19th ICCRTS

"C2 Agility: Lessons Learned from Research and Operations"

UK Experiences and Lessons Identified Using C-BML in Practical Experiments

Topics
Experimentation, Metrics, and Analysis
Modeling and Simulation
C2-Simulation Interoperability

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Abstract: *This paper discusses a number of topics arising from various recent UK experiments in the C2-Simulation domain using the Military Scenario Definition and Coalition Battle Management Languages (MSDL and C-BML). The experiments have supported the goals of various national and coalition activities. The paper describes the use of MSDL for the initialisation, state capture and check-pointing of operational C2 and simulation systems. It also covers the use of C-BML for communicating information between C2 systems and a heterogeneous mixture of other C2, modelling and simulation systems, mostly legacy but some experimental.*

The paper looks at current work to investigate the benefits and challenges of integrating C-BML with chat messaging services – a new technology matched to a ubiquitous capability. Experiences of different middleware options including scripted BML web services and HLA-Evolved are described. C-BML has been used to help develop the underlying architecture for concept simulation-based exercise support tools, some of which have been implemented in prototype form. The paper shows how C-BML is also being considered to help bridge the interoperability gap between an autonomous UAV mission commander's station and an experimental C2 network.

Lessons identified during these practical experiments help inform the continuing development of C-BML specifications, C2 systems and experimental design.

UK Experiences and Lessons Identified Using C-BML in Practical Experiments

Introduction and Background

There has been a need to link and exchange information, particularly orders and reports, between C2 and simulation systems for a long time and for a number of different purposes. In the US-UK Synthetic Theater Of War (STOW) programme of the mid-1990s an early form of battle management language was used. This was the C2 Simulation Interoperability Language (CCSIL) [1]. In practice and with the support tools available at the time this was found to be impractical to develop and use by other than specialists but it demonstrated the potential for operating C2 with M&S in the same network environment.

Constructive simulations, particularly of the Semi-Automated Force (SAF) type, have been used to stimulate operational C2 systems, often running using either a live (i.e. real world) or simulated tactical data network. Operational messages in many formats: ADatP-3, USMTF, UKLEMS, OTH-Gold, CoT, etc are readily generated from SAFs and can fully supply the needs of stimulating these live systems or may be used to augment them. A number of example uses may be cited: Is it possible to investigate how the platoon commander can manage high information levels when operating in a networked tactical environment? What are the benefits [and disadvantages] of sharing coalition situational awareness at different echelons? How will as yet not-in-service communications systems perform when loaded with realistic network traffic levels?

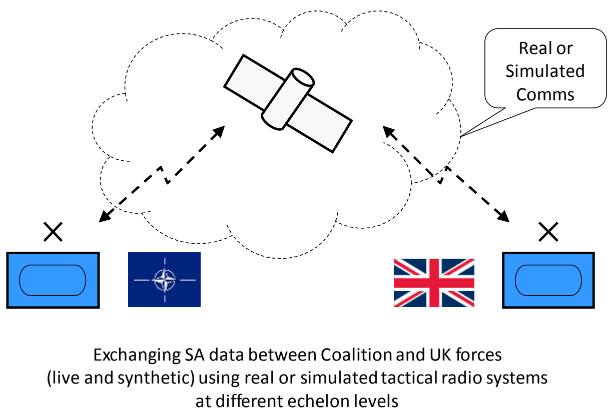

Figure 1 - Using simulation to support communications experimentation

The UK has had experience in all these areas looking at answering research questions, Figure 1 shows a top-level view of types of system represented in this sort of experimentation. Equally important has been the use of simulation to support military training requirements. In these cases simulation often represents forces with which the trainees, the training audience, interact. A trainee may be the subject of a Turing test; is he interacting with other people or a computer system? A typical Computer Generated Force (CGF) simulation includes behaviour models of varying levels of sophistication varying from simple scripted action sequences through finite state machines to complex agent-based models. If a commander can give an order to a military unit he should be able to give the same order to a simulated unit and expect to see a similar effect.

C-BML offers a capability to permit an order created in a C2 system to be expressed in a form which is readily usable by a suitably adapted or natively capable simulation system. Being an open standard it also has a number of bonus points. Coalition interoperability is supported, so too are reports and requests. No longer is it necessary to translate between *n* different message formats, each of which may contain tens or even hundreds of message types. Information may be exchanged between different C2 systems: different types; different nations; and different echelons. C-BML may also be exchanged with robotic systems.

Earlier C-BML Experimentation with NATO MSG-048

The UK became involved in the activities of NATO Modelling and Simulation Groups 048 and 085 whose terms of reference focused on the development and use of C-BML supported by strong experimentation. The work of MSG-048 [2] culminated in 2009 with the development of a complex C-BML federation comprising fifteen systems contributed by seven nations as shown in the following figure. In this federation C-BML was used by both the friendly coalition (Multi-National Force) and the Opposing Force – here role-played by the Netherlands. The federation was able to execute a number of plans and orders developed by military subject experts (SMEs) for different use cases: planning, training and mission rehearsal. The planning vignette used the French simulation APLET to provide faster-than-real-time capabilities and thus permit a number of different courses of action to be evaluated relatively quickly. The training and mission rehearsal vignettes were both supported by real-time simulation.

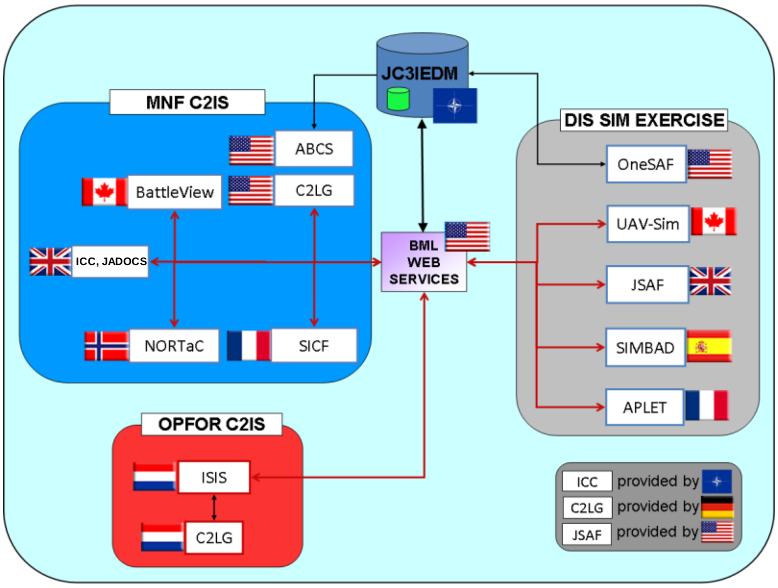

Figure 2 - Systems Used in MSG-048 Final Experiment, Manassas 2009

Developing the scenarios required each nation to contribute to a battle-book containing information about force structures, equipment types, initial locations, APP6 symbol codes and DIS enumerations for use in the simulation environment. This was needed by nearly all the participating systems in one form or another: simulations needed to initialise their units and equipment correctly, C2 systems needed to be able to represent their own units and those of the rest of coalition. The battle-book was an Excel spread-sheet with one page for each nation's assets. This created almost as many problems as it solved: a spread-sheet document with human input cannot enforce the consistency required for initialising this sort of complex system-of-systems. At this time many of the systems used had to be initialised either manually or in system-specific, semi-manual ways. There was no consistent approach which could be used and much time was diverted from developing the C2-Simulation aspects. Challenging requirements from the military exercise director required several vignettes to be used based on scenario check-point (or save) states, units being introduced or removed, relocated or depleted according to the outcome of earlier vignettes.

Enter MSDL

The lessons identified led the MSG-085 technical team to investigate the use of MSDL for the initialisation of such heterogeneous federations. SISO standard MSDL [4] has the ability to describe nine functional areas which cover participants and overlays/tactical graphics. Here we focus on the former. Before dealing further with MSDL, it was recognised that a US standard, the Joint Training Data Services (JTDS) Order of Battle Services (OBS) [3], has been developed for this sort of activity but has the disadvantage of not being an international standard. At that time few simulations and no C2 systems were able either to generate or use MSDL data. Third party MSDL editors (from STS and CAE) were available and these were investigated. Some simulations, e.g. OneSAF, have a native MSDL import/export capability which allows them to be used as MSDL editors.

Using MSDL permitted a new approach to be taken to how the battle-book was defined. Each participant was required to define his own nation's forces using MSDL. These MSDL components were then merged to provide a unified, consistent data source which was distributed to the participating nations. The responsibility for how the MSDL was used was thus devolved. For example, the UK used JSAF as its simulation and in the land domain this works best with echelons below company level so only these lower level echelons were imported.

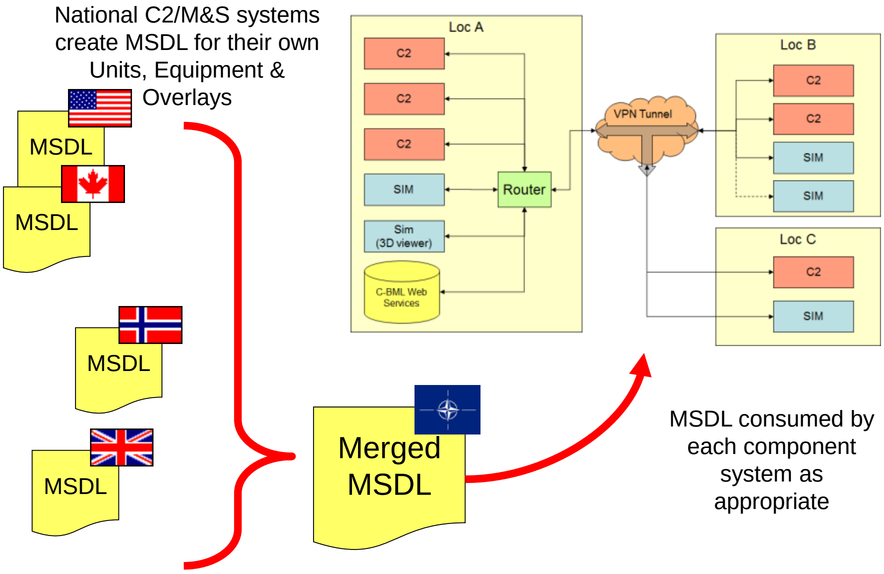

Figure 3 - Using MSDL to Initialise a Multi-National C-BML Federation

Figure 3 shows how multiple national MSDL components are merged for distribution to a C-BML federation, in this case one distributed over a virtual private network (VPN) with participants in three different locations.

A number of use cases were developed including the use of MSDL for check-pointing scenarios, i.e. saving the locations, damage states, etc of all the simulated entities. The saved state, an MSDL document or file, could then be manipulated to provide the start state for a new vignette or scenario according to the requirements of the exercise director. The following figure shows the concept of using MSDL to support the development of alternative restart states.

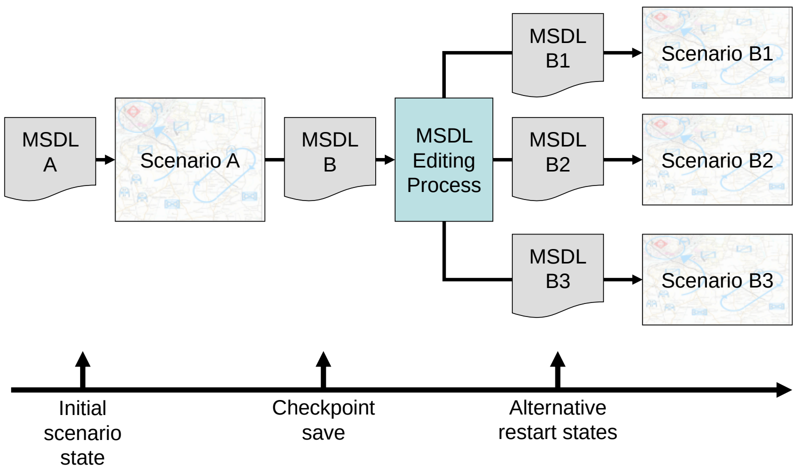

Figure 4 - Use of MSDL to Support Check-pointing

The SISO standard for MSDL was approved in 2008 [4] and in the course of this work a number of extemporisations have been made which will be proposed to the SISO MSDL PDG for consideration in future editions of the standard.

Middleware and Networks

C-BML systems usually require some form of middleware to permit information to be transferred between systems and the systems are distributed across a network.

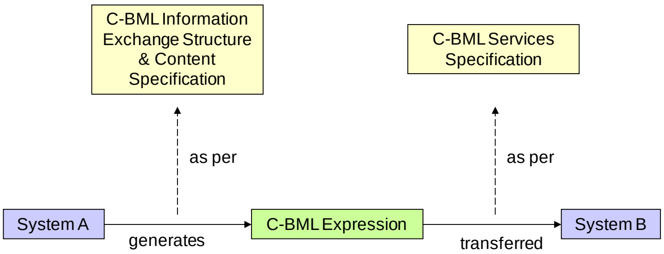

Figure 5 - A Generic C-BML System

In any C-BML system one system produces C-BML messages, usually as XML documents, and other systems consume then as shown in Figure 5. There is usually some form of middleware to enable this, a message passing service, possibly supported by a data-base, other C-BML-related services, e.g. message validation, routing or even simulation services.

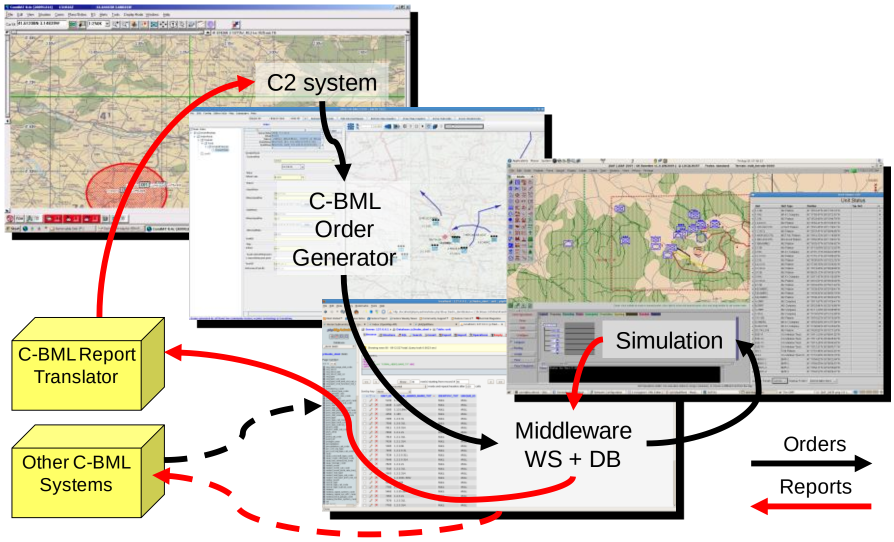

Figure 6 - Example C-BML System

Figure 6 shows a typical C-BML system, in this case interfacing to a legacy C2 system through an order generator and report translator. C2 systems with ‘native’ C-BML capability would allow the C2 user to generate orders directly. These systems are starting to be developed as the benefits of C-BML start to become appreciated in the C2 community.

Early work in support of MSG-048 used the Scripted Battle Management Language web services developed by George Mason University [5] and as these evolved so did the system interfaces necessary to use them. The UK systems have now been modified to use the latest version of SBML which include with their services schema translation functions and MSDL processing capabilities to automate the MSDL processing described above. The UK systems used this system to support the MSG-085 demonstration of December 2013. Schema translation is important in the experimentation domain since schemas are developing for various evaluation purposes. In due course this will be unnecessary as the SISO standards mature.

The second middleware solution which has been used in UK systems is the Coalition Battle Management Services (CBMS) developed by the Virginia Modelling And Simulation Center [6]. CBMS permits message transfer not only of MSDL and C-BML but any XML document. It is built on a searchable XML data-base, CBMS clients communicate using the well understood http RESTful (Representational State Transfer) system, i.e. PUT, POST, GET and DELETE, to transfer XML messages to and from the server.

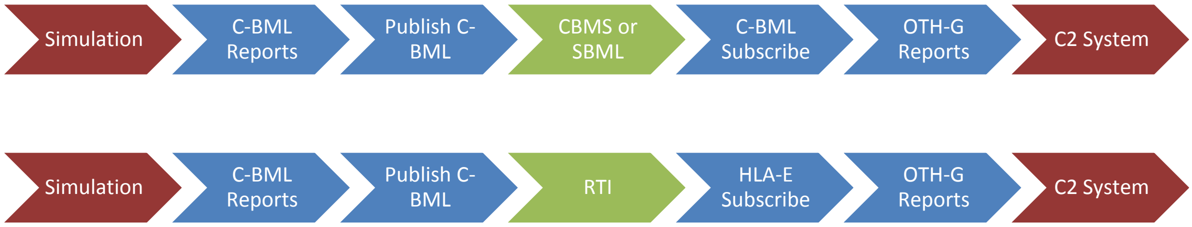

Figure 7 - Example C-BML System Developed to use HLA-Evolved

The IEEE 1516 (2010) High Level Architecture – Evolved (HLA-E) [7] simulation interoperability standard supports modular Federation Object Models (FOMs) and two of these have been developed by NATO MSG-106 [8]. These are the high-level and low-level FOMs. The high level FOM relates directly to the functionality of C-BML and defines interactions for orders, reports and requests as would be communicated with a C2 system. The low level FOM encapsulates direct control of a simulated entity or unit with interactions such as "Change Speed" or "Follow Unit", directives which would not be expressed in a high-level order. The use of HLA-E has become more common in the modelling and simulation community due to the introduction of modular FOMs. The UK has been supporting the evaluation of both of MSG-106's C-BML FOMs. The FOMs are specified using XML documents and the interactions with the Run-Time Infrastructure (RTI) are through software objects, interactions and triggers. Figure 7 shows how HLA-E has been used to replace the CBMS or SBML middleware of a traditional C-BML system for experimentation purposes. In this case simulation-generated C-BML reports flow through the system ultimately to be translated into OTH-Gold reports to be consumed and displayed on a C2 system. Other C2 report formats may of course be supported.

The UK has identified other communication methods which may be used include traditional internet protocols, TCP, UDP, multicast and systems such as the Object Management Group's Data Distribution Service for real-time systems (DDS) [9]. There are a number of other middleware systems which tend to work using an internal representation of battle-space data and supporting a number of message format-specific external interfaces. One example is the STS WISE system which has been extended to work with the GMU SBML system [10]. The UK has used this when participating in the MSG-085 experimentation of late 2013.

Network use for international C-BML experimentation has used a number of network standards. Simple, unclassified networking has been conducted very successfully using OpenVPN [11] tunnels across the internet, even using relatively low-bandwidth 3G cell-phone bridges. OpenVPN was used for much of the work of MSG-048 and -085. Experimentation has also been conducted using formally accredited networks such as the Combined Federated Battle Lab (CFBL) network [12] and the proprietary CISCO DMVPN system [13].

Concepts Extended to the Research Domain

The C-BML principles of breaking system interactions into the so-called 5Ws [Who, What, When, Where and Why] may be extended beyond C2-M&S or C2-Autonomous System interaction. Two [of many] examples which have been investigated in the UK research domain are:

- **ICoViCS** – Improved Control And Visualisation of CGF Systems

The ICoViCS programme aims to develop a way of using a common user interface to control a heterogeneous set of CGF systems. C-BML principles have been used to define the CGF control protocol and a prototype system using HLA-E has been demonstrated.

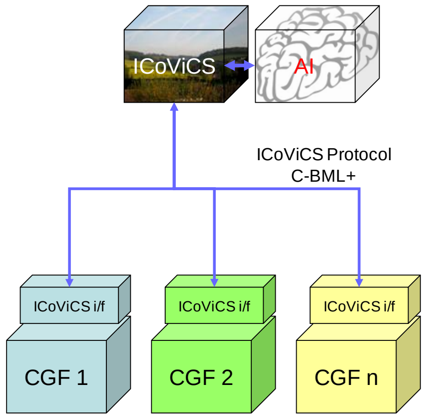

Figure 8 - Example ICoViCS Architecture

Figure 8 shows how a single ICoViCS user interface incorporating or accessing some artificial intelligence capability to give the system user extra capabilities or information, e.g. apportionment information or reasoning about the best CGF to use for a particular task. The ICoViCS protocol also needs to include Federation Execution and Control capabilities, this is something which SISO C-BML, for example, does not support. For this reason an extended C-BML standard was first investigated, referred to as "C-BML+". ICoViCS itself may be a C-BML system in its own right connecting to C2 systems as a regular C-BML-enabled simulation would. As this programme developed it became apparent that the real requirement was not for a common human user interface but for a common user interface standard since the user requirements vary considerably, e.g. the information required for a maritime system will differ from that required for a land system but they may both need to access the same set of CGFs. A prototype ICoViCS system has been developed under the UK research programme. It should be noted that the ICoViCS programme has also covered a much wider range of topics than are presented here including detailed stakeholder interviews, user interface technology reviews, etc.

- **CGF Voice** – Using voice and synthesised speech to interact with CGF systems

This design which uses low-level C-BML principles is a development of some much earlier work into voice control of CGFs. It was felt that it would be worthwhile revisiting this using current speech processing software and up-to-date hardware. The earlier work was very good in the air environment representing a controller interacting with a pilot or navigator or a pilot and wing-man (virtual, man-in-the-loop pilot, agent-based wing-man) using simple, structured messages: change flight level, fly along route, return to base, etc.

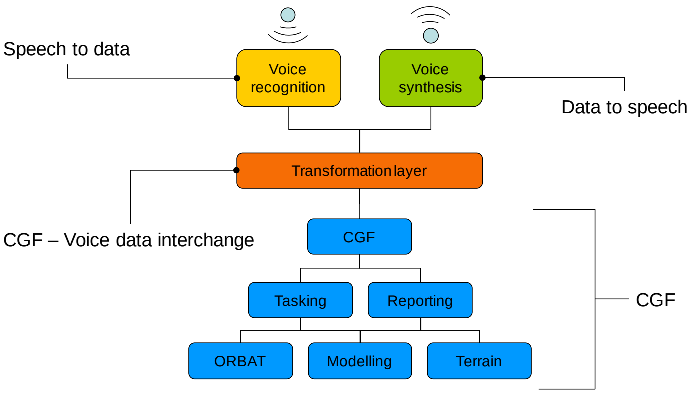

Figure 9 - Example CGF Voice Architecture

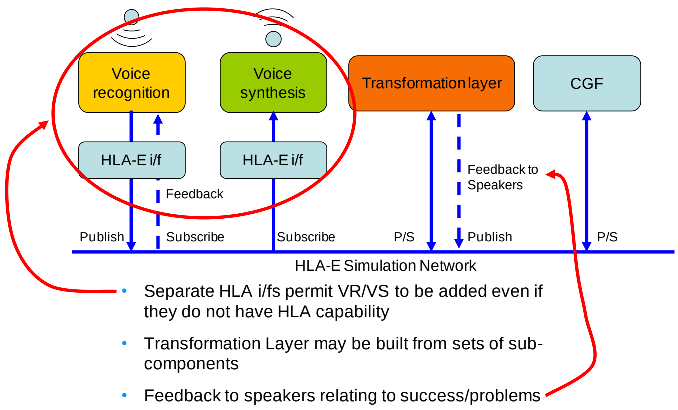

Figure 10 - Example CGF Voice Architecture using HLA-E

Figure 9 and Figure 10 show system architectures which have been developed for the control of CGF systems using voice control. Here again C-BML principles can be used to specify the interface protocols, potentially using an HLA-E interface. Using voice recognition and speech synthesis for CGF control is not new but modern voice engines and computer capabilities makes revisiting this area worthwhile.

Coalition Interoperability Experimentation

NATO MSG-085: C-BML has been used in a number of coalition interoperability experimentation activities. Much of the initial work has been contributing to the work of NATO MSG and has already been referred to above. MSG-048 experimentation ran from 2007 to 2010 and its work culminated in an experiment conducted at GMU, Manassas in 2009. This work entailed the use of a prototype implementation of C-BML developed concurrently with, if not in advance of, the work of the SISO C-BML Product Development Group. The lessons identified were taken up and implemented by MSG-048's successor, MSG-085, particularly those relating to initialisation of heterogeneous systems using MSDL, as described above.

MSG-085 has taken the work further and its members formed Common Interest Groups (CIG) which cut across the technical and operational domains with the aim of developing realistic use cases and relevant experimentation. The UK has mainly been involved in the work of the Technical Infrastructure, Joint Mission Planning (using C-BML and simulation to help a planner evaluate his plans and orders) and Air Operations CIGs. This work has resulted in a number of case studies and demonstrations leading up to a set of demonstrations held at Ft Leavenworth in December 2013.

The technical infrastructure CIG was largely involved in developing and implementing the middleware and networking solutions discussed earlier and for dealing with matters relating to MSDL and C-BML message processing.

Work by the air operations CIG reviewed the use of chat systems in military networks and some experimentation using C-BML to populate Openfire JChat [15] messages was conducted by the technical infrastructure group. This is not simply a matter of sending all C-BML information to a chat stream for two reasons: although C-BML is text-based it is still not very readable; secondly, many C-BML messages are better displayed graphically on a map display, particularly position reports. A C-BML subscription service was established to subscribe only to TaskStatus reports which were sent modified (largely by removing extraneous XML text) to a JChat data stream. The JChat user then has notification of what the simulated units are doing without direct reference to the simulation.

Work conducted by the air operations CIG on the formulation of C-BML messages for specific coordinated tasking such as air-to-air refuelling, troop transport and close air support has been described elsewhere [16], [17].

The Joint Mission Planning CIG has built upon the earlier work of MSG-048 using faster-than-real-time simulation to support course of action analysis. The CIG has taken as its guidance the principles set out in the NATO Comprehensive Operations Planning Directive (COPD) [18] and worked with the guidance of a military officer versed in the COPD process. In the COPD there is an iterative process for developing plans of development and review. As the plans are developed more and more detail is added, resolution on deployments, timings, locations etc. The ability to create digital plans in C-BML and pass them between the planning tools of developing and reviewing authorities and to test them in simulation is a thus very powerful capability. This work was demonstrated at the MSG-085 Ft Leavenworth demonstration.

Using C-BML with an Autonomous System

The concept of use for C-BML has always been to permit direct exchange of C2 information with autonomous and robotic systems as well as between C2 and M&S systems. A number of programmes have looked at this, e.g. [19] for autonomous systems operating in both the air and ground domains. In the UK there has been considerable interest in using agents to ease the workload of UAS mission commanders and payload operators. These agents are the points at which C-BML may be introduced. There already exists a standard protocol for communicating between mission commanders' Ground Control Stations (GCS) (sometimes referred to as the UAS Control System – UCS) and UAS, NATO STANAG 4586 [20]. This is the protocol of both flight control, specifying messages which may be transferred over a data link between GCS and UAS, and command and control. C-BML comes into its own where the GCS or the agent which helps the mission commander needs to interact with other C2 elements in the network-enabled battle-space.

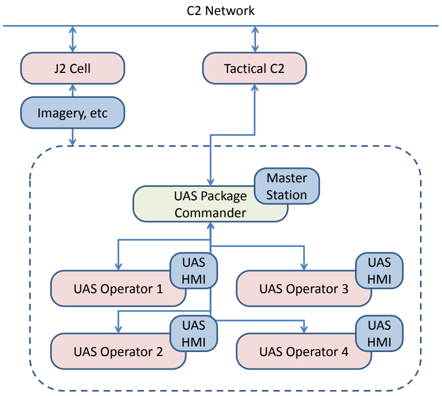

Figure 11 - Example Autonomous System with C2 Connection

Figure 11 shows an example UAS system with multiple simulated, but potentially real, UAS coordinated by a package commander. He is assisted by agents which optimise and deconflict UAS tasking. Current UK experimentation concerns the investigation of how C-BML can be used to help integrate the package commander's work station with other applications on the C2 network thus helping lower his workload. Examples include using C-BML to express Airspace Control Measure Request messages, to publish automated chat reports (as discussed earlier), to permit the UAS package commander to understand the plans and locations of military forces in his area of operations. Experience gained during the MSG-048 experimentation indicated that integrating a single UAS control station into a C-BML federation increased the utility of the UAS and also made much better use of the UAS controller's time and effort.

Conclusions

This paper has described a variety of application areas where C2 and simulation systems have been brought together. It has described work conducted using traditional message formats and with real and emulated communications networks and more recent work using C-BML to exchange information in a coalition environment and to influence the design of new systems. The use of MSDL to support this work has become increasingly important and the proposed alignment and integration of the C-BML and MSDL standards is seen as very beneficial. Whereas several simulation systems have already been adapted to use these standards, the corresponding adoption by the specifiers and developers of operational command and control information systems still has a way to go. C-BML and MSDL standards form part of an enabling technology, in due course their use will be fully transparent to end users.

Early work tended to be simpler in concept, single domain, only two coalition partners, fewer systems to be integrated, focus on reporting not tasking. Use of interoperability standards such as C-BML and the use of C-BML principles permits a much wider systems mixture to be attained, including coalition systems and a much wider functional mixture to be achieved. There are still challenges in this field relating to the standardisation, exploitation and acceptance of these standards, some were issued in [21], but over the recent years steady progress has been made to answer these.

Acknowledgements

The author wishes to acknowledge the support of the UK MoD Defence Science and Technology Laboratory in the development of many of the topics discussed in this paper as well as colleagues within QinetiQ and various organisations participating in the NATO Modelling and Simulation Groups.

Author Biography

Adam Brook is a member of the Training Group at QinetiQ. He has worked in the fields of distributed training systems and simulation-C2 interoperability since 1996 and was a member of MSG-048 since April 2007 and has been in MSG-085 since its inception in 2010. He is a SISO C-BML PDG member. He is supporting the UK MoD Defence Science and Technology Laboratory on the use of MSDL and C-BML.

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