means that the generated code ends up with different calling signatures for functions essentially only requiring string inputs. FOM is not capable of issuing complete ATO in one interaction. FOM has poor mapping to valid C-BML types.

The provided ATO did not specify which schema to which it was conforming. C-BML phase 1 only defines a set of valid types to use, not valid C-ML statements. The variability of C-BML means that the C-BML FOM may not be able to handle to support all cases.

The occlusion of the work is that LBML in its current form is inadequate for use with tasking UAV platforms and very likely all aircraft. It was agreed that in theory it should be possible to implement VBS2 plug-in solution that is capable of ingesting low-level C-BML tasking interactions and outputting C-BML status reports interactions. However, due to deficiencies of the FOM, the solution would not be architected in n extensible modular way. There is need to document design patterns for LBML FOM for air and sea operations as well.

In its current form LBML FOM provides no added value to UAV tasking than that which could be gained by having the VBS2 plugin simply reading the native C-BML ATO. The LBML FOM would also need to be significantly enhanced for it to be suitable to realistically tasking an aircraft.

2.8 Mission Commands Embedded Simulation System Services (USA/Amit Kapadia/Robert Wittman)

The presentation was held by Robert Wittman covering the work by PeoSTRI work in Migrating OneSAF to Emerging Web Application, Virtualization & Cloud Standards-Based Framework. It is identified that simulations currently fielded are growing in capability and complexity hindering ease of utilization and sustainability. The Amry's Common operation Environment (COE) together with emerging technologies provides enablers for simplification. OneSAF modernization path is to achieve agility, simplify simulation delivery and reduce live cycle costs by reusing the common core of the COE Command Post Computing Environment (CPCE), Thin clients Cloud based simulations-as-a-service, and embedded simulation for mission rehearsal, planning and COA analysis.

2.8.1 Key Messages

The adoption of emerging technology enablers is seen as a game changer to simplify and streamline OneSAF. Already several applications and related infrastructure have been migrated to web services. With community involvement collective web tools are shaped. The OneSAF product line advancements are linked to Army architectural frameworks. OneSAF continue to leverage on the larger DoD investments for common and shared solutions. Future investments are jointly aligned in order to create simulation-as-a-service. It is also anticipated that the convergence with COE CPCE enterprise architecture will lead to the delivery of an embedded operational simulation capability.

Simulations that are currently fielded are growing in capability and also in complexity, which in turn has a negative effect on ease of utilization and sustainability. The situation is that the simulation requires large, skilled workforce with dedicated hardware, software and facilities. In federated LVC simulations the participating systems bring monolithic, unique infrastructure, user interfaces etc. The link to Mission Command systems is through adapters. In order to set up exercises significant tie and manpower is needed and also to execute exercises. In the operational domain the complexity arises with the speed and scale of technological advancement, the increasing focus on new frontiers (e.g. cyber warfare, asymmetrical threats, social networks), global access and big data challenges. There is also a demand to reduce manpower. Together with the transformation towards operational adaptability to be agile, responsive and provide tailor able forces, OneSAF has a complex mission in order to reduce hinders and provide ssimplified simulation delivery.

Before 2013 OneSAF was characterized to be a product line arch framework, Requirements derived from Analysis, Research and Training Domains; Thick JAVA Client User Interface; Large footprint, 1st generation of components architecture; Gateway based interoperability (HLA/DIS), Distinct M&S and MC environments; and early MSDL/C-BML adoption. During 2013-2015 OneSAF has adopt Web services and thin client technologies; provide a centralized and distributed simulation capability; loose coupling of 2nd generation of common components; Follows the COE architecture allowing for early integration; and prototyping for virtualization and cloud computing (e.g. Simulation-as-a-service). Beyond 2015 OneSAF will reuse COE CPCE common core; thin client delivery via simulation apps/widgets; cloud based Simulation-as-a-service capability providing anytime, anyplace, on demand ability; and then providing embedded simulation for mission rehearsal, planning and COA development.

Technologies used within OneSAF are standards and COTS. In order to provide web suite development tools such as Dojo Toolkit, HTL5/CSS3/WebGL, apache tomcat, Gut/Maven repositories are used. User interface to enable early integration with COE CPCE is by Ortellium 2525B renderer, Ozone Widget framework, Common MAP API, Open Maps/World Wind. The communication to allow for efficient centralized distributed operations and infrastructure mediation are JSON/XML, Web Sockets, and Apache ServiceMIX. Web services are RESTful Services and SOAP/WSDL, to be prepared for BigData the MongoDB is used (i.e. NotOnlySQL database), COTS applications such as Mozilla Firefox and VMware is use; and for simulation interoperability DIS, MSDL and C-BML is used.

Some of the OneSAF Simulation-as-a-service enablers are: 1) User Data Gateway (UDG) consisting of RESTful web access to OneSAF data model and is the basis for remote access to web tools; 2) Web Control Tool (WCT) which is browser-based interface to control OneSAF units/entities; eliminates the need for operator nodes to have OneSAF baseline installed, Decouples OneSAF's front-end to its back-end; 3) The Web Military Scenario Definition Environment (WebMSDE) provides browser-based interface to laydown simulated units/entities and their associated task, graphics resources etc.; The tool can be used as a standalone or loosely coupled to OneSAF UDG; Collaborative multi-user scenario editing with import and export into MSDL/OBS; 4) The Web After Action Review (WebAAR) record, analyze and generate take-home package for OneSAF simulation runs; 5) The MC Adapter Web Service enables bi-directional simulation of Army MC systems; 6) The MC Adapter Visualization tool consists of Web-based GIS recording, playback and AAR of tactical data flowing through MC adapter; 7) BattleBook that provides access to OneSAF unit/entity compositions and scenario information.

The OneSAF CPCE simulation services then would provide Mission planning and rehearsal, COA analysis and war-gaming, deployed Staff Training, Running Estimates, support AAR.

2.9 Brainstorming and Wrap-up (SWE/Dr. Per M. Gustavsson / USA/Dr. Robert Wittman)

This part of workshop was to summarize and discuss topics for forthcoming development. In the presentation held the rational for the workshop was presented in order to determine if topics had not been covered. A summary of the operational challenges described directly or indirectly from the participants was presented. From the open discussion some questions and discussions were conducted.

2.9.1 Key Messages

The presentation concluded that the request for more capability of simulations to support CD&E, training, mission rehearsal, COA development, analysis etc. require that data can be exchanged in such way that it is simple to connect C2 systems with simulation systems.

For C2SIM interoperation to be fully utilized it require that operational (i.e. C2 and simulation communities) find a suitable business model, that there in the organisation exists champions that want to use interconnected simulations since it provide them with some benefit, that collaboration is imperative in the decision making, and that there is an operational use of digital command and control systems that are connected. Methodological the C2SIM will affect how Command and Control is conducted, from the MSG-085 it was identified that Decision matrixes are something that can be enhanced further together with better representation of RED intent in C2 systems. The simulation side also need to find its champions and use methodology such as SINEX to achieve a controlled way for C3SIM interoperation and of data models to be used for information exchange. Technical simulation systems need to be able to implement command agents (i.e. the capability to execute orders/tasks in a doctrinal sound fashion).

Some questions and thoughts raised:

1) How to educate the Military when simulation is not their priority.

2) Development and procurement is a challenge since a Big Bang approach will not work. Organisations need to be aware that there will be capabilities added over the whole life cycle of a system.

3) MS-DOS to Windows 8 in one step. Both technology and methods needs to be developed. With new capabilities the Command and Control/Decision making models also needs to be developed. Perhaps some decision-making models would utilize the C2SIM technology better than other methods. M to be fully complexity and

4) Tempo in the development is important, so that the ideas become products that can be used.

5) Each nation has invested in technology development that may or may not align to NATO requirements. The nations use of their own systems, even though there are better systems developed by other nations or provided by NATO, in some way hinder the paste of development since there are a lot of version of protocols and mechanisms to consider in the development.

6) For the forthcoming C2SIM development organisations, nations need to bring their stuff to the table to be used by the collaborating parties.

7) Must reach out to NATO CAX, C2 centres, exercises in Trondheim, Viking etc.

3.0 SUMMARY AND RECOMMENDATIONS

The workshop informed the C2 and simulation community concerning the lessons learned in the area of C2-Simulation interoperability by presenting the history, status and current development concerning the development of the C-BML and MSDL standards (presentation 1), the history of NATO activities (presentation 2), projects and experiments using C2SIM interoperability functionality derived from NATO MSG activities (presentation 3-6), SISO standardization (presentation 1) and national initiatives (presentation 7-8).

In the presentations national expectations and requirements for the C-BML and MSDL standards were presented together with highlights from various experimentation and demonstration events. Further the workshop received feedback from the operational community concerning their expectations for C2-simulation interoperability technologies for the conduct of military enterprise activities (e.g. force readiness, support to operations, concept development & experimentation).

For the future of C2-SIM interoperation things to develop further are:

- Curriculum to educate the operational C2 community, Simulation users and vendors so that the C2SIM capabilities are used and requested, that simulation community understands what the benefits are and how and when to use the capabilities, and that vendors understand the technology and then can design and implement products;
- Further evolve the structured experimentation process. Within MSG-085 with several experiments and sub experiments the coordination has been a challenge. The experimentation process by itself could be reduced by other MSG groups and also within in national CD&E initiatives;
- The SINEX approach is interesting. It provides a method to create C2SIM Information Exchange Data Models in a structured and controlled way enabling for simpler integration;
- A variety of infrastructures exist, some are experimental and some are deployable. The availability to use is open and free, open and free in the MSG project and propriety. In order to leverage on C2SIM and reach higher TRLs the current and future infrastructures need to be commercialized (e.g. open source, Open use, licensed model, GOTS, COTS). The infrastructures may also need to be able to handle several protocols presentation 4 and 5);
- The operational usage of C2SIM needs to be expanded to tactical and strategic levels and also include Air, Navy better. The cyber domain also needs to be taken into consideration for the future;
- The MSG-085 activities have showcased that there is a need to include military support activities, such as logistics (supplies, medical, repair). It is also of interest to include intelligence and EW operations;
- After Action Review – require the collection of data – i.e. extract transform and load that calls for "BigData" solutions of storage, search and visualization that further could develop C2 tools that utilize more expression and visualization techniques than geographical maps. Presentation 8 (OneSAF) shows an approach in how such capability can be developed;
- The MSG-085 experiments and demonstrations have raised the interest to include some sort of tactical advice in the C2 systems. It could be possible since reports and orders share the same format and if (when) simulation system can execute orders/tasks variants of Course of Actions can be simulated;
- When the TRL level increases the need for a product management strategy to provide quality is needed. The business model to support such activity the user needs to invest either direct money or their time in the effort. Just as the operational C2 systems and simulation systems the infrastructure is not free. The license models and usage models may vary. But in the end each system and infrastructure has an associated cost to it. The FCISC, TANO, ICC, JSAF, SWORD, SITAWRE, 9LANdBMS are not free of charge. The same will most likely be the case for an infrastructure that supports C2SIM interoperation. Whether it's the Saab/GMU WISE/SBML server, FKIE BML Server, VMASC Server, A MIP based, HLA/RTI based server there is a production maintenance cost associated with the infrastructure.

The concluding three recommendations are:

- Establish an Exploratory Team (ET) that focuses on the operationalization of C2SIM as presented in paper 2.

  1) Development, experimentation and provide a set of tools to ease common use of the MSDL (SISO-STD-007-2008) and C-BML (SISO-STD-011-2014) standards;

  2) Prepare the next generation of C2SIM by developing a C2SIM advanced grammar, business rules, production rules, unified C2SIM logical data model, define a process to generate derived products and continue to capture the national, domain specific and stakeholders requirements;

3) Specify, develop and assess a reference communication infrastructure by defining a set of reference C2SIM services.

- Establish Lecture series (LS) that provide an overview of C-BML and MSDL for military commanders and Industry Leaders and provide detailed technical information of C-BML and MSDL and the C2-Simulation program for military/industry technical staff.
- Support the standardization effort of C2SIM in SISO.