NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

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STO TECHNICAL REPORT **TR-MSG-085**

Standardisation for C2-Simulation Interoperation

(Standardisation pour l'interopération SIC-simulation)

Final Report of MSG-085.

Published November 2015

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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List of Acronyms

2R	Requirements and Recommendations
AAO	Autonomous Air Operations
AAR	After Action Review
ACM	Air Control Measure
ACMR	Airspace Control Means Request
ACO	Airspace Control Order
ADatP-3	Allied Data Publication-3
AMPHIB	Amphibious
AMSO	Army Modeling and Simulation Office (US)
APLET	Aide à la Planification d'Engagement Tactique terrestre
AST	Abstract Syntax Tree
ASUW	Anti-Surface Warfare
ATO	Air Tasking Order
BML	Battle Management Language
C2	Command and Control
C2IEDM	Command and Control Information Exchange Data Model
C2IS	Command and Control Information System
C2LG	Command and Control Lexical Grammar
C2PC	Command and Control Personal Computer
C2SIM	C2-to-Simulation
C4I	Command, Control, Communications, Computers and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
C4ISTAR	Command, Control, Communications, Computers, Information/Intelligence, Surveillance, Targeting Acquisition and Reconnaissance
CAN	Canada
CAPES	Combined Arms Planning and Execution System
C-BML	Coalition Battle Management Language
CBMS	Coalition Battle Management Services
CC	Communication Coordinator
CD&E	Concept Development and Experimentation
CGF	Computer-Generated Forces
CIG	Common Interest Group
CITT	C-BML Industry Task Team
COA	Course of Action
COAA	Course of Action Analysis
COI	Community of Interest
CONEMP	Concept of Employment
CONOPS	Concept of Operations
COP	Common Operational Picture
COPD	Comprehensive Operations Planning Directive
CP	Change Process
CSO	Collaboration Support Office
CST	Concrete Syntax Tree
DIS	Distributed Interactive Simulation
DISTAFF	Directing Staff
DSEEP	Distributed Simulation Engineering and Execution Process

DSS	Decision Support System
DTG	Date Time Group
eCOA	enemy Course Of Action
EEL	Experimentation Event Lead
EEPG	Experimentation Event Planning Guide
ET	Exploratory Team
EXDIR	Exercise Director
FKIE	Fraunhofer Institute for Communication, Information Processing and Ergonomics
FOM	Federation Object Model
FRA	France
FRAGO	Fragmentary Order
FTRT	Faster Than Real-Time
FW	Fixed-Wing
GBR	Great Britain
GMU	George Mason University
GUI	Graphic User Interface
HLA	High Level Architecture
HN	Hosting Nation
HQ	Headquarters
I/ITSEC	Interservice/Industry Training, Simulation and Education Conference
ICC	Integrated Command and Control
ICCRTS	International Command and Control Research and Technology Symposium
IEM	Information Exchange Mechanism
IER	Information Exchange Requirements
IGS	Interactive Gaming Solution
ITEC	International Training and Education Conference
JADOCS	Joint Automated Deep Operations Coordination System
JC3IEDM	Joint Consultation Command and Control Information Exchange Data Model
JCHAT	Joint Chat system
JCW	Joint and Coalition Warfighting (US)
JMP	Joint Mission Planning
JSAF	Joint Semi-Automated Forces
JSON	Java Serialized Object Notation
LFG	Lexical Functional Grammar
LI	Lesson Identified
LL	Lessons Learned
LLI	Lessons Learned Information
LOCON	Low Controller
LVC	Live Virtual Constructive
M&S	Modelling and Simulation
MAGTF	Marine Air-Ground Task Force
MCBL	Mission Command Battle Laboratory
MDA	Model-Driven Architecture
MDMP	Military Decision-Making Process
MIL-STD	Military Standard
MIM	MIP Information Model
MIP	Multilateral Interoperability Programme
MOE	Measures Of Effectiveness

MOP	Measures Of Performance
MR	Mission Rehearsal
MSDL	Military Scenario Definition Language
MSG	Modelling and Simulation Group
MTWS	MAGTF Tactical Warfare System
NATO	North Atlantic Treaty Organization
NCIA	NATO Communications and Information Agency
NOR	Norway
NORTaC-C2IS	NORwegian Tactical and Combat C2IS
NSN	NATO Stock Number
OC	Operational Coordinator
OCD	Operational Concept Description
OCL	Object Constraint Language
ODM	Ontology Definition Metamodel
OIEG	Operations Intent and Effects Grammar
OLPP	Operational-Level Planning Process
OMG	Object Management Group
OneSAF	One Semi-Automated Forces simulation
OOB, ORBAT	Order of Battle
OPFOR	Opposing Forces
OPGEN	General Operational Message
OPORD	Operations Order
OPSTAT	Operational Statistics
OPTASK	Operational Task
OSG	Operational Sub Group
OTC	Officer in Tactical Command
OWL	Web Ontology Language
PDG	Product Development Group
PIM	Platform Independent Model
POW	Programme Of Work
PSM	Platform-Specific Model
RECCE	Reconnaissance
RIF	Rules Interchange Format
ROE	Rules Of Engagement
ROI	Return On Investment
RRS or 2RS	Requirements, Recommendations and Specifications
RW	Rotary-Wing
SA	Situational Awareness
SBML	Scripted Battle Management Language
SDA	System Design Agreements
SDEM	Simulation Data Exchange Model
SDF	Standard Development Framework
SE	Systems Engineering
SG	Study Group
SICF	Système d'Information pour le Commandement des Forces
SINEX	Scenario Initialisation and Execution
SIR	Système d’Information Régimentaire
SISO	Simulation Interoperability Standards Organization
SIW	SISO Interoperability Workshop
SME	Subject-Matter Expert
SOPES	Shared Operational Picture Exchange Services

SSS	System/Sub-system Specification
STANAG	STANdardization AGreement
TA	Technical Activity
TAP	Technical Activity Proposal
TBMCS	Theater Battle Management Core Systems
TC	Technical Coordinator
TOPFAS	Tools for Operational Planning Functional Area Service
TRL	Technical Readiness Level
TSG	Technical Sub Group
TTP	Techniques, Tactics, Procedures
UAS	Unmanned Air System
UAV	Unmanned Aerial Vehicle
UML	Unified Modelling Language
UN	United Nations
UN CEFACT	United Nations Center for Trade Facilitation and Electronic Business
US/USA	United States of America
USMTF	US Message Text Format
UVS	Unmanned Vehicle System
VMASC	Virginia Modeling and Simulation Center
VPN	Virtual Private Network
VV&A	Verification, Validation & Accreditation
WARNO	Warning Order
WISE	Widely Integrated Systems Environment
XML	Extensible Markup Language

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The successful completion of the TA is also due to the real involvement of military organizations and experts who shared their knowledge and experience with the other TA members in order to augment the operational relevance and rationales of C2SIM interoperability. Special thanks go to the United States Mission Command Battle Laboratory who offered to host the final TA demonstration and provided a team of senior military experts to support this event.

Finally, the involvement of the MSG-085 Technical Group members also was significant in meeting the TA objectives and achievements. Their considerable technical contribution allowed for defining a C2SIM exchange infrastructure. Also, the extensive work performed by the group to adapt national systems during demonstration preparation was key to demonstrating the benefits of C2SIM interoperability over a great number of events that targeted large audiences.

Key Audiences

1) NATO Partners	ACT NATO Consultation, Command and Control Agency (NC3A) NATO Industrial Advisory Group (NIAG) NATO Underwater Research Centre (NURC) Allied Command Operations (ACO)
2) National Representatives	Conference of National Armament Directors (CNAD) Agile Mission Group (NRF) NATO Military Committee Nations (customers) National Modelling and Simulation Coordination Offices
3) NATO RTA bodies whose activities largely depend on M&S as a lead investment in various capabilities as well as Net-Enabled Capabilities	Applied Vehicle Technology (AVT) Panel Human Factors and Medicine (HFM) Panel Information Systems Technology (IST) Panel NATO Modelling and Simulation Group (NMSG) System Analysis and Studies (SAS) Panel Systems Concepts and Integration (SCI) Panel Sensors and Electronics Technology (SET) Panel
4) The warfighters and national representatives associated with M&S of any NEC, from "start to finish"	Warfighters at all levels, including planners, decision-makers, analysts/scientists, involved in the following: CD&E Acquisition, T&E, Logistics Operations Training and Exercises Joint Multi-national and Inter-Agency Activities Force Development, Force Generation, Force Employment
5) International C2 and Simulation Interoperability Standards Organizations	MIP SISO C-BML Product Development Group SISO MSDL Product Development Group SISO C2SIM Product Development Group

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Standardisation for C2-Simulation Interoperation

(STO-TR-MSG-085)

Executive Summary

Building technical interoperability standards is a complex and time-consuming process. Command and Control to Simulation (C2SIM) interoperability standardization efforts have been underway for nearly a decade within the Simulation Interoperability Standards Organization (SISO). Under the NATO STO umbrella, in parallel and often in concert with SISO, several Technical Groups have been formed to assist in the validation and development of proposed C2SIM interoperability standards. From 2004 to 2005 ET-016 considered the feasibility of the Battle Management Language (BML) in support of military enterprise activities such as Command Post training. From 2006 to 2010, MSG-048 performed preliminary analyses and performed a series experiments and thus was able to provide an initial set of requirements and recommendations for subsequent BML standardization efforts and also considered the use of the Military Scenario Definition Language (MSDL) for scenario initialization. In 2013, MSG-048 received the NATO Scientific Achievement Award for this work.

The results of the follow-on activity to MSG-048, the MSG-085 TA initiated in 2010, and thanks largely to significant involvement from the operational community, have established a clearer scope and refined set of operational and technical requirements for C2SIM interoperability. The proof of concept has been demonstrated by MSG-085. In addition to work with the operational community, there is much technical effort remaining to improve C2SIM. Both MSDL and C-BML need to have a next generation developed to facilitate both their working together and the scope of the interoperability they are able to achieve. MSDL should meet the needs of a wide range of national and NATO systems, while C-BML should improve both the sophistication of what it can represent and ease of using it to represent sophisticated situations.

As MSDL and C-BML move forward, there is a growing consensus among stakeholders to merge these two activities to generate a unified, more manageable and easier to deploy C2SIM interoperability solution. Toward this goal, MSG-085 already has launched the Scenario INitialization and EXecution (SINEX) initiative, an iterative, systems engineering approach to develop technical interoperability standards. SINEX proposes a sustainable, extensible process and production chain for building, maintaining and evolving C2SIM Interoperability solutions. The proposed SINEX tool set is based on existing products from the Multi-lateral Interoperability Programme (MIP) and the builds on the MIP Information Model (MIM) currently being finalized by the MIP. The results obtained thus far from the SINEX initiative have led to interest in applying a rationalized systems engineering approach to produce an operational relevant, technically mature, unified C-BML/MSDL standard.

Standardisation pour l'interopération SIC-simulation

(STO-TR-MSG-085)

Synthèse

L'élaboration des standards d'interopérabilité est un processus complexe et long. Les travaux pour la standardisation de l'interopérabilité entre les systèmes de commandement et de conduite et la simulation (C2SIM) ont débuté il y a une dizaine d'années au titre de l'organisation des standards pour l'interopérabilité des simulations (*Simulation Interoperability Standards Organization, SISO*). Sous l'égide de l'Organisation pour la Science et la Technologie de l'OTAN (NATO STO), en parallèle et souvent de concert avec le SISO, plusieurs groupes techniques ont été créés pour accompagner la validation et le développement des standards d'interopérabilité C2SIM. Entre 2004 et 2005, l'activité exploratoire, ET-016, a étudié la faisabilité du « *Battle Management Language* » (BML) pour les activités militaires, comme par exemple l'entraînement des postes de commandement. De 2006 à 2010, l'activité technique MSG-048 a conduit des études préliminaires et a mené de nombreuses expérimentations ayant permis d'obtenir un premier ensemble d'exigences et de recommandations pour les travaux de standardisation du BML. Le MSG-048 a également recommandé, pour l'initialisation des scénarios, l'emploi du « *Military Scenario Definition Language* » (MSDL). En 2013, l'activité technique MSG-048 a reçu le « *NATO Scientific Achievement Award* » pour le travail réalisé.

L'activité technique MSG-085 lancée en 2010 dans la continuité du MSG-048 a permis, grâce notamment à la contribution de la communauté opérationnelle, de consolider le besoin et d'approfondir un ensemble d'exigences opérationnelles relatives à l'interopérabilité C2SIM. Le MSG-085 a démontré la faisabilité du concept. Au-delà du travail mené avec la communauté opérationnelle, de nombreux travaux techniques nécessitent d'être réalisés pour améliorer la connexion C2SIM. L'emploi conjoint des standards MSDL et C-BML devra à l'avenir être facilité. La nouvelle version de ces standards indiquera précisément le besoin opérationnel couvert. D'autre part, MSDL devra s'adapter à un grand nombre de systèmes nationaux et de l'OTAN et l'utilisation de C-BML devra être simplifiée et être adaptée pour représenter des situations complexes.

Bien que les standards MSDL et C-BML continuent d'évoluer, les contributeurs s'accordent désormais pour fusionner ces deux activités afin de produire une solution unique plus facile à déployer et évolutive. Pour cela, le MSG-085 a élaboré une approche itérative selon les principes de l'ingénierie des systèmes pour la production de standards d'interopérabilité. Cette approche, identifiée sous le nom de SINEX, pour Scenario INitialization and EXecution, propose un processus viable et évolutif ainsi qu'une chaine de production pour l'élaboration, l'évolution et la maintenance des solutions d'interopérabilité C2SIM. Les dispositifs expérimentaux SINEX sont conçus à partir des outils réalisés par le « *Multi-lateral Interoperability Programme* » (MIP) pour la réalisation du « *MIP Information Model* » (MIM). Les résultats obtenus à ce jour ont suscité l'intérêt. En effet, l'approche permettra de produire un standard opérationnel approprié et techniquement robuste, réunissant C-BML et MSDL.

Chapter 1 – INTRODUCTION

This is the final report of the MSG-085 Technical Activity (TA), *Standardization for C2-Simulation Interoperation*. Its intended audience is the NATO technical community, in particular, those working in the domains of Command and Control (C2) and Modelling and Simulation (M&S).

This document describes the work and findings of the MSG-085 TA that is a follow-on activity to MSG-048. The background for MSG-048 is largely documented in reports related to the MSG-079 workshop evaluation report and MSG-048 final report [1], [6].

1.1 DOCUMENT OVERVIEW

This report is structured as follows:

- Introduction (Chapter 1);
- MSG-085 Overview (Chapter 2);
- C2-Simulation Interoperation Requirements (Chapter 3);
- Use of the Multi-lateral Interoperability Programme Products (Chapter 4);
- MSG-085 Experimentation Events, Workshops and Conferences (Chapter 5);
- Lessons Identified and Lessons Learned (Chapter 6);
- Conclusions and Recommendations (Chapter 7); and
- References (Chapter 8).

1.2 WHY STANDARDIZE C2SIM INTEROPERABILITY?

This chapter provides a concise description of the main motivation behind establishing standards for C2-Simulation (C2SIM) interoperation.

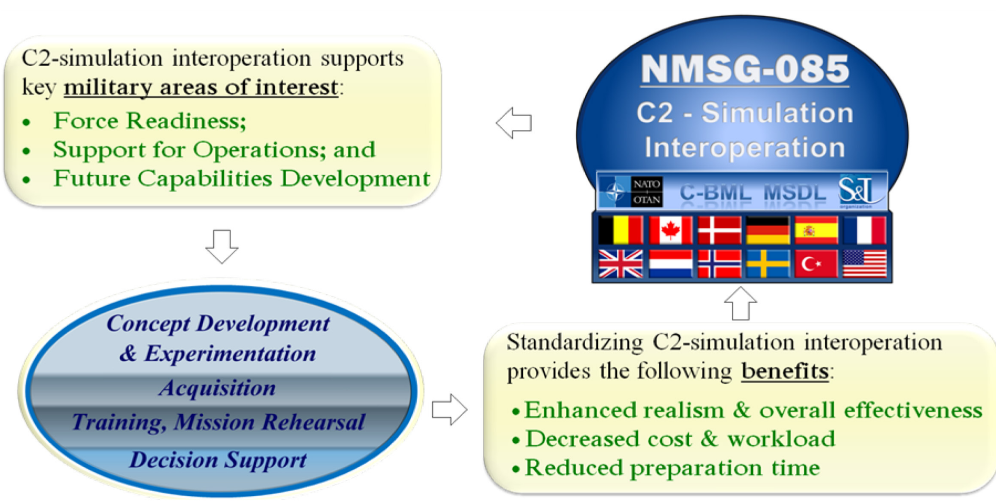

Figure 1-1: C2-Simulation Interoperability Standardization Benefits.

Interoperation among C2 and simulation systems is a common and significant theme in the transformation of modern military forces. It is required to support the military enterprise in the execution of business activities and mission threads such as operational training, information sharing and decision support. This requirement implies the ability to seamlessly integrate C2 systems and simulation systems and to provide the means for a meaningful and unambiguous information exchange. C2SIM interoperation applies to systems-of-systems functioning toward a common goal at different levels:

1) Within services;
2) Across services (i.e. joint); and
3) Across Nations in a multi-national or coalition context.

Furthermore, the advent of autonomous Unmanned Vehicle Systems (UVS) has led to requirements for increased interoperation among C2 systems and the emerging category of robotic forces. The increasing employment of unmanned systems creates the need to develop and validate new concepts of operation and therefore the need for experimentation capabilities. The requirements for communication between C2 systems and robotic systems are similar in many ways to those for communication between C2 systems and simulation systems.

In such a "systems-of-systems" environment, the control of one system by another requires an unambiguous, automated mechanism wherein C2 and M&S concepts can be linked in an effective and open manner. Furthermore, stakeholders have recognized the importance of establishing an internationally accepted standard that provides for a system-independent language and protocols. The MSG-048 Technical Activity explored the technical feasibility of a "Battle Management Language" (BML) as a component of an open framework to link C2 systems and M&S or robotic systems in the NATO context [1]. BML is an unambiguous language used to command and control forces and systems conducting military operations. BML is being developed as a standard representation and means for communicating digitized C2 information such as orders and plans to be understandable for military personnel, for simulated forces, and for future robotic forces. In addition, BML must provide for situational awareness and a shared, common operational picture through digitized reports. BML is particularly relevant in a network-centric environment for enabling mutual understanding. BML also must facilitate C2SIM interoperability in an environment where multi-national distributed integrated capabilities are becoming more common and important.

BML is independent of doctrine but provides a means for expressing doctrine. However BML is not intended as a means to standardize doctrine: the vocabulary must be well defined in the context of the respective application domain to unambiguously generate executable tasks at the end of the process. BML must model these aspects in a way that underlying Information Technology systems (M&S or C2 systems) can exchange information and also can properly interpret the results. Therefore, the Simulation Interoperability Standards Organization (SISO) undertook the development of standard for BML, the Coalition Battle Management Language (C-BML) that uses as the underlying data model, the JC3IEDM. The Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM) was selected since it represents an accepted and well-defined set of information elements. However the JC3IEDM message structure is not part of the C-BML standard.

Use-case scenarios involving information exchange among C2 systems and simulation systems often require a pre-requisite initialization of all systems that is consistent with existing operational and/or simulation databases. This has represented a significant obstacle to C2SIM interoperation. The Military Scenario Definition Language (MSDL), which has been employed by some of the MSG-085 participating Nations as a standard along with C-BML to enable C2SIM interoperation, has been developed as a standard by SISO for the initialization of simulation systems with scenario data using a common format [4].

Interoperation among C2 and simulation systems is required to support military activities such as:

- Force Readiness;
- Support to Operations; and
- Capabilities Development.

Currently, interoperating systems from different manufacturers and/or Nations requires proprietary interfaces that require time and money to develop and maintain. Furthermore, in many cases, in addition to these vendor-specific interfaces, human intervention is required during military scenario definition, initialization and execution. The so-called "swivel-chair" interface entails feeding simulation operators with information that they must translate manually into instructions that the simulations can process. Replacing such operators with a standardized, automated interface can save considerable expense and at the same time result in a more robust and timely operations.

Developing standards that define common interfaces for the exchange of military information among C2 and simulation systems therefore can lead to significant cost-reduction and greatly facilitate systems integration. The benefits of standardizing C2SIM interoperation include:

- Reduced cost and workload;
- Reduced scenario preparation time; and
- Increased realism and overall effectiveness.

The MSG-085 Mission Statement is as follows:

> ***Assess the operational relevance of Coalition Battle Management Language (C-BML) while contributing to C2SIM standardization and assist in increasing the Technical Readiness Level of C-BML technology to a level consistent with operational employment by stakeholders.***

Since the time of the writing of the MSG-085 Programme Of Work (POW), it has become evident that C-BML alone is not sufficient to meet the requirements for C2SIM interoperation, but rather should be utilized in concert with other standards to cover other aspects of C2SIM federation definition, design, development and execution.

1.3 PREVIOUS WORK BY NATO ON STANDARDIZATION FOR C2SIM INTEROPERATION

The Modelling and Simulation Group (MSG) of the NATO Coordination Support Office (CSO) has supported several technical activities related to C2SIM interoperation in recent years. MSG-085 is a follow-up activity to the MSG-048 technical activity that was conducted from 2006 to 2010. The NATO MSG-079 C-BML Workshop was held in February 2010, prior to the kick-off of MSG-085 in June 2010.

1.3.1 NATO MSG-048

The findings of MSG-048 can be found in reference [1]. In addition to a set of lessons learned, rich in experience from the MSG-048 experimentation programme, the reference [1] also provides a set of operational and technical requirements for C2SIM interoperation that has proven useful for the Simulation Interoperability Standards Organization (SISO) C-BML standardisation activities as well as informing the MSG-085 technical activity.

1.3.2 NATO MSG-079

The MSG-079 Workshop took place on February 24-25th 2010 in Farnborough, UK, and included twenty-six presentations proceeded by three keynote speakers. Participation included approximately sixty attendees with representation from twelve Nations [6]. Present at this Workshop, representatives from the Multi-lateral Interoperability Programme (MIP) Future or Block 4 Working Group suggested that the C-BML community consider basing the C-BML standard on the MIP capability to generate "sub-views" comprised of sub-sets of MIP data elements, relationships and business rules.

1.4 C2SIM INTEROPERABILITY

The MSDL and C-BML standards have been developed by SISO to support scenario initialisation and scenario execution, respectively. Initializing and executing operational scenarios are important parts of several military enterprise activities of interest to the MSG-085 Nations. One of the recommendations from the MSG-048 final report suggests that MSDL and C-BML should be harmonized as a pre-condition to establishing a combined C-BML/MSDL standard as a NATO STANdardization AGreement (STANAG). Toward the end of harmonizing the standards, SISO recently has merged the C-BML and MSDL Product Development Groups (PDGs) to form the C2SIM PDG. However, the harmonized standards must contribute towards achieving the benefits of C2SIM cited above. In order for this to occur, there are several conditions that must be satisfied:

- MSDL and C-BML must be mutually consistent and usable in the context of a given specific military enterprise activity;
- The combined MSDL/C-BML standard must be of sufficient technical maturity to support adoption by stakeholders;
- It must be easy to apply changes, when required, to the combined MSDL/C-BML standard in order to support timely releases of new revisions, as dictated by new stakeholder requirements;
- It must be straightforward to apply the combined MSDL/C-BML for the design and development of C2SIM exercises and federations; and
- Future use of the combined MSDL/C-BML standard may require extensions for use by specific communities and therefore it should be possible to easily extend the standard to meet specific C2SIM federation requirements.

Although not mentioned in the original POW, over the course of the MSG-085 Technical Activity it has become apparent that another standard also can be a useful part of designing, developing and executing C2SIM federations. This is the SISO *Distributed Simulation Engineering and Execution Process* (DSEEP). MSDL and C-BML deal mainly with information exchange whereas the DSEEP addresses the process for designing and building a distributed simulation environment. The addition of DSEEP to the areas of interest which is consistent with one of the main lessons learned from MSG-048 that highlights the need for establishing System Design Agreements (SDA) as part of a Systems Engineering (SE) approach to federation development.

1.4.1 Coalition Battle Management Language (C-BML)

In April 2014, SISO approved the initial version of C-BML, a standardized formal language for the exchange of digitized military information among Command and Control (C2), simulation and autonomous systems. C-BML is an interoperability standard that can greatly facilitate the preparation and execution of military scenarios in support of military enterprise activities such as:

- Training;
- Support to Operations; and
- Concept Development and Experimentation.

Preliminary research [8] using C-BML already has shown the benefits that include:

1) Reduced exercise/experiment planning and/or preparation time;
2) Increased realism of the training/experimentation environment; and
3) Decreased cost associated with the decrease in the number of required simulator operators.

The following sections describe the C-BML standard in terms of language components and the corresponding standard specifications.

1.4.1.1 Practical Definition of C-BML

C-BML is intended to be an unambiguous, formal, language for communicating military information for machine-to-machine communication. In general terms, a *grammar* is a set of rules that dictate what **valid** sentences or expressions (i.e. combinations of lexical elements) can be constructed for a given language.

Initiated in 2006 with the formation of the C-BML PDG, SISO's development of C-BML has proven to be a difficult task, as witnessed by the time required to produce the initial balloted Phase 1 specification [5]. As early as 1999, Argo et al. proposed a Battle Management Language (BML) suggesting that the BML expressions be based on a structure that included 5Ws to facilitate the programming of simulated/automated units: Who, What, When, Where and Why [6]. The 5Ws can be described as follows:

- **Who**: The tasking unit; The tasked unit; The supported unit; The supporting unit; The target; The reporting unit; The object of a report.
- **What**: The type of operation or task to be executed; the event being observed.
- **Where**: *Where* is the task to be executed; *Where* is the event being observed?
- **When**: The time the task is to be executed or has been executed; the time an event is observed.
- **Why**: The purpose, motivation, desired effect or result.

C-BML has followed these basic definitions. A graphical example of a simple C-BML task is shown in Figure 1-2. The *Why*, which adds significant complexity has not been included for clarity.

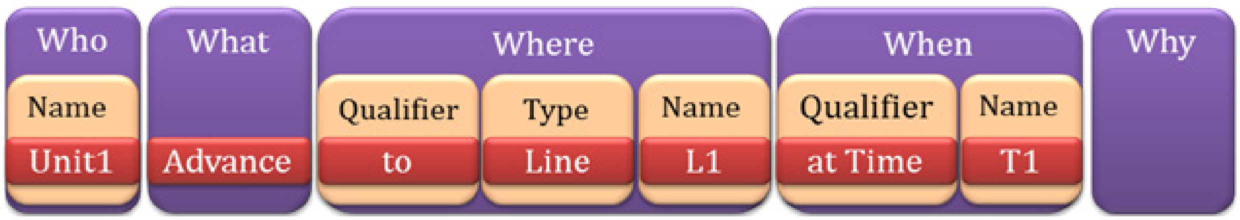

Figure 1-2: Graphical C-BML Example Illustrating 5Ws.

In practice, C-BML expressions will be communicated using one of several concrete syntaxes such as the eXtensible Markup Language (XML) as specified in the C-BML Phase 1 standard. However, other representations like the Java Serialized Object Notation (JSON) also are possible. An example of a simplified XML expression for an Air Interdiction task is shown in Figure 1-3.

```
<Order>
    <AirTask>
        <TaskeeWho>
            <UnitID>CA-UAV</UnitID>
        </TaskeeWho>
        <What>
            <ActionCode>AI</ActionCode>
        </What>
        <Where>
            <WhereID>14010000784100000427</WhereID>
            <WhereLocation>
                <GDC>
                    <Lat>40.062195</Lat>
                    <Lon>47.57694</Lon>
                    <ElevAGL>3000.0</ElevAGL>
                </GDC>
            </WhereLocation>
        </Where>
        <StartWhenTime>
            <StartTimeQualifier>AT</StartTimeQualifier>
            <DateTime>20091022141229.359</DateTime>
        </StartWhenTime>
        <AffectedWho>
            <UnitID>OMF195-B12</UnitID>
        </AffectedWho>
        <TaskID>14099999000000000019</TaskID>
    </AirTask>
    <OrderIssuedTime>20091022141443.000</OrderIssuedTime>
    <OrderID>14099999000000000030</OrderID>
    <TaskerWho>
        <UnitID> 1-HBCT</UnitID>
    </TaskerWho>
</Order>
```

Figure 1-3: Simplified C-BML XML Example.

1.4.1.2 SISO C-BML Product Development Plan

C-BML is of the family of Battle Management Languages (BML) and like other languages is comprised of: *vocabulary*; *grammar*[1]; and *semantics*. The vocabulary and grammar are required to construct valid, syntactically correct expressions representing military information. However, additional information, such as doctrine, is required to correctly interpret the intended *meaning* of this information, which may differ across services, Nations or depending on the nature of the operation. In addition to the vocabulary and grammar components of

[1] Formally, grammars always include vocabularies, but this distinction was made in the interest of defining a standard product development plan.

the C-BML standard, the SISO C-BML PDG also has identified the need for a C-BML ontology to capture and to represent such additional information.

In 2006, the SISO C-BML Study Group produced a report [7] with the following recommendation:

> *"[…] For all versions, the Study Group recommends using the [Command and Control Information Exchange Data Model] C2IEDM and its successor (Joint Consultation Command and Control Information Exchange Data Model – JC3IEDM) as a basis for C-BML reference implementations and standards. […]"*

Reference [7] further recommends that the first version of C-BML be described as a data model (i.e. base vocabulary) defined in XML as a sub-set of the C2IEDM. However it was recognized that there might be a need for extensions to meet requirements from the Modelling and Simulation (M&S) community. It also was recommended that the second version of C-BML introduce the C-BML grammar, while the third version would address the need for ontology-based solutions.

Therefore, the SISO C-BML Product Development Group has established a three-phase plan for developing C-BML as follows:

Phase 1: Establish a *vocabulary* or basic lexicon composed primarily of terminal symbols;

Phase 2: Define a *grammar* or set of production rules that indicates how to combine the vocabulary to form valid expressions; and

Phase 3: Introduce an *ontology* or set of relationships that can facilitate the interpretation of C-BML expressions.

In reality, the plan allows for overlap of the phases, as shown in Figure 1-4 wherein Phase 1 also includes preliminary grammar, and Phase 2 includes preliminary ontology work.

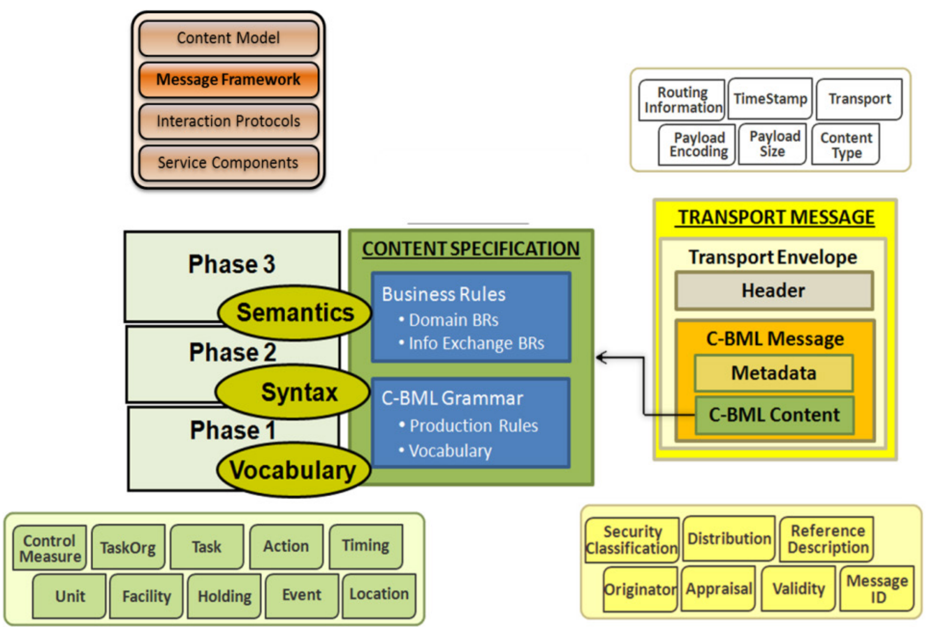

Figure 1-4: SISO C-BML Overview.

The C-BML Phase 1 development activity recently has been completed, resulting in an approved standard. The C-BML Phase 1 product is consistent with the recommendation to use the JC3IEDM [7] as the underlying data model to define the C-BML vocabulary. The new C2SIM PDG has assumed responsibility for the Phase 2 development activity that seeks to build upon the vocabulary defined in Phase 1 and complement this with formal grammar definition and basic ontology.

Since the SISO C-BML and MSDL Product Development Groups recently voted to merge the two groups into one "C2SIM" group that would oversee development of a unified second version/phase of the two standards. The successor to C-BML Phase 2 might take a somewhat different path, although it is reasonable to assume that it will seek to provide continuity with C-BML Phase 1.

Figure 1-4 also illustrates additional elements of the Message Framework as part of the proposed C-BML Standard Development Framework (SDF) [8], such as the C-BML message structure and the distinction between production rules (i.e. grammar) and business rules (i.e. domain-specific or additional logic that is not specified as part of the grammar).

Figure 1-5 illustrates the re-use of the JC3IEDM codes and simple types (shown in the green layer) represented using dashed lines. In this figure, C-BML elements are represented as: codes, entity-types, complex-types (e.g. action-types, facility-types, person-types etc.), and *composites*. The composites include definitions for elements that represent the 5Ws, discussed in the previous sections. Following a successful balloting process in September 2012, the C-BML Phase 1 product became an official standard in April 2014.

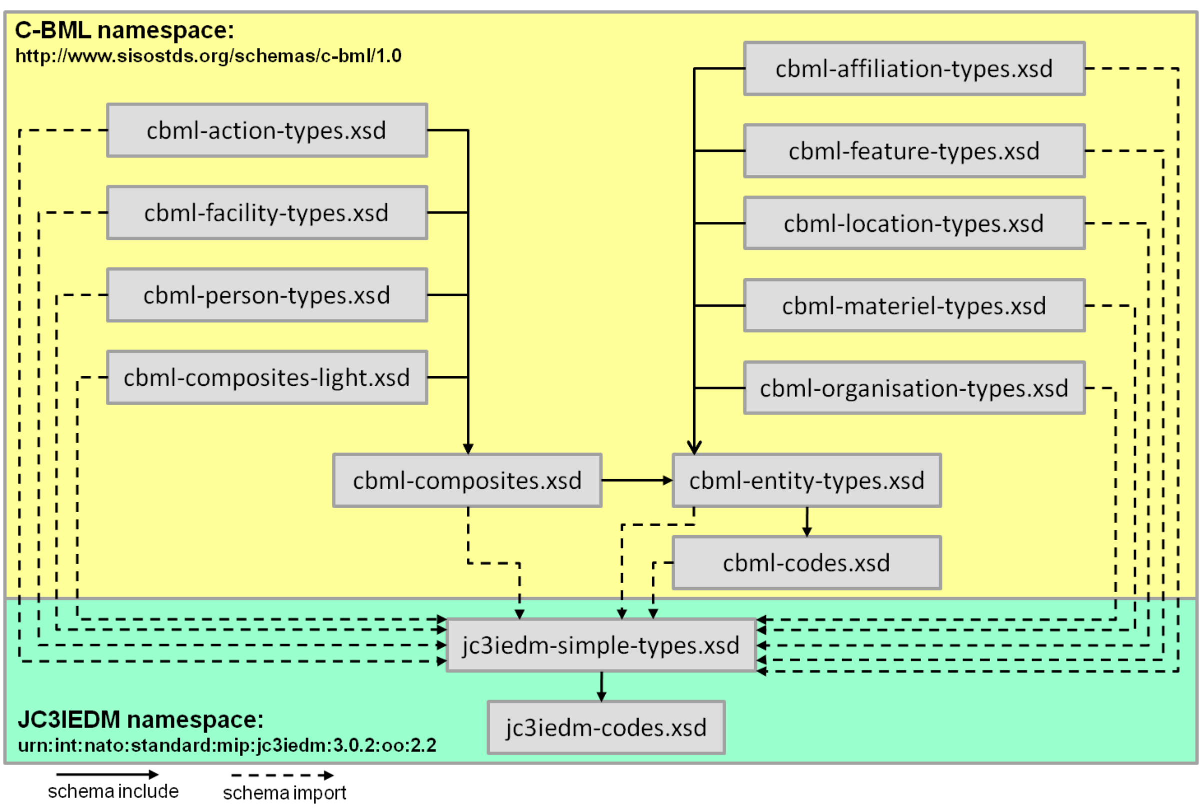

Figure 1-5: SISO C-BML Phase 1 Schema Structure.

1.4.1.3 C-BML Vocabulary and Grammar Considerations

A *formal* grammar is a set of *mathematical* rules that can be used by processing elements called lexers and parsers for processing language expressions. In general terms, a language ***L***, is the set of all expressions (or sentences) that can be formed. It can be generated from a formal grammar ***G***, and therefore can be expressed as ***L(G)***.

A grammar can be defined by a set of production rules ***P*** that operate on a set ***Σ*** of elements referred to as symbols. ***Σ*** is comprised of two sets of symbols: the set of non-terminal symbols ***N***, and the set of terminal symbols ***T***. Non-terminal symbols can be expanded to clauses and other constituents. These symbols are not the expressions or phrases; they are symbols for a generalization of these expressions or phrases.

Terminal symbols are elementary symbols that cannot be broken down further and for the intents and purposes of C-BML they can be considered to form the C-BML vocabulary and may include *keywords*, *identifiers, codes* and *values of core data types*. Non-terminal symbols are clauses, phrases and expressions of which a sub-set is the so-called set of *start symbols*, ***σ***. Non-terminal symbols are used, for example, to represent entities such as *units*, *control-features* or properties such as *temporal-validity* and *location.* Start symbols indicate the roots of valid **complete** expressions or sentences (e.g. *report*, *order*, *request*, *acknowledgement*). Hence, formal grammars can be expressed as quadruples:

$$G = (T, N, \sigma, P)$$

Formal grammars can be represented as trees, or more specifically, Abstract Syntax Trees (AST), where the leaves are terminal symbols and branching points are non-terminal symbols. In order to process formal language expressions using software components, AST are transformed into Concrete Syntax Trees (CST) that also are known as *parse trees* used by parsers.

Examples of BML grammars are the Command and Control Lexical Grammar (C2LG) [11] and the Operations Intent and Effects Grammar (OIEG) [12]. Both of these grammars borrow from Lexical Functional Grammar (LFG) framework that has the benefit of being well-adapted for analyzing and generating natural languages. How well the LFG approach will satisfy user needs for specifying C-BML will be determined as the SISO C2SIM activity goes forward. Some users have expressed the desire for a “simple” grammar that, if necessary, references an ontology that provides information required for interpretation. One perspective is that the language should not impose too many restrictions on what constitutes a *meaningful* expression, but rather only to specify what constitutes a syntactically and structurally complete and correct expression. One way to do this is for the semantics to be represented as an ontology rather than being shaped by the grammar.

1.4.1.4 C-BML Ontology

As described above, a formal language can be defined by a grammar as the set of valid expressions or sentences that are syntactically correct – but in order to interpret these expressions, additional semantics may be required. In some cases, an ontology may not be needed by C-BML consuming applications. However, for applications that utilize inference or reasoning engines, additional information may be required to properly process C-BML encoded information. Ontological means can be used to relate elements of formal language expressions and state facts and assertions that are difficult or verbose to express using traditional formal grammars.

Therefore, the C-BML ontology complements the grammar by adding additional relationships and constraints among *data elements*. Ontologies also allow for specifying information about *data instances* as well. Hence, ontologies may be used during application development to ensure the proper utilization of the C-BML language by applications or may be used during application run-time to construct a knowledge repository to store and derive new information.

The C-BML ontology would define a set of *universal* relationships or semantics that are common to all C-BML producer and consumer applications (e.g. a taxonomy of control features). However, it is unlikely that a single ontology will meet all of the service-specific or community-specific needs and therefore ontology extensions will be required. Hence, the C-BML ontology could be included in the standard as a core ontology based on NATO doctrine and procedures, while allowing for specific communities of interest to extend the ontology to meet their needs.

MSG-085 work on ontology calls for the use of the Unified Modelling Language (UML) from the Object Management Group (OMG) as the central modelling language. Therefore it is of interest to consider how one may represent ontologies using UML. UML can be used to represent conceptual models, sometimes referred to as Platform Independent Models (PIM) in the Model-Driven Architecture (MDA) terminology. However, UML alone does not lend itself to specifying model constraints and for this reason the OMG has developed the complementary Object Constraint Language (OCL) that provides a formal expression of rules such as invariants. Although ontologies also can be considered as conceptual models, UML and OCL are not well-suited to specify ontologies since many of the ontology constructs are lacking. The Web Ontology Language (OWL) that has been developed for this purpose is better suited to represent certain aspects of conceptual model, in particular the specification of restrictions. The OMG has recognized the usefulness of ontologies and of the OWL specification and has created a UML profile called the Ontology Definition Metamodel (ODM) that allows for the representation of an OWL ontology in UML. References [10], [21], [22] advocate an approach wherein an ontology is produced in the form of a set of OWL modules that are generated from an UML ODM ontology constructed following a well-defined process and using a dedicated toolset. The requirements for the C2SIM ontology are still being collected; consequently this work is still of an exploratory nature.

1.4.1.5 C-BML Development Process and Tools – From Phase 1 to Phase 2

The C-BML Phase 1 development activity did not employ a formal process and dedicated tools for elaborating the main product artefact, the C-BML schema, illustrated in Figure 1-5. The schema was handcrafted directly using XML editor tools and therefore although an implicit model can be associated with an XML schema, no corresponding logical data model or conceptual model was constructed as the basis for the schema. This approach has been the source of many difficulties, perhaps the most important of which is an inherent difficulty in applying changes to the existing C-BML Phase 1 product. This makes it difficult to maintain or evolve the Phase 1 products. Also, no formal requirements have been gathered or managed for Phase 1. Thus many questions subsist: *What requirements have been satisfied by specific schema elements? What were the reasons behind a specific modelling strategy? What changes need to be applied in order to maintain consistency with the underlying JC3IEDM vocabulary?* Lessons learned from C-BML Phase 1 drafting activity have been inputs into the proposed C-BML SDF that highlights the need for a Logical Data Model representation and the ability to generate more than one concrete syntax or physical model. The agility that results from this approach is consistent with the process and tools developed by the MIP for the purposes of building and maintaining C2 interoperability solutions (see Chapter 4).

The C-BML Phase 2 Development Activity already has been initiated and has identified several areas that need to be addressed, including:

1) Establishing a set of stakeholder requirements;
2) Defining a normalized, logical data model (i.e. PIM); and

3) Creating a mechanism for the automatic generation of physical model or Platform-Specific-Model (PSM), including XML Schema Description (XSD) documents and possibly preliminary OWL ontology modules.

Reference [21] describes how the use of the MIP Block 4 model and tools will help to achieve the Phase 2 objectives in the form of a well-defined, well-documented, sustainable process and tool chain.

1.4.2 Military Scenario Definition Language (MSDL)

The Military Scenario Definition Language [5] is intended to reduce scenario development time and cost by enabling creation of a separable simulation independent military scenario format, focusing on real-world military scenario aspects, using the industry standard data model definition XML that can easily and dependably be consumed by current and evolving simulations. The initial MSDL capability was prototyped within OneSAF during its early architectural development phase between 2001 and 2004. A SISO Study Group (SG) concluded that there was a community-wide need for a standardized military scenario format to reduce development time and cost, and to enable sharing of valuable scenario products. The standardized scenario format also provides a way to automate the largely manual reproduction of a scenario into multiple simulation scenario formats and reduce the number of errors introduced during this manual process.

In 2006, a formal SISO MSDL standard Product Development Group (PDG) was established with the specific intent of producing a standard Military Scenario Definition Language data model. The PDG reviewed previous OneSAF work, expanded and aligned it with the JC3IEDM. Development included adding some elements such as weather information, and a scenario identification section leveraging the Base Object Model Identification schema and removing elements that were under study or standards development such as the Course of Action structure that was equivalent to the work being pursued under the SISO C-BML PDG. Version 1.0 of the resulting SISO standard was approved in November 2008. Beyond OneSAF, MSDL has been employed by the US Army Modeling and Simulation Office (AMSO), Air Force, and Marine Corps as well as NATO activities including Spain, France, the United Kingdom, Norway, Germany, Canada, and others.

1.4.3 Distributed Simulation Engineering and Execution Process (DSEEP)

The DSEEP deals with engineering and executing (distributed) 'simulation environments', where 'simulation environment' is a generic term that includes Live, Virtual and Constructive (LVC) simulations including all Live assets which are connected together with a common Simulation Data Exchange Model (SDEM) under a set of common agreements. The assets that are connected are called *member applications*. An *environment* where the member applications are simulation and C2 systems is a simulation environment that falls under the definition of the DSEEP. This means that a C2SIM federation can be defined as a simulation environment that contains at least one C2 system, and that uses a C2SIM data exchange model as the SDEM. Not only the SDEM is of importance, also the agreements need to be taken into account. This has led to the idea that when using C-BML and MSDL the terminology and engineering steps to be taken should be aligned with those in DSEEP.

While the MSDL and C-BML standards go a long way to provide standards-based data exchanges between coalition systems, both data models allow flexibility along too many dimensions to have confidence that exchanges between MSDL/C-BML compliant systems will work without additional alignment. For example MSDL allows geographic coordinates to be specified in geocentric (x, y, z) or geodetic (latitude, longitude) coordinates. To ensure system-to-system understanding of locations, MSG-085 participants agreed to exchange geodetic coordinates. Similar agreements are necessary to ensure understanding of even simple C-BML based orders such as movement orders that could potentially include movement routing information constructed from a variety of waypoint-based, referencing based, or start and end-point based data elements.

Chapter 2 – MSG-085 OVERVIEW

2.1 BACKGROUND

The MSG-085 Technical Activity (TA) builds upon the work done in MSG-048. The focus of MSG-048 was on evaluating and demonstrating the technical feasibility of a C-BML-enabled approach to C2SIM interoperation. The MSG-085 TA addressed the problem areas and obstacles highlighted in MSG-048 and provide guidance and input to in support of the finalization of the C-BML standard and its alignment with MSDL. In addition, MSG-085 sought to ensure that the standards support the operational use-cases as collected from the Nations and NATO stakeholders and thus allow for C2SIM interoperation while providing feedback to the community for initiatives that will ultimately result in an increase in the Technical Readiness Level (TRL) of C-BML-related technologies to a level consistent with operational employment.

Although the final goal of the MSG-085 TA does not lie solely in the adoption of a single standard or technology, the participating Nations have identified C-BML and MSDL as the key enabling technologies for C2SIM interoperation.

2.2 OBJECTIVES

The MSG-085 high-level objectives described below are represented graphically in Figure 2-1, taken from the MSG-085 POW [2]. The principal high-level objectives of the MSG-085 are as follows:

- Define the scope and operational and technical requirements for C-BML;
- Establish a set of reference expressions based on NATO operational procedures;
- Assess and leverage available C-BML implementations;
- Address C2 systems and Simulation Initialization Requirements; and
- Demonstrate and communicate the operational relevance and benefits of C-BML for improving the efficiency of military operations.

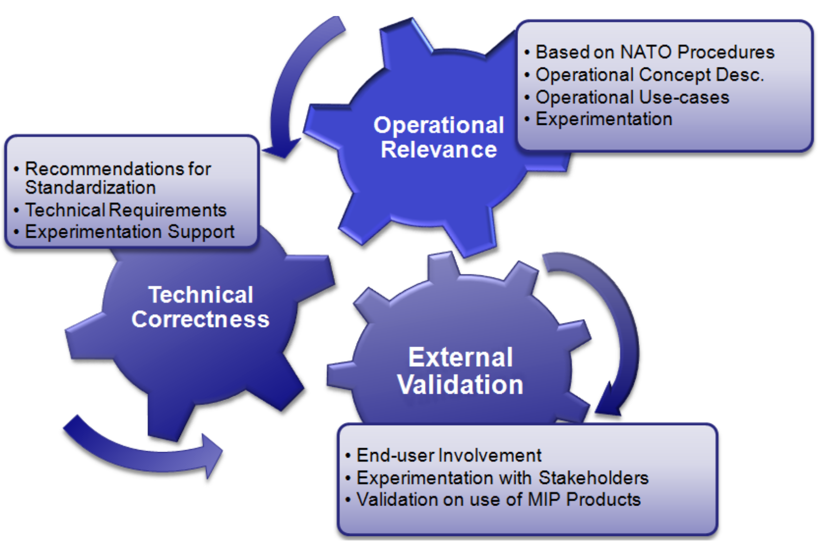

Figure 2-1: MSG-085 Technical Activity Objectives.

2.3 ACTIVITIES

In order to achieve these objectives, the following activities were defined and executed by the group:

- Requirements analysis;
- Establishing recommendations for development and the use of C2SIM interoperability standards;
- Demonstrations, experimentation and evaluation; and
- Organization of communication events.

Figure 2-2 provides an overview of the major activities, events and outputs as a function of a 3-phase programme of work described. In 2012, a one-year extension was requested of the NATO Collaboration Support Office. This extension allowed for additional communication and experimentation events and also for the redaction of the final report.

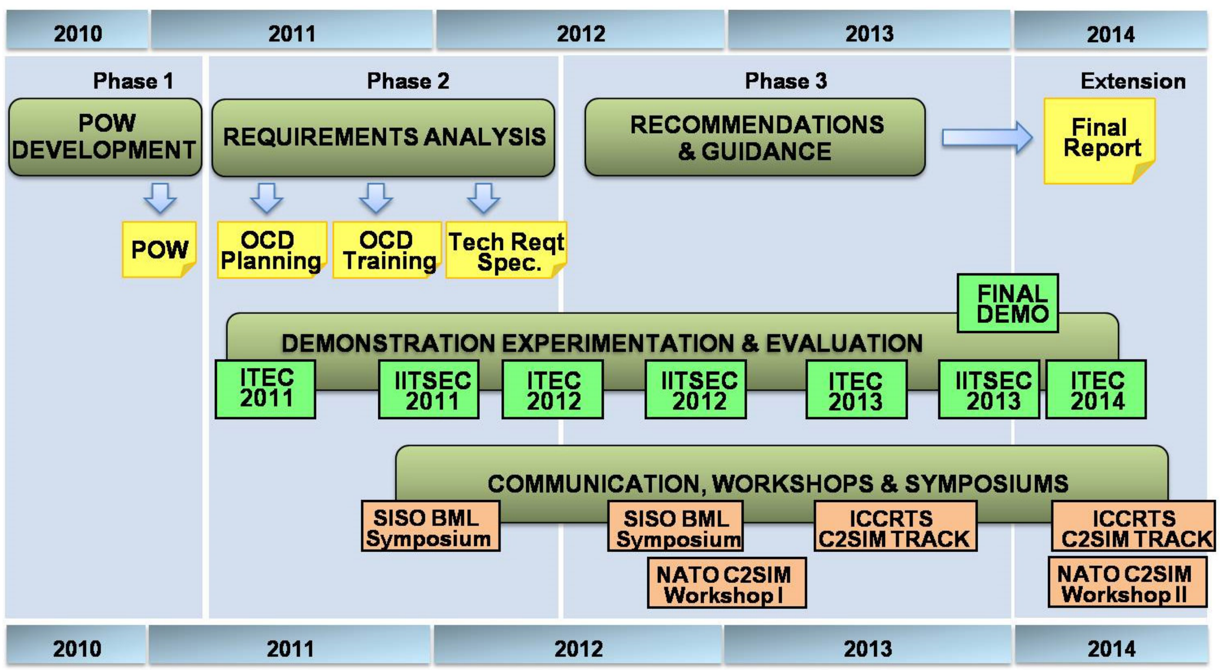

Figure 2-2: MSG-085 Activities and Events Overview.

2.3.1 Requirements Analysis

During the second phase of the technical activity, requirements analysis activities included the elaboration of a set of operational requirements and associated technical requirements. The MSDL and C-BML standards are technical in nature, but must be grounded with an operational context. The operational requirements analysis activity involved defining a set of operational use-cases and the elaboration of Operational Concept Description (OCD) documents for mission planning [13] and for Command Post training [14]. The technical requirements activity linked the operational requirements produced by the Technical Group's operational Subject-Matter Experts (SME) to technical requirements that were derived by a dedicated group that produced a draft technical requirements specification [9].

2.3.2 Lessons Learned and Recommendations

One of the main objectives of MSG-085 was to provide guidance and recommendations to the C-BML community concerning requirements for standardization and for future use of C2SIM interoperability standards. These recommendations were to include:

- Guidance concerning the use of the MIP products;
- Recommendations for developing the C2SIM interoperability standards; and
- Guidance for using the C2SIM interoperability standards and technologies based on the Technical Group's collective experience and lessons learned.

As specified in the Programme of Work, the MSG-085 Technical Group informed the C2SIM community of the lessons learned, recommendations and other findings by organizing demonstrations, symposia and workshops for which the group gave live demonstrations, presentations and submitted papers. The MSG-085 Technical Group also participated in several international workshops and symposia where the group's findings have been documented. The MSG-085 participation in communication events also served to solicit feedback from the larger community of C2SIM stakeholders and is described in Chapter 5. The lessons learned and recommendations are summarized in Chapters 6 and 7, respectively.

2.3.3 Demonstrations, Experimentation and Evaluation

The initial MSG-085 Experimentation Programme planned for a number of experimentation events including:

1) Traditional experiments (e.g. hypotheses-based); and
2) Demonstrations.

Due to time and resource constraints, primarily demonstrations were held during international conferences and trade shows such as I/ITSEC[1] (in North America) and ITEC[2] (in Europe).

These demonstrations illustrated capabilities that were developed, tested and assessed over the course of the MSG-085 lifetime and the preparation for these events required the resolution of technical issues that generated many lessons learned.

The final demonstration built upon the capabilities developed during the previous demonstrations and included an in-depth evaluation from operational SME.

2.3.4 Communication Events, Workshops and Symposia

In parallel with the experimentation events and consistent with Figure 2-2, MSG-085 also organized a number of communication and education events to share the results and findings of the group with community of stakeholders. These events included dedicated sessions and/or symposia held during the two SISO Interoperability Workshops (SIW) and the International Command and Control Research and Technology Symposium (ICCRTS) as well as two NATO MSG Workshops. The demonstrations that were held also contributed to communicating the results and findings of the group.

[1] Interservice/Industry Training, Simulation and Education Conference (I/ITSEC).

[2] International Training and Education Conference (ITEC).

2.4 MSG-085 ORGANISATION

The MSG-085 Technical Activity included participation from thirteen Nations, which led to a programme of work with a significant number of activities and deliverables, as shown above. An organisational structure, shown in Figure 2-3, was put in place to organize these activities and was formed of three groups:

1) The Management Sub-Group formed by the MSG-085 National Leads and the MSG-085 Secretary;
2) The Operational Sub-Group (OSG); and
3) The Technical Sub-Group (TSG).

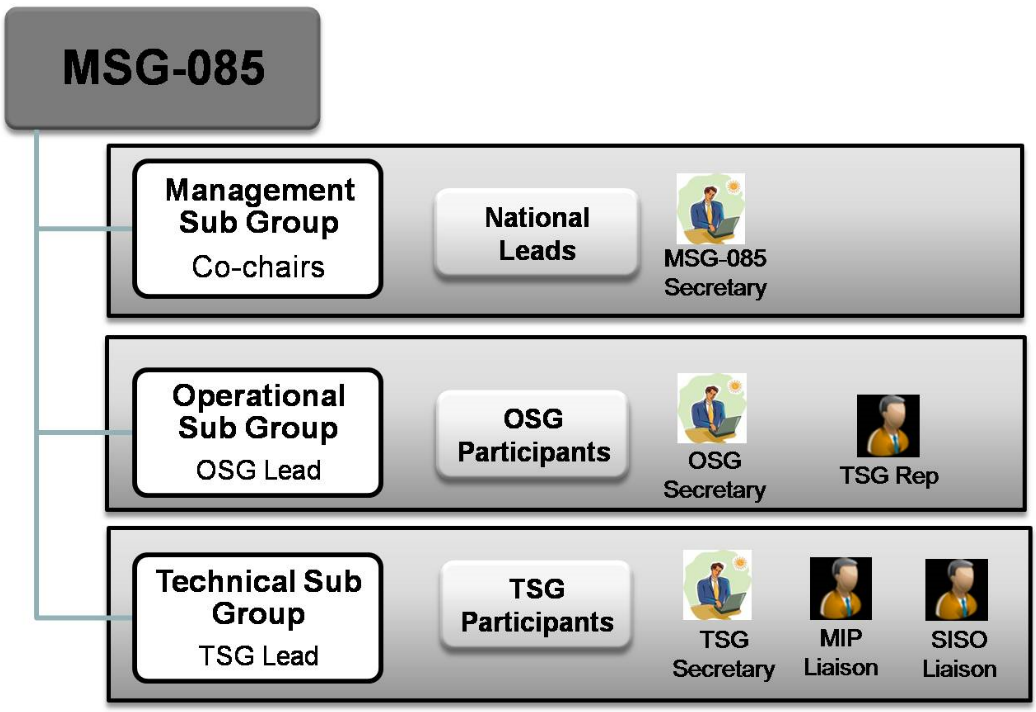

Figure 2-3: MSG-085 Organisation.

The TSG also included liaisons to the MIP and SISO organizations; these are the main technical stakeholders' organizations for the MSG-085 activities.

2.5 COMMON INTEREST GROUP (CIG) APPROACH

The MSG-085 Technical Activity included participation from 13 Nations. Meetings were held at a pace of four times per year with additional participation from a smaller group of Nations at the I/ITSEC and ITEC conferences. Meeting attendance generally ranged from 30 – 40 participants. National representation and interests varied greatly from Nation to Nation and covered the Air, Land, Maritime and Joint/Combined domains. For this reason, early in 2012, it was decided to form a series of Common Interest Groups (CIG) that could explore specific themes or topics in accordance with national interests. Each CIG developed a work plan consistent with and traceable to the MSG-085 POW activities and deliverables.

2.5.1 Common Interest Group Organisation

The formation of the CIG was not intended to replace the existing organizational structure as described in the MSG-085 POW [3], but rather to complement the OSG and TSG activities through focused efforts on specific military domain enterprise activities where C2SIM interoperability issues needed to be addressed.

Figure 2-4 depicts the overall CIG approach wherein specific CIG comprise both technical and operational SMEs from the TSG and OSG, respectively. Each CIG performs activities in its dedicated focus area and then reports back to the TSG and OSG on a regular basis.

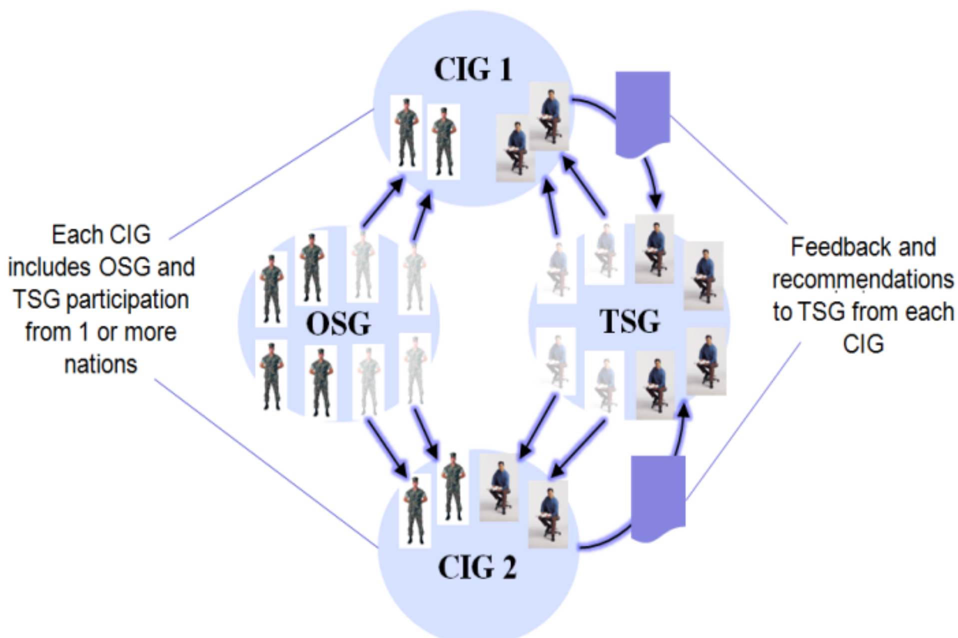

Figure 2-4: Common Interest Group Approach.

CIGs were encouraged to hold regular meetings outside of the MSG-085 general meetings and also to hold individual and combined demonstrations and other experimentation events. Some CIGs did not perform experimentation events but rather focused on analysis and producing documents.

2.5.2 MSG-085 Common Interest Groups

In February 2012, Common Interest Groups were formed (see Figure 2-5) for the following focus areas:

- Autonomous Air Operations (AAO);
- Land Operations;
- Maritime Operations;
- Joint Mission Planning;
- Technical MSDL/C-BML Messaging Infrastructure; and
- Requirements Recommendations and Specifications (2RS), (added in February 2013).

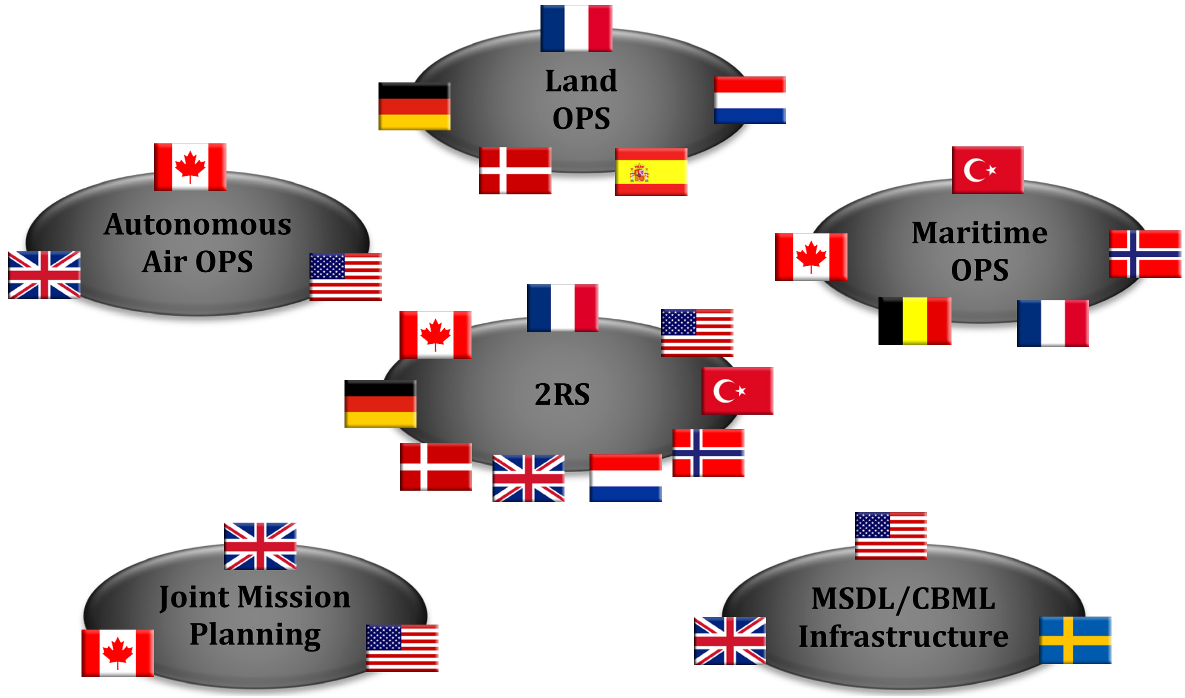

Figure 2-5: MSG-085 Common Interest Groups.

Figure 2-5 indicates the participation by the Nations in the different CIGs. The outputs from the CIGs were provided to the OSG and TSG as contributions to the MSG-085 deliverables as specified in the POW. In November 2012, a CIG Workshop was held during which demonstrations and briefings were made (see Section 5.6).

2.5.2.1 MSG-085 Autonomous Air Operations (AAO) CIG

The focus of MSG-085 was on standardization for C2SIM interoperation. However, technologies such as the Coalition Battle Management Language (C-BML) also provide for interoperability among C2 systems, simulations and autonomous systems. As stated in the POW, the requirements for communication between C2 and autonomous systems are in many aspects similar to those for communication between C2 and simulation systems.

The focus of the AAO CIG was on Concept Development and Experimentation (CD&E) using a distributed simulation-based experimentation environment. In particular, the air domain provided the context for exploring new concepts and approaches for capabilities that include autonomous systems employment within C4ISTAR[3] architectures. These architectures will leverage net-enabled services in order to achieve automated information exchanges in support of new capabilities.

The AAO CIG objectives are as follows:

- Elaborate a set of services that support automated information flows for the purposes of developing new C4ISR/C4ISTAR architectures, and exploring relevant autonomous air operations concepts within this context;

[3] Command, Control, Communications, Computers, Information/Intelligence, Surveillance, Targeting Acquisition and Reconnaissance.

- Extend and refine the current C-BML standard to include requirements for air operations information exchange and in support of the net-enabled services approach; and
- Demonstrate and compare the use of different C-BML messaging infrastructures.

Lead Nation: Canada.

Participating Nations: Great Britain, United States.

2.5.2.2 MSG-085 Land Operations CIG

The CIG Land Operations aims were to specify, develop and demonstrate improved C-BML capabilities for land-focused training and planning purposes. Hence, the CIG works focused on the following objectives:

- Enhancing land manoeuvre logistics features (sustainment of fuel and personnel in addition to ammunition consumption and status of devices);
- Defining request/order/report for artillery support;
- Extending the list of tasks that C-BML is able to support to address stabilization phase of operations;
- Providing for exchange of information between simulations and legacy C2 systems according to operational interfaces and flow of information; and
- Defining a consistent operational initialization process between coalition C2 and simulation systems.

In order to achieve these goals, a new, non-parsing BML server developed by FKIE[4] was used. The MSDL schema was enhanced in order to define unit types consistent with JC3IEDM dictionaries, to use NATO APP-6 standard symbols (for units, boundaries, etc.) and for the logistic domain to initialize holdings of units by using the NSN (NATO Stock Number) codes.

In addition, a new CBML message structure was also developed so that exchanges between systems were consistent with the real operational flow of information. Several new CBML expressions were added, such as:

- Operational message 'Roger' / 'Apercu': Acknowledgement message reporting the status of an order and in case of failure the reasons why;
- Call for fire (Neutralize, Destruction, Illuminate, Obscure): Request for support (artillery fire) used either from a simulated unit to a C2 system, or from a C2 system to a simulated supporting unit;
- Start Firing / Suspend firing: Task command to start or resume, suspend or cancel a request for support; and
- Firing reports: Provide status (In progress, Completed, Cancelled, etc.) of a requested task.

These improvements were demonstrated in December 2012 during a demonstration event at GMU and I/ITSEC based on an operational scenario reused from the Viking 2011 exercise. The C2 systems SICF, SIR, SITAWARE, TALOS and C2LG and simulations SWORD and VR-Forces were provided by participating Nations.

Lead Nation: France.

Participating Nations: Denmark, Germany, Netherlands, Spain.

[4] Fraunhofer Institute for Communication, Information Processing and Ergonomics (FKIE).

2.5.2.3 MSG-085 Maritime Operations CIG

While there have been numerous publications on the use of BML for the land domain and the air domain, few public results are available on the application of BML to maritime operations. The maritime CIG evaluated the applicability of the SISO C-BML Draft Specification to capture orders that cover selected parts of the maritime surface warfare domain, and to identify necessary extensions. More specifically, the CIG analysed relevant parts of the Operational General Matter (OPGEN), Operational Tasking Anti-Surface Warfare (OPTASK ASUW) and Operational Tasking Amphibious (OPTASK AMPHIB).

Example OPGEN and OPTASK ASUW orders were developed based on the Viking 2011 Bogaland Scenario. The corresponding formatted message templates [18] were analysed in order to extract Information Exchange Requirements relevant to interpretation of orders by a computer. The Information Exchange Requirements, captured in form of a System/Sub-system Specification (SSS), were input to the MSG-085 C2-Sim Initialization Requirements. The example orders were mapped to the SISO C-BML Draft Full Schema, showing that even though the main concepts of maritime operations could be captured it would be necessary to introduce additional attributes and domain values. This is trivial in the case of extending existing enumerations. Identified tasks were mapped to the C2LG. The results of this activity were published in [20].

Lead Nation: Turkey.

Participating Nations: Belgium, Canada, France, Norway.

2.5.2.4 MSG-085 Joint Mission Planning CIG

The JMP CIG was formed to investigate how C-BML/MSDL could be used in support of joint service and coalition military mission planning, particularly how C-BML-enabled planning tools could be used to evolve operational plans and orders, which can be evaluated using Faster-Than-Real-Time (FTRT) simulations. Reference was made to two significant NATO documents:

- Allied Joint Doctrine for Operational-Level Planning (AJP-05) [27]; and
- The Comprehensive Operations Planning Directive (COPD) [28].

These determine the conventional NATO processes for joint mission planning.

The JMP CIG looked at how MSDL and C-BML could be used to assist both the operational planning and the technical support communities. In particular, attention was paid to how MSDL and C-BML can be used to support the planning phase (4b) of the Operational-Level Planning Process (OLPP) which forms part of the COPD particularly at the Joint Force, Military Component command levels and echelons below.

The CIG has developed processes to support the OLPP whereby consistent sets of orders can be developed across echelons in a collaborative manner using C-BML-enabled simulations and analysis tools. Different Courses Of Actions (COAs) developed as C-BML orders, e.g. at Brigade level, are executed in simulations to help Commanders select optimal COAs. These COAs are in turn developed by lower echelon component Commanders using simulation support and their results fed back or back-briefed to the higher echelon command for verification and approval.

This process is illustrated in Figure 2-6, below.

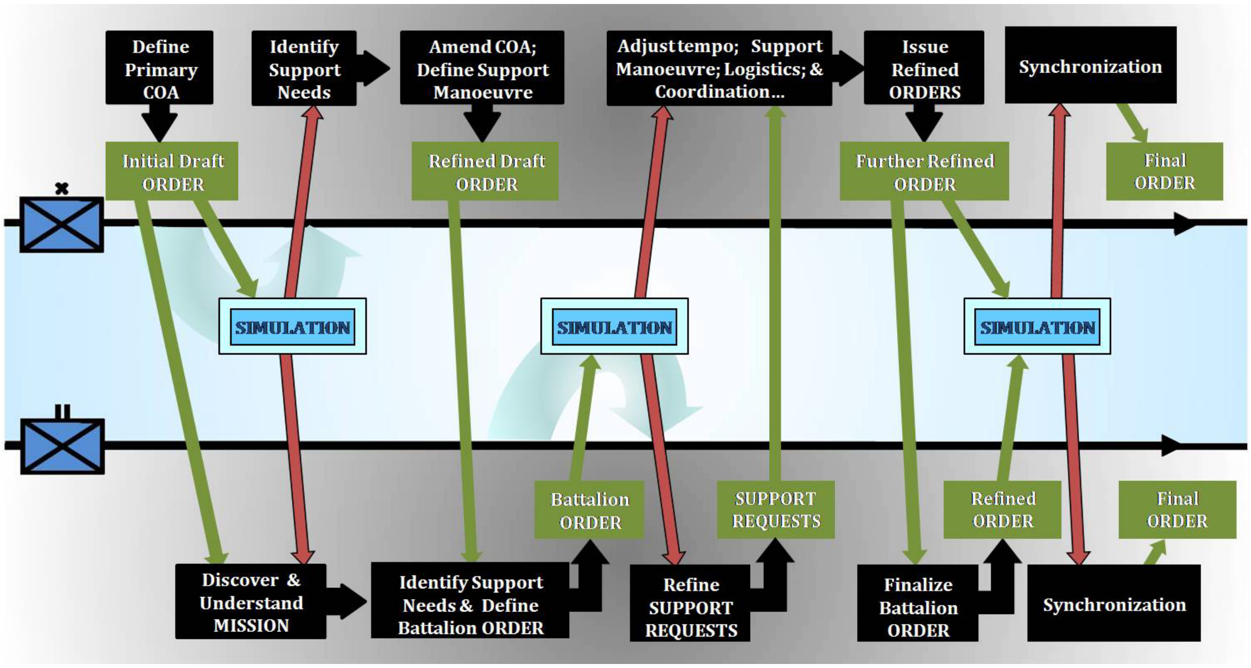

Figure 2-6: Collaborative Joint Mission Planning Process.

The JMP CIG aimed to investigate metrics which could be used to help evaluate alternative plans for the main functional areas required for mission planning, e.g. time to reach objective, expected attrition, and degree of logistics support required.

A separate strand was to investigate potential tools that could be used to support JMP concepts. These tools included analysis and simulation tools:

- Tools for Operational Planning Functional Area Service (TOPFAS);
- One Semi-Automated Forces (OneSAF);
- Joint Semi-Automated Forces (JSAF);
- Aide à la Planification d'Engagement Tactique terrestre (APLET);
- Integrated Gaming System (IGS); and
- MAGTF[5] Tactical Warfare Simulator (MTWS).

Technical solutions to support the JMP CIG's concept were developed by the Infrastructure CIG.

Lead Nation: Great Britain.

Participating Nations: Canada, USA.

[5] Marine Air Ground Task Force (MAGTF).

2.5.2.5 Technical MSDL/C-BML Messaging Infrastructure CIG

The Infrastructure CIG was responsible for identifying, demonstrating and maturing end-to-end capabilities using MSDL and C-BML technologies to ensure all necessary facilities would be available for experimentation/ demonstration. As such, it was concerned primarily with network facilities, MSDL/BML servers, and a well-established portable suite of systems for demonstration.

Network concerns included use of the Internet, both for system development and integration and for conduct of experiments and demonstrations. Ultimately this included use of cellular-based Internet to provide stable, low-cost access with adequate capacity for the Final Demonstration where wired Internet access was not available to MSG-085. Security was provided by an OpenVPN system, with a server hosted by the GMU C4I Center. The JCHAT system also was provided for coordination.

This CIG also developed a set of use-cases and a foundational architecture as a basis for C2SIM services required for the MSG-085 experimentation activities to receive/store all MSDL/BML messages and distribute them to other participating systems. Servers available included the Scripted BML server (SBMLserver) from GMU C4I Center, the non-parsing reimplementation of SBMLserver from Fraunhofer FKIE, and the non-parsing CBMS from Virginia Modeling and Simulation Center (VMASC, who were not able to participate in the Final Demonstration). Non-parsing servers are simpler and can have higher performance, but they cannot support schema translation, a feature that facilitated interoperating a variety of C2 and simulation systems in the Final Demonstration. During the year before the Final Demonstration, SBMLserver was re-implemented as WISE-SBML [23], a higher-performance parsing server based on the Widely Integrated Systems Environment (WISE) from Saab Corporation. Also for the Final Demonstration the FKIE server and WISE-SBML were linked, enabling expanded service that interoperated the CIG Land Ops configuration with the Infrastructure CIG's demonstration configuration (see next paragraph) and the TALOS system operated by Spain in Madrid [24].

The demonstration configuration was intended to be readily available and extensible for conferences and for integration testing with other elements of MSG-085. It included a Battalion/Brigade-level C2 systems, 9LandBMS from Saab Corporation (which also was used as a surrogate C2 system by US elements in the Final Demonstration, due to unavailability of a compatible US system); the OneSAF Computer-Generated Forces (CGF) constructive simulation, used primarily for ground elements; the JSAF CGF, the NATO Air C2 system ICC, and the air coordination system JADOCS, used primarily for air elements; and the WISE-SBML server. This configuration has been used in several demonstrations, including multiple I/ITSEC and ITEC events and the MSG-085 Final Demonstration.

Lead Nation: USA.

Participating Nations: Great Britain, Sweden.

2.5.2.6 MSG-085 2RS CIG

In February 2013, a new CIG was formed to focus on the technical aspects of how to produce and maintain a coherent set of C2SIM interoperability standards, which has proven to be difficult in the past based on feedback from those familiar with the SISO C2SIM interoperability standardization efforts.

One of the main goals of this activity was to provide a comprehensive set of Requirements and Recommendations (2R) to the standardization bodies while proposing a concrete means to produce the required Specifications (S) – or 2RS. This activity focused first on the definition of a proposed standard development process based on systems engineering principles and inspired by the existing process currently in use by the MIP called the *Change Proposal Process*.

Another main goal of the 2RS CIG was to produce a prototype production chain that implemented the proposed process. This toolset that was developed made use of existing MIP products. This prototype production chain was used to produce a usable set of XML schemata based on requirements gathered from the other CIGs.

The prototype production chain built on the tools developed under the Scenario INitialization and EXecution (SINEX) initiative described in greater detail in Chapter 4. SINEX offers a simplified user interface to an UML workspace wherein it is possible to:

- Manage requirements;
- Specify data models that can reuse existing model elements;
- Trace requirements to model elements; and
- Generate model products such as documentation, XML schemata and HLA FOM modules.

If required, advanced users can work directly with the UML interface.

The 2RS CIG also worked on the integration C2SIM interoperability standards with the existing DSEEP standard for federation design. This work led to establishing a draft C2SIM DSEEP overlay for the development of federations comprised of simulation and C2 systems.

The 2RS CIG produced a draft C2SIM interoperability process description document and also demonstrated the SINEX production chain during I/ITSEC 2013 at the NATO booth.

Lead Nation: France.

Participating Nations: Canada, Denmark, Germany, Great Britain, Netherlands, Norway, Turkey, USA.

2.6 DELIVERABLES

Consistent with the MSG-085 Programme of Work, the MSG-085 Technical Activity has produced the following set of deliverables:

1) The current MSG-085 Technical Activity Final Report, including recommendations for the standardization of C2SIM interoperability.

2) Operational and Technical Requirements Documents:

   a) Operational Concept Description-Part I: Course of Action Analysis – Planning [13];

   b) Operational Concept Description-Part II: Command Post Training [14]; and

   c) Technical Requirements Specification for C2SIM Interoperability Standardization [9];

3) MSG-085 Experimentation Programme Documentation [16].

4) A Proposed set of Reference Expressions for C2SIM interoperation [19].

Chapter 3 – REQUIREMENTS FOR C2SIM INTEROPERATION

One of the main objectives of the MSG-085 Technical Activity was to establish a set of operational and technical requirements that could serve as a basis for subsequent standards development. Toward this goal, two separate sub-groups were formed:

- The Operational Sub-Group (OSG); and
- The Technical Sub-Group (TSG).

These groups coordinated to ensure that the operationally relevant requirements were identified by the OSG and served as the primary inputs to the TSG for the derivation of the set of requirements that could then be used for the purposes of standards development. This chapter describes the work that was conducted toward this objective.

3.1 OPERATIONAL REQUIREMENTS

The OSG has produced several key outputs including two OCD documents. In addition, the OSG has established a set of operational use-cases that contributed to the definition of the scope and high level requirements for C2SIM interoperability with respect to the areas and domains that were considered.

In general, an OCD document describes a proposed system in terms of the user needs it will fulfill, its relationship to existing systems or procedures, and the ways it will be used. The OCDs are used to obtain consensus among the acquirer, developer, support, and user agencies on the operational concept of a proposed system. The OCD focuses on communicating the user's needs to the developer and the developer's ideas to the user and other interested parties. The OCD first describes the current situation and system(s) that are used and elaborates the needs for an upgraded or new system, summarising limitations that exist in the current situation and identifying differences associated with different states or modes of operation. Then the new system is described in terms of one or more operational scenarios illustrating the role of the new or modified system, its interaction with users, its interface to other systems and all states or modes identified for the system.

The following sections summarize the two OCDs produced by the MSG-085 Technical Group.

3.1.1 Operational Concept Description – Course of Action Analysis

This OCD [13] addresses the use of both C-BML and MSDL standards for Course Of Action Analysis (COAA), which is part of national, and coalition Military Decision-Making Processes (MDMP) and more specifically "wargaming" activities.

Currently, the majority of Command Posts perform COAA with little use of simulation systems. The wargaming is mainly a force ratio assessment activity and the systems supporting the MDMP are mainly information systems. Nevertheless, there are few systems that are able to support the C2 staff for the analysis of future situations, which have become increasingly complex. However, it is conceivable to envision that there will be many more systems able to support MDMP in the future.

In addition, the MDMP supports collaboration poorly and is performed sequentially without involvement of subordinate units. The distinction between 'Cold planning' and 'Hot planning' is clearly stated. The first deals with the execution of MDMP during peace time to identify the better response against a probable threat. The second is performed during military operations and is time constrained.

Ten operational requirements are identified and described to enhance the current situation without introducing additional delays. They are proposed to:

- Reduce C2 and simulation operators' workload;
- To shorten the time needed to make the systems ready;
- To reduce the learning curve;
- To diminish mistakes introduced by operators; and
- To downsize cost.

These system requirements are:

- C2 systems should provide native functionality to manage simulation execution remotely;
- An evaluation context[1] should be introduced to enable the C2 staff to define and work concurrently on different COAs;
- An evaluation context should be re-usable to enable the C2 staff to update an existing COA;
- C2 system should request a verification of an evaluation context and its completeness;
- C2 system should request simulation outputs dealing with a specific evaluation context;
- Exchanged information should specify the doctrine chosen for different forces;
- Exchanged information should be consistent with the simulation capabilities (e.g. simulations can handle a limited set of tasks and expressions which are listed within the evaluation context);
- Exchanged information should address the combined arms (e.g. artillery, logistics, signals);
- Simulation DTG (Date Time Group) should not constrain the C2 time; and
- Exchange of information should be fully automated (i.e. simulation becomes a black box).

These requirements are the basis for the description of a new system or federation of C2 and simulation systems. The interactions between the federates are described to illustrate the functions of the proposed operational planning procedure that improves understanding at multiple levels, identifies risks early and provides more detailed feedback.

[1] An evaluation context introduces measures and other parameters that allow for the relative comparison of different COAs.

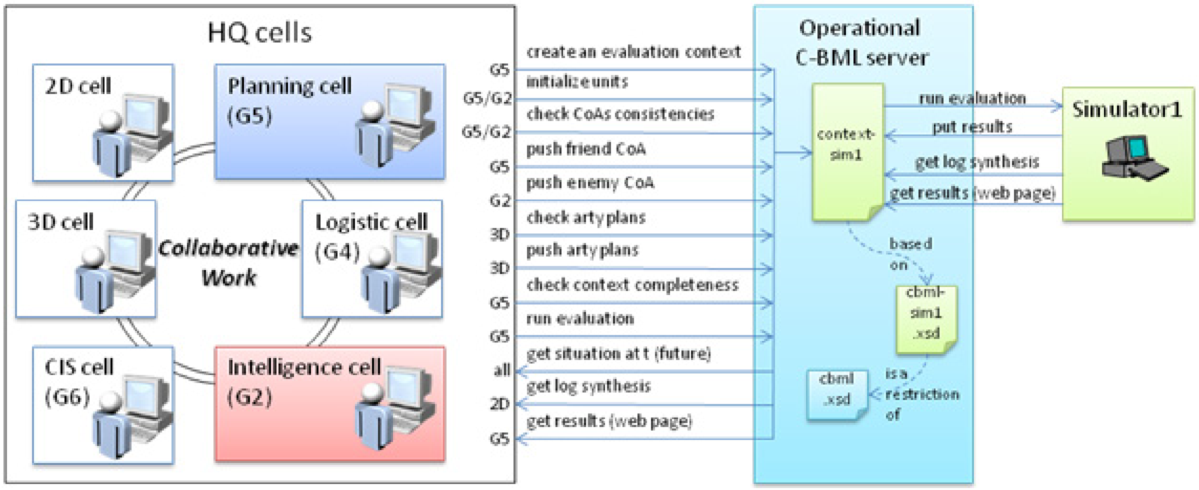

Figure 3-1: View of Proposed System and Interactions for Operational Planning.

3.1.2 Operational Concept Description – Command Post Training

Reference [14] describes the operational concept for Command Post training. In Command Post training the following users of the training system may be identified, who are all under control of the Exercise Director (EXDIR) with their DIrecting STAFF (DISTAFF).

- **TA** – Training Audience, the trainees.
- **HICON** – Plays the role of the trainees' Commanders and is under control of DISTAFF.
- **FLANCON** – The Flanking (Neighbouring) Forces of the Trainees (under control of DISTAFF).
- **LOCON** – Provides the interface between the TA and the simulation. LOCON receives orders sent by the TA and translates them into commands for the simulated forces. In addition, LOCON dynamically reports simulation results to the TA. LOCON is under control of DISTAFF for exercise control.
- **OPFOR** – Plays the role of the enemy during the training exercise.
- White Cell is comprised of role players that play all incidents or events that are not handled by the simulation system (under control of DISTAFF).

One primary TA is considered, although in some Nations, multiple training audiences are sometimes targeted. In the case of multi-level training, some Nations also consider the possibility of training the LOCON or HICON with the primary TA.

Although there are currently a variety of C2SIM integration levels in the different Nations, in the most basic current situation the users all use their native (C2) systems and communication means without the help of new C2SIM interoperability concepts. A "swivel chair interface" is used where both commands to the simulation systems and reports coming from the simulation systems are handled manually. The orders are sent via the Combat Net Radio system among the different levels of command (Brigade, Battalion and Company) as shown in Figure 3-2. Orders that are to be simulated are displayed on the LOCON C2 systems where operator(s) transform(s) the level of the order into a level that can be executed by the simulation.

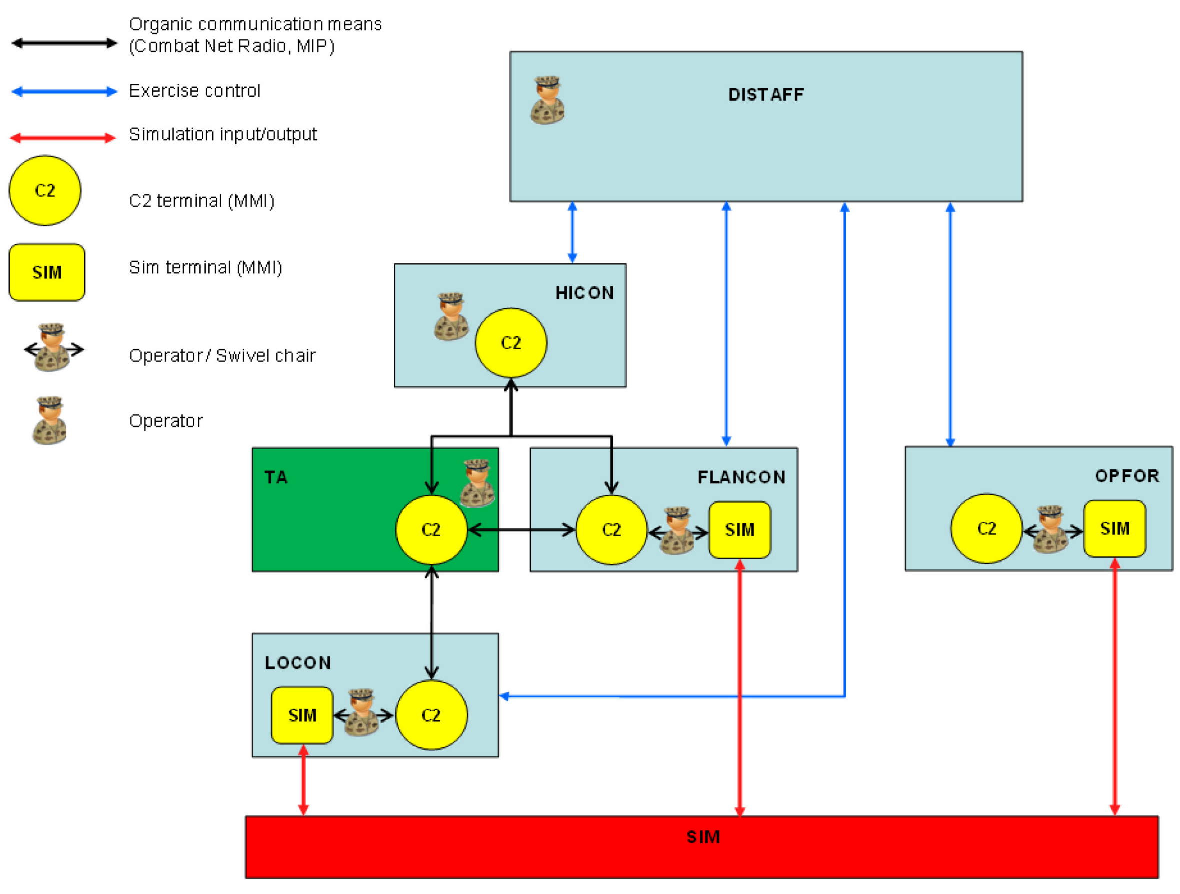

Figure 3-2: Current Typical Command Post Training Environment.

The OCD elaborates on the need for automating information flows among C2 and simulation systems and summarizes limitations and drawbacks of existing systems. A proposed system that represents a first step toward addressing these issues is elaborated in the OCD and shown in Figure 3-3. In this figure the swivel chair interface has been removed and the number of simulation terminals has been reduced since the operators utilize only their C2 systems. A C2SIM gateway is shown in the figure, but it can be expected that in the future it will not be required since C2 and simulation systems will be able to be interfaced directly.

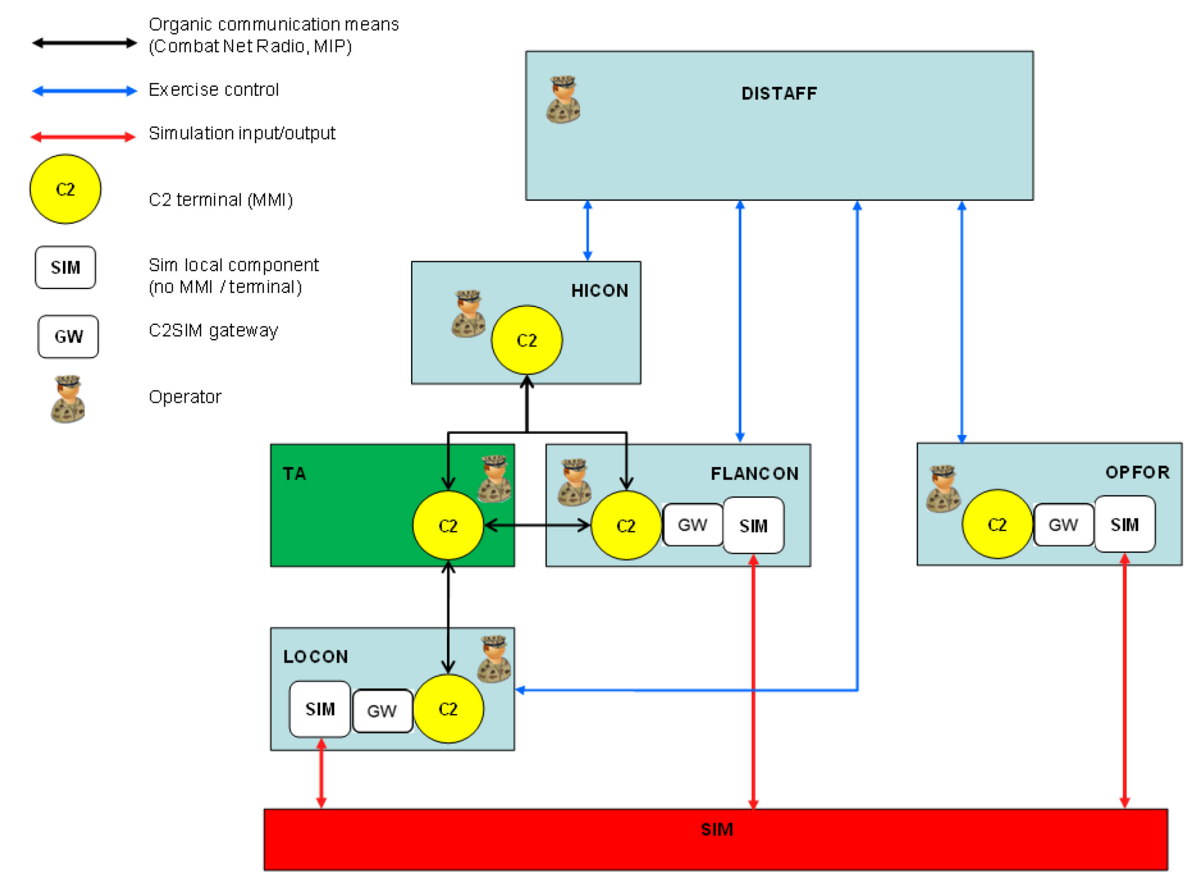

Figure 3-3: Proposed First Step for Command Post Training Environment.

Since most existing military constructive simulations are capable of executing only low level orders (e.g. Platoon and below), LOCONs still are necessary for transforming higher level orders (e.g. Company level orders) to orders that can be executed by the simulation (e.g. Platoon level). In the future, as available CGFs become more intelligent, it is to be expected that type of order transformation will be automated and will become a feature of more and more simulation systems. This future capability is reflected in the proposed architecture for a future Command Post training environment shown in Figure 3-4 where the LOCONs no longer are needed; the TA use their C2 systems that are directly interfaced to the simulation.

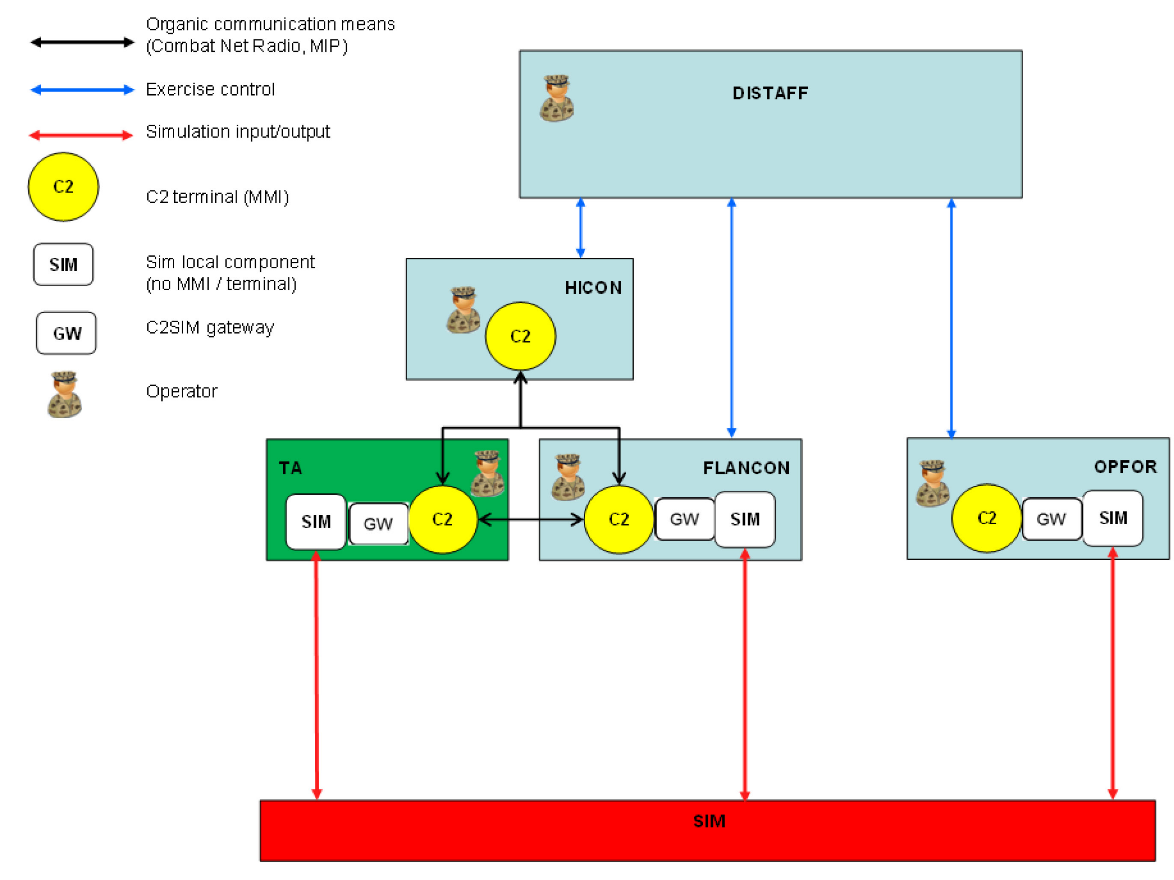

Figure 3-4: Proposed Future Command Post Training Environment.

In the longer-term, it is possible to imagine that OPFOR and FLANCON orders also will be transformed from the level at which they are issued by the DISTAFF to a level that can be executed by simulation systems, consistent with the architecture depicted in Figure 3-5. Building such an environment will be a complex environment because it requires a level of sophistication of CGFs that generally does not exist today, as it requires that the simulated forces act sensible and in a tactically correct manner. At present, this is generally not possible at the Battalion level and above. Therefore the first area where this can be expected should be when the TA is at Company level and below.

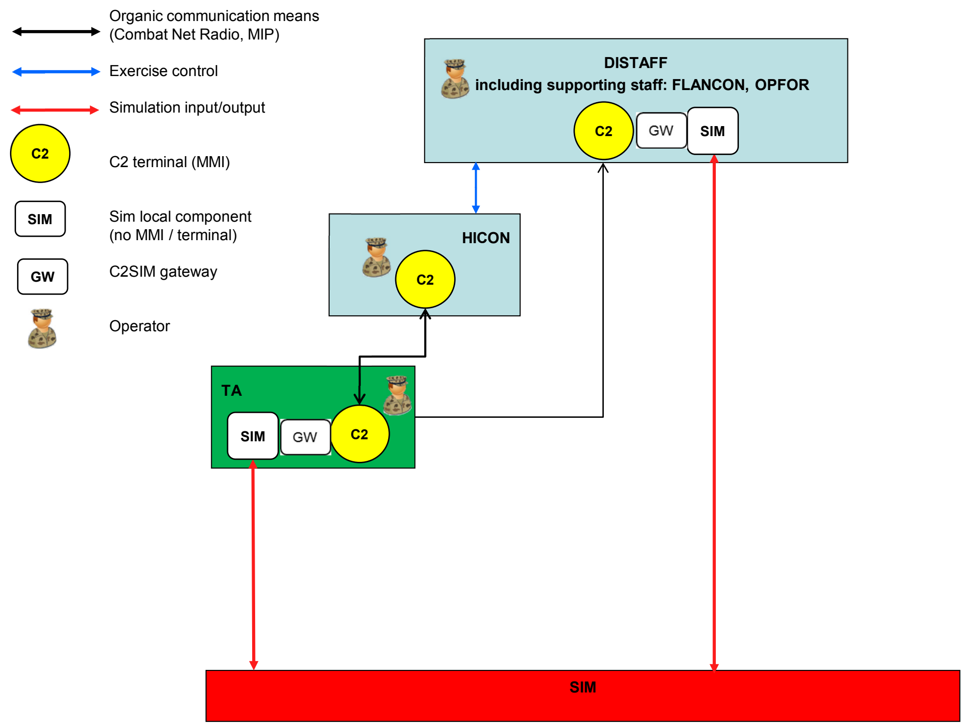

Figure 3-5: Proposed Future CP Training Environment w/OPFOR and FLANCON in DISTAFF.

The OCD presents an initial set of operational requirements, based on a set of use-cases that are relevant for three phases in the MDMP that are distinguished, the preparation phase, execution phase and evaluation phase.

3.2 DOMAIN-SPECIFIC CONSIDERATIONS

This section describes issues, requirements and concerns that are related to specific domains.

3.2.1 Air Operations

Technologies such as the Coalition Battle Management Language (C-BML) provide for interoperability among C2, simulation and autonomous systems. As stated in the POW [3], the requirements for communication between C2 and autonomous systems are in many aspects similar to those for communication between C2 and simulation systems. In particular, the AAO CIG considered use-cases for experimentation involving autonomous aerial assets such as Unmanned Aerial Vehicles (UAV). In addition, this CIG performed analyses and established C2SIM interoperability requirements for the air domain.

Earlier work on air operations by MSG-085 and its predecessor, MSG-048, has examined specific issues relating to representing higher level air operations C2 information such as Air Tasking Orders (ATO), Airspace Control Orders (ACO) and Airspace Control Means Requests (ACMR) using C-BML. This work has included integration of air planning and tasking tools including NATO's Integrated Command and Control system (ICC) into a heterogeneous C2SIM federation. The AAO CIG established requirements and integrated simulated Fixed-Wing (FW), Rotary-Wing (RW) air vehicles and, in particular, Unmanned Aircraft Systems (UAS) into a representative, networked air operations environment. Aircraft simulation was performed principally by the Joint Semi-Automated Forces (JSAF) constructive simulation.

The AAO CIG has been able to draw on experience gained in earlier Canadian national research on the use of agents to support the use of autonomous UAS in a net-centric environment. The CIG also investigated how C-BML could be used to direct lower-level, more dynamic air tasking such as air-to-air refuelling, troop deployment/recovery using helicopters and close air support.

One of the main goals of CIGs was to reach a stage whereby new capabilities developed under the CIG activities could be integrated with the work of the other CIGs as part of the 2013 MSG-085 experimentation activity leading to the MSG-085 Final Demonstration event.

The AAO CIG has worked on C-BML expressions with the aim of implementing current and future air operations capability using C-BML and to help inform the SISO C-BML PDG in its work. For instance, if an operational message is required which cannot be formulated in the current instantiation of C-BML, and then these requirements are fed through to the C-BML PDG for consideration in future standards developments. Similar work has been undertaken with MSDL.

A number of operational messages have been covered. Three terms that are well-defined for air operations are particularly important:

- Airspace Control Means;
- Airspace Control Orders; and
- Air Tasking Orders (ACMs, ACOs and ATOs).

Respectively these correspond to geographical overlay components, overlays, i.e. collections of ACMs, and collections of aircraft missions relating to the ACOs. Two main ACO/ATO formats are used, these are US Message Text Format (USMTF) and NATO APP-11(C) (ADatP-3) and they differ only in minor details. NATO’s Integrated Command and Control (ICC), an air operations planning tool, has been used to prepare the ‘raw material’, the ACMs/ACOs/ATOs, for these investigations. Other air operations planning and coordination tools have also been used for related work. A basic requirement established by the AAO CIG for the current work is that the C2 system should not be specially modified for this work, hence the standard operational message formats are used and separate message translators provided.

Figure 3-6 shows the relationship among ACMs, ACOs and ATOs and indicates which have been implemented in the AAO CIG testbed architecture.

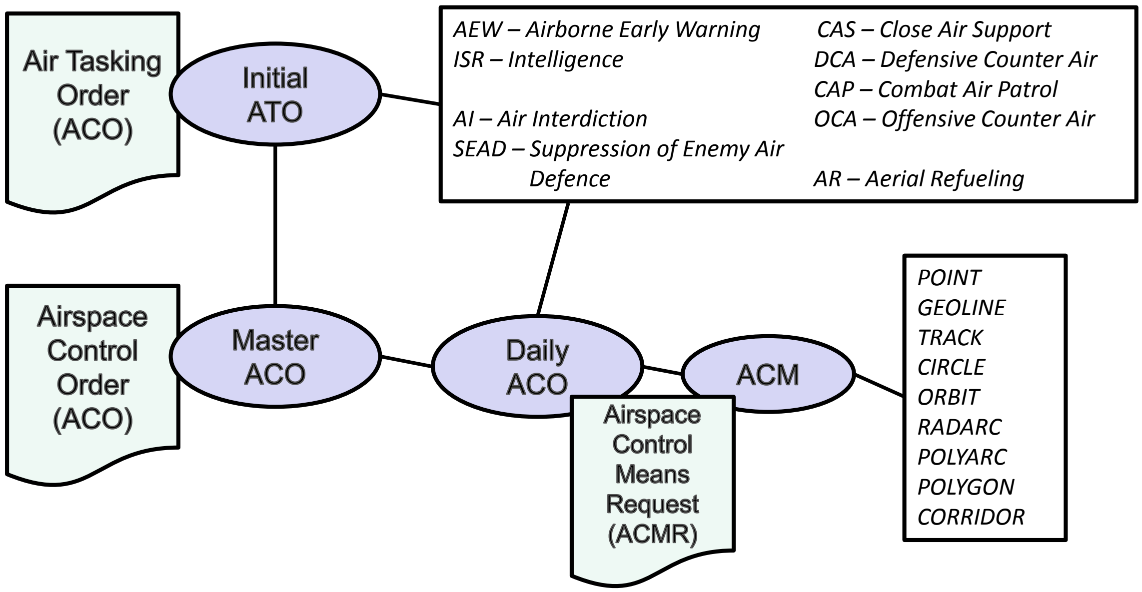

Figure 3-6: C-BML-Enabled Air Operations: Operational Messages Covered.

The study work has been supported by a number of experiments using:

- National and NATO operational planning and execution tools: NATO ICC, TBMCS, JADOCS and a UAV ground control station;
- Various simulations, principally JSAF but also OneSAF and a generic UAV simulation;
- C-BML/MSDL middleware: Coalition Battle Management Services[2] (CBMS) and the Scripted Battle Management Language server[3] (SBMLserver);
- C-BML translator applications for legacy C2 and simulation – various CAN-GBR developments; and
- A Dynamic Multi-cast Virtual Private Network to permit secure multi-national distributed experimentation to take place.

The experimentation architecture has led to the design of an infrastructure and process description to support the needs of Coalition air operations experiments.

3.2.2 Land Operations

The CIG Land Operations has specified, developed and demonstrated improved C-BML capabilities for land-focused training and planning purposes. More specifically, the CIG has identified and defined a set of information elements and messages required to implement the following:

- Exchange of messages among legacy C2 systems and simulations systems according to operational interfaces and flow of information;
- OPerational ORDer (OPORD), including new C-BML tasks to address stabilization phase of operations;

[2] CBMS developed by the Virginia Modeling, Analysis and Simulation Center.

[3] SBML developed by the George Mason University C4I Center.

- Land manoeuvre situation reports, recce reports and logistics reports (sustainment of fuel, personnel, ammunition consumption and status of devices); and
- Request/order/report for artillery support.

The work on these improvements has resulted in the identification of specific issues and concerns for Land operations that could eventually be generalized to other domains. Those issues are described in this section, with examples/illustrations took from the CIG Land Operations experimentation.

3.2.2.1 Task Parameters

The parameters needed for each task are not standardized in the C-BML schema and should not be standardized, because expected missions parameters for one simulation may depend on the task verb, the hierarchical level of the tasked unit and its unit type. Mission parameters may also vary from one C2 system to another one (because of different doctrines).

For example in SWORD (French simulation), the RECCE task needs only a route (line) when a combat Platoon is tasked, but the RECCE task needs an objective area and two boundaries when a combat Company is tasked.

To exchange tasks between systems without ambiguities and to automatically process them, the CIG Land Ops CIG recommendation is to capture those constraints with standardized business rules templates.

3.2.2.2 Task Geometry

The task geometry issue is different from task parameters because it deals with the meaning of the geometry attached to a task. The APP-6 symbols embedded the meaning of the geometry (for example, a block ‘T’ mission is made of a front line where the unit should stand and wait for the enemy – upper part of the T – and a back location – bottom point of the T) – but the current C-BML schema is not designed to support APP-6 symbols for action tasks, and it contains a limited set of codes describing the role of a geometry attached to a task. To continue with the Block mission example:

- SIR (French C2 at Battalion and Company levels) defines it with an oriented line or an area;
- SWORD (French simulation) requires an area; and
- MIL-STD-2525B and APP-6 define it with a ‘T’ symbol.

In order to simplify future interoperation of C-BML compliant systems, C-BML could propose a solution that enables some automatic conversions between the tasks geometries expected by the systems. These automatic conversions can be done by the systems themselves or maybe by the infrastructure if the conversions are very simple and don’t depend on the tactical situation.

3.2.2.3 Observation Reports

During implementation of the C-BML gateway for the SIR system, an issue has been identified inside the observation reports dealing with Detected or Recognized observations. Those observations describe the unit’s type and its level, but do not provide the unit’s identifier (only known when the observation is an Identification), or a track identifier. Without an identifier, when a unit would observe the same enemy unit twice, the C2 gateway will have to generate a new ID for this detection, and two objects will be displayed on the SIR system instead of one. The recommendation is to add a track identifier in the observation report.

3.2.2.4 C2 Systems Overwhelmed

The C2 systems can be overwhelmed by the C-BML messages sent by simulation, when simulation runs faster than real time. This effect also has been noticed for observation reports when simulation runs at real time. To avoid this issue, the simulation must time regulate message generation according to operational procedures.

3.2.2.5 Systems are Very Sensitive with Time

Two issues were identified:

- Future DTG (Date Time Group) messages are cancelled and thus not displayed by C2 system; and
- Past DTG orders are cancelled by the simulation and thus not displayed.

While it was not a problem for demonstrations, this should be taken into account in the future standard. The initialization of systems may share for example a consistent DTG that may also be updated during the scenario execution.

3.2.3 Maritime Operations

C-BML was initially created with a focus on Land Operations. Earlier work by MSG-085 and its predecessor, MSG-048, also included Air Operations.

Maritime Operations are very different from Land Operations in nature. While land tasks are typically given in a sequential order (i.e. do Task 1, then Task 2) against a known enemy or terrain objective, some maritime tasks are given without identifying the enemy. A typical task is to patrol an area: to make sure the enemy does not enter the area or to use force against any enemy within the area. Due to the nature of such a task, there are implicitly several tasks running in parallel:

- Patrol the area until a surface vessel is detected;
- If a surface vessel is detected, suspend patrolling, identify the surface vessel;
- If the surface vessel is identified as hostile, force it to leave the area; and
- If showing hostile intent, attack in accordance with Rules Of Engagement (ROE).

In this scenario, only the patrolling task has a specified start and end time and an associated geographic area. The other three tasks are conditional and depend on the results of these tasks and on the ROE. These conditional tasks add complexity to the modelling. Firstly, modelling tasks in C-BML is not based on acting on results of actions, so this requires a new approach for modelling. Secondly, from a simulation perspective, it is hard to decide when a condition that evokes another task has occurred. Besides conditional tasks or other suspended tasks, there are inherent tasks the vessel should execute continuously due to the nature of Naval Warfare, such as maintaining a Recognized Maritime Picture.

The Maritime CIG used formatted naval operational message specifications stated in NATO APP-11(B) and example orders as input to develop a set of Information Exchange Requirements (IER). More specifically, the CIG identified a set of information elements in OPGEN, OPTASK ASUW and OPTASK AMPHIB relevant to digital orders and their execution by a simulation. The IER were captured in form of a System/Sub-system Specification (SSS) document that specifies requirements covering the following areas:

1) Maritime Task Organization, including Officer in Tactical Command (OTC) location. This can be extended to include warfare Commanders.

2) Basic control features, such as: way points, routes and patrol areas.

3) Movement of forces in formation, i.e. sector screen.

4) A set of maritime tasks, e.g. patrolling.

5) Naval Gunfire Support.

Items 1 – 3 were successfully modelled using the C-BML Full Schema. Additional domain values to existing enumerations were added when needed. When modelling the task organization in C-BML, it was decided to distinguish between the equipment (hardware) and the organization (personnel), consistent with JC3IEDM modelling practices. This is often ignored in maritime orders. Regarding item 4, task modelling the results divided in three equally sized categories:

- Successfully mapped;
- Schema required the addition of new domain values; and
- Schema required structural changes/additions.

For modelling Naval Gunfire Support, the Maritime CIG proposed the use of the Schema elements developed by the Land Ops CIG for Indirect Fire Support.

3.3 TECHNICAL REQUIREMENTS

A Technical Requirements Specification was produced [9] and served as the starting point for subsequent requirement analyses. Figure 3-7 shows the overall organization of requirements and subsequent document structure. This document was produced using automated documentation generation capabilities that were offered by the UML environment used by the MSG-085 Technical Sub-Group to establish an initial set of requirements for C2SIM interoperation. For scenario initialization, requirements were reverse-engineered from the existing MSDL Version 1.0 specification. For scenario execution, initial requirements were taken from the SISO C-BML Phase 2 Drafting Group and then complemented by inputs provided by the Air, Land and Maritime Operations CIGs.

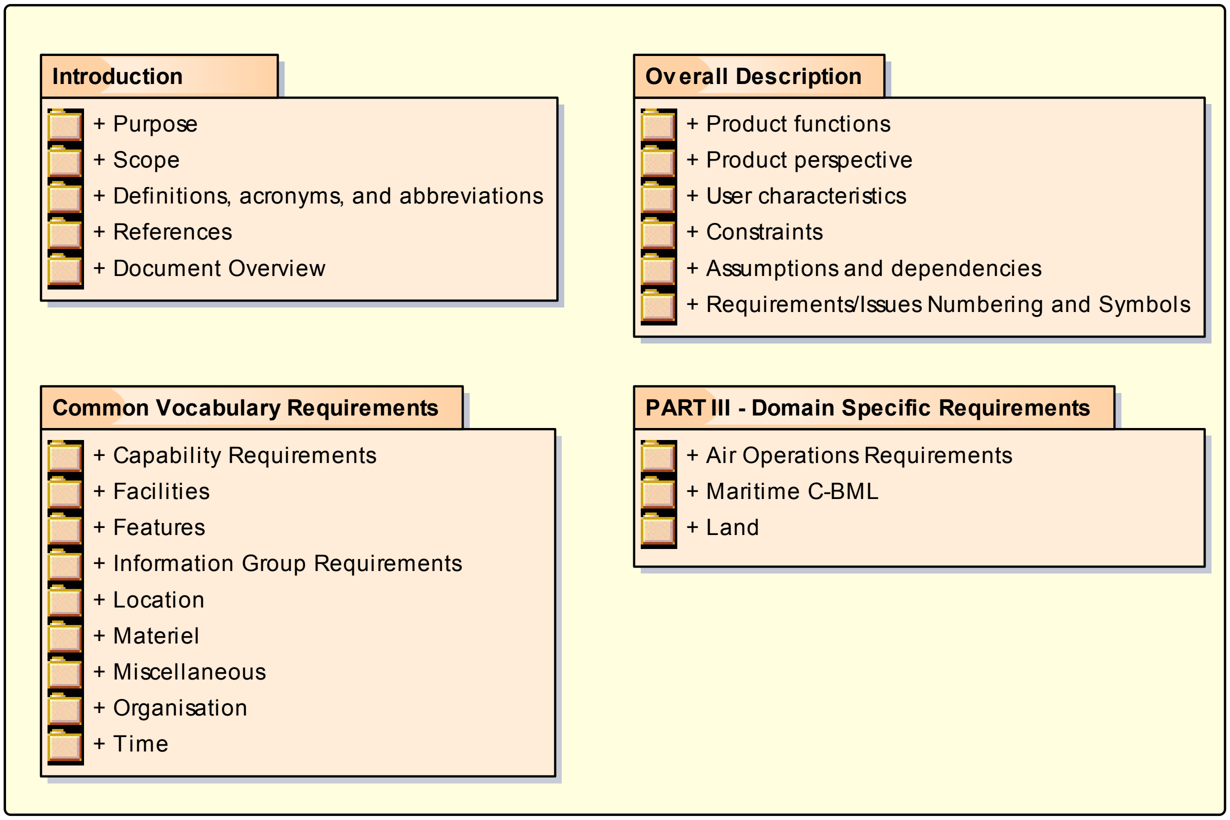

Figure 3-7: C2SIM Interoperability Technical Requirements Overview.

As shown in the figure, *assumptions*, *constraints* and *dependencies* also were captured as part of this initial requirements analysis activity. An example of a constraint is the mandated re-use of the MIP JC3IEDM as the primary source for vocabulary. In addition, throughout the analysis *issues* were identified and recorded. An example of an issue is the need to align the MSDL-derived and C-BML requirements for the definition of *units*.

Chapter 4 – THE USE OF MIP PRODUCTS FOR C2SIM STANDARDIZATION

The following sections provide an overview of the latest version of the MIP products, namely the MIP Information Model (MIM) and associated toolset, and how these products can be utilized to build a requirements-based, sustainable, standardized C2SIM interoperability model and derived standard products. The MIM is the slated successor to the JC3IEDM and incorporates many improvements and features described below.

4.1 MIP PRODUCTS OVERVIEW

4.1.1 The MIP Information Model[1]

The MIP is a joint effort of 29 Nations and NATO to support interoperability of C2 systems. Its standardization efforts cover technical as well as procedural and operational aspects of the information exchange. The current MIP specification, the MIP baseline 3.1, is based on the JC3IEDM, which has been ratified under NATO STANAG 5525. In recent years, the MIP has been working on a successor to the well-established JC3IEDM that combines the rich operational content of the JC3IEDM with state-of-the-art technologies. This new model, called MIP Information Model (MIM) breaks with several design constraints of the JC3IEDM while at the same time maintaining all the operational concepts. Thus, the MIM has operationally the same expressiveness as the JC3IEDM. The first and most obvious difference between the JC3IEDM and the MIM is the choice of modelling language. While the JC3IEDM is described as an entity-relationship model using the IDEF1X notation, the MIM is described as a class model in the UML.

This difference has several implications:

- **Platform Independence:** Since the JC3IEDM was modelled in a way that it directly maps to a database schema that can be used with the Data Exchange Mechanism of MIP, the JC3IEDM can be seen as a PSM. This makes it more difficult to create other representations of the JC3IEDM such as XML schemata or ontologies, even though these mappings have been done in the past. The MIM, in contrast, has been designed from the beginning to support the approach of MDA and as such can be considered a PIM. Concepts such as primary keys or globally unique identifiers have been removed from the model and will be re-introduced when generating PSMs.
- **Clarified Semantics:** As a PSM with a long history, the semantics of the JC3IEDM are not always easily comprehensible, since the structure of the model is influenced by technical constraints and design rules as well as operational requirements. Much effort has been spent on clarifying the meaning of the MIM. Toward this goal, all of the associations of the MIM have been evaluated with respect to their definitions, role names and navigability. Furthermore, a rewording of all definitions has resulted in a better comprehensibility of the intended meaning and usage of attributes and classes. One of the most important additions was the use of stereotypes on attributes to categorize them according to the UN CEFACT class words.
- **Formal Consistency Rules:** In the JC3IEDM several usage and consistency rules (often called business rules) have been expressed in tabular form and free text. In the MIM, most of these rules have been addressed by making the structure of the model more explicit. For example, rules constraining the allowed values in attribute combinations have been remodelled such that only valid combinations are

[1] See: https://mipsite.lsec.dnd.ca/Public%20Document%20Library/MIM-Information_Sheet.pdf.

expressible in the model. In the cases where this was not possible or desirable, the rules have been formalized using the OCL.

- **Documentation:** The documentation of the MIM is currently under development. The first chapters already have been written. The documentation will be part of the MIM, using object diagrams to illustrate the intended use of the model. Some scripts have been implemented to ensure the consistency of the examples and the underlying class model. Generating the full documentation from the model automatically will ensure an up-to-date and consistent documentation, subsequent to model changes.

Another important difference between the JC3IEDM and the MIM is the conceptual separation of the information model from the exchange interface specification. In the future, MIP will deliver multiple small interface specifications, each covering one specific operational capability. These specifications will all be based on the MIM, but will use only a small sub-set of the model's elements. This so-called capability-based approach allows the MIP Community to be much more open to input from other communities. In the JC3IEDM the addition of a single attribute or value to a coded list would require the release, implementation and test of a new baseline. In the future, these modifications will only appear in those interface specifications that are based on the modified part of the respective model.

In addition to being platform independent, the MIM has some additional features that make it easier to understand and use. One of its key features is the separation of metadata (e.g. time, source, security classification), information groups (e.g., overlays), and operational core elements (e.g. objects, actions, plans/orders). This means that the core elements can be described in a stateless, source-independent, and context-free manner and consequently allows for a much cleaner and stricter specification.

For example, previously a more complicated relationship occurred since any object in the JC3IEDM may have multiple statuses. This allows for multiple reports for the same object made by different observers, as well as keeping track of the change of the status over time. A status report may also refer to a future desired/estimated status for planning purposes.

So the MIM took the approach to remove these different dimensions. Consequently, the association between Object and Status became a one-to-one relationship and the status attributes have been merged with the Object hierarchy. Since adding these different dimensions back to the model is a simple transformation, the MIM did not lose any expressiveness.

The high-level core elements are depicted in Figure 4-1. Since all operational concepts of the JC3IEDM have been retained, this view looks very similar to a view of all independent entities of the JC3IEDM. The core of the model comprises an extensive hierarchy of battle space objects such as Organisations, Materiel, Facilities, Features, etc. This taxonomy contains approximately 150 different classes.

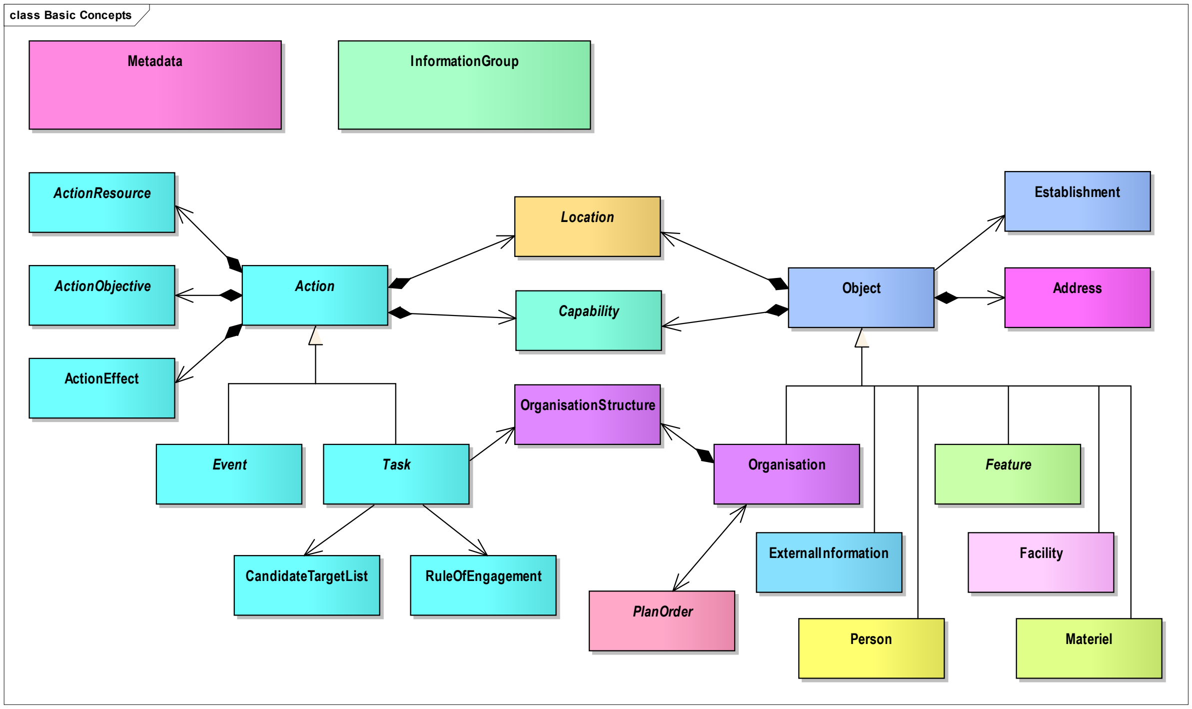

Figure 4-1: MIM Core Classes.

Another part of the model allows the specification of Actions along with their Resources, Objectives and Effects. At the time of writing, the Action structure of the MIM is under discussion and will be revised in accordance with feedback from the C-BML community.

The Location hierarchy includes absolute and relative points, lines, surfaces and volumes. One of the many differences between the MIM and the JC3IEDM is that in the MIM Locations are modelled as part of a composition relationship (or strong association), which means that, according to UML semantics, location instances cannot be re-used. This gives locations the notion of value objects, i.e. they are defined by their exact coordinates and do not need an additional identifier in the PSM.

Since it is assumed that metadata is applicable to all kinds of information and all information may be grouped, information groups and metadata are not linked explicitly to the core elements of the MIM. Instead, a transformation will create the necessary links when generating the PSMs. This greatly reduces the number of associations in the MIM and thus greatly improves the comprehensibility and clarity of the model.

4.1.2 MIP Change Process and Tools

The experience of maintaining and extending an extensive information model in a multi-national environment has shown that it is essential to keep track of all changes that modify the model in order to be able to trace them back to their authors and rationales. Furthermore, the established process of developing the model requires that all changes and their rationale be accepted unanimously. Thus, in a community-driven specification process, change proposals have to be discussed and documented prior to applying them to the model. To ensure that a proposed change can be applied to the model without manual intervention once it has been accepted by all stakeholders, Fraunhofer FKIE has developed a tool that accepts change proposals in an XML format as input to the tool that applies them to the model. While performing the formally described changes on the model, the tool also enforces several consistency checks and notifies the user of possible derivations from design rules and best practices. Since the tool can be used to validate a change proposal prior to putting it up for vote, it is obvious that an accepted change proposal will be applicable to the model without requiring manual intervention and thus the possibility of introducing errors is nil.

Another major advantage of this process is that it creates the potential for parallel work. Since each change proposal only specifies particular desired modifications to the model, the tool performing these changes can identify overlaps in conflicting change proposals. Even though this may seem trivial, it is the basis for the previously described capability-based approach in which each capability package defines a small sub-set of the MIM and then modifies/extends this sub-set, as required.

The MIP has developed and maintains several different tools that support the previously mentioned change process, as shown in Figure 4-2.

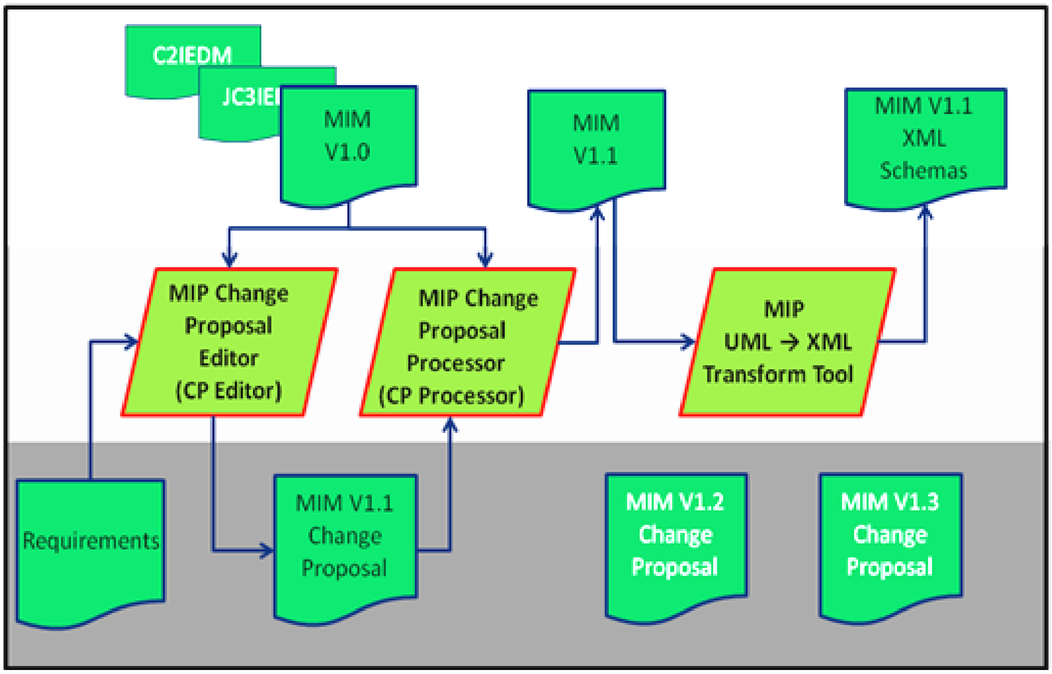

Figure 4-2: MIM Tools Overview.

CP Editor: The CP Editor is a tool that can be used to load and browse the MIM and to create change proposals. It still is in early stages of development but already has the capability to visualize minimal sub-views of the MIM. A minimal sub-view is defined as all classes, attributes and associations that are required to be compliant with the MIM. The idea of a minimal sub-view is similar to the concept of a *Transactional* as described by OMGs *Shared Operational Picture Exchange Services* (SOPES). The graphical editor is shown in Figure 4-3. The left side of the editor is a tree view of the model, showing all packages, classes and attributes as well as all tagged values of the currently selected element. At the bottom, all associations of the currently selected element are shown. The center and the right side of the editor are two different views on the sub-view. The center is a graphical view with the explicitly included classes shown in light blue and the required classes shown in gray. The right side is a more textual view of the same sub-view definition.

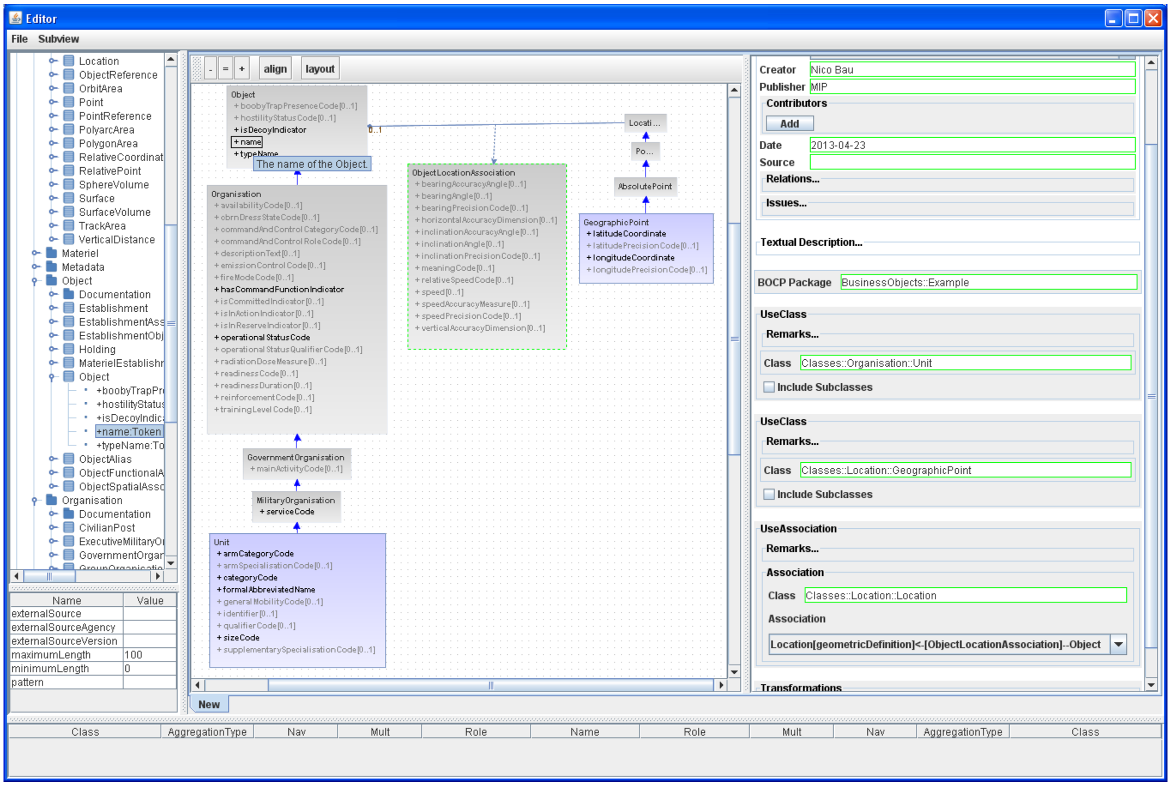

Figure 4-3: MIP Model Editor.

CP Processor: The CP Processor applies a formal change proposal to a model and can execute change proposals created using the CP Editor. Currently, two types of change proposals are supported:

1) A sub-view definition (also called Business Object Change Proposal) is a change proposal that creates a minimal sub-view which contains all elements defined in the change proposal. By default, the minimal sub-view does not include optional attributes. However, the sub-view definition can define optional elements explicitly, as well as suppressing mandatory attributes by setting them to a fixed value.

2) A formal change proposal describes the intended changes both formally and textually. These formal changes are basic operations such as “create”, “modify” or “delete” on UML elements such as packages, classes, attributes, stereotypes and associations.

Transform Tool: According to OMGs MDA approach, a PIM such as the MIM can be transformed into a PSM. The transform tool supports multiple transformations that can be applied to the model in order to (re)introduce certain aspects or patterns in the model. For example it is possible to add the value “unknown” to all enumerations in order to allow users to express that a value may not be known.

As described in the MSG-085 POW [3], one of the objectives of MSG-085 was to investigate the optimal use of the MIP products for C2SIM standardization. This activity entailed coordination with the MIP concerning the use of the MIP products and included:

- The use of emerging MIP models;
- The use of the evolving MIP toolset;

- Interaction with the MIP to ensure a proper understanding concerning the use of the model and tools; and
- Requests from MSG-085 for changes to the MIP model and toolset.

The change requests were primarily aimed toward satisfying C2SIM specific requirements but also included suggestions for improvements to the MIP model itself. Some of these suggestions were accepted and included in the official MIP product release. The exchanges between MSG-085 and the MIP were channeled through MSG-085 members acting as MIP Liaisons.

4.2 A PROCESS AND TOOLSET FOR C2SIM INTEROPERABILITY STANDARD DEVELOPMENT

The exchanges between the MSG-085 MIP liaisons and the MIP resulted in a productive collaboration, including the formation of a CIG for exploring the elaboration of a process and toolset for the management of C2SIM interoperability standards based on the MIP model and tools. From 2013 on, this work was conducted as part of the newly formed 2RS CIG (see Section 2.5.2.6). The main goal of this CIG was to define a dedicated process and prototype tool chain for building a sustainable, extensible C2SIM interoperability standard based largely on existing MIP tools. The CIG's combined efforts have produced the Scenario INitialization and EXecution (SINEX) initiative that has been identified by the NATO Communications and Information Agency (NCIA) as a potential part of the future NATO C2SIM Interoperability solution[2]. The SINEX approach is described in references [21], [23] and is summarized below.

The work performed included the definition of a C2SIM standard development process and a prototype production chain based on the use of the MIP products has been proposed.

The process and production chain is summarized in Figure 4-4 and Figure 4-5. Figure 4-6 shows the proposed inputs and outputs for the SINEX process applied to the C-BML and MSD standards with respect to existing bodies of work in C2SIM interoperability. Figure 4-7 is a screenshot of the prototype tool that was developed as part of the MSG-085 2RS CIG activity.

[2] http://www.dodccrp.org/events/18th_iccrts_2013/post_conference/plenary/jense.pdf.

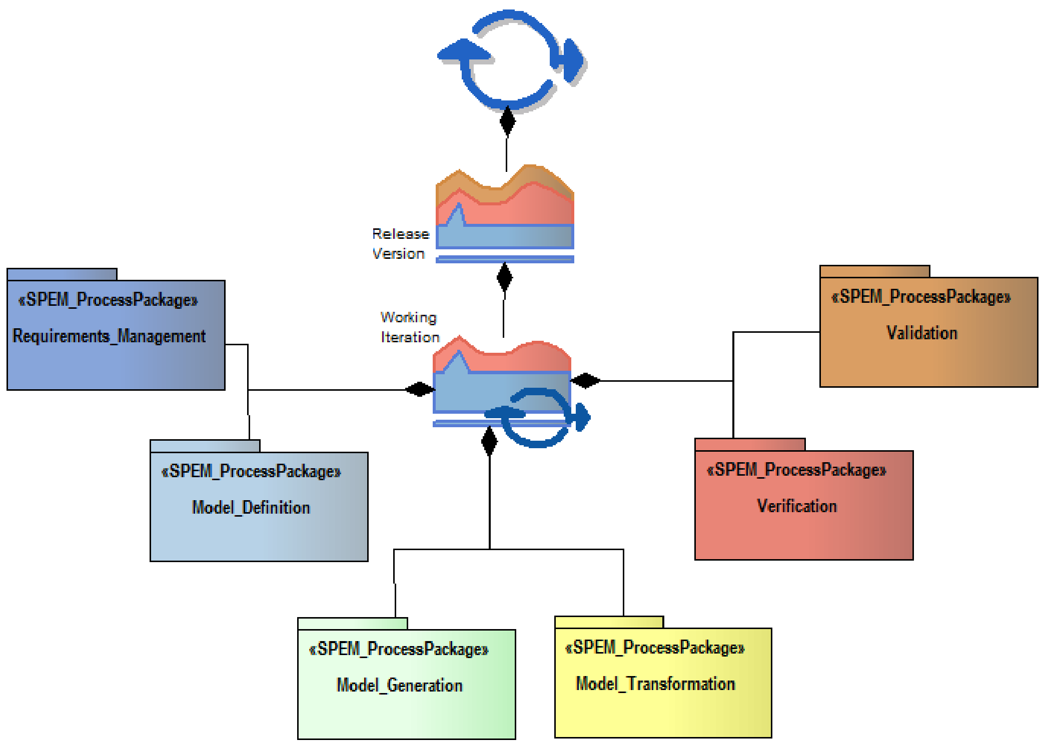

Figure 4-4: SINEX Process Overview.

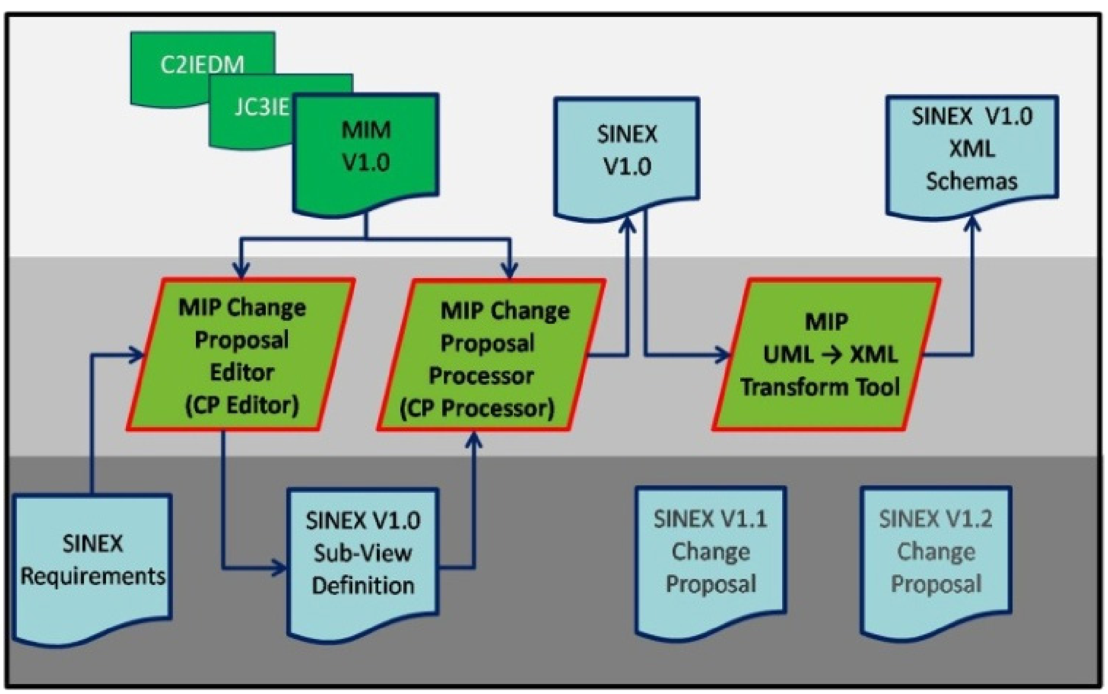

Figure 4-5: SINEX Production Chain.

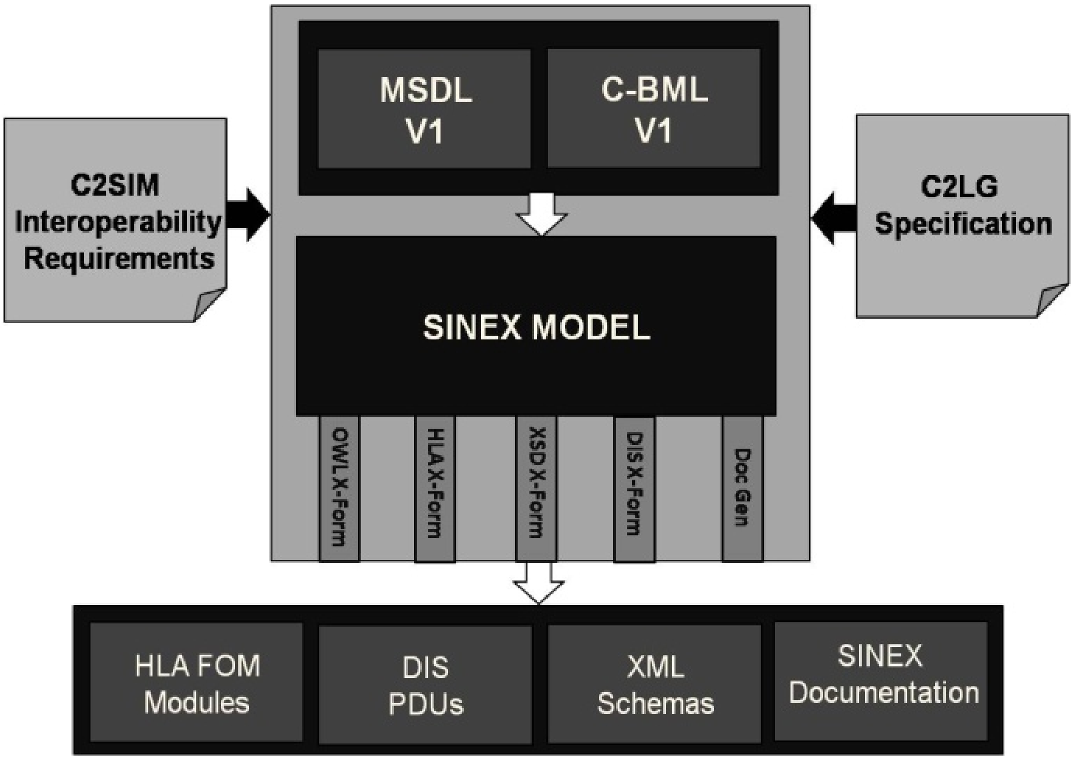

Figure 4-6: SINEX Inputs and Outputs.

Figure 4-7: SINEX Prototype Tool.

The SINEX approach has been suggested as a means for ensuring a proper convergence of the C-BML and MSDL standards. Preliminary work in this area has shown that SINEX is feasible as a means for defining and evolving a combined C2SIM interoperability standard with traceability to stakeholder requirements [22].

Chapter 5 – EXPERIMENTS, WORKSHOPS AND CONFERENCES

The experimentation programme represents an important part of the MSG-085 programme of work. The experimentation programme is comprised of a series of events, primarily demonstrations. These events have several purposes:

- They confirm the operational relevance and measure the benefits of existing C2SIM interoperability approaches;
- They identify limitations and areas of improvements of existing technologies;
- They help to inform the broader community concerning the state-of-the-art in C2SIM interoperability; and
- Perhaps the most important of all, the lessons learned from these events contribute to the elaboration of a set of recommendations for standardization bodies that are developing C2SIM interoperability standards.

This chapter summarizes the experimentation events conducted by the MSG-085 Technical Activity. It also summarizes the various communication and education events that were organized by and/or included significant participation by MSG-085 members. In addition to the events described below, MSG-085 organized several internal workshops, including workshops on:

- Applied Ontology for C2SIM Interoperation; and
- A multi-domain C2SIM Interoperability Workshop.

The following sections highlight the events that were held in public forums.

5.1 EXPERIMENTATION EVENT PLANNING GUIDE

Consistent with the MSG-085 Programme of Work, the MSG-085 Technical Activity included an experimentation programme comprised of experiments and demonstrations in order to:

1) Verify the operational relevance of C2SIM interoperability standards such as MSDL and C-BML;
2) To identify shortcomings and areas requiring further attention; and
3) To communicate findings and lessons learned to the broader community [2].

In order to facilitate the preparation and execution of experimentation and demonstration events, MSG-085 developed an Experimentation Event Planning Guide (EEPG) [15].

In addition to a number of internal experimentation events, MSG-085 held public demonstrations at least twice a year during the course of the MSG-085 Technical Activity. In general, these events took place at the I/ITSEC and ITEC conferences at the NATO CSO booth. The EEPG was useful for both experimentation events and demonstrations.

The EEPG describes the different types of experimentation events typically held by Modelling and Simulation Groups (MSG) and suggests an organizational structure for attributing roles and responsibilities among the different participants. Most importantly, it defines a set of documents that generally are required in order to properly plan, execute and communicate the results of the event.

5.1.1 Types of Experimentation Events

Experimentation is the art, process or practice of performing experiments. The underlying paradigm of an experiment, which is hypothesis-based, is to manipulate something to see what the result is. For the purposes of the MSG-085 Experimentation Programme, other events, such as demonstrations and tests also were included as experimentation events. The EEPG defines these different types of possible experimentation events as follows:

- **Experiments** – To prove or disprove specific hypotheses and/or to determine the relationship between different things.
- **Demonstrations** – To share obtained results or demonstrate proven capabilities; Demonstrations show and/or explain how things work.
- **Tests** – To confirm a specific functionality or quality of something based on pre-established pass/fail criteria and other metrics.

The MSG-085 Experimentation Programme consisted primarily of demonstrations.

5.1.2 Experimentation Event Documentation

The EEPG also specifies the basic components required to properly document an experimentation event. In short, event description documents should include the following elements:

- **Experimentation Event Description and Overview** – A summary and narrative that provides the details associated with the specific experimentation event (demonstration harness) to include, but not limited to, the venue, location, country participation, synopsis of systems / capabilities, dates, and general overview of goals and objective.
- **Technical Architecture Description and Overview** – A layout, pictorial or drawing of the technical architecture in terms of configuration, network resources, national systems and capabilities. This will also include a summary and narrative that provides the descriptive details associated with all of the components, interfaces and configuration of the experimentation architecture.
- **System Design Agreements (SDA)** – This description will also include the system design agreements that stipulate common interfaces, federation agreements and other conventions.
- **Operational Scenario** – Each experiment will include an operational scenario that will drive the event. This section of the appendix will include a description of the scenario with details of units, platforms, sensors, manoeuvre, geographical location, etc., and the script that will be followed during the experiments.
- **Integration and Test Plan** – Describes the integration and test plan that will allow for the integration, verification and tracking of the experimentation capability.
- **Start-up and Execution Procedures** – A description of the procedures required to initialize the experiment and execute the script.
- **Facilities, Equipment and Resource Requirements** – Information pertaining to what facilities, equipment and resources are being utilized to support the experimentation event.
- **Schedule** – A milestone chart, graphic or slide that depicts the high level actions, meetings, test events, workshops, telephone conferences, execution events, etc. that support the experiment event.
- **Evaluation** – After each experimentation event, the lessons learned and technical and operational evaluations will be captured.

- **Brochures, Leaflets, Posters and Presentations** – All the documents and publicity that are generated to socialize the experiment event.

5.1.3 Experimentation Event Organization

The EEPG defines an organizational structure to ensure that the various roles and responsibilities are allocated and tracked. These roles include:

- An Experimentation Event Lead (EEL);
- A Hosting Nation (HN);
- A Technical Coordinator (TC);
- An Operational Coordinator (OC); and
- A Communication Coordinator (CC), as shown in Figure 5-1.

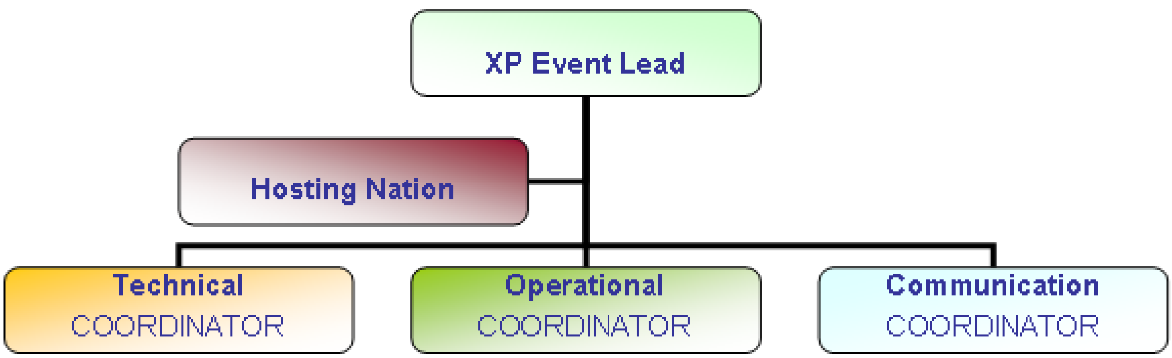

Figure 5-1: Experimentation Event Organizational Structure.

The roles and corresponding responsibilities are described in Table 5-1.

Table 5-1: Experimentation Event Roles and Responsibilities.

Role	**Responsibilities**
Experimentation Event Lead (EEL)	Experimentation Architecture Description Manage and Track Schedule/Risks
Hosting Nation (HN)	Experimentation Facilities, Equipment and Resource Requirements Experimentation Schedule
Technical Coordinator (TC)	Technical Architecture and System Design Agreements (SDA) Experimentation Integration and Test Plan Experimentation Evaluation (Technical)

Role	Responsibilities
Operational Coordinator (OC)	Operational Scenario Experimentation Start-up and Execution Procedures (with support from TC) Experimentation Evaluation (Operational)
Communication Coordinator (CC)	Brochures, Leaflets, Posters, Presentations

5.2 APRIL 2011 – BML RESEARCH SYMPOSIUM

In spring 2011, the George Mason University C4I Center organized a BML Research Symposium that was held on the Friday April 8 2011 following the SISO SIW Spring 2011 in Boston. The purpose of this symposium was to present a community update on leading-edge work in BML in the form of a series of invited talks, (see agenda in Annex A.1). The event was chaired by Dr. Stan Levine who headed a Program Committee with representatives from NATO MSG-085, SISO C-BML and the US Army.

5.3 MAY 2011 – ITEC DEMONSTRATION

The first MSG-085 demonstration took place during ITEC 2011 and focused on the use of MSDL for the initialization of multiple C2 and simulation systems comprising a C2SIM federation, (see Figure 5-2).

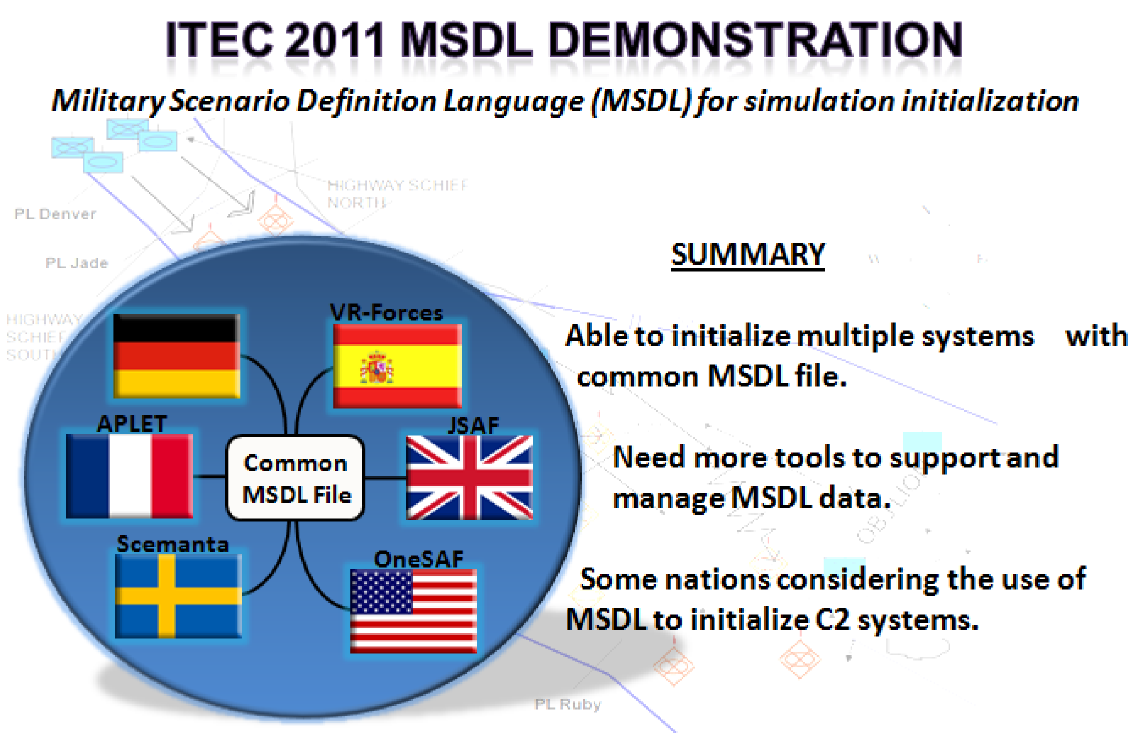

Figure 5-2: ITEC 2011 MSG-085 Scenario Initialization Demonstration.

5.3.1 Goals

The goals of the demonstration event are the following:

1) Validate that the MSDL standard could be used to merge coalition initialization inputs and support consistent initialization across a coalition simulation federation. Initial coalition participants included members from France, Germany, Great Britain, Spain and the United States;
2) Establish an engineering process and rhythm for coalition collaboration using MSDL and C-BML technologies within the MSG-085 organization; and
3) Provide lessons learned back to MSG-085 participants in the use of MSDL technologies in support of both simulation and C2 initialization.

5.3.2 Architecture

An independent distributed architecture was used by the individual Nations to provide their task organizations within independent MSDL formatted files to the MSDL integrator. The MSDL integrator then integrated the task organization and provided a final MSDL file back to all participants for import into their systems.

5.3.3 Results

The demonstration development activity produced the following feedback to the MSG-085 activity:

1) MSDL Integration tools are lacking, but could be developed in a short timeframe building on common tools such as Excel, Notepad++, and Visual Basic Scripting.
2) In addition to the MSDL standard data model federation agreements were necessary to ensure common interpretation of the data.

5.4 DECEMBER 2011 – I/ITSEC

The demonstrations performed during I/ITSEC 2011 extended the ITEC 2011 demonstration described above. The event focused on scenario initialization including pre-planned orders provided in C-BML format and referenced within the MSDL file. This demonstration also included MSDL/BML servers using different information exchange infrastructures while encouraging a maximum participation from the MSG-085 Nations. As shown in Annex A.2, the use-case being demonstrated was that of Distributed Coalition Training. The demonstration event included three demonstrations based on three different vignettes:

1) Air Reconnaissance;
2) Combined Operations and Logistics; and
3) Ground Manoeuvre.

The focus of the demonstrations was on leveraging both MSDL and C-BML for scenario initialization **and** execution, respectively. Multiple "Capability Harnesses" were provided to support the Nations' requirements for exchanging information among C2 system, simulation and tools for scenario initialization and execution. Demo Harness 1 was based on the GMU Scripted Server Infrastructure and Demo Harness 2 utilized the Coalition Battle Management Service (CBMS) infrastructure provided by the US Joint and Coalition Warfighting (JCW).

5.4.1 Goals

The goals of the demonstration event were the following:

1) There is a need to be able to initialize heterogeneous C2 and simulation systems in a coherent and systematic manner. MSDL can contribute to accomplishing this. This is the subject of continuing work and includes suggested extensions and amendments to both SISO C-BML and MSDL standards, consistent with the MSG-085 Programme of Work.
2) It is important to be able to conduct experimentation, and ultimately operational planning and training, using systems that are not co-located but distributed, potentially across several Nations. In principle, it should not matter whether systems are co-located, but in practice coordination is more difficult so processes and tools are required to coordinate and facilitate distributed activities. To this end, during the demonstration, C-BML systems were connected from nodes in Great Britain, Norway and the USA.
3) Real Command Post training activities involve more than combat-related tasks. Therefore, the addition of logistics reports allowed for a more realistic capability that added realism to the training environment.

Finally, one of the goals of this event was to demonstrate how the use of MIP products, such as a JC3IEDM database, can be employed as part of an information exchange infrastructure that can facilitate the exchange among systems that potentially use different schemas to define their message sets and other documents.

5.4.2 Architecture

Each of the three vignettes employed an independent distributed MSDL/BML Server implementation and architecture. The figures below depict the operational and technical view of each of the vignettes.

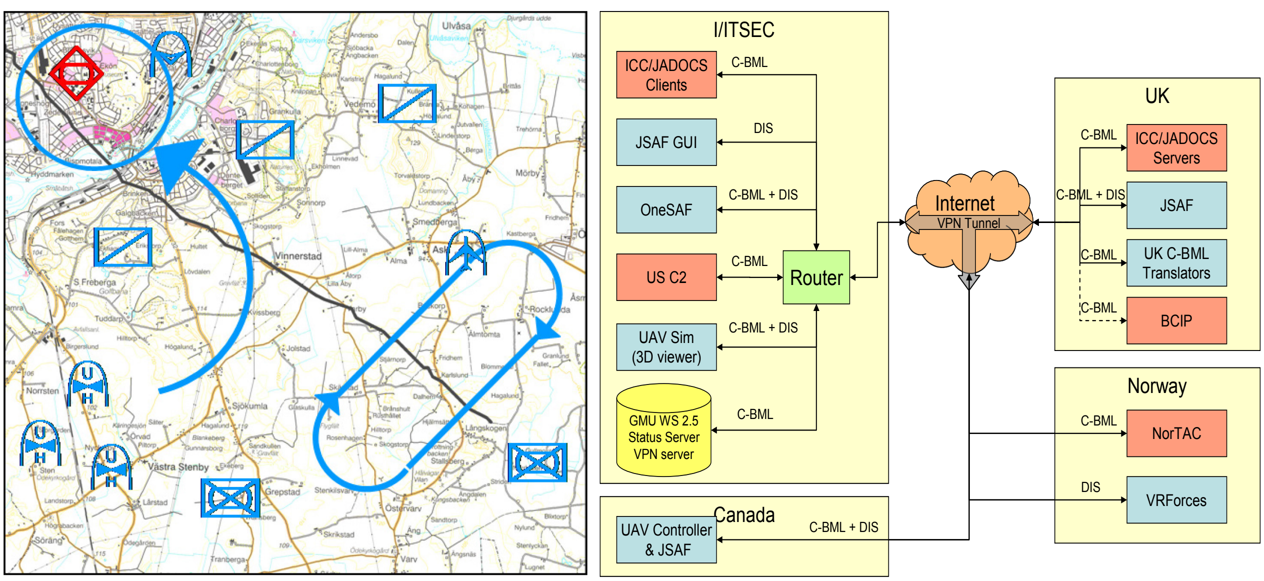

Figure 5-3: Air Reconnaissance Vignette.

5.4.3 Results

In addition to the results recorded from ITEC 2011 several positive conclusions were drawn from the vignette development and demonstration focused activities. The conclusions include:

- Two independently developed MSDL/C-BML messaging infrastructures were successfully used to service initialization/re-initialization and order-based message traffic to a variety of C2 and simulation clients;
- The MSDL transmittal file was successfully extended with logistics and C-BML related data; and
- The use of MSDL/C-BML within the simulation and C2 initialization process led to shorter scenario preparation times than previous experience without the MSDL technology.

Many C2 orders provided to the simulations in C-BML format require additional artificial intelligence within the simulations to execute them with minimal import and transformation of the order set.

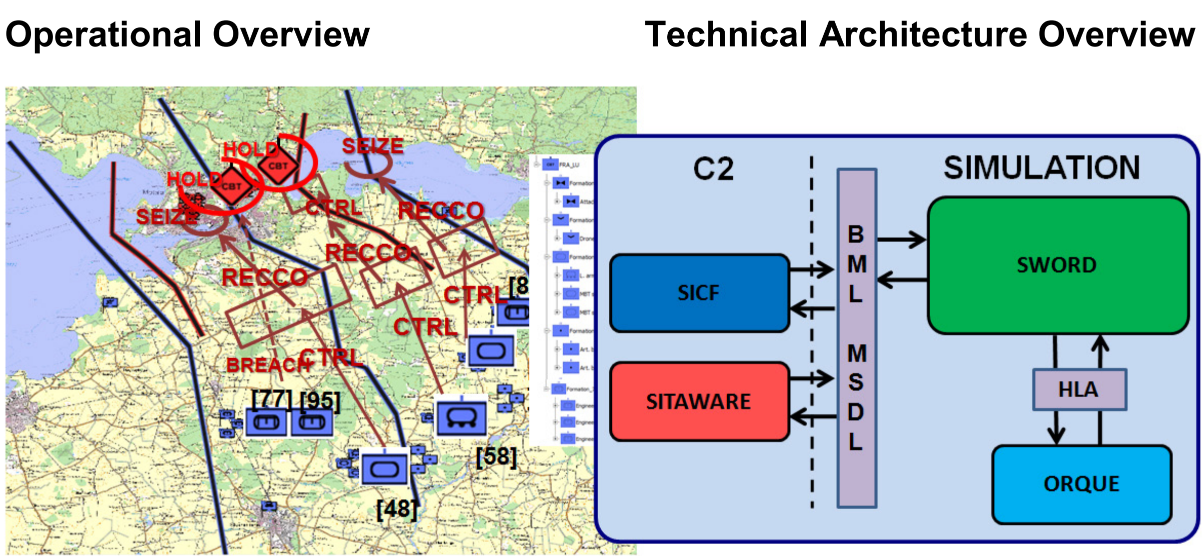

Figure 5-4 : Combined Operations and Logistics Vignette and Architecture.

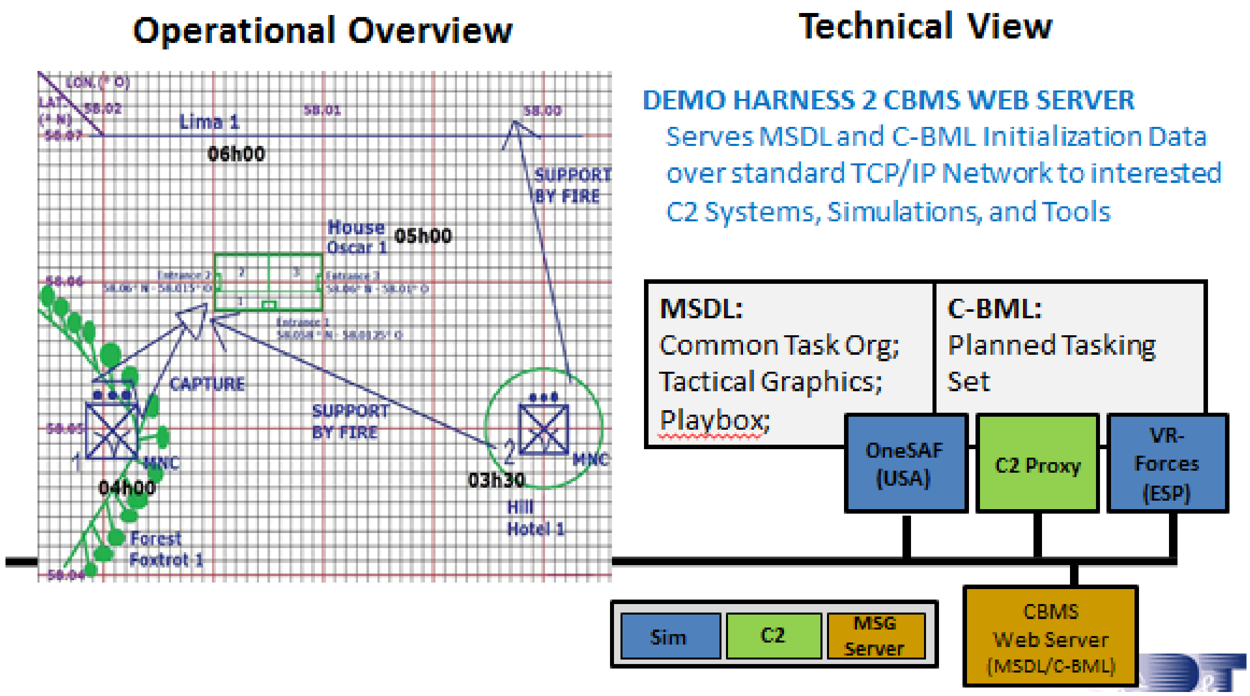

Figure 5-5: Ground Manoeuvre Vignette and Architecture.

5.5 SEPTEMBER 2012 – BML RESEARCH SYMPOSIUM

Organized by the George Mason University C4I Center with support from with support from MSG-085 members, the 2012 BML Research Symposium took place during the Fall 2012 SIW. Topics covered include:

- MSDL/C-BML alignment;
- Operational Requirements for C-BML; and
- C-BML Standards Development; and
- C-BML Messaging Software, (see Figure 5-6 for symposium overview and Annex A.3 for detailed agenda).

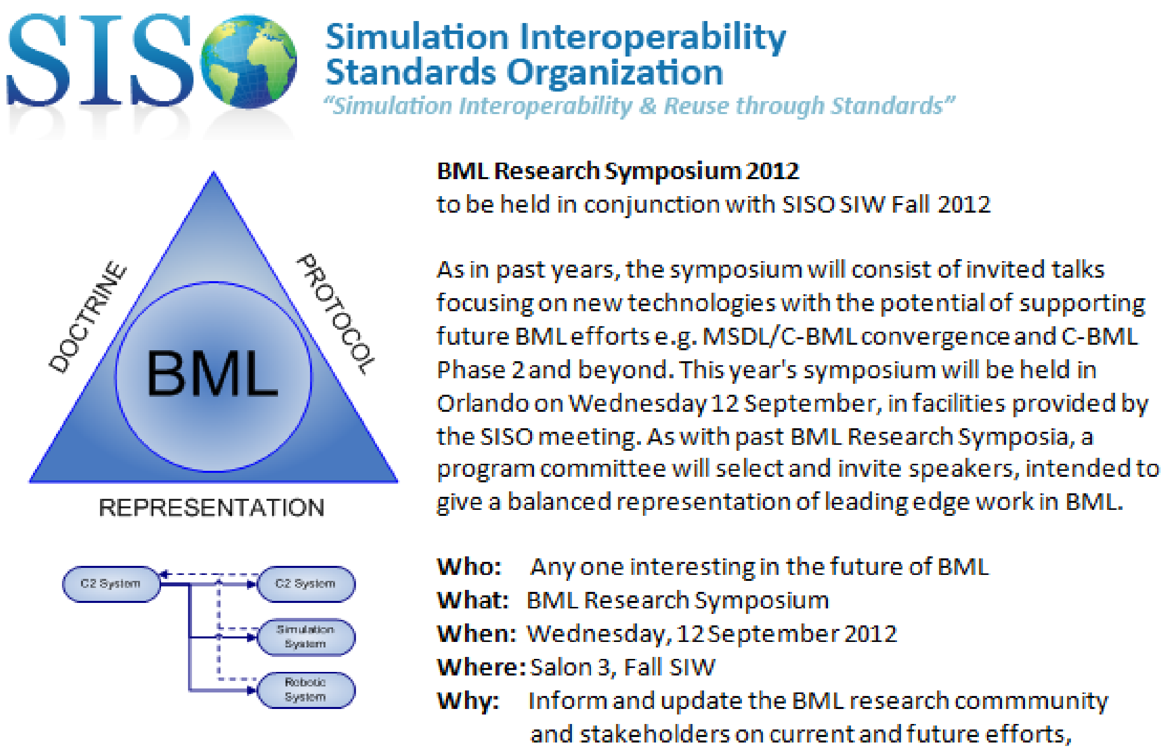

Figure 5-6: September 2012 BML Research Symposium Overview.

5.6 NOVEMBER 2012 – CIG WORKSHOP

In November of 2012, MSG-085 held a CIG Workshop in Fairfax, Virginia in order to share the results and findings of the various CIGs (see Workshop Agenda in Annex A.4). The workshop included detailed presentations and demonstrations with invitations to the operational community to attend.

Some CIGs provided live demonstrations with C2 and simulation systems while other CIG presented the results of analysis and other paper studies.

The workshop took place over several days. The first few days involved final preparation while the last day was reserved for the actual live demonstrations and briefings, as shown in the figure above. Briefings from each CIG presented the findings and lessons learned from their respective activities.

These results also were shared with the broader community during I/ITSEC 2012, during which a series of demonstrations were held at the NATO booth (see Section 5.7). In addition, several MSG-085 Nations shared the results and findings by participating in the NATO MSG-119 C2SIM Interoperability Workshop (see Section 5.8) that took place during I/ITSEC 2012. The results of the CIG efforts conducted in 2012 also were presented during the Spring 2013 SISO Interoperability Workshop (SIW), (see Section 5.9).

5.7 DECEMBER 2012 – I/ITSEC DEMONSTRATION

In early 2012 NMSG-085 formed a number of CIGs:

- Technical Infrastructure;
- Maritime Operations;
- Land Operations;
- Joint Mission Planning; and
- Autonomous Air Operations.

Each group comprising operational and technical specialists from across the MSG whose principal aim was to study requirements, use-cases and identify solutions relating to the use of C-BML and MSDL in these domains. An important aim of all the CIGs has been to work towards developing supporting knowledge and complementary skills which were used in MSG-085's final experimentation programme and contributed to the group's body of results and findings.

5.7.1 Goals

The goals of the demonstration event were the following:

1) To illustrate how it is possible to initialize heterogeneous C2 and simulation systems in a coherent and systematic manner.
2) To show the potential for conducting operational planning and training, using systems that are not co-located but distributed, potentially across several Nations.
3) To demonstrate the added realism of Command Post training activities by including more than combat-related tasks. Therefore, the addition of logistics reports allowed for a more realistic training environment.
4) To show how the C2SIM interoperability technologies developed by the Nations can be utilized across several domains, including land operations and also air operations that involved the use of operational ACO and ATO.

5.7.2 Architecture

Figure 5-7 and Figure 5-8 show the operational context and technical architecture for the Air Operations demonstration. Figure 5-9 and Figure 5-10 show the operational context and technical architecture for the Land Operations demonstration, Figure 5-11 and Figure 5-12 show the operational context and technical architecture for the Air/Land Recce demonstration.

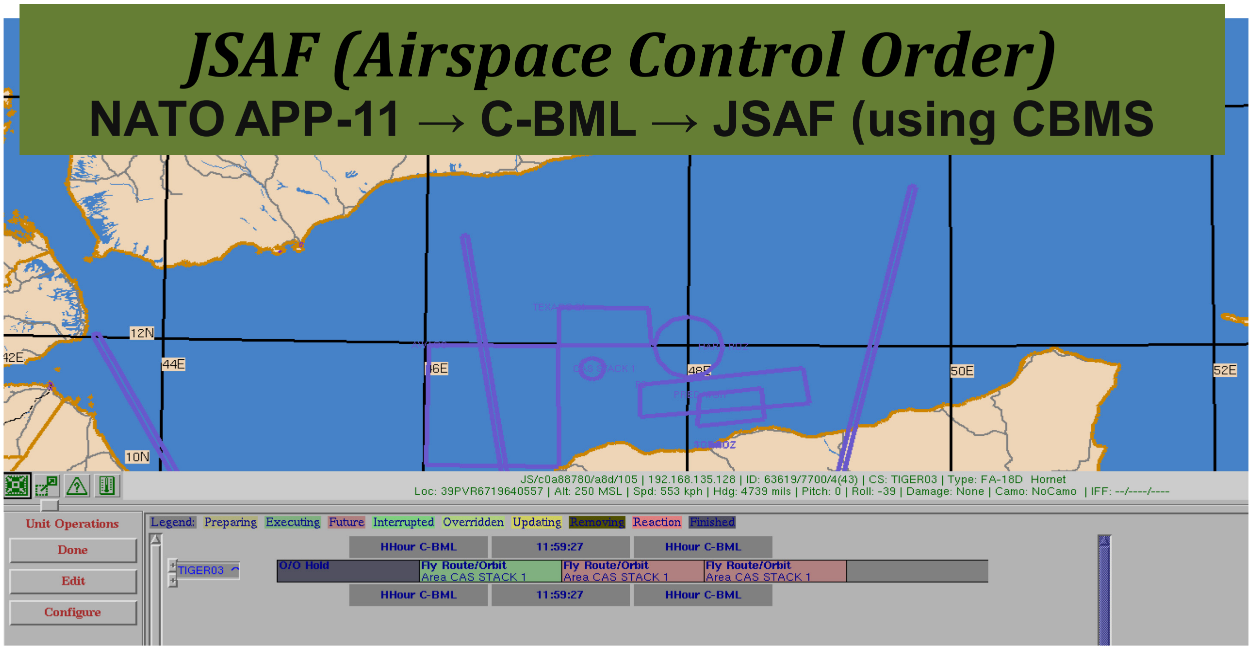

Figure 5-7: BML-Enabled Air Ops Context.

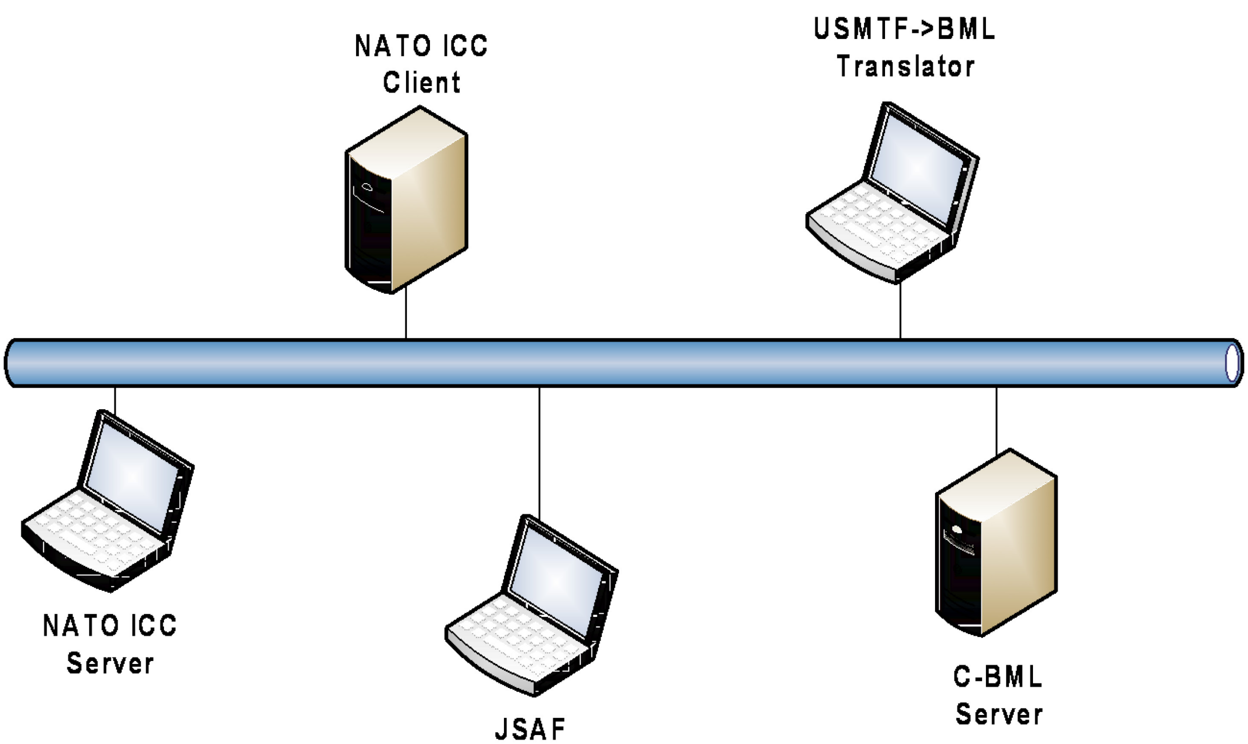

Figure 5-8: BML-Enabled Air Ops Architecture.

Figure 5-9: Land Ops Demo Context.

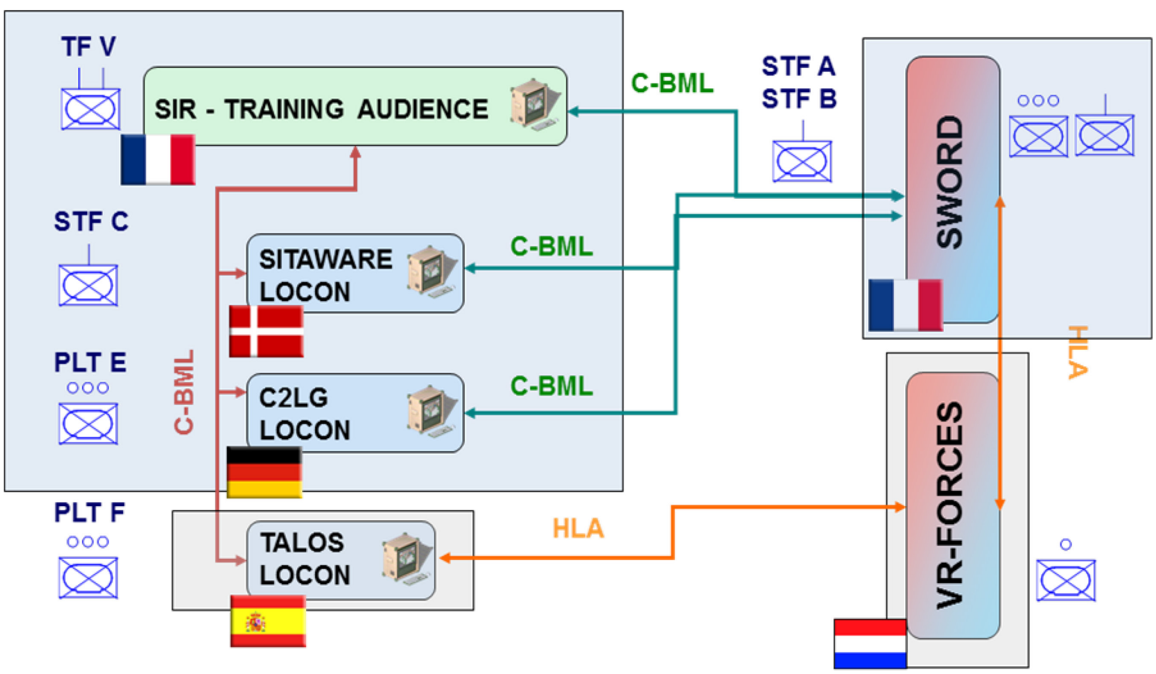

Figure 5-10: Land Ops Demo Architecture.

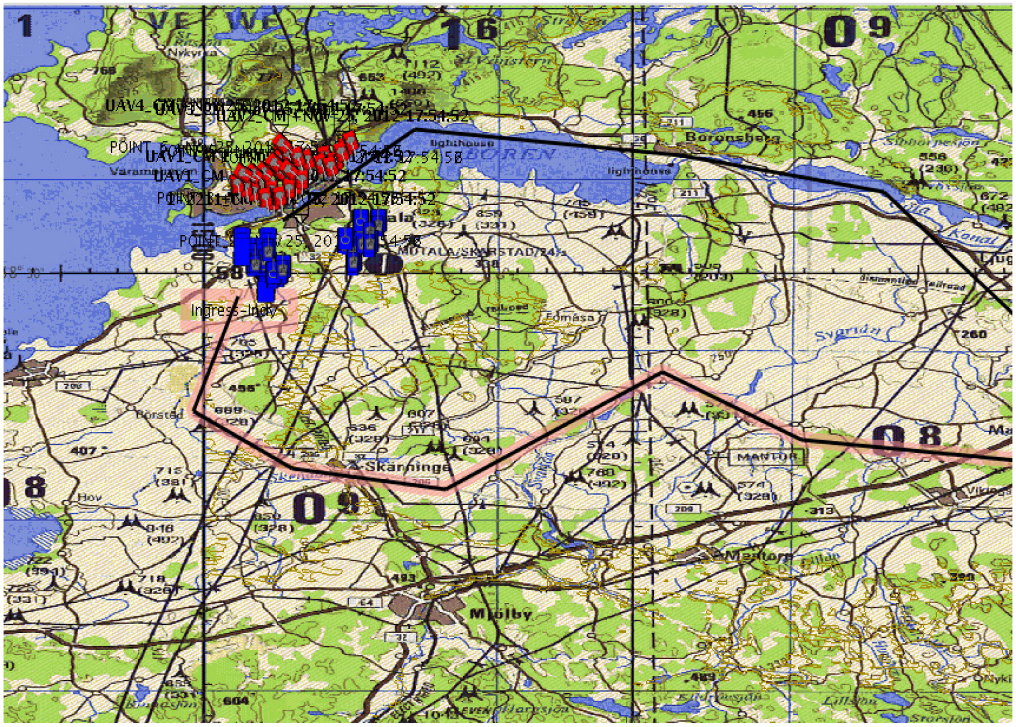

Figure 5-11: Air/Land Recce Demo Context.

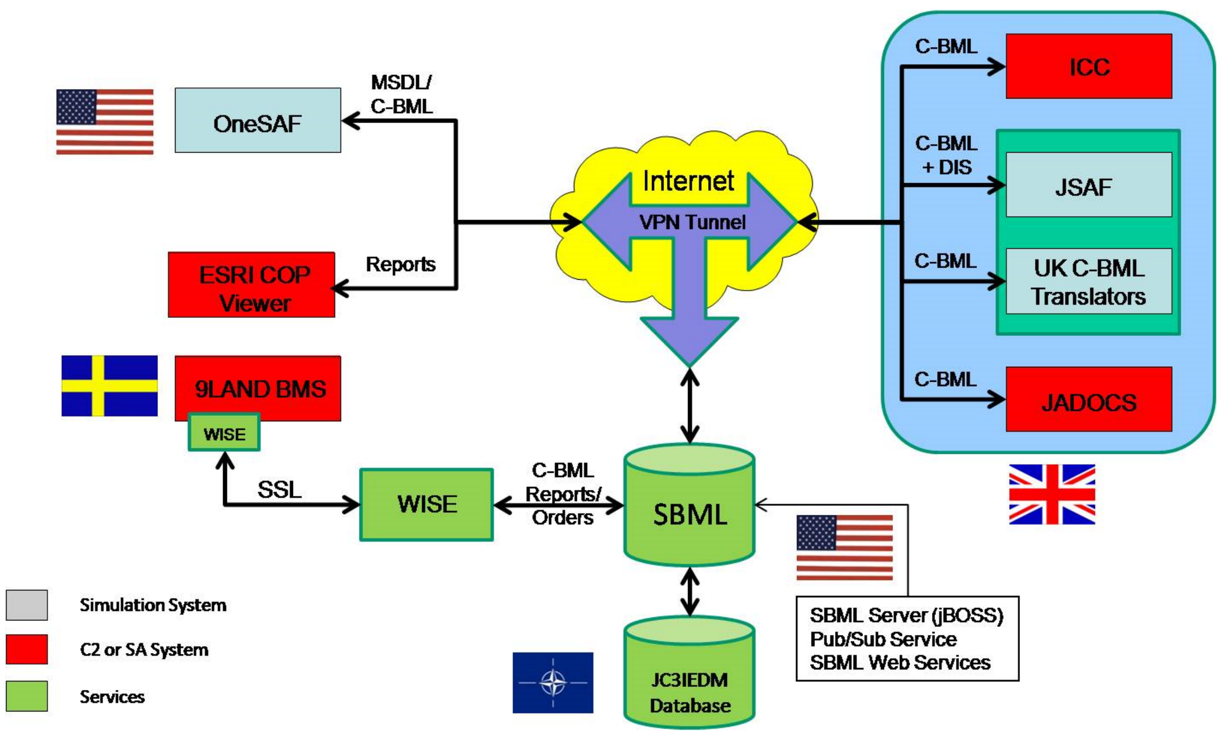

Figure 5-12: Air/Land Recce Demo Architecture.

5.7.3 Results

The demonstrations were well-attended and were repeated several times. They included participation from Nations participating remotely by connecting over internet.

5.8 DECEMBER 2012 – MSG-119 C2SIM INTEROPERABILITY WORKSHOP

Chaired by France, and organized by the NATO MSG-085 Technical Group, the NATO MSG-119 C2SIM Interoperability Workshop took place on Wednesday December 5th 2012 during the *Interservice Industry Training Simulation and Education Conference* (I/ITSEC) that was held from December 3-6th 2012. The MSG-119 workshop was attended by approximately 60 participants representing about 20 Nations. During the first part of the workshop a panel of technical experts provided overviews of the C2SIM interoperability standards (MSDL and C-BML) and on the use of C-BML messaging infrastructures to exchange information among C2 and simulation systems. Then a series of operational demonstrations were given to clearly illustrate the cost-savings, time-savings and other benefits of leveraging C2-to-simulation interoperability standards and also to show that technologies such as MSDL and C-BML are rapidly maturing toward a level consistent with operational employment by stakeholders.

Annex A.6 presents the workshop agenda and background information. The MSG-119 Technical Evaluation Report provides a summary of the workshop activities and discussions, and also offers a perspective on the state-of-the-art of C2SIM interoperability standards [8].

5.9 APRIL 2013 – SPRING SISO INTEROPERABILITY WORKSHOP

During the Spring 2013 SISO Interoperability Workshop, MSG-085 members presented a series of papers describing the results and findings from the CIG activities described in the previous sections. These papers included work from the Air, Land and Maritime domains and other C2SIM related work, (see Table 5-2).

Table 5-2: MSG-085 CIG Papers Presented at Spring 2013 SISO Workshop.

13S-SIW-002	A Systems Engineering Approach to M&S Standards Development: Application to the Coalition Battle Management Language
13S-SIW-009	C2SIM Interoperability Experimentation for Autonomous Air Operations
13S-SIW-022	Towards a Maritime Domain Extension to Coalition Battle Management Language: Initial Findings and Way Forward
13S-SIW-031	Lessons Learned from NMSG-085 CIG Land Operation Demonstration
13S-SIW-032	Low-Level Battle Management Language
13S-SIW-039	Next Steps in MSDL/C-BML Coordination for Convergence

5.10 JUNE 2013 – C2SIM INTEROPERABILITY SESSION DURING ICCRTS 2013

During its Wachtberg meeting in February 2013, MSG-085 agreed to support a BML Symposium in conjunction with the International Command and Control Research and technology Symposium 2013 (ICCRTS-2013) and designated Dr. Mark Pullen of the GMU C4I Center to contact the management of ICCRTS-2013 and work out a plan for achieving this. During that process, ICCRTS General Chair Dr. David Alberts offered to create a Track addressing C2SIM Interoperability. Dr. Hans Jense of NCIA agreed to provide a kick-off talk and was co-opted by ICCRTS as a plenary speaker, which had the commendable effect of exposing the benefits of C2SIM and the work of MSG-085 to other attendees. Other authors and presenters recruited from academia, government and industry for the Track are listed below. Many of these presentations were made by MSG-085 participants. Technical papers[1] and industry presentations are shown in Table 5-3 and Table 5-4.

Table 5-3: MSG-085 Papers Presented at ICCRTS 2013.

Kevin Heffner, Nico Bau, Michael Gerz: *An Approach Using MIP Products for the Development of the Coalition Battle Management Language Standard*
Saikou Diallo, Ross Gore, Anthony Barraco: *Integrating CPOF, JSAF and ONESAF through CBMS*
Kevin Heffner , Kevin Gupton: *Implementing a Standards Development Framework for the Coalition Battle Management Language*[2]
Per Gustavsson: *Developing a Command and Control Methodology for Increased Automation – Using Simulation to Improve Mission Planning and Execution*
Per Gustavsson, Michael Hieb: *The Operations Intent and Effects Model: A Command and Control Methodology for Increased Automation*
J. Mark Pullen, Douglas Corner, Per Gustavsson, Magnus Grönkvist: *Incorporating C2SIM Interoperability Services into an Operational C2 System*
Thomas Remmersmann, Ulrich Schade, Alexander Tiderko: *Interacting with Multi-Robot Systems Using BML*
Shim, Lee, and Cho: *Analysis for Information Exchange Capability of Battlefield Networks Using M&S*

Table 5-4: Industry Presentations Presented at ICCRTS 2013 C2SIM Session.

Jonas Hällström, Saab: *C2 in Tactical Operations: Train as you Fight*
Kevin Galvin, Thales: *Potential Exploitation of C2-Sim Interoperability Research to Support the UK Warfighter*
LtCol Bernardo Neto, Brazilian AF: *C2-Simulation Studies in ITA-GMU Testbed*
Robert Wittman, MITRE: *Command Web: Operational Web-Enabled C2-Simulation*

[1] For more details, see http://www.dodccrp.org/events/18th_iccrts_2013/post_conference/html/home.html.

[2] Nominated for Symposium Best Paper.

5.11 DECEMBER 2013 – I/ITSEC DEMONSTRATION[3]

MSG-085 held a series of demonstrations highlighting the benefits of the latest technologies for C2SIM interoperability to the Warfighter. Battalion and Brigade level Joint and Combined Mission Planning demonstrations were given at the NATO booth. These demonstrations illustrated how these technologies could be used to perform mission planning in a more effective, collaborative fashion. Another series of demonstrations were given that provided an overview of the SINEX process and toolset: a collaborative approach to developing and maintaining C2SIM interoperability standards.

5.11.1 Goals

The goals of the demonstrations were:

- To show illustrate how C2SIM interoperability solutions also can lead to new ways of performing military activities such as joint and combined mission planning; and
- To present a new approach for specifying, building, evolving and sharing C2SIM interoperability solutions using an engineering process.

5.11.2 Architecture

The operational context and technical architecture are shown in Figure 5-13 and Figure 5-14, respectively. They are the same as those utilized for the final demonstration that took place the following week.

Figure 5-13: I/ITSEC 2013 Scenario.

[3] See NATO press release at: http://www.cso.nato.int/page.asp?id=1682.

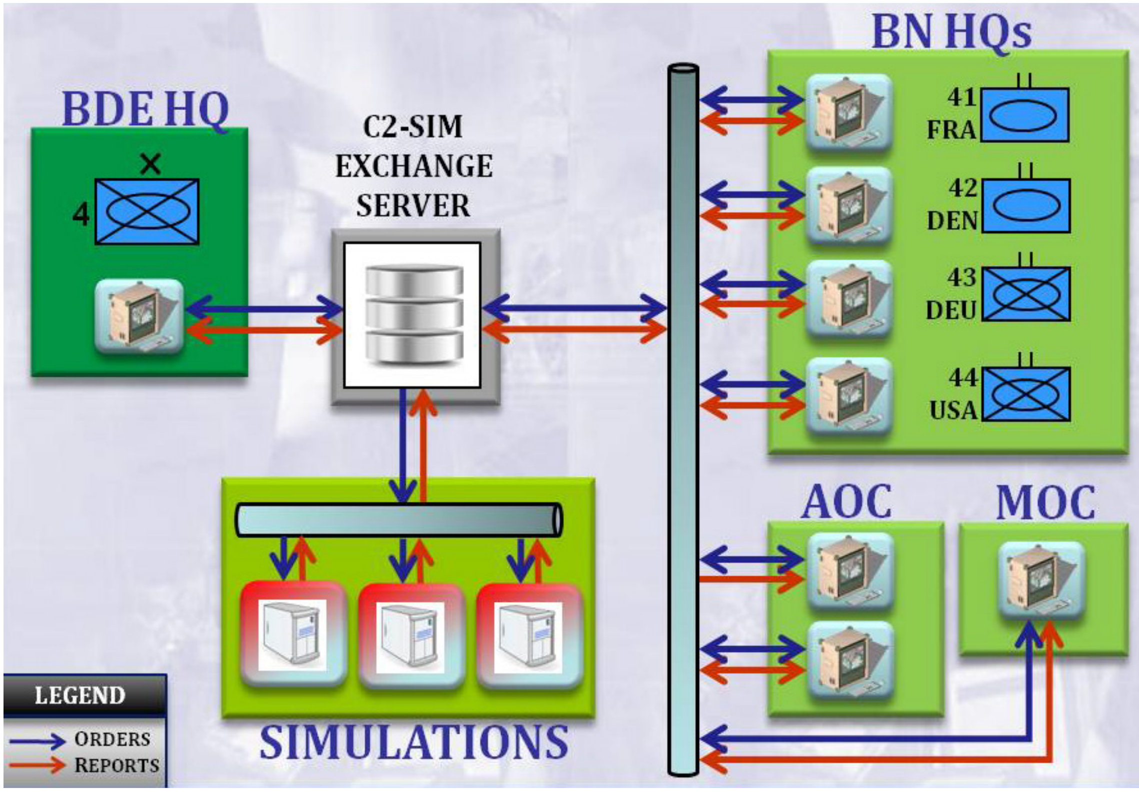

Figure 5-14: I/ITSEC 2013 Architecture.

5.11.3 Results

The demonstrations were well-attended and were repeated several times. The mission planning exercises included participation from Nations participating remotely by connecting over internet.

The SINEX demonstration illustrated how it is possible to rapidly generate an XML schema based on a common information model using a structured approach and a highly automated toolset. The resulting XML schema then can serve as the basis for a standardized or community-specific C2SIM information exchange. The SINEX collaborative approach to developing and maintaining C2SIM Interoperability standards demonstrated military information can be shared efficiently among C2 and simulation systems for the purposes of performing military enterprise activities. The SINEX demonstration was based on the architecture and prototype described in Chapter 4 and illustrated in Figure 4-6 and Figure 4-7.

5.12 DECEMBER 2013 – FINAL DEMONSTRATION, US ARMY MCBL

MSG-085 presented a demonstration featuring military operational use of C2 systems interoperating with combat simulations on 12 Dec 2013. The demonstration was hosted by the Mission Command Battle Laboratory (MCBL) at Fort Leavenworth, Kansas, and featured six national non-US C2 systems and five national simulations, supported by servers from two different Nations, linked into a single system-of-systems. Standards used were the Military Scenario Definition Language (MSDL), Coalition Battle Management Language (C-BML), along with elements of the JC3IEDM.

The operational focus of the demonstration was joint and combined mission planning, operating in a breakthrough parallel, collaborative mode across Brigade and Battalion echelons of a multi-national coalition force. Personnel and systems from nine Nations (23 personnel) participated at Leavenworth while personnel from Spain and the United Kingdom participated from their home locations via Internet links. Military SMEs provided by the MCBL played roles of Brigade and Battalion Commanders and contributed a critique of the operational employment that was highly positive and also offered avenues for future improvement.

The demonstration was well attended by US and international military and supporting civilian personnel, who offered mainly positive comment and also recommendations to improve operational utility, for example the need to resolve security issues before deployment. The senior military attendee was Brigadier General Thomas S. James, Director of the US Army Mission Command Center of Excellence, who stated very positively that the category of systems demonstrated by MSG-085 should have an important role in supporting a wide range of future military operations by the US and its coalition partners.

5.12.1 Goals

The main purpose of the demonstration was to show how C2SIM interoperation technologies can be used to facilitate collaborative distributed planning. In particular, the goal of the demonstration was to show that these technologies can contribute to increased collaboration among Brigade and Battalion Commanders during COA development.

5.12.2 Architecture

The featured capability was *Joint and Combined Mission Planning*. The architecture of the demonstration system-of-systems that was assembled is shown in Figure 5-15.

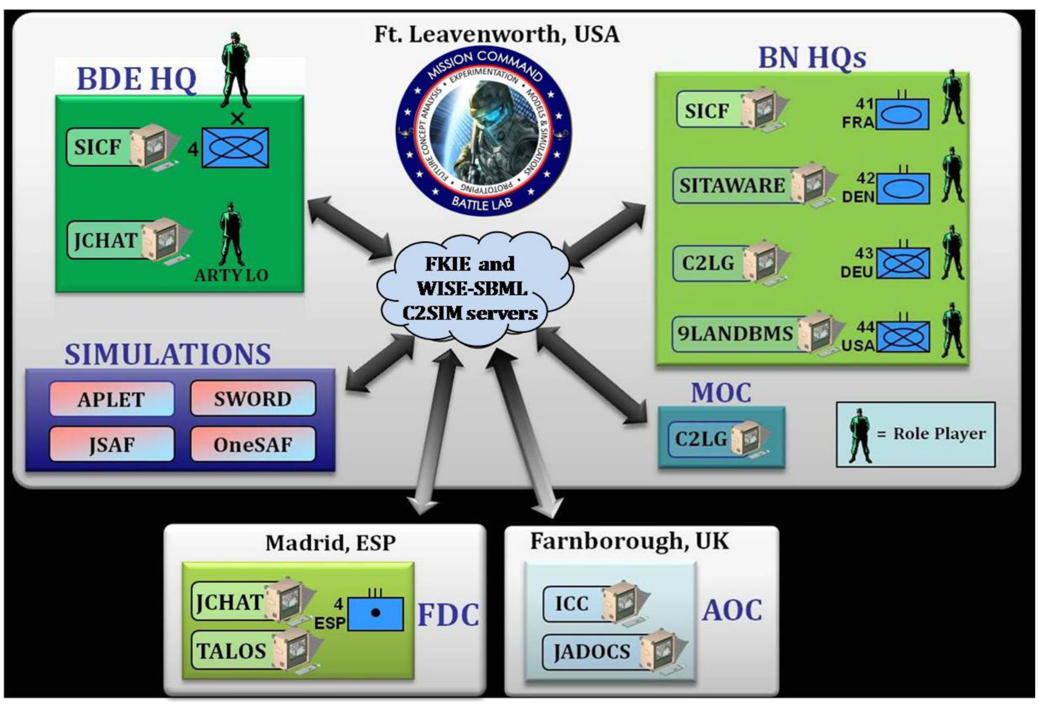

Figure 5-15: MSG-085 Final Joint and Combined Mission Planning Demonstration Architecture.

5.12.3 Results

The main results of the demonstration can be summarized with respect to the following achievements:

- *Network Sophistication*: The MSG-085 network included two remote participants and operated with two linked servers and three schemata (C-BML Full, while available on the WISE-SBML server, was not used by any of the systems). This models the sort of operation expected in operational BML use.
- *Setup Process*: The MSG-085 systems came together smoothly. There were a few problems but mostly they "just worked".
- *Audience Impression*: The Final Demonstration audience got the message "We have an exciting new capability and it works very well to improve some unmet needs of coalition C2, using interoperable simulations."

In short, MSG-085 succeeded in achieving the main demonstration goal: proving the concept that C2SIM in the form of MSDL and C-BML is ready to be tested in real coalition operations.

5.13 JUNE 2014 – C2SIM INTEROPERABILITY SESSION DURING ICCRTS 2014

Following the success of the C2SIM track in ICCRTS-2013, MSG-085 decided during its Copenhagen meeting in October 2013 to support a C2SIM Interoperability Track at ICCRTS-2014, and again turned to Dr. Pullen to coordinate. Although Dr. Alberts had not been planning to repeat this topic, he readily agreed to add it. In 2014 there will be only paper presentations (no industry briefings), but nevertheless the track covers two full days of the conference, a new first for BML technical meetings. Again in 2014, many of the presentations are by MSG-085 participants:

Technical papers[4]:

- Adam Brook: *UK Experiences and Lessons Identified Using C-BML in Practical Experiments*.
- Brett Burland, LtCol Jens Inge Hyndøy, James Ruth: *Incorporating C2-Simulation Interoperability Services into an Operational Command Post*.
- Bruno Gautreau, Kevin Heffner, Ole-Martin Mevassvik, Nico de Reus, Lionel Khimeche: *A Proposed Engineering Process and Prototype Toolset for Developing C2-to-Simulation Interoperability Solutions*.
- James Hilton, Saikou Diallo, Ross Gore: *C2 Agility: Lessons Learned from Research and Operations*.
- Lt Cdr Patrick Lara: *A Message Exchange Protocol in Command and Control Systems Integration, Using the JC3IEDM*.
- Francisco Loaiza, Steve Wartik, John Thompson, Dale Visser, Edward Kenschaft: *The Best of All Possible Worlds: Applying the Model Driven Architecture Approach to a JC3IEDM OWL Ontology Modeled in UML*.
- LtCol J. Bernardo Neto, Michael Hieb, Paulo Costa: *Agility through Automated Negotiation for C2 Services*.
- J. Mark Pullen, Lionel Khimeche: *Advances in Systems and Technologies Toward Interoperating Operational Military C2 and Simulation Systems*.

[4] For more details, see: http://www.dodccrp.org/events/19th_iccrts_2014/post_conference/html/track9.html.

- Thomas Remmersmann, Ulrich Schade, Alexander Tiderko: *Commanding Heterogeneous Multi-Robot Teams*.
- Samuel Singapogu: *Opportunities for Next Generation BML: Semantic C-BML*.
- Robert Wittman: *OneSAF as an In-Stride Mission Command Asset*.

5.14 OCTOBER 2014 – C2SIM INTEROPERABILITY WORKSHOP

The possible topics to be covered include:

- Overview of Key Military Enterprise Activities addressed by C2SIM Interoperability.
- Update on C-BML and MSDL Standardization.
- Summary of MSG-085 Technical Activity:
  - Results and findings; and
  - Recommendations for standardization.
- Highlighted use-cases leveraging C2-SIM interoperability:
  - Successful use of MSDL and C-BML standards; and
  - National and coalition experimentation.
- Introduction to the Scenario INitialization and EXecution (SINEX) Initiative.
- Present the new NATO MSG C2SIM Interoperability Technical Activity.

5.14.1 Scope

Through presentation, discussion and debate, attendees will acquire knowledge and experience in the different topic areas to exploit C-BML and MSDL technologies.

It is expected that all participants will develop a shared understanding of the issues and opportunities regarding the use of C-BML and MSDL standards to ease C2SIM interoperability.

Meeting proceedings will be produced including recommendations for NATO and the Nations.

5.14.2 Registration

Please visit www.cso.nato.int and look for registration details for MSG-138.

5.14.3 Agenda

0830 – 0900: Registration

0900 – 0945: Overview of C-BML and MSDL Standards Development (USA / Dr. Robert Wittman)

0945 – 1030: History of C2SIM NATO Activities (FRA / Mr. Lionel Khimeche)

1030 – 1100: Break

1100 – 1130: Leavenworth Demonstration Operational Impact (NOR / LtCol Hyndoy)

1130 – 1200: Leavenworth Demonstration Technical Impact (DEU / Mr. Thomas Remmersmann)

1200 – 1330: Lunch

1330 – 1400: Foundational Infrastructure (USA / Dr. Mark Pullen)

1400 – 1430: C-BML Maritime (NOR / Mr. Ole Martin Mevassvik)

1430 – 1500: VBS2, C-BML FOM and MSDL (GBR / Dr. Kevin Galvin)

1500 – 1530: Break

1530 – 1600: Mission Command Embedded Simulation Systems Services (USA / Mr. Amit Kapadia)

1600 – 1630: Brainstorming and wrap-up (USA / Dr. Robert Wittman)

Chapter 6 – LESSONS IDENTIFIED AND LESSONS LEARNED

The NATO Lessons Learned Handbook distinguishes among: *lessons identified, lessons learned* and *lessons learned information* as follows [17]:

Lesson Identified (LI)	*This is a mature observation with a determined root cause of the observed issue and a recommended remedial action and action body, which has been developed and proposed to the appropriate authority.*
Lesson Learned (LL)	*An improved capability or increased performance confirmed by validation when necessary resulting from the implementation of one or more remedial actions for a lesson identified.*
Lesson Learned Information (LLI)	*Any information that is generated as part of a LL process as well as information generated after activities that is not formally part of a LL process such as after action reviews, periodic mission reports, first impression reports, final exercise reports, trip reports, hot wash up output, meeting minutes, etc. (proposed definition).*

This chapter describes the LI, LL and LLI from the various experimentation events, communication events and other activities such as analysis or modelling.

6.1 VARIABILITY OF C2SIM INTEROPERATION REQUIREMENTS (LL)

C2SIM Interoperation requirements vary across services, Nations and also depend on the themes and focus areas of specific training, mission rehearsal or experimentation events.

Inherent differences in the manner in which military operations are conducted by different forces must be taken into account in the development of C2SIM interoperability standards. This lesson learned has resulted in the recommendation to track stakeholder requirements as part of the standardisation process and has led to a proposed C2SIM Interoperability Standardisation and Extension Process.

Furthermore, various organisations have different goals and roadmaps concerning their expectations concerning the Return On Investment (ROI) of employing C2SIM interoperability technologies. For example, for some stakeholders, the desired goal may be to reduce the number of simulator operators required to hold a specific training event. This is an example of a **cost-reduction measure** for a **sustaining capability**. Other stakeholders are focused on **future capability development** that ultimately implies a changing how military operations are conducted. For example enhanced automated information exchange as an enabler for self-synchronisation of the battlefield is an example of a **disruptive technology** for a **future capability**. Figure 6-1 illustrates the differences and implications of introducing sustaining and disruptive technologies into military enterprise activities to establish new capabilities, Concepts of Employment (CONEMP) and Concepts of Operations (CONOPS)[1].

[1] A CONOPS or CONEMP generally evolve from a concept and is a description of how a set of capabilities may be employed to achieve desired objectives or end state.

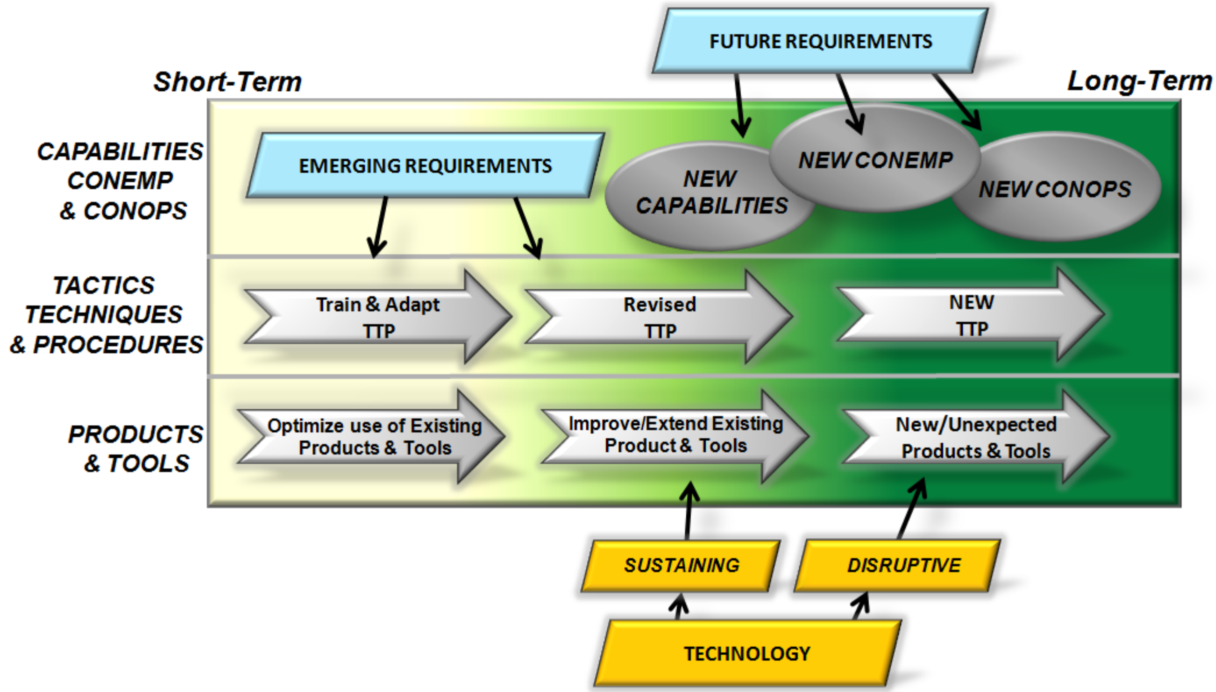

Figure 6-1: Sustaining versus Disruptive Technologies [c/o Pegasus Research and Technologies].

As different communities and Nations work toward establishing common data interoperability standards, it is essential that differences in requirements and expectations among stakeholders are properly recorded and managed such that an appropriate C2SIM interoperability standard roadmap that is suitable to all parties can be constructed.

6.2 COMBINED STANDARD SCENARIO DEFINITION, INITIALISATION AND EXECUTION (LL)

Military enterprise activities such as Command Post training generally require *scenario definition*, *scenario initialisation* and *scenario execution*.

These are all part of the same workflow and maintaining separate standards for military scenario definition and for military scenario execution can be problematic. Therefore a more holistic approach to military scenario definition, initialisation and execution likely would be more practical and economical to implement.

The end-goal of stakeholders is to conduct military enterprise activities such as training, experimentation or the conduct of operations. For this, they require a functional, representative system-of-systems that includes a C2SIM federation. Therefore, it is important to place the focus on defining the means to simplify the definition, construction and execution of C2SIM federations.

Maintaining separate standards for scenario definition (i.e. MSDL) and for scenario execution (i.e. C-BML) leads to significant time being spent in defining and evolving these standards and also in applying these standards to systems. These standards should be merged in order to form a coherent, unified standard for Military Scenario Initialisation and Execution.

Furthermore, throughout the experimentation programme, experience has shown that specifying schemas for scenario initialisation and execution is not sufficient. System Design Agreements also are required to ensure that the C2SIM federation is able to function properly and support the goals of the military enterprise activity. Therefore, similar to the DSEEP approach taken by the simulation community, there is a need to standardise the process by which C2SIM federations are designed and executed. This is further discussed in Section 6.5.

6.2.1 C2SIM Core (LI)

The SISO MSDL/C-BML specifications are sufficient for basic operations of manoeuvre warfare, but insufficient to meet the broader need of other military operations and support functions.

There exists a core set of BML who/what/when/where data that is nearly universal for military orders and reports of all Nations participating in MSG-085; it was largely captured in the IBML09 schema defined for MSG-048 and proved its utility again in the MSG-085 final demonstration, where it was satisfactory for all the air/ground activities desired by the Operational Sub-Group. All indications were that it would have been satisfactory for maritime operations as well, but in the end those operations were not carried out. However, beyond this core, a wide variety of data elements and document contexts are needed for the full breadth of BML. Yet creating a single massive schema leads to impractical complexity. Requirements for C2SIM interoperation vary across services and Nations; and they also depend on the themes and focus areas of specific training, mission rehearsal or experimentation events. Thus, an approach that standardises a core data model and methods for extending that model to needs of a specific instance is the clear path forward.

6.2.2 Need to Create Unified C2SIM Standard (LL)

The SISO MSDL and C-BML specifications can be made to function together, but new, harmonised versions are required for most effective C2SIM interoperation.

The SISO MSDL and C-BML standards can be made to function together, although this requires ignoring some aspects of each. However, they were not designed to work together so their approach to combining initialisation and tasking/reporting is not harmonious. A new generation of BML standards where initialisation and tasking/reporting are integrated and harmonised is needed in order to meet future BML needs in the coalition environment. The standard could be packaged either as one unified specification or in two parts, initialisation and tasking/situational awareness. However, it is essential that the package be fully integrated, which in turn will require an integrated SISO Product Development Group (PDG). Participants in the current SISO MSDL and C-BML PDGs have recognised this and have voted unanimously to reorganise as a single PDG before the end of 2014.

6.2.3 Standardising Core Data Model versus Schema (LI)

It is more effective to standardise a core data model and procedures to extend it, than to standardise a schema.

It is reasonable to infer that MSG-085 implementers of C-BML found the SISO C-BML Phase 1 “Full Schema” to be impractical to implement. Several MSG-085 implementers so stated and none of them chose to use the “Full Schema”, even though it was possible to interoperate it with other schemata in use, using the schema-translating server capability that was available. Yet, despite its complexity, it is clear that the “Full Schema” is inadequate to provide tasking and situational awareness for many aspects of military operations, for example logistics, engineering, medical services, and telecommunications. Another group developing interoperability capabilities for NATO, the Multi-lateral Interoperability Programme (MIP) was faced with a similar explosion of complexity. MIP has explored an alternative which they have shown to be effective: create a core data model, provide tools and standard methods to expand that model as needed, and also provide tools to generate an instance schema on ad-hoc basis. The MSG-085 "2RS" CIG explored this approach in depth and has developed a convincing demonstration of its utility.

6.2.4 C2SIM Standard Extensibility (LI)

The "one-size-fits-all" approach is not viable for building C2SIM interoperability standards.

Differences across services, Nations and other communities make it impractical to try and develop a standard that meets all requirements from all stakeholders for all activities. Therefore, C2SIM interoperability standards must provide the "greatest common denominator" AND allow for rapid and easy extension of standards products as required to meet specific C2SIM federation requirements.

Therefore, a data interoperability approach that defines a common core that is extensible has many advantages over an approach that seeks to establish a *universal* standard that can meet the requirements of all communities.

6.2.5 C2LG Tasking Grammar (LL)

The C2LG Tasking Grammar provides a useful basis for unambiguous tasking and situational awareness in C2SIM interoperation that can be extended to a full semantic capability.

The MSG-085 Technical Sub-Group made a study of the role of grammar in tasking. Grammar defines structure and syntax, but does not include the semantics that determine whether expressions "make sense" or not. For example, using SISO C-BML it is possible to task a tank to fly. The C2LG was developed to be, in the words of Albert Einstein, "as simple as possible, but no simpler than that" as a means of representing C2 information that is used by automated processes. It limits tasking to a set of very simple structures and introduces lexicality and thematic roles that constrain statements to those that make sense. If fully implemented, it will not allow an order for a tank to fly. Future BML systems can be expected to feature an expanded role for semantics, for example: including "frames" that consider whether the "what" action is consistent with the "where"; including "types" for objects that restrict conditions under which they are referenced; and considering the capabilities of each "who" when they are tasked. Such future systems will, as a first step, include C2LG or a similar grammar to deal with frames and types and, as a second step, an ontology to capture the capabilities. As a result, automated systems will issue taskings that make sense, just as human warfighters orders couch their tasks in the light of the constraints of the real world.

6.2.5.1 Pragmatic Approach (LL)

The successes achieved during the MSG-085 demonstrations and experiments are largely due to the pragmatic approach to grammar that was employed. Example expressions were been derived from the different grammar proposals in order to determine the content these expressions conveyed. Then, a family of XML schemata were developed. Although some variations existed among these schemata, collectively they were able to convey the relevant content required for the various demonstrations and experiments. Reference [19] is an internal document that has been generated by MSG-085 and includes sets of BML expressions for ground operations, air operations, and maritime operations that were used in MSG-085's experiments and demonstrations (see Chapter 5). Information exchange using BML messages during some of these events entailed the use of multiple BML web services (e.g. GMU and the FKIE).

One problem that was encountered was that some simulation systems require that certain task assignments include specific geographical features in order to interpret assigned task as intended. At times, the required geographical feature data is not part of the BML expression. For example, an *attack*[2] task is defined as: "*to conduct a type of offensive action characterized by coordinated employment of firepower and manoeuvre to close with and destroy or capture the enemy*." However to execute an attack task, some simulation systems do not require to specify the enemy but rather require a geographic point as a target. The solution to this problem that was adopted was to provide the location of the enemy as a geographical target point. This proved sufficient as long as the enemy did not move substantially during the period of time between the issue of the order to attack and the execution of that order. In some instances, additional geographic information was required for attack tasks. For example, the French simulation system require coordination lines, namely left and right border of the attack corridor, to execute attack tasks. This problem illustrates that although the semantic grounding of BML on the JC3IEDM has proven to be successful, there are limits when tasks implemented in a simulation system do not agree with the corresponding definition of the same task in JC3IEDM. Also, in some cases the JC3IEDM does not fully cover Nation-specific or service-specific doctrine that may be implemented in simulation systems.

6.2.6 Advanced Grammar Approaches (LI)

The BML Grammar must meet the needs of a wide range of requirements with varying level of complexity.

As mentioned in Section 6.1, there are significant differences in requirements and expectations across stakeholders from different communities and Nations. Some Nations require only a simplified grammar to capture the structure and syntax of structured data messages in support of sustaining capabilities.

A grammar typically defines structure and syntax and does not include the semantics that determine whether expressions "make sense" or not. Advanced grammar approaches may introduce the *lexicality* or *thematic roles* that introduce business rules into the grammar. This approach can be useful for some future capability development that will involve intelligent systems or automated systems that will process complex messages, some of which may involve natural language type expressions. However, it cannot be assumed that this is the general case. Therefore, the grammar might be restricted to a simple set of production rules that specify only structure and syntax. However, a mechanism is required to specify business rules such that they can be communicated independently of the messages and/or utilized as part of advanced grammar approaches.

6.2.6.1 Production Rules versus Business Rules (LI)

It is important to separate the production rules (i.e. grammar) from the business rules. The grammar is common to all users of the standards whereas the Business Rules may depend on national doctrine or specific rules of engagement. For illustrative purposes, production rules should allow for the construction of the following statement:

(1) **UNIT_1** *tasks* **UNIT_2** *to* **MOVE** *from* **LOCATION_1** *to* **LOCATION_2** *at_time* **T1**.

However, it then becomes important to be able to define business rules that complement the production rules. Examples of possible business rules are:

[2] As per the JC3IEDM 3.1.4 definition.

(2)

For **MOVE** *with* **NUM_OF_LOCATION = 2; LOCATION_1** *cannot_be_equal_to* **LOCATION_2.** **UNIT_1** *is_not_subordinate_of* **UNIT_2.** **T1** *is_equal_or_greater_than* **OPERATIONAL_TIME_STAMP.**

To support complex grammar approaches, it therefore is necessary to specify business rules in a manner that allows for their translation as *complex* production rules, such as those specified by Lexical Functional Grammar approaches. Toward this goal, business rules may be defined using one of the so-called *rules languages* such as the Rules Interchange Format (RIF) family of languages [26]. The use of RIF languages also is consistent with an ontology-based approach discussed further in Section 6.6.1.

6.2.6.2 Lexical Functional Grammar Approaches (LI)

Lexical Functional Grammar (LFG) approaches for C2SIM interoperability languages such as C2LG and OIEG have been proposed for consideration by standardization bodies and therefore have been considered during the MSG-085 Technical Activity. However, the C2LG approach is much simplified compared to *classical* LFG languages since, for example, it does not include f-structures or a-structures. The most important feature in C2LG that has been borrowed from the LFG approach is the concept of lexicality. This offers in a simple way LFG's principles of completeness and coherence. Otherwise, the grammar would allow orders like:

(3)

UNIT_A1 *tasks* **UNIT_A**2 *to* **ADVANCE** *for* **UNIT_ B** *at* **CONTROL_POINTBRAVO** *before_time* **ALHPA**.

This expression has two problems:

1) It specifies "for UNIT_B", that is known as an *affectedWho* in C2LG, although "advance" does not requires it; and
2) It specifies a location, whereas an ADVANCE task should specify a destination or a direction.

LFG approaches are especially useful for capturing natural language aspects of military information. Several use-cases where LFG-type languages would satisfy C2SIM interoperation requirements have been identified. These include "Intelligent Chat" capabilities and "Voice Command-to-C2 system-translation". However, for the majority of C2SIM requirements identified during the MSG-085 Technical Activity, LFG-type grammars generally are not required. Some stakeholders have articulated the need for a "simple" grammar that might be extended to include user-specific business rules.

The use of OIEG as a means for representing Commander's Intent is still an area of research, but may prove useful in the future in bridging the gap between a human commander and a machine interface.

6.3 NEED TO FORMALLY MANAGE STANDARD PRODUCTS (LL)

6.3.1 Maintain Logical Data Model, Generate Derived Products (LL)

Don't build the model as an XML schema; build a *logical data model* and generate XML schemas.

C2SIM interoperability often is achieved through the sharing of XML schema that define the structure and content of the information to be shared. Therefore it is tempting to standardize sets of XML schema. However, for all but the simplest of data models, this has proven to be problematic since it rapidly becomes difficult to evolve schemas to satisfy new requirements. Other standardization organizations such as the MIP already have put into place methods and tools to define and evolve a logical data model using UML.

Using a Model-Driven Architecture (MDA) approach, it then becomes possible to generate derived products such as XML schemas. Furthermore, this approach allows for the parallel production of other equivalent derived products such as HLA-FOM modules or OWL ontology modules. Beyond the advantage of saving time and ensuring a coherent set of derived standard products, this approach also avoids human-error that may occur when manually modifying XML schema.

6.3.2 Standardisation of the Process and Production Chain (LL)

Utilise a standardised approach and process and publicly available tools to develop and maintain the logical data model and to generate derived products such as XML schemas, HLA FOMs and JSON objects.

Toward the goal of employing a MDA based on an extensible core logical data model, it becomes important to define a process by which stakeholder requirements can be collected, managed and effectively traced to the derived standard products. The process should include important steps such as verification of requirements and also validation of the derived products. Standardising the process will facilitate the extension process such that communities can define and build community specific extensions in the same way.

Along the same lines, a publicly available toolset that is consistent with the standardized approach can greatly facilitate the creation of community extensions. Moreover, there are additional benefits to developing a common production chain for use by the standardization and by the solution providers. For instance, community specific extensions can be proposed as subsequent use by other communities and/or as candidates for standardization.

6.4 C2SIM INFRASTRUCTURE LESSONS LEARNED (LL)

6.4.1 Supportability of Coalition C2SIM Interoperation (LL)

Technical teams from coalition partners are able to work quickly to assemble a system-of-systems with C2 systems and simulation systems from each partner, based on clear specifications for data sharing.

The final demonstration of MSG-085 involved ten Nations, using a total of six national C2 systems and five national simulations. Some of these had been adapted to MSDL/C-BML as long ago as 2009, while others were adapted in 2013, but all underwent hardening in 2013 that increased their Technology Readiness Level (TRL) to an estimated level five or better. While the various participating Nations began MSG-085 with different levels of experience with regard to distributed, networked operations, everyone was able to adapt the available technologies to their national systems, work as a team to test their systems, correct any problems, and bring their C2 and/or simulation systems into the system-of-systems assembled for the MSG-085 final demonstration. This experience holds great promise for a time in the not-so-distant future when C2SIM interoperation becomes routine to the point where the national participants in a coalition organisation can begin interoperating over a common network immediately upon receiving notice of a mission.

6.4.2 Distributed Use of Coalition C2SIM Interoperation (LL)

It is practical to assemble and use a C2SIM system-of-systems over a network that has moderate performance; co-location of participants is not required.

Most of the development and testing required by MSG-085 was accomplished over the Internet, using Virtual Private Network (VPN) technology for privacy. No classified data or capabilities were involved. In addition to the C2SIM interoperation traffic, it proved quite practical to use Internet teleconferencing tools within the VPN to coordinate ongoing activities. For the final demonstration, national systems of Great Britain and Spain were operated from Farnborough, Great Britain, and Madrid, Spain, respectively. The network capacity required was not large, despite a scenario that reflected realistic operations on the part of a multi-national Brigade consisting of four Battalion-size elements. Moreover, because of restrictions on use of the Internet at the demonstration facility, the Internet links used came through cellular telephone, not through high-capacity "land lines".

6.4.3 Combining Various Versions of MSDL/C-BML (LI)

There is a need to be able to work simultaneously with various versions of C2SIM interoperation standards.

Dealing with multiple versions of the BML specification is a practical necessity. This is because the schema of choice for each participating C2 and simulation system was selected and implemented, at the time that system first joined a coalition environment; while some updates to interfaces of individual systems may occur, the national proponents generally are not willing to invest resources in each major schema revision. The discrepancy among schema formats can be dealt with by a translating server, which parses order/request/report XML input and converts it to a common internal data model, then produces equivalent XML documents under the schemas used by other participating systems. This approach is applicable wherever the semantics of the schemata are aligned, regardless of the syntax employed; it was used in the MSG-085 final demonstration with success.

6.5 NEED A C2SIM DSEEP OVERLAY (LI)

6.5.1 A Standardised Process for the Use of MSDL/C-BML for Building C2SIM Federations

Additional coalition-wide best practices and data exchange agreements are necessary to support advanced interoperability within a coalition of C2 and simulation systems.

Data exchange agreements are necessary to ensure understanding of even simple C-BML based orders such as movement orders that could potentially include movement routing information constructed from a variety of waypoint-based, referencing based, or start and end-point based data elements. To this end, existing simulation-based process standards such as the Distributed System Engineering and Execution Process (DSEEP) and associated federation agreement activities should be included as part of any standards-based interoperability approach.

6.5.2 Stakeholders Include Both C2 and Simulation Communities (LI)

It is important to include stakeholders from both the simulation and C2 system user communities in the process of defining the C2SIM standards and adapting them for use in a specific event.

To engineer and execute a C2SIM federation, we should recognize that the process involves two communities of stakeholders: C2 stakeholders and simulation stakeholders. The involvement of both communities throughout the DSEEP process is mandatory to achieve the end-users needs.

The solution is to describe in the C2SIM DSEEP overlay the responsibilities of each community and their interactions. The C2SIM DSEEP overlay has been drafted on this topic.

6.5.3 End-Users' Perception of Federation Execution (LI)

Ensure the operational relevance of the information to be exchanged.

During the federation design, stakeholders should ensure that the operational situations and orders to be displayed on the end-users' systems are relevant to the purposes of the specific activities to be conducted. Therefore, the messages and data exchanged during federation execution must contain the necessary and sufficient information to support these activities.

The key elements of interest have been defined in the C2SIM DSEEP Overlay. These elements are extracted from the lessons learned of the MSG-085 experimentations, and are described along with proposed solutions. They are:

- For report message processing:
  - Level of detail of information required by end-user and/or C2 system (e.g. training a Brigade HQ requires aggregated observation message, while training a Battalion HQ requires single vehicle observation messages);
  - Ground truth vs. perceived truth (e.g. ground truth is not relevant for training);
  - Simulation information filtering (e.g. C2 systems may only need a sub-set of information provided by simulation, depending on their role and capabilities); and
  - Information overload (e.g. message rates from simulations can overload C2).
- For order/requests message processing:
  - Orders/requests may call for behavior not present in simulation (e.g. unit's type or level not handled by simulation, task verb not handled by simulation); and
  - The doctrine according to which the C2 systems generate orders/requests can differ from the doctrine that is implemented in the simulation systems.

6.5.4 C2SIM Reference Architecture, Services (LI)

A C2SIM reference architecture should be defined to facilitate C2SIM federation design.

Various C2SIM infrastructures exist (like FKIE C-BML server, SBML GMU server, CBMS VMASC server) and a member application usually functions with only one specific infrastructure. It is likely that federation design will lead to the use of several C2SIM infrastructures. To facilitate this integration, a reference architecture should be defined or standardised along with the definition of services (mandatory or optional services).

The services should also implement requirements that are not today addressed, but that are important for an operational use of the federation like late joining federates, save and restore points, or time management (see next section).

This implies a need to:

- Design a C2SIM reference architecture with the services it should contain (mandatory or optional services); and
- Adapt the C2SIM DSEEP overlay to explain when and how to use those services.

6.5.5 Time Management (LI)

C2SIM federation design must account for inherent differences in the time management mechanisms between simulation and C2 systems.

What distinguishes simulation systems from most other type of systems is the ability to and necessity to manipulate time. Usually, C2 systems are locked to the current real-world time, whereas simulations manipulate time as a variable – and this may results in some unprocessed messages or errors inside the C2 system during the federation execution. For example during CIG Land Operation experimentation, the French SIR system popped up a dialog warning the operator that a message hasn't been processed because of a DTG (Date Time Group) in the future.

Currently, this issue has been described in the C2SIM DSEEP overlay, which also includes several technical solutions at different time frames. For the long time-frame, time management services should be defined and standardised in a Reference C2SIM federation, and implemented by infrastuctures, C2 and simulations systems.

6.6 FUTURE REQUIREMENTS FOR C2SIM INTEROPERATION (LI)

6.6.1 Ontology and Business Rules (LI)

Need to develop a BML Ontology and finalise an approach for specifying Business Rules.

The SISO Product Nomination for C-BML calls for the development of a C-BML ontology. Until recently, little work has been done in this area. Although the use of ontology remains primarily a subject of research, the future C2SIM interoperability standards should support the optional use of ontological means in support of advanced use-cases. The MSG-085 Technical Group has defined two families of use-cases for a C-BML ontology:

1) The construction and/or validation of C-BML messages; and
2) The specification of constraints, triggers and criteria required for task execution.

6.6.1.1 Validation and Construction (LI)

When constructing C-BML messages, the grammar will ensure that the message structure is well-formed. However, additional validation may be required to ensure that the message is consistent with the national doctrine, procedures and/or rules of engagement for a specific operation. This additional validation can be implemented using sets of business rules that can be associated with ontologies. At the information-producer side, interfaces called *Smart GUIs* can facilitate the construction of valid messages by guiding the user through context-sensitive menus and forms. Alternately, at the information-consumer side, other sets of business rules can validate that the message that has been received is consistent with the doctrine, procedures and rules of engagement of the consuming system.

6.6.1.2 Message Correction (LI)

In some instances, a message may be deemed *invalid*. Therefore it may be rejected or it may be possible to correct the message based on knowledge of which business rules failed. For example for certain C2 systems, a FIX task may require a start point and a vector – but it is possible that only two points are provided, consistent with the manner in which other C2 systems specify FIX task information. A "Message Correction" mechanism could allow for an automatic conversion of two points into one point and a vector and also to convert a start point and vector into two points, as required.

6.6.1.3 Message Conversion (LI)

In the case of a Task, it may be possible to use the explicit information contained in business rules that have been established for a specific national force (e.g. Norway) and specifically convert the task for use by another force (e.g. France) while taking full consideration of both the military capabilities of both forces and their difference in national warfighting doctrine.

6.6.1.4 Specifying Task Qualifiers, Triggers and other Criteria (LI)

Task start and end times are specified as absolute times or relative times. Relative times reference the start/end times of other tasks. However in some cases, the start or end of a given task may depend on a set of criteria that determine when the task can commence or when it has been completed. These task start/end criteria can be associated with set of conditions that are expressed as business rules. For example, a SEIZE task may be considered completed based on criteria that indicate the number and operational status of the remaining enemy units above a certain troop size.

Similarly, task qualifiers such as ***"HASTY*"** **ATTACK** can be expressed in terms of a set of rules that define when specific HASTY ATTACK conditions have been satisfied.

Finally, rules of engagement could be specified as sets of business rules, such as shown in Table 6-1.

Table 6-1: Example Rules of Engagement.

I. UNIT *may_employ* **DEADLY_ FORCE**, *If* : A. **UNIT** *has_been* **FIRED_UPON**; B. {**ARMED_ELEMENT** or **MOB**} *threaten* **HUMAN_LIFE**; C. **ELEMENT** *has_demonstrated* **HOSTILE_INTENT**; **1. ELEMENT** *has_demonstrated* **HOSTILE_INTENT,** *If* : i. **WEAPONS** *are* **PRESENT**; ii. **WEAPONS** *are* **AIMED**;
II. **UNATTENDED_MEANS_OF_FORCE** *are_not* **AUTHORIZED**; **UNATTENDED_MEANS_OF_FORCE** = {**BARBED_WIRE**, **MINE**, **BOOBY_TRAP**, **TRIP_GUN**}

6.7 VALIDATION OF OPERATIONAL RELEVANCE (LL)

6.7.1 C2-to-C2 Exchanges (LL)

It was identified that a simple C2-to-C2 interoperability solution was needed during experimentations, without having to implement and deploy regular C2-to-C2 gateways.

The solution to this issue has been to develop a C-BML message header, adding new information to C-BML messages like the sender and the recipient units. This solution has been validated through experimentation.

6.7.2 Logistic Domain (LL)

Up-to-date information about unit consumables, equipment and personnel is important in military situation assessment and planning. The MSDL and C-BML schemas need to be extended in order to better support this capability.

The NATO Stock Number (NSN) was used to identify equipment across all NATO Nations, including different simulation and C2 systems. The MSDL schema was adjusted to allow describing the initial logistical situation. The BML schema was also extended to report about changes in the logistic situation, e.g. when ammunition is consumed.

6.7.3 Acknowledgments (LL)

Acknowledgement of orders by receiving systems is necessary in different situations.

The first case is when an order is given to the simulation system. The simulation system can send an acknowledgment if it is able to execute the order or it can respond with an abort and give a reason. Reasons could be:

1) The order does not comply to the requirements by the simulation system; and
2) The order is not formatted correctly.

For example, the simulation may receive an order that specifies unsupported missions or that contains erroneous or missing geographic features – or the simulation may be missing equipment required to execute a specific action. This led to a faster creation of an executable order. Acknowledgment can also be used for C2 to C2 communication to inform the superior unit the operator has read or committed to the order.

6.8 NEED FOR INCREASED STAKEHOLDER INVOLVEMENT (LI)

6.8.1 Challenges to Engage Industry (LI)

Industry involvement is required to ensure the development of usable C2SIM interoperability standards products.

Although efforts have been made to engage industry through SISO and initiatives such as the C-BML Industry Task Team (CITT) this after some initial success lapsed due to insufficient resources to maintain the effort. The establishment of a merged C-BML/MSDL PDG within SISO and a proposed follow-on TA to NMSG-085 should reenergise industry engagement. A C-BML/MSDL/C2SIM certification process should be considered as another mechanism for industry engagement. For the latter to be taken forward it requires NATO/Government/Industry sponsorship.

6.8.2 Employment of C2SIM Interoperability Technologies (LI)

Need to increase the trial use of C2SIM interoperability technologies to include more stakeholders.

MSG-085 has demonstrated that C2SIM is ready to begin the process of incorporation into national and NATO military systems. However, this does not mean that all systems intended for operational use should be converted immediately to have a C2SIM capability. The next step should be trial use of C2SIM in operational systems in carefully controlled environments, so that both operational military and technology suppliers learn how best to deploy this new capability. On the operational side, this process must be followed by introduction of appropriate doctrine. On the technical side, the C2SIM capability needs to be both hardened and broadened. This can be accomplished in the context of a follow-on TA that works with early adopters in the military community.

6.8.3 Need for NATO Lecture Series (LL)

Inform the community on the use and benefits of C2SIM products.

As part of the wider dissemination of both the operational benefits and technical composition of the current C2SIM products a NATO Lecture Series should be run and a TAP has been proposed by GBR and provisionally supported by both the FRA and the USA to establish this TA.

6.9 REQUIREMENT FOR A FUNDED DEVELOPMENT ACTIVITY (LI)

Effective development of C2SIM standards requires a funded technical activity to develop and validate the technical approach before it is codified as a standard.

Considerable frustration during MSG-048 came from the assumption that SISO would develop standards and MSG-048 would use them. When SISO did not produce a standard in time for this approach to work, MSG-048 adopted for experimentation a schema that had been produced by its national technical members. This proved to be a successful approach and it was used in the MSG-048 final experimentation, validating its utility in that environment. A schema derived from the final ones used by MSG-048 ultimately was adopted as a significant part of the SISO C-BML Phase 1 draft standard.

At the outset of MSG-085, some confusion remained on the appropriate sequence of activities in standards development. During MSG-085 it became clear that SISO lacks both the resources to develop coalition BML standards and a means of validating those standards in use, whereas MSG-085 had both and as part of its activities has developed a new approach (see Lessons Learned 1 and 5 for details) that clearly offers a better technical approach for the future. As a result, a new picture of the appropriate relationship between the NATO MSG and SISO for coalition standards has emerged: technical activities conducted by the MSG should develop usable alternatives and validate their utility by application in the target environment; the resulting specifications should be provided to SISO for codification into standards documents. This cycle has been demonstrated to be effective by other successful standards bodies, such as the Internet Engineering Task Force, and represents the best path forward for C2SIM interoperability standards:

- Technical providers develop an approach;
- Appropriate users apply the approach to validate it; and
- A standards body then codifies the approach.

Chapter 7 – CONCLUSIONS AND RECOMMENDATIONS

The MSG-085 TA has made significant progress in advancing the standardisation of C2SIM interoperation toward the goal of providing a capability that can improve the decision-making and training in coalition military operations. Starting with a concept, the community involved in C-BML/MSDL, both in NATO and SISO, has achieved continued progress toward the goal that, in the not too distant future, military coalitions will be able to come together and benefit from interoperating C2 and simulation systems across all Nations participating.

While commendable progress has been made toward the goal of establishing a set of standardised, technically mature C2SIM interoperability products, much remains to be accomplished. The feasibility of C2SIM was demonstrated by MSG-048 and the utility of C2SIM interoperability has been demonstrated by MSG-085. What remains is to engage the operational military community in the various NATO Nations and provide them compelling evidence, in the form of well-supported training events that incorporate mission planning and mission rehearsal, that the products that enable C2SIM interoperability should be an integral part of NATO and national C2 systems.

In addition to work with the operational community, there is much technical effort remaining to improve C2SIM interoperability. SISO C2SIM PDG needs to include a next generation of both MSDL and C-BML to facilitate both their working together and the scope of the interoperability they are able to achieve. MSDL should meet the needs of a wide range of national systems, while C-BML should improve the sophistication of what it can represent and while making it easier to use. Based on success thus far, a coordinated effort should continue toward that goal.

Based on the results and findings of the MSG-085 a new TA is required to achieve the recommendations set out below.

7.1 OPERATIONALISE MSDL AND C-BML STANDARDS

One of the aims of the C2SIM community is to raise the Technical Readiness Level (TRL) of the capability to TRL 7. To achieve this operationalisation of C2SIM in its current form, which includes C-BML and MSDL standards, would be an important first step. This implies the integration and testing of national C2SIM interoperability products that implement current C-BML and MSDL standards and also their utilisation during multinational or coalition events. The transfer of these products to the operational community will facilitate the familiarisation of these technologies by the end-users.

7.2 EDUCATE BROADER COMMUNITY ON C2SIM TECHNOLOGY EMPLOYMENT

There is a need to:

- Engage with industry, academia and government in the form of NATO/Industry workshops, conferences, lectures and demonstrations.
- Participate in one or more coalition exercises to further demonstrate the utility of C2SIM to the military users.

7.3 ADVANCE C2SIM INTEROPERABILITY

It is important to continue progress in the development of the C2SIM technology and their standardisation. This will require effort to:

- Capture additional stakeholder requirements for C2SIM interoperability;
- Develop extensions to cover additional national and domain specific requirements;
- Develop a unified C2SIM model;
- Develop a C2SIM ontology, advanced grammar and business rules;
- Define a set of reference C2SIM services; and
- Develop a C2SIM DSEEP overlay.

7.4 SUPPORT NEXT GENERATION OF C2SIM INTEROPERABILITY STANDARDS DEVELOPMENT

After these technologies have been validated by operational use, they need to be turned over to SISO for standardisation. The new SISO C2SIM standard then becomes a candidate for standardisation as a NATO STANAG.

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Annex A – MSG-085 EXTERNAL EVENT AGENDAS AND POSTERS

A.1 APRIL 2011 – BML RESEARCH SYMPOSIUM

8:00	Introduction and Purpose of BML	Stan Levine
8:15	**KEYNOTE Address** *On BML: "The oxen are slow, but the Earth is patient"* *A sponsor's perspective on BML development and application* slides	Dr. Amy Henninger
08:45	*Operational Use-cases for BML* slides video	Jens Inge Hyndoy
09:15	*C-BML Grammar, Ontology and French Military Requirements* slides	Jean-Gabriel Herbinet
09:45	Coffee break	
10:15	*An Operational Perspective on BML* slides	COL Robert Kewley
10:45	*Coalition BML Agreements/Activities* MSG-085 Standardization for C2-Simulation Interoperation UK-FRA BML activity called SAFIR BML collaboration between Germany and France NLD-NOR BML collaboration using MAKs VR FORCES slides	Lionel Khimeche
11:15	*Grammar Research That Supports SISO C-BML Phase 2* slides C2LG Specification	Bastian Haarmann
11:45	*Battle Command Activities in BML* slides	Ted Troccola
12:15	Lunch Break	
13:15	*A Platform-Independent JC3IEDM as a Semantic Reference for Future Interoperability Solutions* slides	Nico Bau
13:45	*Aligning C-BML and MSDL* slides	Rob Wittman
14:15	*Coalition Battle Management Services* slides video	Saikou Diallo
14:45	*Open Source Software for Battle Management Language* slides	Mark Pullen
15:15	Coffee break	
15:30	*On the Use of the Web Ontology Language (OWL) for C-BML Standards Development* slides	Kevin Gupton
16:00	*Using BML in Support of UAV Training and Experimentation* slides	Kevin Heffner
16:30	*Scaling to the Enterprise,* *Challenges in Scalable BML Applications* slides	Jeff Abbott

A.2 I/ITSEC 2011 DEMONSTRATION

A.3 SEPTEMBER 2012 – BML SYMPOSIUM AGENDA

Agenda

08:15 – 08:30 Introduction - Dr. Stan Levine

Sim Research

Invited talks focusing on new technologies with the potential of supporting simulation systems by using current and future BML efforts e.g. MSDL/C-BML convergence and C-BML Phase 2 and beyond. The view point is from the simulation side, doctrine, technology, methods etc. adapting into legacy systems, developing new systems etc.

08:30-09:00 MSDL Version 2 and C-BML Convergence — Dr. Rob Wittman, MSDL PDG Co-Chair

09:00-09:30 BML between simulations. — Jérôme Martinet (MASA Group)

C2 Research

Invited talks focusing on new technologies with the potential of supporting C2 systems by using current and future BML efforts e.g. MSDL/C-BML convergence and C-BML Phase 2 and beyond. The view point is from the C2 side, technology, methods etc.

09:30-10:00 Operational requirements for C-BML and systems initialization. — Lionel Khimeche, DGA (French MOD)

10:00-10:30 ***Break***

10:30-11:00 OneSAF Mission Command Integration. — Amit Kapadia, PEO STRI/CERDEC

Infrastructure Research

Invited talks focusing on new technologies with the potential of supporting the underlying needs of BML from a generic perspective.

11:00-11:30 Strategies for Future MSDL Version 2 and C-BML Phase 2 Alignment — Dr. Kevin Heffner, C-BML Phase 2 DG Editor

11:30-12:00 A Standards Development Framework for C-BML Phase 2 and Beyond — Kevin Gupton, ARL:UT & Dr. Kevin Heffner

12:00-13:30 ***Lunch***

13:30-14:00 Interoperability solutions with BML. — Jérôme Martinet (MASA Group)

14:00-14:30 - Advances in open source software for BML — Dr. Mark Pullen, GMU

14:30-15:00 - CBMS: A System of Systems Interoperability Enabler — Dr. Saikou Diallo, VMASC

15:00-15:30 ***Break***

Wrap-up:

15:30 - 16:30 Summarize the presentations and to pinpoint three challenges for the three domains listed above. (Disussions) — Dr. Stan Levine


NATO
OTAN
MSG-085
S&T organization
Nov 2012 C2-Sim Interoperability Workshop
Military requirements:
Enable and enhance command post forces readiness and support to operations.
Problem statement:
Need cost-effective, efficient, way to connect C2, simulation and autonomous systems in order to:
• Enhance realism & overall effectiveness
• Decrease cost and workload
• Reduce preparation and response time
Solution:
Standardize exchange of digitized military information for C2-Sim interoperation.
C2
SIM
WORKSHOP AGENDA
10:00-10:15 Welcome & Introductory remarks
10:15-11:15 Infrastructure CIG Debrief
11:15-12:15 Maritime Operations CIG Debrief
12:15-13:15 Lunch
13:15-14:30 Land Operations CIG Debrief
14:30-15:15 UAV/Air Operations CIG Debrief
15:15-15:45 Joint Mission Planning CIG Debrief
15:45-16:00 Wrap-up
MSG-085 CIG Workshop, Fairfax VA
November 28th, 2012
10:00 am-16:00 pm

A.4 NOVEMBER 2012 – CIG WORKSHOP

NATO OTAN

MSG-085

S&T organization

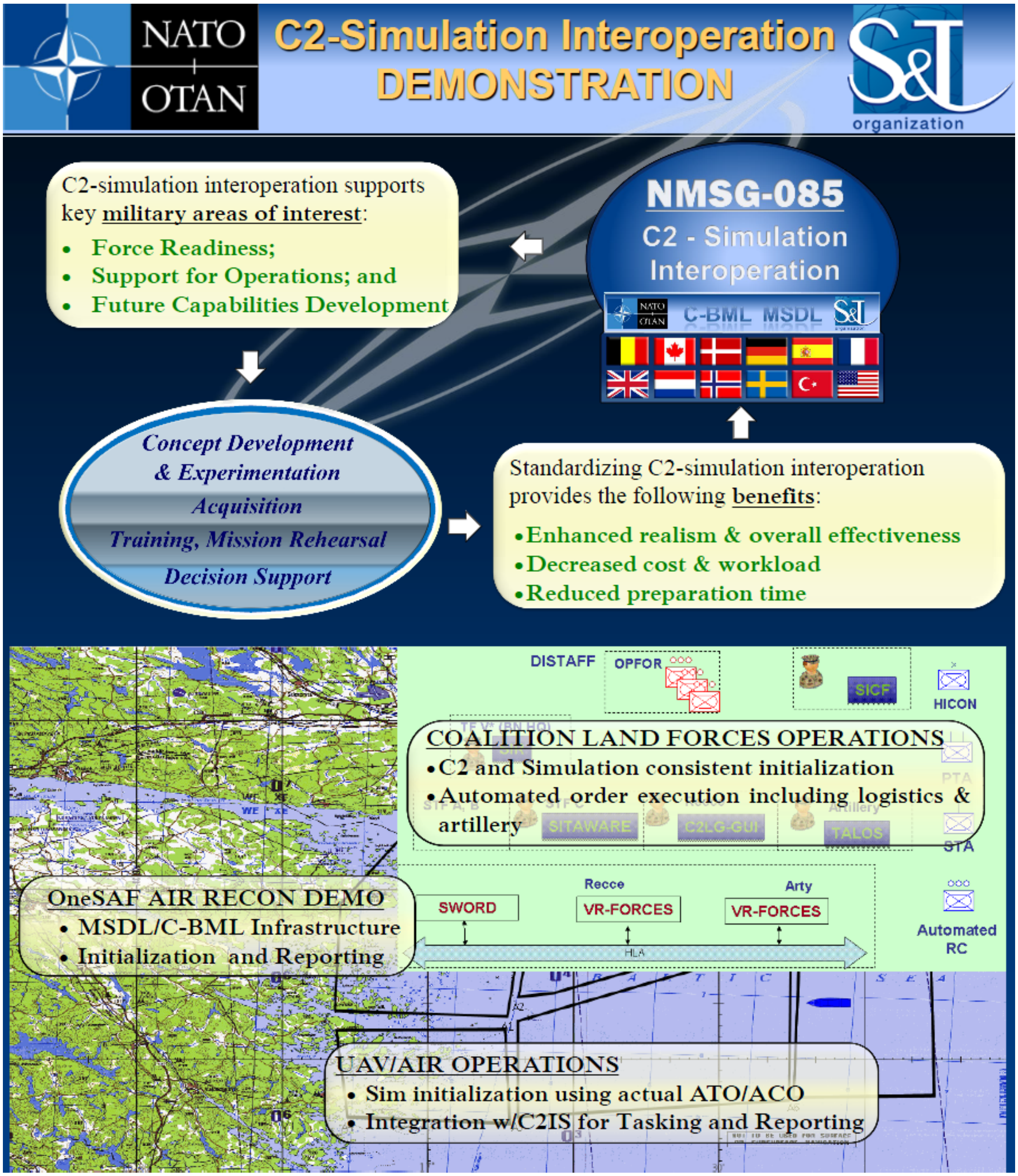
C2 to Simulation Interoperability Workshop

BACKGROUND: The NATO Modelling and Simulation Group (NMSG) efforts include a wide range of activities supporting major NATO initiatives. One such initiative, MSG-085, is working in the area of interoperation between C2 and Simulation Systems with the aim of achieving a "train as you fight" environment in support of NATO operations. Through the use of the standardised Coalition Battle Management Language simulated systems will be able to exchange orders and reports with real C2 Systems in distributed exercises.

The MSG-085 Experimentation Programme is a key component to the Technical Activity. The goal is to establish a capability that can be deployed in the medium-term and that will improve NATO Forces effectiveness. In order to be more efficient, MSG-085 is divided into Common Interest Groups (CIGs) that provide dedicated work in different C2-simulation interoperation technical and operational areas, including: Land Ops; Maritime Ops; UAV/Air Ops; Joint Mission Planning; and C2-Sim infrastructure.

MSG-085 COMMON INTEREST GROUPS: **Land Operations CIG** demonstration focuses on command post exercise training. It highlights the benefits of the use of standards to save LOCON resources and time during exercise preparation. Therefore, the demonstration addresses first the use of an effective initialization process based on MSDL of systems involved for the exercises. MSDL exchange format enrichments rationales and contents are also shared . Second, the demonstration deals with the execution of an operational scenario derived from VIKING 2011 training exercise. Hence, it highlights the use of CBML for two new military areas that are logistics and artillery. Corresponding CBML schema improvements are introduced. In addition, the demonstration intends to prove that CBML is also relevant for C2 to C2 exchange. **UAV/Air Operations CIG** will focus on a Joint Training Exercise use-case where C-BML is utilized in several ways: 1) first to initialize the simulated aircraft in the Joint Semi-Automated Forces (JSAF) simulation with respect to the Airspace Control Order (ACO) and Air Tasking Order (ATO) received from NATO ICC Air Command and Control (C2) System; 2) control the execution of aircraft behaviour during the scenario execution; and 3) to provide the means for the simulation to update the C2 systems via standard reporting mechanisms. The default aircraft behaviours respect the Airspace Control Measures (ACM) as specified by the ACO while executing tasks such as: Aerial Refueling (AAR), Suppression of Enemy Air Defense (SEAD), Offensive CounterAir (OCA), Defensive CounterAir (DCA), Airborn Early Warning (AEW) and Tactical Air Reconnaissance (TRAL). The Common Operational Picture (COP) of the Joint Automated Deep Operations Coordination System (JADOCS) C2 system is updated via an automated reporting mechansim that receives C-BML reports generated by the simulation. **Maritime Operations CIG** will demonstrate the initial capabilities of the Maritime C-BML with a basic Naval scenario. In the scenario, Coalition Task Force (CTF) 401, which includes three Task Groups consisting of frigates with organic helos, mine hunters, mine sweepers and LPDs, is responsible for conducting Maritime Interdiction Operations (MIO) ashore of Oxelösund to control maritime traffic. CTF 401 is also responsible for supporting the amphibious forces in the pre-landing phase. Allocated task units/task groups will execute babysitting operations for protecting Mine Counter Measure (MCM) forces that are isolating and clearing the obstacles in the entrance and vicinity of the harbor Oxelösund. CTF 401 protects MCM forces against air and surface threats. **Infrastructure CIG** demo will be cast as an Air Recon in Bogaland/Motala supporting several variants of BML and CBML within OneSAF. We will show MSDL initialization using info provided from a C2 system with an associated CBML files as well as other files showing the power and flexibility of the MSDL extension design. This will be followed up with BML formatted observation and location reports sent from OneSAF. OneSAF will also accept and respond to BML orders via the GMU server.

A.5 DECEMBER 2012 – I/ITSEC DEMONSTRATION



A.6 MSG-119 C2SIM INTEROPERABILITY WORKSHOP

NATO OTAN

MSG-119

C2 to Simulation Interoperability Workshop

Background

During the last decade, considerable progress has been made in establishing interoperability-enabling standards in both the Command and Control (C2) domain, through the work of the Multilateral Interoperability Programme (MIP) and within the M&S community through the efforts of the Simulation Interoperability Standards Organization (SISO).

The interoperation between command & control information systems (C2IS) and simulation systems is a common theme in the transformation of modern military forces. This is required to support the military enterprise in the execution of business activities and mission threads such as operational training, information sharing and decision support. This implies the ability to seamlessly integrate C2IS and simulation systems and to provide the means for a meaningful and unambiguous information exchange. This applies to systems of systems functioning toward a common goal at different levels: (1) within services, (2) across services (i.e. joint) and (3) across nations in a multinational or coalition context.

Enabling such information exchange in a timely, efficient and cost-effective manner requires a standardized language and interfaces that allow C2 and simulation systems to interoperate. This the scope of the Coalition Battle Management Language (C-BML) being developed by SISO.

Use-case scenarios involving information exchange across C2IS and simulation systems often require a pre-requisite initialization of all systems that is consistent with existing simulation and/or operational databases. This currently represents a significant obstacle to C2-simulation interoperation. Approved by SISO in 2008, the Military Scenario Definition Language (MSDL) also has been developed as a standard by SISO to enable C2IS-simulation interoperation, with regard to the initialization of simulation systems. Version 2 of MSDL currently is being drafted to address requirements such as convergence and alignment of MSDL with C-BML.

I/ITSEC 2012, Orlando FL
December 5th, 2012
8:30am-11:30 am

Contact NATO MSCO staff for details
msg@cso.nato.int

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14. Abstract

The interoperation between Command and Control (C2) systems and simulation systems is a common theme in the transformation of modern military forces. This is required to support the military enterprise in the execution of business activities and mission threads such as forces readiness, decision support and acquisition. This implies the ability to seamlessly integrate C2 and simulation systems and to provide the means for a meaningful and unambiguous information exchange. This applies to systems of systems functioning toward a common goal at different levels: 1) within services; 2) across services; (i.e. joint) and 3) across Nations in a multi-national or coalition context.

In 2010, the NATO Research and Technology Organization started the three-year Modeling and Simulation Task Group "Standardisation for C2-Simulation Interoperation" to assess and document the C2 and Simulation interoperability standards developed by SISO to be used for multiple military applications. This final report documents the completed work of this Task Group, designated MSG-085. It includes the continued progress made to demonstrate the utility of C2-Simulation interoperability. This report leverages the knowledge of C2-Simulation experts to merge current standards towards a unified, more manageable and easier to deploy C2SIM interoperability.

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