INTEGRATING COMMAND & CONTROL WITH MODELLING & SIMULATION TO EVALUATE COURSES OF ACTION

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ABSTRACT

It is standard staff procedure to confront own courses of action (OCOA) with adversaries' courses of action (ACOA) by letting G3/S3 and G2/S2 respectively develop layers on the map or in the C2. Systematic SitaWare has a planning layer concept that is ideal for the development of the different COAs in the planning process. This is how the Royal Danish Defence College and others use SitaWare to compare different COA, but it has been identified that an automated confrontation could speed up the process and also improve the quality of the resulting conclusions.

The recent releases of Coalition Battle Management Language (C-BML) and the five "W's" has proven very useful, and a R&D project using SitaWare from Systematic, SWORD from MASA and the experience from the Royal Danish Defence College was initiated earlier this year to investigate this technology further. The aim of the project is to evaluate the value of C-BML, propose improvements to the standard, and to develop a demonstrator to be tried out at the Danish Defence general staff course over the coming years. The project is closely related to the work in NATO MSG 085, which will benefit from the work.

Through this paper we will describe the project and the technological experiences made so far. The operational planning processes and expected value related to the project will be part of the presentation.

1.0 INTRODUCTION

In the military planning process it is important to verify the assumptions and conclusion of a given plan by analysing the Courses of Action (COA). It is standard procedure to compare Own Courses of Action (OCOA) with the Adversaries' (enemy) Courses of Action (ACOA) in the early planning phase. The process of confronting OCOA and ACOA, also called COA analysis, is traditionally done in a "war game" like setting. Having plans in the form of physical overlays and paper, the war game is performed with similar tools – that is the progress and confrontation is drawn on overlays.

Important aspects of good war gaming is to be able to perform it quickly (timing is crucial), with good confidence of the result (high quality), and preferably with many possibilities examined.

With the introduction of Command and Control (C2) systems to the planning process, plans are now in digital form and there is thus an opportunity to facilitate the war game within the C2 system, using digital overlays already created. There is a slight advantage by war gaming in this way in the form of a speedup of drawing, reuse and exploration of different possibilities. The actual execution of the war game is still a manual process, however.

Keeping in mind the important aspects of a good war game, the digitalisation of the military plans can contribute even further to achieve better results faster. Parallel with the development of C2 systems for use in the field, there is development of Modelling and Simulation (M&S) software tools for training which can potentially transform the manual process of performing the war game into an automated process.

Up until now the C2 and the simulation worlds have been separated by the lack of common data exchange protocols - there has been no common standard for interoperability between the two domains. This lack of interoperability means that the operational user was unable to re-use the COAs created in his C2 system for automated COA analysis, as well as having to learn to use an entirely new set of simulation tools.

If it were possible to communicate the COA aspects of a military plan from a C2 system to a simulation system, it would be possible to automate the war game while retaining the familiar user interface for the operational user. The results of the war game should likewise be communicated back to the C2 system in order to make the final judgement of the quality of the plan. The turnaround time from plan design to order issue could be reduced as the simulation system is much faster at war gaming than the manual approach. The simulation system will follow the exact instruction with high predictability, applying randomness only in those places where nothing else is specified. Furthermore, everything that is modelled in the simulation system can be taken into account. This would satisfy the need for swiftness, confidence and good quality.

In this paper the usage of Coalition Battle Management Language (C-BML) is explored as an interoperability standard for exchanging COA information between the C2 world and the simulation world to achieve the aforementioned goals. Since this paper documents our first attempts at performing this integration, focus is placed on the technical and conceptual aspects of this work, whereas operational consequences are left to be explored in the future.

2.0 CONTEXT

The defence domain contains many different problem spaces, each having their own set of proposed solutions, standards and products associated. Interoperability is difficult to achieve even within the same problem space – such as C2 systems – so that achieving interoperability across different problem spaces can be an additional challenge. In the following sections the state of the art of the current solutions will be discussed and how C-BML attempts to bridge the gap between the two problem spaces of C2 systems and M&S systems.

2.1 The M&S System Problem Space

A modelling and simulation tool in a defence context is a piece of software that makes the modelling of the Theatre of war possible with enough detail to enable a useful simulation of the theatre of war. The simulation is thus a digital version of the physical world and makes it possible to study consequences and implications of all sorts of input parameters.

The simulation tool enables the user to define a starting point with an initial set of parameters, also called a scenario. Similar to the current situation view in a C2 system, this scenario contains information about organisation structures, unit positions, status and holdings. Once the scenario is completed and orders have been developed for the units the user can start the simulation. Usually the simulation speed can be adjusted from "real time" to a factor of e.g. 50 times real time. The tool also enables the user to interact with the simulation and add further parameters or adjust existing ones – thus tweaking the model. The tool supports concept from the defence domain: Order of Battle (ORBAT), military symbols, capabilities, holdings etc.

In order to yield accurate results most simulation systems will use very detailed simulation models, including line of sight for individual soldiers, weather influence on equipment, movement, and visibility as well as other details. As a consequence of this detailed simulation models, orders must typically be specified with much detail and precision as well. This includes the requirement for task parameters, such as boundary lines for units, as well as a task vocabulary that is both very extensive but also very precise.

During and after the simulation of the scenario it is possible to follow important properties of the scenario, such as casualties, fuel and ammunition consumption, movement etc.

Figure 1: A screenshot from the MASA SWORD simulation system.

2.2 The C2 System Problem Space

A C2 system in the military domain is a piece of software that allows the user to give orders for a mission to subordinates in order to achieve strategic or tactical objectives. This involves controlling personnel, equipment and facilities. A computer based C2 system thus has the capabilities to communicate these orders digitally between military organisations.

Typically a C2 system includes functionality for situation awareness, i.e. getting an overview of the current situation in the theatre. This can be done by displaying forces movement in a Graphical Information System (GIS) with standard military symbols. The GIS has concepts of map overlays that relates directly to the real world.

The forces are divided into groups based on hostility. So there will be a group of friendly (own) troops, a group of enemy troops and typically also neutral and unknown troops. On the GIS this is shown through different colours and symbol shapes and sometimes placement on certain overlays.

To represent the hierarchy of control of own forces the C2 system has the concept of an ORBAT. There is typically a relation from the organisations in the ORBAT to the own forces on the GIS.

Some C2 systems also include the capability to perform military planning. This capability is what is used as an integral part of the evaluation of COAs with simulation systems. Planning in C2 systems include the process of developing the plan, and issuing the plan as an order. The elements of a plan are: text, overlays, task organisation (the ORBAT for the mission) and sometimes also structured tasks. It is the structured parts of the plans and orders in a C2 system that would allow a simulation system to simulate a given order, assuming that the order is defined with enough detail and precision to be usable by a simulation system.

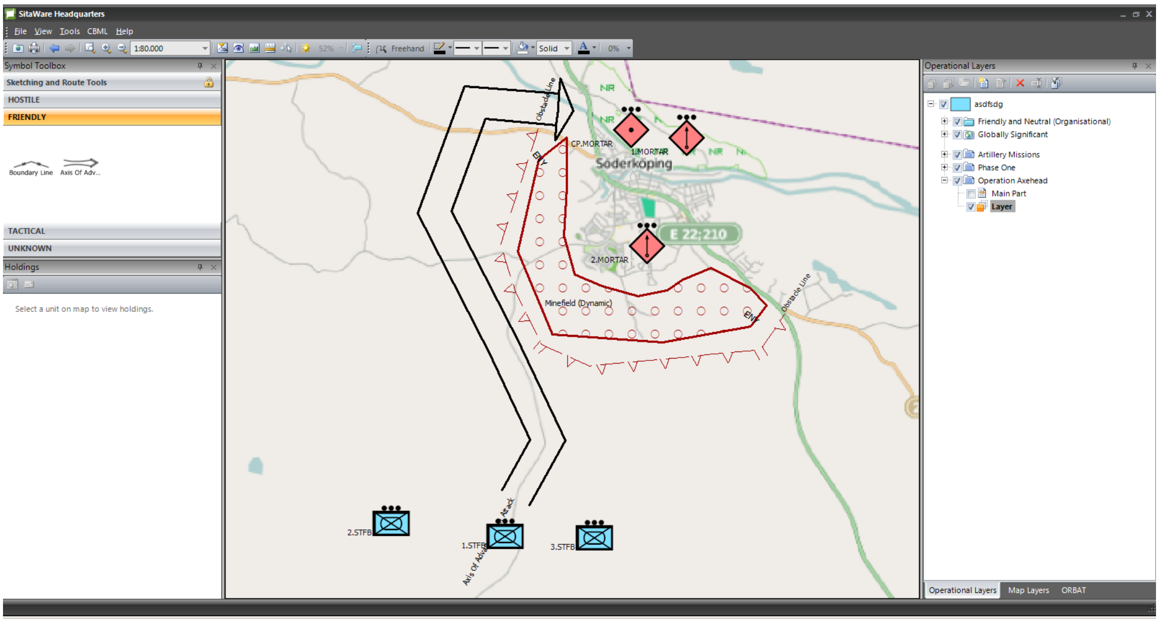

Figure 2: A planning screen shot from the SitaWare C2 System

2.3 Interoperability Between Systems

C2 Systems usually support a mix of proprietary communication protocols for internal use, as well as different international standards to achieve interoperability with systems from other vendors. There is an abundance of these different communication protocols, all with different origins, purposes and scope. For example, NATO friendly force information (NFFI) is limited to friendly force tracking, while over the horizon Gold (OTH-G) has a strong focus on maritime operations. One of the most widely used interoperability standards is developed in the multilateral interoperability programme (MIP). MIP defines a structured information exchange data model – the latest one is called Joint Command, Control and Consultation Information Exchange Data Model (JC3IEDM) [1]. MIP also defines business rules that define which combinations of data in the model are allowed, the MIP Implementation Rules (MIR), as well as a standard for exchanging the data – the Data Exchange Mechanism (DEM). The JC3IEDM is of special relevance here, because it is often used as the basis for other standards and communication systems.

In a similar manner to the C2 system problem space, there exist multiple standards for data exchange between simulation systems, high level architecture (HLA) being one of the most widely used. Although both C2 systems and simulation systems often support one or more interoperability standards, most C2 and simulation systems have only implemented interoperability standards within their own problem space. The challenge therefore lies in making these systems interoperable with each other. One possible approach would be the adaption of an existing interoperability standard, however these standards are often either too narrow or too broad in scope to properly bridge the gap between C2 and simulation systems. Instead C-BML was chosen to bridge this gap – which has been developed for this specific purpose – in combination with the Military Scenario Definition Language (MSDL).

2.4 C-BML

Work on the C-BML [2] standard begun in September 2004 as a study group under the Simulation Interoperability Standards Organization (SISO). In 2006 a proper Product Development Group (PDG) was started in SISO to begin development of the standard. The following excerpt of the C-BML Product Development Plan describes the premise for the development of the standard:

> *"In order to improve simulation interoperability and better support the military user with M&S-based capabilities an open standards-based framework is needed that establishes operational and technical coherence among C2 and M&S systems. The objective capability will enable automatic and rapid unambiguous initialization and control of one by the other."*

The product development plan from September 2006 also outlines three distinct development phases, summarized below:

1. Specification of a data-model based on a subset of the JC3IEDM. The structure of the model will be defined through an Extensible Markup Language (XML) schema.
2. Introduction of syntax, semantics and vocabulary. Focus on rigorous definition and documentation of tasking and reporting concepts.
3. Development of battle management ontology to enable conceptual interoperability.

The C-BML standard that is used as reference in the NATO Modelling and Simulation Group 085 (MSG-085) has not evolved beyond Phase 1 outlined above. Although it appears that work has begun on phase two, no actual work products for phase two are available to the public on the SISO website. The current version of the C-BML standard thus consists of the following elements:

- XML schemas defining how a valid C-BML message can be composed
- A document describing various planning examples
- A set of example C-BML messages, based on the above document and referenced by it.

2.5 MSDL

MSDL is another standard maintained by SISO in a NATO PDG [3]. It is used for exchanging scenarios, including the situation, organization structure, and courses of action to be taken. The representation is based on XML with a XML-Schema, and enables situation exchange (one point in time) between simulation systems, but also between simulation systems and C2 systems.

3.0 SOLUTION DESCRIPTION

Systematic has developed a demonstrator project that integrates the SitaWare Headquarters C2 system [4] with the MASA SWORD simulation system [5]. The following sections give a more in-depth discussion of the technical solution details.

3.1 Solution Components

The demonstrator project consists of a SitaWare extension that adds C-BML related functionality to the SitaWare Headquarters Client. This extension allows the user to exchange MSDL and C-BML messages with the open BML Server. MASA has also implemented extensions to communicate with the OpenBML server - one extension for C-BML messages and another extension for MSDL messages. Figure 3 - Overview of the demonstration setup shows an overview of the different components and how they interact with each other.

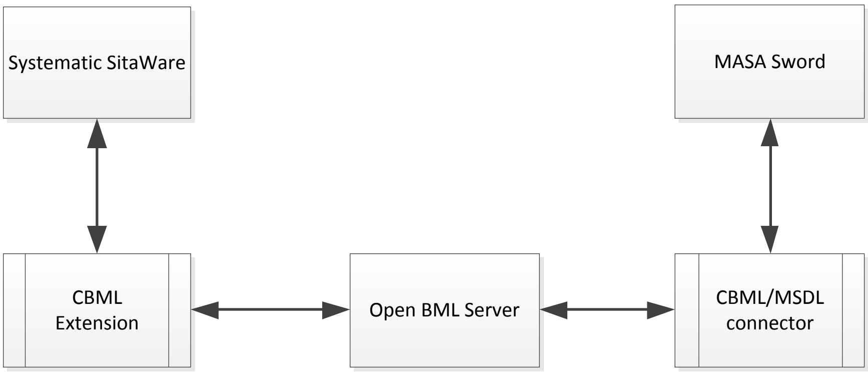

Figure 3 - Overview of the demonstration setup

3.2 Workflow: Interaction between SitaWare and SWORD to conduct COA analysis

The first step in the process of COA analysis is the alignment of the initial situation, also called scenario, between all participating systems. For the purpose of COA analysis the scenario includes force structures, holdings, location and status information. In principle either system may be used to define the scenario before the beginning of the exercise. However, to ensure full compatibility of the exchanged information with SWORD we relied on defining the scenario in SWORD during development of the demonstrator. This way it was possible to adapt the SitaWare C-BML extension to the already implemented capabilities of SWORD. Figure 4 shows the defined scenario in the SWORD system.

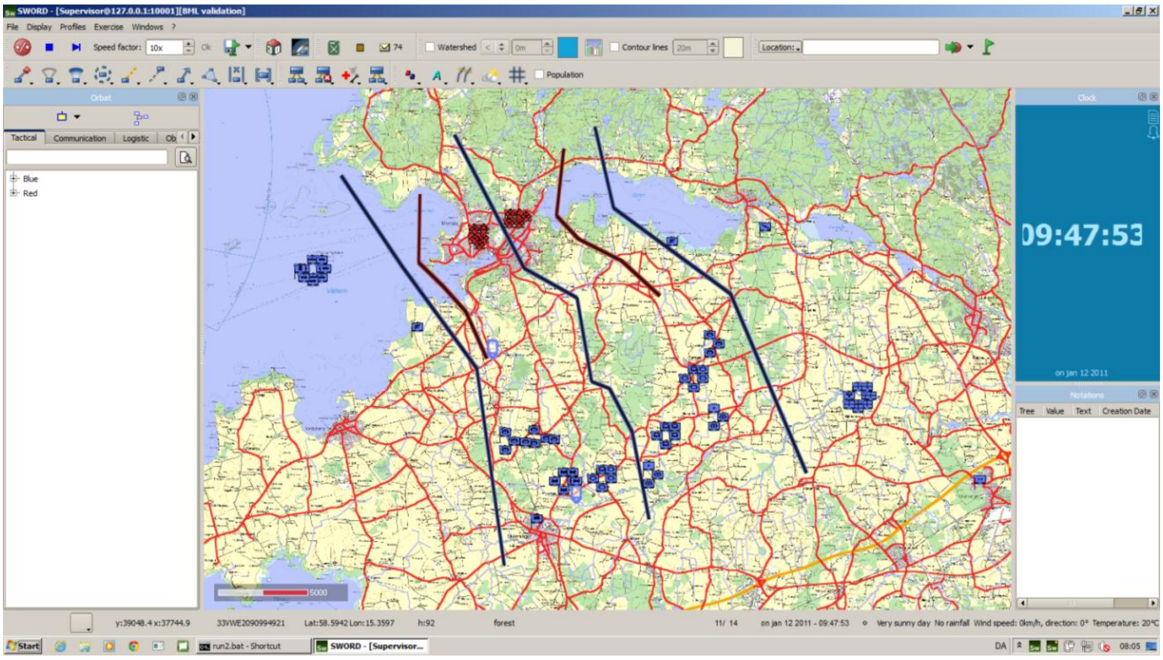

Figure 4 - The scenario displayed in SWORD

After development of the scenario in SWORD it is sent to the OpenBML server as an MSDL message through the BML connector. The user is then able to use the SitaWare C-BML extension to pull the MSDL message from the OpenBML server. Once the MSDL message is fully processed the user is able to see the scenario in the SitaWare client. Figure 5 shows the current situation in SitaWare after the MSDL message has been received from SWORD through the OpenBML server.

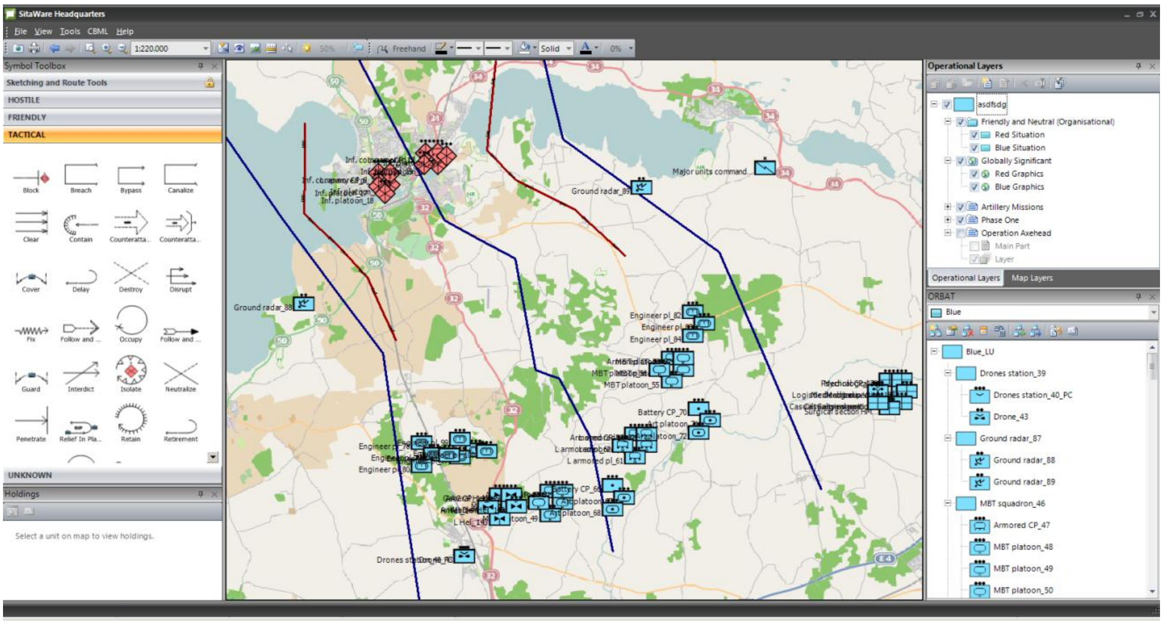

Figure 5 - The same scenario displayed in SitaWare after receipt of the MSDL message

The user can now begin to define orders in SitaWare. Each order contains a task organisation structure that must be based on one of the organisation structures in the received scenario. The user may place these units on a plan overlay and define the plan through tactical graphics. All required information for one given mission in collected in a task object. This contains references to the involved units, tactical graphics and timing details. Figure 6 shows how orders and tasks are handled in SitaWare.

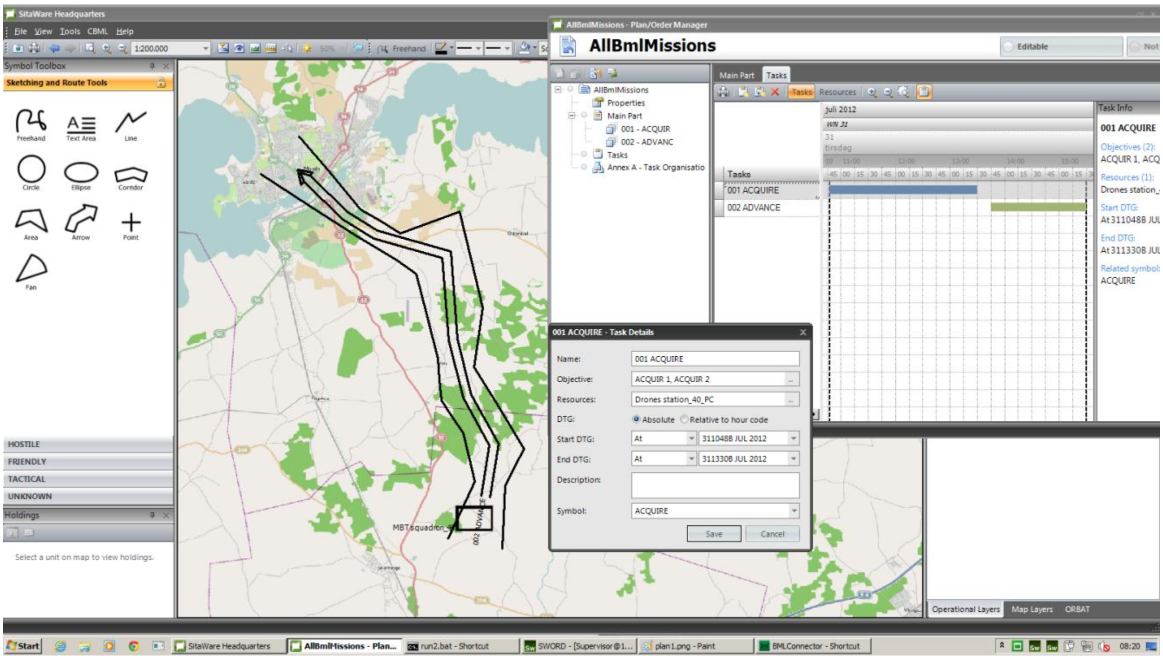

Figure 6 - A sample Task in SitaWare

Once the order is complete the user may send the order as C-BML message to the OpenBML server. If the SWORD BML Connector is running it will pick up the new order and transmit it to SWORD for execution. If the order is valid execution will begin immediately and during the execution SWORD will send C-BML reports to the OpenBML server. These reports contain information about location, holding and status changes, as well as information about unit sightings by other units. The SitaWare C-BML extension will use the report to update the COP in SitaWare, so that it is possible to follow and evaluate the progress of the operation in both SWORD and SitaWare.

4.0 EVALUATION OF C-BML

The development of the demonstrator project allowed Systematic to gain new insights into the use of C-BML to facilitate communication between C2 and M&S systems. These insights cover not only the more technical aspects of the C-BML standard, but also the process of developing a C-BML capability with the current version of the standard. The following sections will discuss our findings from this learning process.

4.1 Maturity Level

The C-BML standard is still in early development and is lacking both the processes and the work products of a more mature standard. For example, the C-BML standard contains no documentation of the operational and system requirements and the exact scope of the C-BML standard remains undefined.

Without properly documented requirements, it will be difficult to assess how a given decision affects fulfilment of the requirements – simply because the requirements are not known. There is no way to know when a given work product is good enough, or in which direction to proceed, or which parts to focus on.

Beyond the requirements, the entire C-BML standard is lacking proper documentation. Elements seem to have been picked from the JC3IEDM and included in the XML schema without explanation. Business rules are not defined at all, except for in the XML schemas themselves. There is no guidance as to whether Multilateral Interoperability Programme (MIP) rules apply to the elements included in C-BML, and if so which ones. There is little to no explanation as to how C-BML is to be used. The examples presented are very rough in nature and require extensive study to understand.

This ad-hoc approach to standard development is not necessarily a problem. In the early development phase where the focus is placed more on understanding the issues rather than developing proper work products this approach lends itself well to experimentation and learning. Nevertheless, in order to proceed further from phase one of a more managed approach is necessary to ensure long-term success.

4.2 C-BML Tools and Documentation

Compared to some other interoperability standards, such as MIP, C-BML makes extensive use of XML technologies which can aid in the development process. Using a code generation tool like Xsd2Code on the supplied XSD schemas quickly results in automatically generated code for a C-BML domain model. Although the generated code is in many ways not as comfortable to use as a manually created and fine-tuned domain model, it significantly speeds up the early implementation.

Unfortunately the XSD schemas are very large and complex, and the current version of the C-BML standard has little actual documentation to aid in the development. The XSD schemas alone only provide the syntax, but not the semantics to express a given concept in C-BML. Therefore having to learn how to use the generated model without good documentation reduces the advantage of quickly getting started working on an auto-generated domain model. With the help of some sample C-BML orders from MASA it was possible to speed up this process considerably.

Once the C-BML domain model has been generated and the proper usage is understood it becomes apparent that the C-BML specification, at least with respect to orders, is relatively well designed. The focus in any C-

BML order is to address the 5 “W”s quickly and efficiently, making it easy to use once it is understood.

The nested structure of an XML document also lends itself well to expressing object oriented information without having to rely on complex relational association tables and key management as is the case in e.g. MIP. This potential advantage of using the nested XML document structure is not made use of in all cases, one example being control measures[1]. Control measures in a C-BML order are all listed under the `<ControlMeasures>` tag and are referred to by name whenever required instead of being nested directly inside the relevant `<Task>` tag. Arguably this structure allows the reuse of defined control measures in different tasks, but whether this is of any importance considering the scope and use of C-BML is debateable.

4.3 Alignment of Capabilities between C2 and M&S Systems

After the first successful transmission of a C-BML order through the OpenBML server to the SWORD system more effort was put into the task of supporting as many capabilities in C-BML as possible. In this phase we soon discovered that a common language, such as C-BML, is not enough to guarantee success. Just as conversations between non-native English speakers may fail due to different thought patterns, similar issues were experienced due to capabilities that were not aligned completely.

The simplest example of this issue is the lack of common understanding of orders and tasks. Because SWORD must yield predictable and repeatable results to be useful, orders and tasks must usually be specified in very precise terms. On the other hand, SitaWare is developed primarily with ease of use for the human end-user in mind and therefore deals with orders and tasks in a more organic fashion. In SitaWare an order can be created entirely as a textual document, which the SWORD system would be unable to process in a meaningful manner. Usually, in addition to the textual parts, an order in SitaWare will contain map overlays with symbols depicting the concept of the order in graphical terms, such as unit positions, boundary lines and movement arrows. Although these tactical graphics have clearly defined meanings and are well understood by the operational users, they are often more broad in scope than what is acceptable to SWORD.

To be able to translate order and task information into terms that SWORD is able to process, it was necessary to introduce rules specifying how orders and tasks must be expressed in order to be translated correctly to C-BML. Each task must be expressed using the task concept that is available in SitaWare plans and orders. This task concept connects the following pieces of information:

- Task resources – The unit(s) executing the task.
- Task symbol – The task symbol representing the action to be taken. This symbol also contains the required geographic information, such as where a unit should move to.
- Task objective – Any supporting tactical graphics, such as boundary lines.
- Timing – When a task is to be started or stopped.

Since the symbols supported by SitaWare are not as precisely defined as required by SWORD, the name of the given task symbol is used to identify the type of task to execute. This approach hampers the usability of SitaWare as the user has to manually connect all the relevant pieces of information in each task object as well as being forced to adhere to a strict naming scheme for the task symbols. Furthermore the user is required to specify boundary lines for each task, as this is currently a requirement for SWORD.

4.4 Minor Issues with C-BML

The previous sections deal mainly with broad generic challenges in C-BML. In addition to these several minor issues were identified that bear mentioning at this point.

[1] Control measures in C-BML are any kind of symbol that further define or restrain a given task, e.g. a boundary lines.

One of the identified issues is support for different coordinate formats - currently the C-BML standard allows locations to be specified using any of four different formats. At first glance this may appear to make the standard more flexible, but this flexibility also means that implementers are required to support all four coordinate systems when reading C-BML. If the C-BML standard would prescribe a single coordinate format this might mean that any given application would have to translate at most one coordinate format. Presently implementers must support all four of them, potentially quadrupling the required work effort depending on which coordinate formats are already supported. It should be noted that in the Systematic C-BML demonstrator project support for only a single coordinate format was implemented after alignment with MASA.

Another issue with C-BML is the use of names as the only kind of identifier. To avoid key clashes due to duplicate names it is sometimes necessary to append unique suffixes to some elements such as control measures. This limitation is most likely of a temporary nature and a deliberate choice to speed up development of the standard.

5.0 FUTURE WORK

The scope of this paper has been limited to the more technical aspects of using C-BML because the demonstrator project has not yet progressed beyond the technical proof-of-concept stage. A more advanced test setup involving a scenario with multiple nations and systems is planned for the next MSG 085 meeting in Istanbul. This test and others following it will provide us with the data required to draw conclusions as to the operational value and reliability of combining M&S systems with C2 systems to perform COA analysis.

In addition to evaluation the use of C-BML for COA analysis, Systematic expects to investigate further possibilities of using C-BML in C2 classrooms as interaction mechanism between SitaWare and simulation tools.

6.0 CONCLUSION

Integrating C2 systems with M&S systems allows the user to perform COA analysis and training with the same tools that are used in real missions, making the task simpler and possibly faster for the user. The development of the demonstrator project has shown that a good implementation of this concept is not trivial to implement, as two distinct issues have to be taken into consideration.

The most obvious issue, the lack of a common language between C2 and M&S systems, could be solved with the C-BML standard. Although somewhat immature, the C-BML standard gives a very promising first impression. To be truly useful stakeholders would need to participate more directly in the development of the C-BML standard and try to address the issues with lack of requirements management and documentation presented in this paper. For the time being the C-BML standard still requires close cooperation with all involved parties to ensure interoperability.

A less obvious issue is the lack of alignment of capabilities between C2 and M&S systems. In the current version of the demonstrator project, the operational user must adhere to strict naming schemes and develop plans and orders in a very strict manner because the task concept has different levels of granularity in the two systems. More effort should be spent on aligning the task vocabulary between systems to arrive at a solution that is useful to both the operational user and the M&S system. The SitaWare user interface can also be enhanced to better support the development of orders that are suitable for M&S systems without being cumbersome.

Finally, the value of our solution to the operational end user ultimately remains unknown, as the project has not progressed beyond the early technical experimentation phase yet and operational users have not been involved. However, considering the positive effect of automation in other areas Systematic remains positive that the effort will ultimately result in great benefits to the operational user.

[1] Multilateral Interoperability Programme. Retrieved 2012, from MIP Website: https://mipsite.lsec.dnd.ca/Pages/Default.aspx

[2] SISO C-BML - COALITION - BATTLE MANAGEMENT LANGUAGE. Retrieved 2012, from SISO Website: http://www.sisostds.org/StandardsActivities/DevelopmentGroups/CBMLPDGCoalitionBattleManagementLanguage.aspx

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