An Expanded C2-Simulation Experimental Environment Based on BML

Dr. J. Mark Pullen
C4I Center
George Mason University
Fairfax, VA 22030, USA
+1 703 993 3682
mpullen@c4i.gmu.edu

Nico de Reus
TNO, Oude Waalsdorperweg 63
The Hague, 2509 JG
The Netherlands
+31 70 3740236
nico.dereus@tno.nl

Dr. Kevin Heffner
Pegasus Simulation
+1 514 655-2023
k.heffner@pegasim.com

Ole Martin Mevassvik and Anders Alstad
Norwegian Defence Research Establishment, FFI
PO Box 25, NO-2027 Kjeller, Norway
+47 6380 7423
{ole-martin.mevassvik, anders.alstad}@ffi.no

Lionel Khimeche
Délégation Générale pour l'Armement (DGA)
16 bis, avenue Prieur de la côte d'or
94114 ARCUEIL CEDEX France
+33 1 42 31 95 46
lionel.khimeche@dga.defense.gouv.fr

Ricardo Gomez-Veiga and Sergio Galan Cubero
R&T ESP MoD/ISDEFE
C/ Edison Nº 4
Madrid, Spain 28006
+34 91 271 13 6
{rgveiga, sgcubero}@isdefe.es

Dr. Ulrich Schade
Fraunhofer FKIE, Neuenahrer Straße 20
53343 Wachtberg, Germany
+49 228 9435376
Ulrich.schade@fkie.fraunhofer.de

Adam Brook
QinetiQ, Cody Technology Park
Ively Road, Farnborough, Hampshire GU14 0LX, UK
+44 1252 396427
rabrook@QinetiQ.com

Keywords:
Coalition Operations, Command and Control, Simulation, Web Services, C2 Reports

ABSTRACT: *The NATO Modeling and Simulation Group Technical Activity 48 (MSG-048) was chartered in 2006 to investigate the potential of a Coalition Battle Management Language for multinational and NATO interoperation of command and control systems with simulation systems. Its work in defining and demonstrating a basic capability for this purpose has been reported in previous SIW papers. This paper addresses Phase 3 of the Technical Activity, which validated the BML paradigm by interoperation of multiple C2 and simulation systems in experimental support of operational military users. The new capability was the basis for a week-long event at Manassas, Virginia in November 2009, which was supported by a previous collaborative integration using the Internet. The experimental configuration combined six national C2 systems and five national simulations along with middleware from two other nations, including an updated BML server that implements the publish/subscribe paradigm for BML and a C2 Lexical Grammar interface that was used by several nations. BML provided a common C2-simulation linkage without humans in the information exchange loop. This paper provides a description of the experimental system of systems and results, along with the successes and lessons learned. The results support further development of the BML concept and should inform the work of the SISO C-BML Product Development Group. We conclude with a projection of the work of MSG-085, the successor to MSG-048, which will focus on operational and standardization issues.*

1. Introduction

This paper reports on the third phase of a multinational project that is evaluating a capability for interoperation of Command and Control (C2) systems with Modeling and Simulation (M&S) systems for coalition operations. The approach followed provides for rapid, effective information sharing among coalition organizations. Key enablers of this capability are an emerging standard language for military operations, the Battle Management Language (BML), and a Web service repository based on the Joint Command, Control and Consultation Information Exchange Data Model (JC3IEDM) of the Multinational Interoperability Programme (MIP).

The BML initiative seeks to provide standards for the widely accepted need to interface C2 systems with simulation systems. The implementation of BML we employed uses the JC3IEDM as a system-independent community vocabulary for passing plans, orders, and reports among C2 systems and simulations. BML enables interoperability among Service, Joint and Coalition systems by providing a common means of exchanging information that all C2 and simulation systems can implement. The predecessors to the work described here was reported in [6] and [25]. The Web service schema and software which provided the basis for interoperation was developed under the SIMCI Combined Project 2008 and 2009 [5].

2. Background

This section provides brief background on BML and on the NATO MSG-048 Technical Activity in order to set the stage for understanding of the demonstration. More details are available in [1-16].

2.1 BML

BML began in work sponsored by the US Army's Simulation-to-C4I Interoperability Overarching Integrated Product Team (SIMCI OIPT). Carey *et al.* [7] describe the overall process used to show the feasibility of defining an unambiguous language, based on manuals capturing the doctrine of the US Army. Extensible BML (XBML) project, sponsored by the US Defense Modeling and Simulation Office (DMSO) and the US Joint Forces Command (JFCOM), built on the US Army's initial work. Its two main objectives were: (1) using Service Oriented Architecture (SOA) technology for information exchange among the systems' interfaces and (2) using the MIP's Command and Control Information Exchange Data Model (C2IEDM, an earlier version of the JC3IEDM) as a basis to represent the information to be exchanged between the systems It also served as the basis for an international experiment, driven by interest of the Exploratory Team formulating the proposal that led to MSG-048 [9]. The next step was Joint BML (JBML), which expanded into the Joint arena by including ground, air and maritime domains and urban warfare. JBML was demonstrated successfully in May 2007 and achieved considerable technical progress by creating a revised Web service schema, based on lexical grammar and designed to facilitate expansion into other military realms. In parallel with JBML, the US Army Topographic Engineering Center (TEC) has developed a geospatial BML (geoBML) which will bring a wealth of geospatial data to the C2-M&S environment [10].

2.2 MSG-048

Coalition operations have a need for interoperability that is even greater than that of national Service and Joint operations. Because coalitions must function under greater complexity due to significant differences among doctrine and human language barriers; the agility to train and rehearse rapidly before the actual operation is highly important [11]. The NATO RTO Modeling and Simulation Group (MSG) recognized this need and chartered Technical Activity MSG-048 to explore the promise of BML in coalitions combined with SOA technologies [12]. The first major demonstration by MSG-048, in which BML supported only the exchange of orders, is described in [8]. The second major demonstration expanded BML to include Reports [25] and a new Integrated BML schema (IBML). The remainder of this paper describes the final major activity of MSG-048, involving experimentation.

3. MSG-048 Experimentation Architecture

Our 2009 effort improved over previous work by expanding the number of systems interoperating. In order to do this, it expanded the Service Oriented Architecture (SOA) communication paradigm, as implemented in Web services, to include publish/subscribe, so that the various C2 systems could subscribe to Reports of interest and the simulation systems could subscribe to Orders of interest, avoiding the need to poll the BML Web service for updates and thus increasing both computational and communications efficiency. However, it was still necessary to limit reporting rates of the simulations to a one-minute interval for each reported object.

3.1 Purpose and Architecture

The architecture used for the 2009 experimentation is shown in Figure 1. Its primary purpose was to evaluate the effectiveness of BML in maintaining common state to the degree required for effective interoperation among the C2 and simulation systems. Six C2 systems and five simulations achieved interoperability with the support of a Web service repository and a middleware graphical user interface (GUI).

4. Experimentation Plan and Results

The experiment described in this paper is part of a series of discovery experiments conducted by MSG-048. The experiments conducted in 2007 and 2008 focused on technical interoperability and to gather experience with BML. This last experiment was a warfighter experiment, allowing military personnel to evaluate a BML capability and in, order to do so, expanding what was used in earlier technical experiments. The purpose of the experiment was to get an indication of the military benefits of BML and to evaluate the current capability in order to generate future requirements.

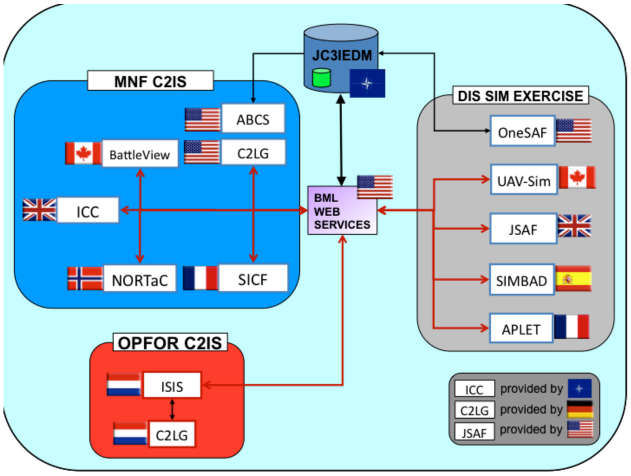

Figure 1. MSG-048 experimentation architecture 2009

Preparation for the experiment started in March 2009. The experiment was conducted 2-6 November 2009 at the George Mason University Manassas, Virginia Campus. During the preparation phase there were two face-to-face integration events in addition to numerous tests using the Internet. Three different groups were formed during the preparation phase: an experimentation team defining and leading the work, a technical team, and a scenario team. The development process is further described in section 7.

During the experiment, the systems were deployed into two different rooms, one room for technical operators supervising the simulation and BML server and one room for C2 systems with operators and experiment participants. The experiment design was to use BML to support two Battalion Commanders conducting a joint coalition operation. The Battalion Commanders were supported by a Brigade Commander controlling air support units (aircraft and UAVs) and a reconnaissance squadron. No battalion Staff was established for the experiment due to the lack of availability of SMEs. Opposing forces were controlled by the experiment scenario team. The scenario is further described in the next section.

BML has a potential use in several applications involving simulation to C2 information exchange. The experiment was divided into vignettes, each addressing a separate application: Planning, Training, and Mission rehearsal. The system configurations for the different vignettes are shown in Figure 2 through Figure 4.

During the planning vignette BML was used to support Course of Action assessment, coordination and battalion plan improvements. This vignette made use of faster than real-time simulation to be able to run through the plans quickly. Simulated situation reports for ground truth and perceived truth for both own forces and enemy forces were available for display on the C2 systems.

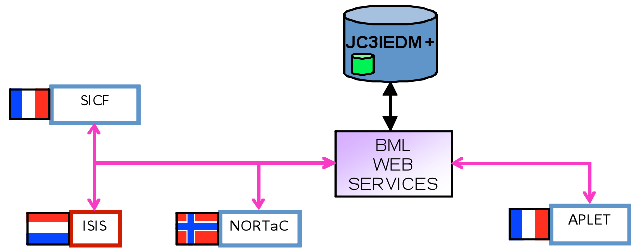

Figure 2. Planning vignette configuration

The training vignette exercised only a few hours of the entire operation and was simulated in real-time. The Battalion Commanders were able to issue fragmentary orders (FRAGOs) to their forces and to request air support. In this vignette only reports normally being part of a Common Operating Picture were available to commanders (blue force tracking and perceived truth for friendly forces).

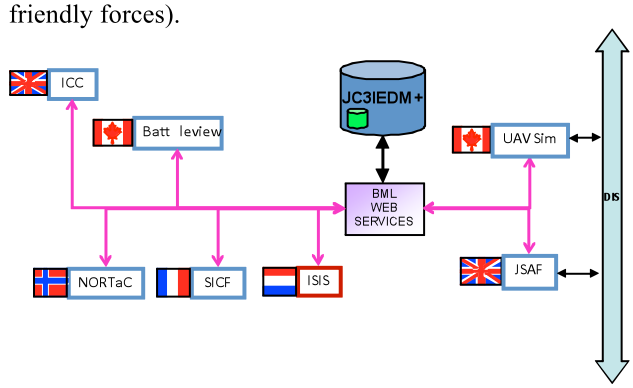

Figure 3. Training vignette configuration

The mission rehearsal vignette was similar to the training vignette with the exception that it provided a more complete environment due to availability of reconnaissance units.

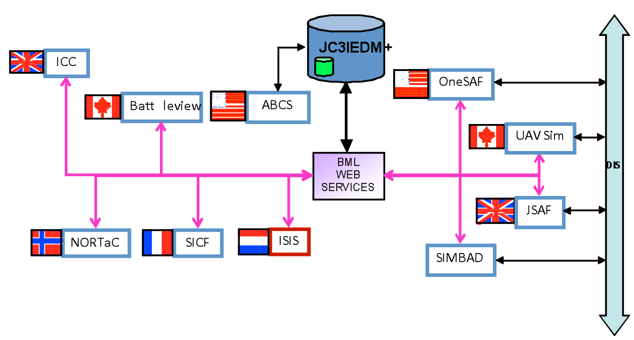

Figure 4. Mission Rehearsal vignette configuration

The data collection during the experiment was based largely on qualitative measures like observing the experiment and interviewing the military participants. A questionnaire was used to collect the opinion of the participants with respect to both the concept of BML and the capability provided for the experiment. Due to the small number of participants no statistical analysis has been performed on the questionnaire responses.

The overall feedback from the military users was that they very much supported the BML concept. The most imminent application for BML was considered to be training. Some other observations are as follows:

- There is a need for better mechanisms to coordinate operations across orders and nations, such as exchanging control features and referencing tasks.
- The use of other nations' simulation models is not optimal as there are differences in tactics and doctrines. However this can be mitigated in most cases if considered when creating orders.
- The commanders had very limited staff support during the experiment. Increased staff support would improve the realism of the experimentation environment. Battle functions like logistics and artillery should be available.
- Current C2 systems are not designed to change plans quickly.
- The scenario used in the experiment was considered relevant. However the complexity of the scenario could be reduced without negative impact to the experiment.
- The BML schema used was sufficient to meet the basic requirements for expressing the orders and reports used in the experiment.

Simulations can provide a more information rich environment than available in real operations (higher report rates, availability of perfect blue force tracking, etc.). This can lead to information overload for C2 systems and the BML server. The use of publish and subscribe services effectively reduced the load on the BML server and the C2 systems.

- Subscription filters enabled the C2 systems to receive reports according their needs (e.g. filter combinations of red/blue force and ground/perceived truth).
- Order subscription simplified system initialization of and reception of FRAGOs during execution.
- Aggregation of situation reports (e.g. report platoon instead of single entities) should be performed by the simulation systems to avoid unnecessary load on the BML server.
- Simulations should be able to control their report rate according to scenario or application requirements.

Scalability and robustness of the BML infrastructure is critical. BML message validation and error handling are important capabilities to ensure robustness. Multi-threading and load balancing would increase server scalability. A list of some of the future additional capabilities identified is as follows:

- It must be possible to discover entities during run-time in order to exchange a realistic COP.
- The BML language should provide an expanded capability of action-temporal associations.
- Time management across C2 systems and simulations has to be considered if BML is to support FRAGOs in combination with faster than real-time simulation.
- The initialization process needs to be investigated further. Topics that should be addressed are synchronous vs. asynchronous initialization, exchange of unit definitions, initial unit position and status. Also, use of the Military Scenario Definition Language (MSDL) should be explored.

5. Experiment Scenario

A scenario, called "Operation Troy," was built by the SMEs that participated in MSG-048. These SMEs acted as the Brigade Staff that sent out the order to their subordinates. The exercise area was the Caspian Sea region used in earlier demonstrations. This allowed reuse of components that were prepared in 2007 and 2008. The Multinational Brigade consists of French and Norwegian battalion and a US reconnaissance element, with UK air component and a Canadian UAV company. The Mission given to the Brigade was to maneuver rapidly from an attack position along Phase Line Denver to seize objectives LION and TIGER, destroy Enemy forces in zone and secure objectives along the international border to enable establishment of Caspian Federation (CF) regional military stability. Figure 5 displays the situation. The expected enemy Order Of Battle as given by the Brigade staff is shown in Figure 6.

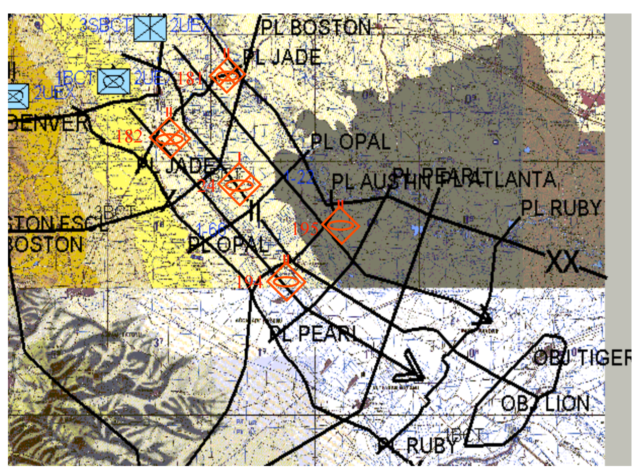

Figure 5. Brigade order overlay

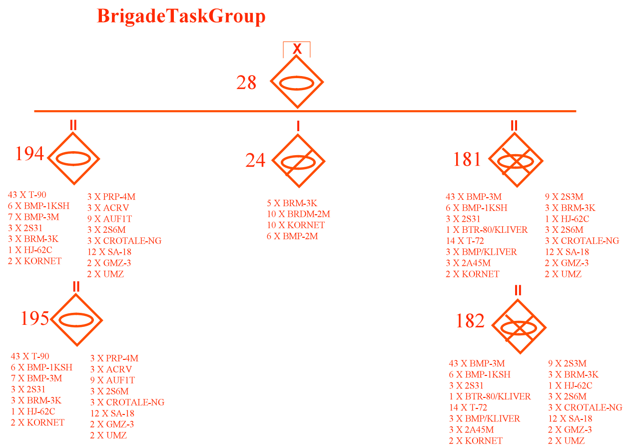

Figure 6. Enemy order of battle

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

The Battalion commanders developed their own Courses of Action (COAs) which they transformed into BML in order to send the plans to the simulations. An example COA overlay is given below. It was made by the French Battalion commander.

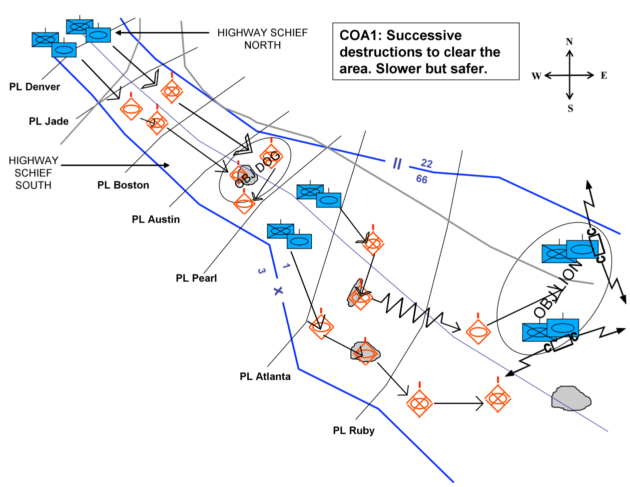

Figure 7. A French Course Of Action

The C2 systems had been prepared to issue Fragmentary Orders in order for the Blue forces to be able to respond to unforeseen situations and for the Red units to initiate unforeseen situations (as seen by the Blue forces). The plan was for this capability to be used by the instructor SMEs, who played the Red Forces. This capability was not used due to lack of time; however, a FRAGO was issued by the UAV commander, who targeted an enemy location from the UAV, which had been given appropriate weapons and thus served as a UCAV.

6. National C2 Systems

This section describes the C2 systems, which were provided by Canada, France, Netherlands, Norway, the UK and the USA.

6.1 Canada C2 System: BattleView

BattleView is a C2 system developed by Thales Canada for the Canadian Forces (CF) that is 100% JC3IEDM compatible. BattleView's capabilities include operation monitoring, directing and planning. BattleView was the only Canadian system that was fully compliant with the MIP JC3IEDM. The platform used for the experimentation was an actual field workstation used by Canadian soldiers. This made BattleView a logical choice for the Canadian contribution to the experimentation. However, use of BattleView for this purposee was conditional in that no modifications could be made to the BattleView system.

The BattleView system was used to support a Canadian UAV unit consisting of Predator-B aircraft performing intelligence and weapons fire tasks based on planned tasks and unplanned tasks (FRAGOs). The BattleView system includes its own JC3IEDM database (called the CF-ODB). As shown in Figure 8, the BML-to-BattleView gateway converted BML messages (e.g. ORDERS, REPORTS) by interfacing directly to the CF-ODB. As reports generated by the UAV were received by BattleView, the situational awareness displays were updated automatically, thus providing for enemy and own friendly force positions and status, including task status. Similarly, when BattleView published orders to the UAV unit, they were received and executed with no human intervention by the UAV simulation.

A unique aspect of the Canadian contribution was that, for the first time, a simulated robotic force element was commanded directly through BML as part of MSG-048 experimentation.

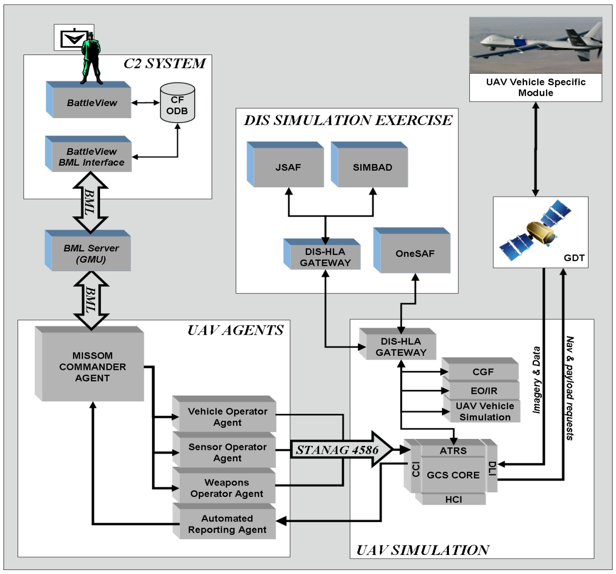

Figure 8. Canadian systems architecture

6.2 France C2 System: SICF

SICF (Système d'Information pour le Commandement des Forces) is a Land Forces C2 system deployed for French Division and Brigade Command Post. In addition SICF is also used by the CRR-FR (Rapid Reaction Corps France) and the EuroCorps. SICF shortens the decision action cycle providing each dedicated cell with operational functions such as:

- G1 (Personnel): management by categories (civilian and military);
- G2 (Intelligence): intelligence follow up, intelligence preparation battlefield, and information collection plans;
- G3 (Operation): situation awareness, generation of orders, fire support, terrain analysis, air battlespace management, and combat engineers;
- G4 (Logistics): logistic planning, personnel support, maintenance, medical support, supply and spare parts, logistic status board, an dmovement planning;
- G5 (Planning): COA's confrontation, contingency planning, targeting, and NATO operations planning;
- G6 (CIS): network planning, HQ administration, technical switch over, and help desk;
- G7 (AAR): record and replay of situations and events;
- G8 (LegAd): rules of engagement and management;
- G9 (CIMIC): CIMIC management, NGOs, population, industrial and cultural risk analysis, and quick impact projects.

SICF is MIP compliant. It is mostly deployed overseas during coalition operations.

6.3 Netherlands C2 System: ISIS

ISIS is the Royal Netherlands Army's C2 system used at staff level. Comparable systems for unit (command vehicles, tanks, etc.) and dismounted level (soldier) are OSIRIS and XANTHOS. In the MSG-048 2009 experiment, ISIS was used as the opposing forfce (OPFOR) C2 system by the experiment OPFOR, who issued the enemy order to the simulators. The OPFOR was able to issue FRAGOs for the enemy.

Since BML is still under development, ISIS does not yet have a BML interface. Therefore, as in the 2007 and 2008 BML demonstrations, ISIS was enabled with a postprocessor (called gateway) to issue BML orders and to receive BML reports. This postprocessor was upgraded compared to the previous demonstrations, such that the user didn't have to complete the BML order coming from the gateway. The gateway itself sent a complete BML order to the German IBML editor (see section 8.2 below), who sends it to the Web services. The reports coming back from the Web services go directly into the gateway. Figure 9 below shows the architecture.

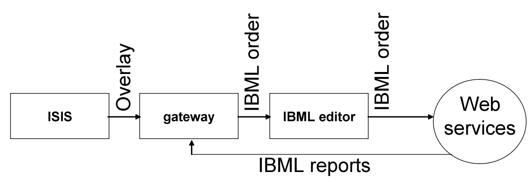

Figure 9. ISIS-Gateway architecture

6.4 Norway C2 System: NORTaC-C2IS

NORTaC-C2IS is a Norwegian system for tactical army operations. It was developed by Kongsberg Defence & Aerospace (KDA). During the 2009 experiment, NORTaC-C2IS was used to support the 1-22 Battalion Commander in plan development and to present status and situation reports available to the 1-22 Battalion.

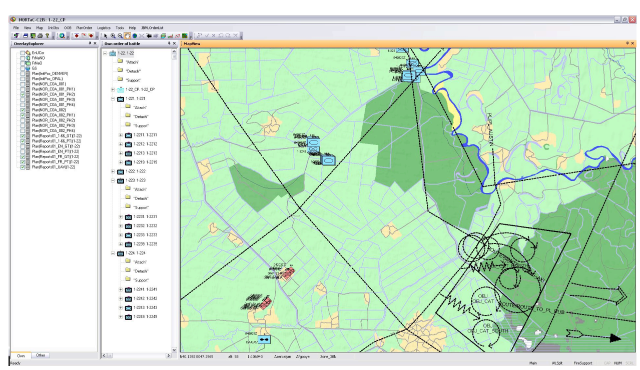

Figure 10. Battalion order displayed in NORTaC-C2IS

In 2008, KDA developed a BML extension that enabled the user to define basic orders through the NORTaC-C2IS graphical user interface. Orders expressed in NORTaC-C2IS are stored in a C2IEDM database. Norwegian Defence Research Establishment (FFI) has developed "FFI C2-Gateway" which maps order data from the NORTaC-C2IS C2IEDM database to BML, in addition to mapping data in BML reports to C2IEDM. This gateway also provides a capability to create temporal associations between tasks. The combination of NORTaC-C2IS and FFI C2-Gateway allowed the user to create BML orders and FRAGOs, in addition to providing a graphical view of the reported ground truth and perceived truth for both enemy and own forces.

6.5 UK C2 System: ICC

The UK deployed the Integrated Command and Control (ICC) which is of NATO origin. ICC is an air planning tool and can be used to prepare Airspace Coordination Orders (ACO) and Air Tasking Orders (ATO). It also can be used to display a live, joint operational picture. In addition, the Joint Automated Deep Operations Coordination System (JADOCS), of US origin, was used to display C-BML General Status Reports (GSRs).

Stand-alone BML translator interfaces were built for these systems, so that none of the UK applications needed to be modified. These interfaces permitted all the UK systems to exchange C-BML orders and reports with the other national systems via the C-BML web services. The roles were:

- To convert ICC-generated ACO and ATO document information into C-BML orders;
- To subscribe to C-BML GSRs in order to create OTH-Gold messages to send to ICC and JADOCS.

The UK systems permitted the investigation of any special problems associated with the implementation of orders for joint operations and the different basic reporting requirements of ground and air units. Compared with MSG-048's main 2008 experiment, this was a considerable advance in the complexity for the UK system integrating existing UK components with new web services and providing a greater range of simulated force elements and capabilities.

The UK team used their C2 systems to prepare orders for and monitor a fast air component of the coalition force in the real-time mission rehearsal and training vignettes. The UK military SME worked with the coalition planning team and used ICC to develop an ACO and an ATO for these vignettes. The ACOs and ATOs were translated into C-BML orders and published *via* the C-BML web services. The air element for the scenario consisted of an airborne command and control aircraft (an E3D), a tanker and several four-ship strike units sequenced to provide Close Air Support (CAS) capability throughout the vignette.

The ATO provided a set of pre-defined missions for each aircraft or flight of aircraft. For CAS this included scheduled flights to pre-defined Combat Air Patrol (CAP) orbits. The ATO could not be used to direct the time-sensitive targeting required to support ground operations. (ICC has an associated application which may be used for this purpose, but it was not necessary to use this.) Instead, real-time targeting for the strike elements via FRAGOs was achieved using the same Canadian BattleView system which was used to task their UAV; NorTAC could also be used in the same way.

BML GSRs created by the simulations were subscribed to and displayed on ICC and JADOCS.

6.6 USA C2 System: ABCS

The US Army Manuever Control System (MCS), part of the Army Battle Command System (ABCS), was used in the experimentation as a situational awareness viewer for reports produced by the OneSAF simulation (see below). It was unique within the MSG-048 configuration in that it received information from OneSAF in JC3IEDM format via a distributed US Army JC3IEDM Reference Implementation (RI). In turn, that RI exchanged BML Orders and Reports with the MSG-048 BML server, using BML. A "back to back" (B2B) BML client was used to couple the two JC3IEDM systems.

7. National Simulation Systems

Simulation systems were provided by Canada, France, Spain, the UK, and the USA.

7.1 Canada Simulation: UAV-SIM

The UAV-simulation shown in Figure 8 was comprised of two systems: the UAV-agents application and the UAV System simulation.

The UAV-agents application received BML Orders and FRAGOs from the BML server and processed these orders. This process required applying decision logic and translating assigned tasks into STANAG 4586 messages, the NATO standard for controlling UAV systems. Similarly, data received from the UAV system was processed and converted into intelligence and other reports before being published to the BML server. In addition to own and OPFOR position and operational status reports (e.g. battle damage assessment), the UAV-agent application also provided task status reports to BattleView.

The UAV system simulation included a simplified GCS emulation that directly emulates operator inputs. This in turn generates STANAG-4586 compliant messages, the NATO standard for controlling UAV systems. Thus the interface was the same as that used to control actual UAV systems. The UAV system simulation hosted a CAE STRIVE^{TM} CGF simulation that participated in DIS exercises that included JSAF, OneSAF, and SIMBAD simulations. The UAV system simulation included simplified logic that allowed for an Automatic Target Recognition System (ATRS) emulation that enabled an automated intelligence gathering capability.

7.2 France Simulation: APLET

APLET (acronym for "Aide à la PLanification d'Engagement Tactique") is a French MoD program which aims to provide M&S capabilities for Courses of Action Analysis (CoAA). Addressing French Brigade Command Post planning requirements fitted with C2 system, SICF, APLET deals mainly with issues regarding C4I and simulation systems interoperability. In addition, APLET models cover both regular and irregular warfare and counter insurgency operations (COIN).

APLET's main objectives are to:
- Automate the Military Decision-Making Process for Course of Action Analysis, MEDO (Méthode d'Elaboration d'une Décision Opérationnelle);
- Bridge the gap between C4I and simulation systems in order to ease the exchange of information in a more efficient and standardized manner;
- Develop multi level models capturing the French doctrine and an efficient technical architecture to provide CoAA results in a tight period;
- Produce an unambiguous Operation Order (OPORD) from selected COA

The APLET technical architecture shown in Figure 11 is a client/server architecture based on CORBA. This allows starting simulation more rapidly and provides replay capability similar to a digital video recorder. APLET data model is based on JC3IEDM to enable interoperability with C2 systems that are MIP compliant. APLET supports both SICF and C-BML exchange mechanisms based on standardized OPORD, request and reports XML format.

7.3 Spain Simulation: SIMBAD

The Spanish constructive simulator SIMBAD was designed to be used in the Spanish training centre (CENAD) to train battalion-level task force command posts in course of action and logistic support. Military units are typically represented in SIMBAD at the level of aggregation of platoons. The object model used within SIMBAD is based on C2IEDM structures.

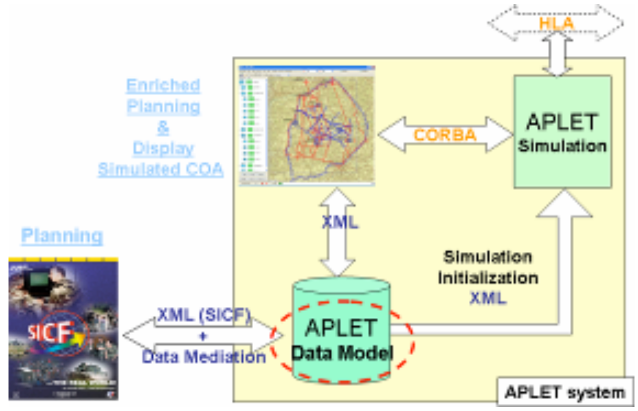

Figure 11. APLET Technical Architecture

Some of the main features of SIMBAD are:
- Predefined ROEs, engagement tables and algorithms, and a set of configurable parameters.
- A Tactical Event Manager, which also deals with time management issues.
- GIS-based GUI, which can represent both geographical and tactical layers.
- HLA interface (using a proprietary, C2IEDM-inspired FOM).

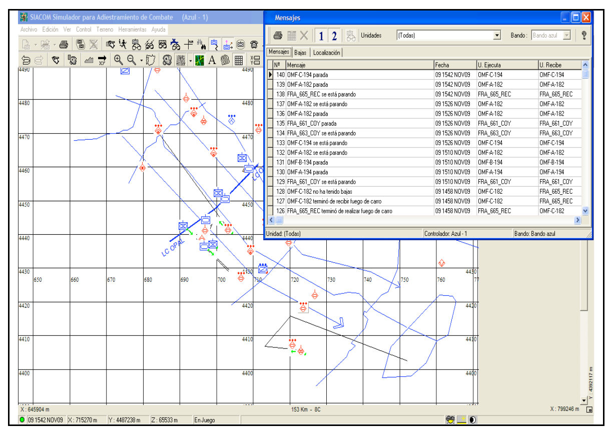

Figure 12. SIMBAD running several orders

Due to design principles, motivated by the way in which this simulator is used to train commanders, SIMBAD offers almost no automation to the user, who is responsible for initiating and controlling the execution of elementary actions such as "move" or "engage" in order to undertake operational tasks.

For this experiment, two gateways were added to SIMBAD:

1. A gateway to allow the transformation of BML orders containing operational tasks into elementary actions that could be understood by SIMBAD. In the same way

the gateway allow SIMBAD to produce BML reports from the information generated by the system.

2. A gateway to allow the system exchange information with the other simulation systems (JSAF, OneSaF and UAV SIM) though DIS.

SIMBAD participation was planned to support mission rehearsal activities, nevertheless during the experiment SIMBAD provided limited support to training activities. This addition proved that military plans/reports can be expressed using BML regardless the system that needs to interpret them afterwards, as well this modification shown the experimentation's system architecture flexibility, allowing the unplanned late modifications with almost no impact on the rest.

7.4 UK Simulation: JSAF

The UK deloyed the Joint Semi-Automated Force 2007 (JSAF 2007), of US origin. This is a real-time, constructive, entity-level, computer-generated force model. An interface to JSAF 2007 was used to task simulated air and ground units from subscribed C-BML orders and to create and publish C-BML GSRs. JSAF 2007 simulated both air and ground forces (coalition and opposing) and was used to create BML reports for consumption by the full range of C2 systems. JSAF also interacted with the other real-time simulators (SIMBAD, UAV and OneSAF) using DIS, typical in a heterogeneous synthetic environment. JSAF is an entity level simulation but tasking is usually at company or platoon level for ground units and flight or individual aircraft for air units. BML tasking by coalition C2 systems (SICF, NorTAC and ISIS) was all at company level.

Simulation of all ground forces except those of the USA was split between JSAF and SIMBAD. JSAF simulated 1-22 (NOR) BN and half the OPFOR BNs, while SIMBAD simulated 1-66 (FRA) BN and the remaining OPFOR units. This helped ease the simulation load as only a single instance of JSAF was available. However, because of the way the simulations were tasked it was not necessary to issue separate orders to the different simulators. The simulation configuration remained transparent to the C2 systems. When a simulator received an order it would task those only units it was simulating. For some vignettes, JSAF also simulated and tasked the full range of ground forces.

The DIS capability meant that the Canadian UAV simulator and US reconnaissance force, simulated by OneSAF and controlled through the SIMCI system could interact, particularly detect, report on and engage OPFOR units being simulated by JSAF and SIMBAD.

For ease of use BML reports should be bundled into sets with a common property. The schema used would permit a bundle of unrelated reports, e.g. ground truth and perceived truth, friend and foe, friend and ally. The reports were in fact bundled into sensibly related groups before they were dispatched and this greatly simplified the operation of the web services and the subscribing C2 systems.

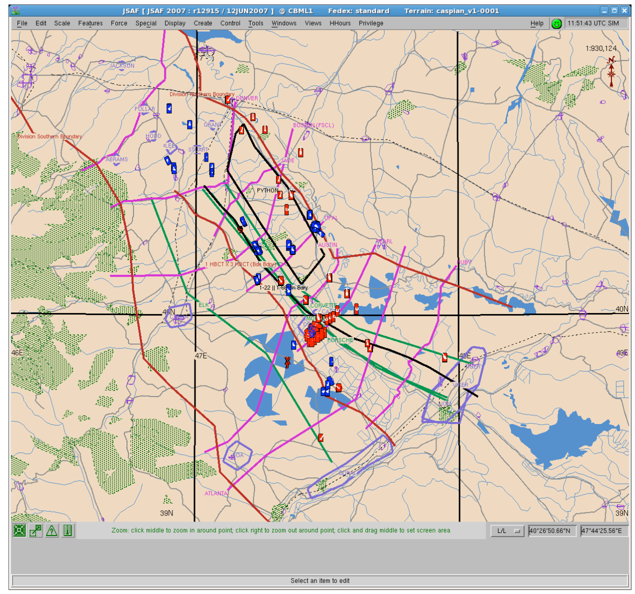

Figure 13. JSAF screen showing 2009 scenario

7.5 USA Simulation: OneSAF

The US Army simulation OneSAF provided a simulation of the reconnaissance element, a battalion-sized force. It received Orders via BML. The configuration used by the US Army system is shown in Figure 14.

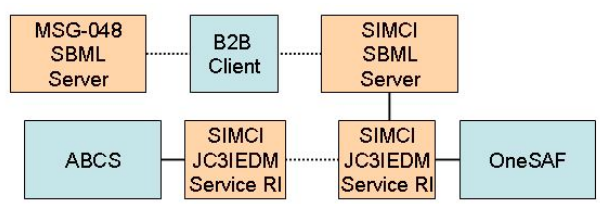

Figure 14. US Army C2-Simulation Configuration

8. Supporting Software

Two software systems provided general support for interoperation of C2 and simulation systems. These were the Scripted BML Web Service (SBML) and the C2 Lexical Grammar (C2LG) GUI.

8.1 US Scripted BML Web Service

Another US technical contribution to the MSG-048 experimentation was an open source Web Service that expanded on the one used in 2008 (Figure 10) [17, 18]. The new service, reported in [5] and [24], has the properties that:

- Scripts can be created or revised with much less time and effort than previous services coded in Java
- The scripting language offers only a minimal set of features, so that opportunities for error are reduced
- The script representation defines the mapping used concisely
- The service supports publish/subscribe; this was quite important to the MSG-048 configuration, because the alternative, polling, would have greatly diminished overall performance by sapping a significant portion of the server's capacity.

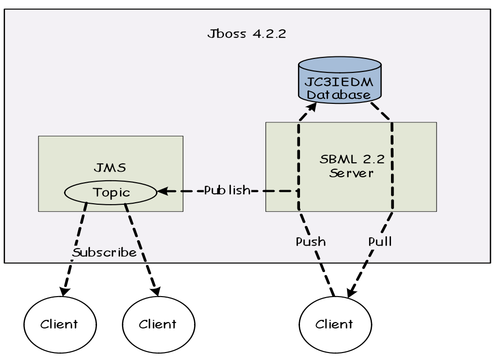

Figure 15. Scripted BML Web Service

8.2 Germany C2LG IBML Editor

Fraunhofer FKIE has developed a GUI to allow and to facilitate the formulation of orders and reports according to the rules of the BML grammar "Command and Control Lexical Grammar (C2LG)" [13, 19]. The GUI includes plug-ins that allow it to be connected to other systems. By this, the GUI had been used integrated, e.g., in the Netherlands ISIS C2 System (cf. section 6.3), or standalone as an order input connected to the Scripted BML web service (cf. section 8.1).

To formulate an order, the data flows as follows. The order will be formulated within the GUI from the scratch if the GUI is used stand-alone. If the GUI is integrated in a C2-system, e.g., in ISIS, it receives a pre-formulated version of the order to complete. The GUI uses drop-down menus and a map. In the map, units, facilities, features and locations can be selected (by mouse click) to speed up formulation, especially formulation of spatial information. When an order is completed, it is mapped into the IBML representation and delivered to the simulation systems via the Scripted BML web services. See [25] for more information on C2LG and the operation of the editor.

9. Development Process

MSG-048 was developing a complex system, which was made more difficult by physical and cultural distances. We followed a distributed, collaborative development process, which would not have been possible without access by all teams to the Internet. Beginning in March 2009, both the Experiment Team and the Technical Team held teleconferences nearly every week via Internet audiographic conferencing technology. In a sequence of these teleconferences, the schema to be used was established as a refinement of the IBML used in 2008. The SBML service, adapted for publish/subscribe under a US Army SIMCI project [5], was made available via Internet to all teams, to be used for development and integration testing. National systems were upgraded to publish/subscribe and most of them were able to reach interoperability before the group ever came together for final integration testing. Two physical integration events were held: September in Portsmouth, UK and October in Paris, France. Continued Internet testing was used to resolve remaining problems, followed by final integration in Manassas the day, before experiments began.

It would not be accurate to say that all of this development with smoothly. In fact, despite all the risk reduction there were technical problems even during the experimentation. Nevertheless, interoperability was achieved, many of the experimentation goals were met, and we learned a great deal about how BML will need to be supported in MSG-085. We therefore believe the process followed was basically successful and shows that the technologies used, and the overall BML concept, provide a sound basis for future work.

10. Future Plans

The MSG-085 Technical Activity, *Standardization for C2-Simulation Interoperation*, will commence in mid-2010 and will be a continuation of the work done in MSG-048. The work of MSG-048 has greatly contributed to validating the usefulness of BML in support of coalition operations. MSG-085 has been chartered to build upon this and work towards the end goal of taking coalition BML closer to operational deployment.

The objectives of MSG-085 are: to further clarify the scope and requirements of coalition BML; to reach a consensus regarding the manner to produce a digitized order; to assess available open-source reference implementations and to demonstrate how coalition BML complements MIP standards. As did MSG-048, MSG-085 will provide further recommendations for standardization of coalition BML. Its technical activity will be conducted with close involvement from the end users in the operational community, a process started in MSG-048.

11. Conclusions

BML is a powerful, general approach to interoperability of coalition C2 and simulation. We were able to achieve interoperability among a total of eleven systems in a few months of work. As in the past, the availability of a BML implementation on the Internet was an essential feature in this rapid development; adding a publish/subscribe capability to that service proved essential to scalability for multiple, interoperating systems.

MSG-048 has completed its planned work and is in the process of writing its final report. A successor, MSG-085, has been chartered in recognition of the potential demonstrated under MSG-048. It will be more operationally focused, with the goal of showing how to use BML in NATO operations. We look forward to participating in that activity.

12. References

[1] Sudnikovich, W., J. Pullen, M. Kleiner, and S. Carey, "Extensible Battle Management Language as a Transformation Enabler," in *SIMULATION,* 80:669-680, 2004

[2] Tolk, A. and J. Pullen, "Using Web services and Data Mediation/Storage Services to Enable Command and Control to Simulation Interoperability," 9th IEEE International Symposium on Distributed Simulation and Real Time Applications (DS-RT 2005), Montreal, Canada, 2005

[3] Pullen, J., M. Hieb, S. Levine, A. Tolk, and C. Blais, "Joint Battle Management Language (JBML) - US Contribution to the C-BML PDG and NATO MSG-048 TA," IEEE European Simulation Interoperability Workshop, June 2007

[4] Levine, S., M. Pullen, M. Hieb, C. Pandolfo, C. Blais, J. Roberts and J. Kearly, "Joint Battle Management Language (JBML) Phase 1 Development and Demonstration Results," IEEE Fall Simulation Interoperability Workshop, Orlando, FL, 2007

[5] Levine, S., L. Topor, T. Troccola, and J. Pullen, "Net-Enabled Technology Facilitated M&S/BC Interoperability," IEEE Fall Simulation Interoperability Workshop, Orlando, FL, 2009

[6] Pullen, J. *et al.*, NATO MSG-048 Coalition Battle Management Initial Demonstration Lessons Learned and Way Forward, IEEE Spring Simulation Interoperability Workshop, Providence, RI, 2008

[7] Schade, U. and Hieb, M., "Formalizing Battle Management Language: A Grammar for Specifying Orders," *2006 Spring Simulation Interoperability Workshop*, IEEE Spring Simulation Interoperability Workshop, Huntsville, AL, 2006

[8] Perme, D., M. Hieb, J. Pullen, W. Sudnikovich, and A. Tolk, "Integrating Air and Ground Operations within a Common Battle Management Language," IEEE Fall Simulation Interoperability Workshop, Orlando FL, 2005

[9] Sudnikovich, W., A. Ritchie, P. de Champs, M. Hieb, and J. Pullen, "NATO Exploratory Team – 016 Integration Lessons Learned for C2IEDM and C-BML," IEEE Spring Simulation Interoperability Workshop, San Diego CA, 2006

[10] Hieb, M., S. Mackay, M. Powers, M. Kleiner, and J. Pullen, "The Environment in Network Centric Operations: A Framework for Command and Control," 12th International Command and Control Research and Technology Symposium, Newport, RI, 2007

[11] Tolk, A, M. Hieb, K. Galvin, L. Khimeche, and J. Pullen, "Developing a Coalition Battle Management Language to facilitate Interoperability between Operation CIS and Simulations in support of Training and Mission Rehearsal", 10th Command and Control Research and Technology Symposium, McLean, VA, 2005

[12] Galvin, K., W. Sudnikovich, P. deChamps, M. Hieb, J. Pullen, and L. Khimeche, "Delivering C2 to M&S Interoperability for NATO - Demonstrating Coalition Battle Management Language (C-BML) and the Way Ahead," IEEE Fall Simulation Interoperability Workshop, September 2006

[13] Schade, U. and M. Hieb, "Development of Formal Grammars to Support Coalition Command and Control: A Battle Management Language for Orders, Requests, and Reports, 11th International Command and Control Research and Technology Symposium, Cambridge, UK, 2006

[14] Hieb, M. and U. Schade, "Formalizing Command Intent Through Development of a Command and Control Grammar," 12th International Command and Control Research and Technology Symposium, Newport, RI, 2007

[15] Blais, C., K. Galvin and M. Hieb, "Coalition Battle Management Language (C-BML) Study Group Report," Paper presented at IEEE Fall Simulation Interoperability Workshop, Orlando FL, 2005

[16] Tolk, A., S. Diallo, C. Turnitsa, and L. Winters, "Composable M&S Web services for Net-centric Applications," in *Journal of Defense Modeling and* Simulation 3:27-44, 2006

[17] Pullen, J., M. Hieb, and S. Levine, "Using Web Service-based Command and Control to Support Coalition Collaboration in C2 and Simulation," 13th International Command and Control Research and Technology Symposium, Bellevue, WA, 2008

[18] Pullen, J., Dr. Corner, S. Singapogu, and P. McAndrews. "Interpreted Web Services as a Tool for Development of Command and Control-Simulation Interoperability," 13th IEEE International Symposium on Distributed Simulation and Real Time Applications (DS-RT 2007), Singapore, October 2009

[19] Schade, U., and M. Hieb. "Battle Management Language: A Grammar for Specifying Reports," IEEE Spring Simulation Interoperability Workshop, 2007, Norfolk, VA

[20] de Reus, N., R. de Krom, O. Mevassvik, A. Alstad, U. Schade and M. Frey, "BML-enabling national C2 systems for coupling to Simulation,", IEEE Spring Simulation Interoperability Workshop, Newport, RI, 2008

[21] Hügelmeyer, P., Schade, U. & Zöller, T. (2007). Application of BML to inter-agent communication in the ITSimBw simulation environment. *Proceedings of the 2007 Winter Simulation Conference*, December 2007, Washington, DC.

[22] Gustavsson, P., M.R. Hieb, M. Groenkvist, V. Kamath, Jakob Blomberg, and Joakim Wemmergard. "BLACK-CACTUS – Towards an Agile Joint/Coalition Embedded C2 Training Environment," Paper Presented at the IEEE Spring Simulation Interoperability Workshop, Providence, RI, 2008

[23] Schade, U. and M. Hieb, "A Linguistics Basis for Multi-Agency Coordination," Paper presented at 12th International Command and Control Research and Technology Symposium, Newport, RI, 2007

[24] Pullen, J., D. Corner and S. Singapogu, "Scripted Battle Management Language Web Service Version 1.0 Operation and Mapping Description Language," IEEE Spring Simulation Interoperability Workshop, San Diego, March 2009

[25] Pullen, J., et. Al., "Adding Reports to Coalition Battle Management Language for NATO MSG-048," IEEE 2009 European Simulation Interoperability Workshop, Istanbul, Turkey, 2009

Author Biographies

ANDERS ALSTAD is a Research Scientist at the Norwegian Defence Research Establishment (FFI). His work is within the field of modeling and simulation. His interests are in design and development of distributed systems.

ADAM BROOK is a member of the Simulation and Training Group at QinetiQ. He has worked in the fields of distributed training systems and simulation-C2 interoperability since 1996 and has been a member of MSG-048 since April 2007. He is leading development of a UK C-BML capability for MSG-048 on behalf of the UK MoD Defence Science and Technology Laboratory.

SERGIO GALAN CUBERO is a system engineer with ISDEFE and assigned to the M&S office in the R&T organization of the Spanish MoD. He supported the Spanish SIMBAD system in the MSG-048 experiments.

DR. KEVIN HEFFNER holds a BS in Engineering from the State University of NY at Buffalo and a Ph.D from University of Paris 6. He has worked in the field of modeling and simulation for 20 years. His work includes applying model-centric concepts to flight simulator architectures and interoperability among C2, simulation, and automated forces, particularly those involving UAVs.

LIONEL KHIMECHE is an R&T program manager in the field of M&S for planning and forces readiness at the DGA (Delegation Generale pour l'Armement) / Center for Defense Analysis. His main topic of research deals with C4I-Simulation Interoperability. He co-chairs the NATO Technical Activity on C-BML and he leads several international projects for cooperation.

OLE MARTIN MEVASSVIK is a Principal Scientist at the Norwegian Defence Research Establishment (FFI). His research interest is within the area of modeling and simulation, with application to training and experimentation.

DR. J. MARK PULLEN is Professor of Computer Science at George Mason University. In this project he led development of the Scripted BML Web Services.

NICO DE REUS is a member of the scientific staff in the M&S department at TNO Defence, Security and Safety in the Netherlands. His current work focuses on modelling & Simulation in general and bringing Simulation to the Battlefield in specific. His current work focuses on C2-Simulation interoperability.

DR. ULRICH SCHADE is a senior research scientist with Fraunhofer FKIE and is associate professor to the Institute for Communication Science, Bonn University. He is an expert in computational linguistics and has contributed greatly to the understanding of how formal grammar can improve the development of BML.

RICARDO GOMEZ VIEGA is an ISDEFE systems engineer for the C2ISR office in the R&T organization of the Spanish MoD. For the last five years he has served as project leader in the C2, ISR and C2-interoperability areas. His domains of expertise include software architectures and the software development process.