Chapter 5 – LESSONS LEARNED

This chapter highlights the lessons learned during the four-year Technical Activity of MSG-048. In addition to valuable insight and feedback provided by operational SME throughout the MSG Technical Activity, many of the lessons learned were of a technical nature. The following section focuses on the technical lessons learned while the successive section presents the operational lessons learned, including the results of analysis and feedback provided by active and retired military personnel during the final experimentation, as described in the previous chapter.

5.1 TECHNICAL LESSONS LEARNED

Technical lessons learned deal with C-BML issues, from a standardization perspective (e.g. digitizing military information), from an implementation perspective (e.g. software development, integration, application initialization and execution, validation and error-handling) and from a software infrastructure perspective (e.g. network and system performance considerations).

5.1.1 Managing Orders

Procedures need to be established for the correct handling of C-BML orders. This permits different classes of order (such as: Warning Orders, Main Orders and Fragmentary Orders) to be used in representative ways. This is a non-trivial task.

5.1.2 Managing Reports

Entity Tracking – MSG-048 experiments indicate that the reporting frequency required for blue force tracking varies as a function of level of aggregation (e.g. lower level of echelon requires higher update rates) and service (e.g. air entities generally require higher update rates than ground entities).

Limiting Simulation Reporting Rate – Simulations, operating individually or as a federation, are typically able to generate reports at rates that can easily overload C2 systems. As a consequence, it will be necessary to either limit the rate at which simulation reporting occurs and/or provide for intermediate applications that can process/filter/queue reports before sending them to the C2 system.

Bundling of Reports – It was found to be useful to provide a mechanism for bundling multiple reports into one message in order to reduce the message payload overhead. In addition, there are differences among C2 systems regarding which organization echelon the C2 system is designed to receive and visualize data from reports. If possible, future infrastructure should have services for combining reports (e.g. entity position reports) into aggregated company position reports. Report bundles require headers to indicate the type of reports contained in the bundles.

Future report management also may require the use of geographic and report type filtering.

5.1.3 System Execution Management

Experience from utilizing C-BML has illustrated the value of a C-BML management facility for initialization and synchronization. The need mostly is bound to cases where C-BML is exchanged between C2 and simulation

systems, but is also necessary to handle cases where multiple C2 systems collaborate on the same scenario. The requirements for system execution management can be separated as follows:

System Initialization – Concerned with starting up and synchronizing all participating systems in the correct sequence, in addition to ensuring that all systems are initialized with the same set of scenario data and pre-conditions (task organization, unit positions, time, etc.).

Synchronization – The MSG-048 experimentation identified the need for synchronizing participating systems with regards to time, in addition to ensuring that all systems have access to the same underlying data (e.g. definition of units discovered during run-time).

Traceability and Debugging – It is inevitable that errors and performance problems occur when a heterogeneous set of applications are set to exchange C-BML messages. In order to enable tracing and debugging of such C-BML exchange, it is necessary to exchange meta-data such as identification of sending application and sent timestamp together with C-BML messages. Future work must consider whether such C-BML meta-data fits best in a kind of C-BML message header or such meta-data should be provided by the communication infrastructure utilized. In addition, the infrastructure should offer the capability to capture and replay the C-BML traffic for debugging and analysis.

Validation of C-BML Expressions – When exchanging C-BML expressions, the C-BML messaging infrastructure should be capable of validation at both the sending and receiving sides. Furthermore, some level of validation also should be performed by the C-BML expression producing and consuming systems. As system configurations are tested and optimized, it may be necessary to deactivate some levels of validation for performance reasons; however validation mechanisms are required in order to proceed with initial system configuration and testing.

5.1.4 Performance and Architecture

Specific C-BML-enabled use-cases and scenarios will have different configurations and requirements. For example they may utilize significantly different network topologies, (e.g. a distributed mission rehearsal versus an embedded decision support system) and may operate at different reporting rates.

The variety of architectures leads to varying needs for the C-BML communications infrastructure. For example, as mentioned above, reporting rates may require that the C-BML system be tailored to specific performance needs. Similarly, C-BML-enabled command and control involving robotic systems may involve wireless networks that require additional message validation, acknowledgement and re-transmission mechanisms.

Other performance considerations have already been mentioned in the above paragraphs (e.g. bundling of reports and simulation reporting rate limits).

Use of Publish and Subscribe – The early MSG-048 demonstrations used a simple client-server architecture where C2 systems had to poll a server for new reports, an approach which does not scale. The 2009 experiment also utilized client-server architecture, but supplemented the polling with a service that published reports to subscribing clients according to pre-defined “Topic” expressions. This architecture clearly illustrated performance gains of using publish and subscribe subscription mechanisms in contrast to polling.

Subscription/Filtering Mechanisms – Reports must be delivered to and ingested by all subscribing C2 systems within a short period of time to avoid differences in the Common Operating Picture (COP). C2 systems differ in maximum supported report frequency. Furthermore, the required report rate may depend on the echelon at which the C2 system is operating. If possible, future infrastructure should offer the possibility to filter reports by rate per object and by other attributes such as geographic area, force, echelon, perceived/ground truth, etc.

Faster Than Real-Time Scenario Execution – It was found that simulations had different approaches to report frequency when running faster than real-time. Some systems kept the reporting rate constant when scaling simulated time, while others scaled the reporting rate equivalent to simulated time scaling, producing a higher overall reporting rate. Experience from the 2009 experiment showed that keeping the report frequency constant probably is the best approach.

This is because the operational picture gains little with increased frequency while high reporting rates put strains on the C2 systems and communication infrastructure.

C2 Systems in Faster Than Real-Time Scenario Execution – C2 systems typically are not designed to handle time and information progressing faster than real-time. This caused issues such as overloading the processing capability of some C2 systems and time related issues associated with delayed receiving reports and sending of orders. Future work can address the former through better support for filters/topics and by keeping report frequency constant (see earlier sections). The latter category of issues partly can be addressed in part by system execution management services (see previous section); however, it is likely that some C2 systems also will require some custom modifications.

5.1.5 C-BML-Specific Language Lessons Learned

This section describes some of the lessons learned related to C-BML language constructs and, in particular, how these constructs need to evolve in order to support requirements for C-BML-enabled coalition operations.

C2LG Grammar – The Command and Control Lexical Grammar (C2LG) developed by Schade and Hieb was used to motivate the original JBML schema that has evolved under MSG-048 usage in 2007, 2008 and 2009. This grammar ensures that tasks expressed in C-BML do not have ambiguous parsing. Furthermore we are convinced by our experience interfacing several C2 and simulation systems that the simple, straightforward representation obtained by using the “5 Ws” concept in a schema motivated by the C2LG has been a major factor in rapid implementation of C-BML by MSG-048. Associated with the C2LG is an editor that allows BML-encoded Orders and Reports to be inspected, and if necessary, modified as they flow from C2 or simulation client to the BML server and back. This is both a strong aid to debugging and a powerful way to transition clients that are not yet fully BML-capable. The MSG-048 group endorses the continued use of the C2LG in C-BML systems, expanding its use into the operational context.

Role of the JC3IEDM – In principle, C-BML could be implemented over any data model. However, the experience in MSG-048 is that the choice of the JC3IEDM as a lower-level representation has two distinct advantages:

1) JC3IEDM provides C-BML with a well-developed vocabulary for military operations and avoids the need to develop a new dictionary that would duplicate all the previous effort that has gone into the JC3IEDM; and

2) Some national C2IS are based on the JC3IEDM, so that interfacing them to a C-BML system that has been designed to be fully JC3IEDM compatible greatly reduces implementation effort.

5.1.6 Collaborative Internet Meeting and Testing

Open Facilities, Open Source and Open Internet Access – Because of the number and variety of participants, development of BML capabilities is greatly expedited when it occurs in open facilities where participants can come and go with minimal impediments. Availability of common supporting software under open-source

licensing extends the benefits of minimal barriers to the technical environment. Further, this principle extends strongly to distributed development: the ability to use a server and available copies of the server software, located on the open Internet, for development and testing proved to be a tremendous enabler of development by individual national groups, two-nation teams and, to a lesser extent, the full MSG-048 technical group. As BML approaches operational status, it may become necessary to give up this benefit, or employ different network infrastructures because of security requirements.

Collaboration Software – The power of the Internet extended far beyond providing communications for distributed operation. The participants in MSG-048 were spread across eight Nations and major parts of two continents. Information support for successful collaboration was facilitated by two software suites.

First and foremost, the open-source Trac/Subversion system provided a shared repository for documents, with integral version management, which could be updated by any team member using a free client and accessed by all, through ordinary web browsers. The Trac/Subversion repository was used asynchronously and greatly facilitated MSG-048 information sharing.

Beyond this, there is an important role for focused, synchronous discussion. MSG-048 held weekly teleconferences over the audiographic, open-source Network Education Ware (NEW) Internet teaching/ conferencing system from the GMU C4I Center.

The resulting coordination and shared communication strongly supported collaborative, distributed development. It is an important lesson learned that this style of blended asynchronous-synchronous group communication should be a part of any distributed development activity.

5.1.7 System Engineering Support for Experimentation

The MSG-048 TA included an experimentation programme of significant complexity that required considerable preparation, organization and collaboration. Technical Activities that undertake experimentation of comparable or greater amplitudes should ensure system engineering support and put into place measures to facilitate integration and testing such as:

1) Commitment to design documents or technical agreements;
2) Component validation to optimize system integration of national systems; and
3) Dedicated system engineering support for tasks such as configuration management, coordination of integration/testing and schedule tracking.

5.2 OPERATIONAL LESSONS LEARNED

While MSG-048 was focused more on technical capabilities than on operational considerations, the 2009 effort included aspects intended to begin the process of evaluating the operational benefits of coalition BML. Data collection during the MSG-048 2009 experiment was based largely on qualitative measures such as 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. The overall feedback from the military users, who were recruited, based on having limited exposure to BML, was that they very much supported the BML concept.

5.2.1 Operational SME Assessment of 2009 Experimentation

Due to the number of Subject-Matter Experts (SME) available, these results are based on a limited number of responses. Statistical analysis is therefore considered irrelevant. All operational participants strongly supported the BML concept after participating in the experimentation.

Impact on Preparation and Execution of Military Operations – All suggested applications of BML (training, mission rehearsal, and analysis of plans) were endorsed by the SMEs. Based on the their experience with the experimentation vignettes that were executed, the use of BML was considered least likely to improve conducting operations and to be most valuable for warfare preparation phases of training, planning and mission rehearsal.

C-BML STANAG – C-BML was considered a key element to improving interoperability in coalition forces, including NATO. Participants agreed that a NATO STANAG should be developed, however only after further experimentation, in order to establish a more mature C-BML.

Need for Further Experimentation – All SMEs agreed that the technical capability was not mature and lacked capabilities with respect to tasks, control measures, task coordination and reports. Further experimentation was suggested. The questionnaires indicated that the capability provided was not thoroughly exposed to the experiment participants. This reflected primarily the C2 and simulation interfaces, since the underlying C-BML was not seen by the users.

Further experimentation should include additional capabilities for coordinating tasks. This might involve both temporal coordination and using control measures. For Brigade operations there was a requirement to coordinate the operations of the two battalions. This was not possible with the BML capability used in the 2009 experiment. A complete experimental environment should include a staff and C2 system for the highest echelon involved, correctly interfaced to the maneuver elements. Lack of such a capability detracts from realism and credibility of the overall activity.

Scenario Definition – The scenario was considered sufficient and relevant but could be improved. Future experiments should include a wider spectrum of operations such as irregular warfare and stabilization operations. Future experiments also should support a wider range of combat functions (artillery, engineering, etc.).

One participant indicated that the scenario was too complex and that there were too many systems. The BML capability was hidden in that complexity. That participant recommended starting with a battalion level exercise. Another participant thought that the Brigade level was relevant but more battle functions such as logistics and artillery should be included in the simulations.

5.2.2 Obstacles and Barriers in Adopting BML

Obstacles to the success of BML that were identified fell into technical and cultural categories in addition to challenges in development of a standard.

Cultural/National Differences – Ideally, SMEs would use only national systems with which they are thoroughly familiar. The use by an SME of C2 systems from other Nations is difficult due to differences in doctrine, tactics and procedures. One example is that the Norwegian forces have integrated reconnaissance capability while French forces use a dedicated company. Such details must be considered when tasking the units.

Similarly, the use by SMEs of other Nations' simulation models is not optimal as there are differences in tactics and doctrines. For example, simulation models have differences in information requirements depending

on the domain modelled, the echelon targeted, the degree of automation, complexity and probably also on national distinctions. For each participating simulation (model service interface), information requirements should be captured and briefed to SMEs. An example is that one of the simulations used requires a path consisting of exactly two points to perform reconnaissance or a support task.

The following table indicates the wide variety of order types (JC3IEDM action codes) issued by the different national C2 systems during the MSG-048 2009 Operational Experimentation.

Table 5-1: Examples of Action Codes Used During MSG-048 Experimentation.

CAN (UAV)	FRA	NLD (OPFOR)	NOR	UK (AIR)	USA (RECCE)
TCARRC CLARSP	DESTRY FIX PLAN RECCE SCOUT SUPPRT	ANARWF ATTRIT COVER HARASS SUPPRS	ATTMN FIX SECURE SEIZE	AIRDEF ARCCTL CLARSP	MOVE

Modelling and Simulation Challenges – For modelling and simulation in support of planning and decision-making (course of action analysis) the results from Manassas indicated that the biggest challenge is the simulation and underlying models, not BML itself.

5.2.3 Conclusions

Despite these limitations, participants unanimously agreed that the BML technology has the potential to change the way coalition warfighting is conducted in a very positive way.

5.3 NATO MSG-079 C-BML WORKSHOP[1]

A key activity under the terms of reference of MSG-048 is that of education and dissemination of information relating to C-BML and the activities of the group itself. The MSG-079 C-BML Workshop was organised by a sub-committee from MSG-048 to help fulfil this requirement and was held at Farnborough in the UK in February 2010.

5.3.1 Overview

The NATO Modelling and Simulation Group MSG-048 organized an unclassified workshop in Farnborough, United Kingdom, on 24 – 25 February 2010 on the subject of C-BML. An audience of approximately 60 participants attended the workshop with representatives from NATO, NATO/Partners-for-Peace (PfP) and other Nations. The audience was diversified and was composed of attendees from the military, government R&D laboratories and a significant representation form industry. A total of 25 presentations were provided during the two days, preceded by three keynote presentations.

[1] This section is taken, in part, from reference [55]. Paraphrased or extracts are shown in italics.

Participation included representation from 12 Nations including: Canada, Denmark, France, Germany, Great Britain, NATO NC3A and RTO, the Netherlands, Norway, Spain, Sweden, Turkey and the United States of America. Participation was divided evenly between government and industry (45%/45%) with 10% participants from academia.

5.3.2 Presentations

The presentations were divided into eight sessions that covered the following areas.

Day 1 – Feb 24th 2010	**Day 2 – Feb 25th 2010**
1) BML Operational Requirements	5) Perspectives on BML
2) MSG-048 (C-BML) Overview	6) C2-Simulation Interoperability
3) BML in Theory and Practice	7) JC3IEDM and BML
4) BML Coalition Developments	8) Other BML Research Activities

The workshop programme and presentations are available on the NATO RTO site at:

http://www.rta.nato.int/meetings.aspx.

5.3.3 Workshop Summary

The following paragraphs are taken from the MSG-079 C-BML Workshop Technical Evaluation Report [55]:

"The C-BML technology is gaining both attention and recognition from the military, in particular with the latest achievements of the MSG-048 group. As this group is completing its last round of activities, a conference on the theme of C-BML was highly anticipated in order to:

1) *Measure the technical readiness level of the technology;*
2) *Provide a forum for discussion amongst the C-BML, Community of Practice (CoP) and to a larger extent in the Community of Interest (CoI); and*
3) *Present the latest developments in the C-BML arena. This report will provide a summary for each of the previously stated objectives, and make recommendations based on the current C-BML technology technical situation and observed trends for its development."*

"This conference also provided a unique opportunity for a wide audience to present and discuss some key challenges facing C-BML development, and in some cases potential solutions. Also, of equal importance to the challenges are the limitations of the technology, whether they are based on technical basis, or as will be explained later in the report on cultural causes. It is of prime importance to understand these limitations in order to provide the adequate solutions, or to restrain the employment of the technology to a limited scope. This report will also provide a portrait of the current challenges and make recommendations for future actions, as applicable."

The workshop received positive feedback from attendees. It provided an update to the C-BML community on the state-of-the-art of C-BML. It also served an educational role by giving up-to-date information on:

- Background of C-BML;

- Theoretical Description of C-BML;
- Practical Experience with C-BML; and
- Future Work with C-BML.

During the workshop, several discussions and exchanges took place among representatives from MIP, SISO, NATO, Industry, Government and the Operational Community.

The following recommendations are also extracted from the Technical Evaluation Report [55]:

1) MSG-085 should consider creating and organizing a C-BML Community of Interest (COI) as part of its programme of work.
2) The C-BML COI should investigate means to facilitate communication and collaboration between interested industry and government stakeholders.
3) The C-BML COI should also liaise with the industry and national partners to promote a common understanding of what C-BML is and the benefits of utilizing a C-BML approach.
4) The elaboration of an international standard for C-BML is a high priority and should be supported by the C-BML COI through active involvement in C-BML standardization activities.
5) Most if not all of the C-BML COI efforts should be directed toward the development of the SISO C-BML as the standard for C2-simulation and C2-robotic systems interoperability.
6) As part of the SISO C-BML standardization activity, measures should be taken to ensure coordination with the SISO MSDL Product Development Groups (PDG) is effective, with the intended objective to align both standards.
7) NATO should consider initiating a C-BML STANAG development activity in order to leverage and build upon the SISO C-BML standardization activity and to ensure the latter includes all of the relevant NATO requirements.
8) There needs to be an increased interaction with the operational community in the development of the SISO C-BML standard in concert with the MSG-085 Technical Activity, including coordination with the MIP and NC3A.
9) A significant portion of the C2 systems that exist in the various Nations are neither JC3IEDM, nor C2IEDM-based, therefore it is essential for the C-BML (future) standard to position itself independently from these two MIP standards.
10) On a technical note, it is recommended that C-BML specification be decoupled from the transport mechanisms, as a C-BML implementation could be used for different applications that may or may not require: web services, publish and subscribe or other communication schemes; asynchronous versus synchronous communications; high or low volume of data transfer; speed of transfer; etc.

5.4 SUMMARY OF LESSONS LEARNED

The MSG-048 Technical Activity included a three-year experimentation programme and an international Workshop on C-BML in collaboration with the NATO RTO (i.e. MSG-079). This Technical Activity has provided a set of valuable lessons learned described above. Much of this experience and insight has been shared with stakeholders and organizations such as SISO.

As the C-BML question moves from “if” to “how”, it is time to seek closer ties and involvement with the operational community. The following chapter articulates a set of recommendations based primarily on the lessons learned and seeks to promote, amongst other things, to facilitate the communication and coordination among C-BML stakeholders.