Taxonomies, Ontologies, and Battle Management Languages – Recommendations for the Coalition BML Study Group

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ABSTRACT: *Battle Management Language (BML) is defined as an unambiguous language to command and control forces and equipment conducting military operations and to provide for situational awareness and a shared, common operational picture. BML is being designed as a standard representation of a "digitized commander's intent" to be used for real troops, for simulated troops, and for future robotic forces. Three views have been identified as necessary to describe BML:*
(1) A Doctrine View – BML must be connected to doctrine;
(2) A Representation View – BML must model relevant aspects;
(3) A Protocol View – BML must specify the underlying protocols for transferring BML.

Ongoing research is coping with several questions; for example, if these views are sufficient, how they are interconnected, what implementations and alternatives exist, and many more. Is BML a taxonomy, an ontology, or something else? How is BML related to these terms? Should it replace military ontologies or benefit from them? Can we migrate results from related efforts of the open standards community, such as mapping of ontologies to Platform Independent Models (PIM) or to the Resource Description Framework (RDF)? How will this influence the ongoing evolution of the DoD Architecture Framework (DoDAF) and the Universal Joint Task Lists of the Joint Forces and the Services?

This paper references related efforts and tries to create a map showing how they are interrelated, where they are mutually exclusive and where they are supportive. However, the list of related efforts is neither complete nor exclusive. Based on Lessons Learned within national and international applications and collaborations involving BML, tentative recommendations for community discussion will be given. The paper does not present ready to implement solutions. It is written as a discussion paper to be used in the Simulation Interoperability Standards Organization (SISO) study group on Coalition BML and in the NATO M&S Group Exploratory Team ET-16 dealing with the same topic.

1 Introduction

Battle Management Language (BML) efforts were recently summarized for the Simulation Interoperability Standards Organization (SISO) as well as for the NATO M&S Group [1, 2]. In the studies described in those papers, BML is defined as an unambiguous language to command and control forces and equipment conducting military operations and to provide for situational awareness and a shared, common operational picture. However, what is necessary to make BML unambiguous? Are XML and a reference data model sufficient, or just necessary? Is a common reference model necessary, or are alternatives possible? Are the weak semantics of a taxonomy sufficient, or do we need to enumerate allowed terms and vocabularies? Alternatively, do we need to express even stronger semantics through higher-level ontology languages? Can we capture this information in a form acceptable to the three target application domains: Command and Control Systems, Simulation Systems, and Robotic Systems? Do we need just one BML or one BML with different dialects? Alternatively, is BML more a meta-construct describing different BML versions applicable to special needs?

Within this paper, we try to answer some of these questions and specifically try to show a possible way forward for the Coalition BML study group of SISO. The authors try to define the terms often used in these contexts and put them into a bigger picture. We also try to make the connection to neighbor, but not identical, programs that will influence the BML development, such as the Missions to Means Framework (MMF) and other topics. Finally, we end with recommendations on how to proceed in the study group.

This paper is a contribution to the current discussion and represents the view of two academic partners, VMASC and MOVES, in the BML team. Any contributions or alternative views are welcome and equally important to the views expressed in this paper for discussion in the study group. This paper draws conclusions from the work VMASC and MOVES have been involved in during recent years; but the paper does not claim to be complete or exclusive. The academic community is seldom defined by a homogeneous view of a particular solution for a new problem, so consideration of different viewpoints on BML and its applicability is a healthy process.

2 Definitions of Basic Terms

In order to cope with the variety of issues introduced above, some basic definitions are necessary. Unfortunately, use of terms such as dictionary, glossary, taxonomy, ontology, and data model is fraught with ambiguity. What is referred to by one group as an ontology can be seen as a taxonomy to another? This section gives an overview and provides definitions of terms used in this paper.

2.1 Dictionaries, Glossaries, Taxonomies, Ontologies, and Data Models

The diversity in terminology used to describe information exchange structures does not always facilitate communication; so let's start with some definitions.

- A **Dictionary** is a reference work that lists words, usually in alphabetical order, and gives their meanings and often other information such as pronunciations, etymologies, and variant spellings. Its main purpose is the enumeration of entities with basic definitions.
- A **Glossary** is a reference work that lists entities and their meanings. Quite often cross-references between similar or related terms are made, but the overall structure remains flat. The main purpose is the definition of the terms. Dictionaries and glossaries are very similar.

In particular in computer science domains, dictionaries and glossaries are often referred to as **Controlled Vocabularies**. The common idea is that the vocabularies are completely enumerated, well defined and controlled by a common registration authority.

- A **Taxonomy** can be best defined as a tree structure of classifications for a given set of objects. At the top of this structure is a single classification—the root node—that applies to all objects. Nodes below this root are more specific classifications that apply to subsets of the total set of classified objects. The main purpose is the classification of terms. Sometimes, the networked structures are also referred to as a **Thesaurus**, as neighbor terms are often similar enough to be interchangeable in an appropriate context.
- An **Ontology** is an attempt to formulate an exhaustive and rigorous conceptual schema within a given domain. Although this is typically a hierarchical data structure containing all the relevant entities, it is not necessarily a tree. Furthermore, in addition to the entities the ontology contains relationships and rules (such as theorems and regulations) within that domain. Therefore, a taxonomy is a subset of an ontology. Daconta, Obrst, and Smith describe an "ontology spectrum" identifying weak semantic representations such as relational databases and taxonomies at one end of the spectrum and strong semantic representations such as formal logics at the other end [3].
  In practice it is agreed that an ontology should contain at a minimum not only a hierarchy of concepts organized by the subsumption relation, but other 'semantic relations' that specify how one concept is related to another. The main purpose is the definition of entities and their relationships.

In other words: If a formal specification concisely and unambiguously defines concepts such that anyone interested in the specified domain can consistently understand the concept's meaning and its suitable use, then that specification is an **Ontology**.

In summary, there are different concepts available starting with lexical definition of terms (dictionary), definition of their meaning (glossary), classification of

terms (taxonomy), and interrelationship of terms (ontology).

All these terms, in particular taxonomy and ontology, are somewhat mixed in the concept of **Data Models**.[1] Whenever we use computers to evaluate, execute, or store the concepts described above, we use data models. The data models can be used in the sense of a meta-data model (describing the elements needed to describe the element), but in the end, we will have a data model for the information. Every data model at least implicitly defines an ontology by the terms and their relationships expressed in the data model.[2] Of particular interest are reference data models, such as the Command and Control Information Exchange Data Model (C2IEDM), since they combine many of the features discussed above:[3]

- Every view, association, table, attribute, and (enumeration) attribute value is well defined, so that the terms used in the C2IEDM entail a *glossary*.
- The structure of the C2IEDM follows the principle of concepts and sub-concepts. This defines a class structure defining a *taxonomy*.
- As the relations between these classes are captured as well, C2IEDM is at least the core of an *ontology* describing joint Command and Control.

This view must be distinguished from the view of a data model directly describing the elements necessary for an ontology, which is more like a meta model view to capture the necessary information. This is referred to as an ontology representation language; e.g., the Ontology representation language for the semantic web called OWL (see section 4.2).

2.2 Exchange Principles

We want not only the unambiguous definition of information elements, but the unambiguous exchange of this information as well. As this information is stored in data models, we can apply exchange principles for data models to cope with the challenge of unambiguous information exchange. As described in [5], database development evolved from homogeneous into heterogeneous and finally federated databases.

As shown in figure 1, three schemas are necessary to cope with a homogeneous database serving different applications, namely:

- The internal schema (implementation of the data base, often seen as the physical schema containing the implemented tables and views),
- The conceptual schema (which is the "perfect" view of the database as presented to the applications, often normalized and referred to as the logical schema), and
- The external schemas (the views of each application).

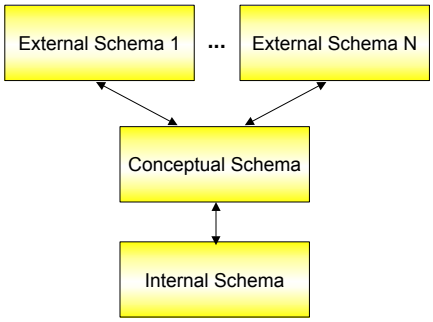

Figure 1: Notional Schema of Homogeneous Databases

It is worth mentioning that only in very rare applications are internal and logical data schemas identical. For example, to achieve higher performance in database operations the "pure" logical schema aligning with Codd's rules for normalized database systems is often denormalized.

The ANSI/X3/SPARC of the American National Standards Institute (ANSI) standardized the four level schemas for distributed databases, as shown in figure 2.

When databases are distributed, this is typically done based on the conceptual schema, resulting in the four level schemas for distributed databases. The idea is that one common conceptual data model is distributed to various database implementations. The local conceptual schema can vary (as not all tables must be hosted on all implementations), but they should all be part of the common conceptual schema.

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[1] In the context of this paper, object models and data models are considered similar enough to be treated the same.

[2] Data models are also used to capture ontologies. To order this discussion, the introduction of metamodels may be necessary, as recommended in [4].

[3] The complete current documentation on C2IEDM including script can be downloaded from http://www.mip-site.org.

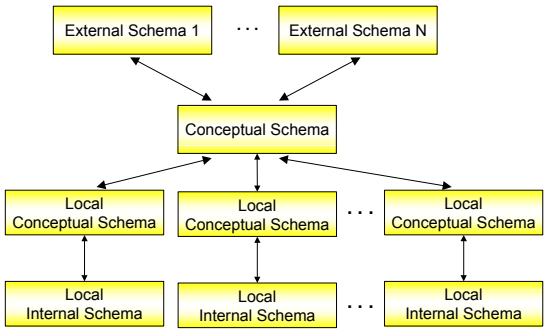

Figure 2: *Notional Schema of Distributed Databases*

While this is a valid academic approach, applicable when starting from the beginning, in practice the local schema seldom conform to one common conceptual schema. This practicality led to the idea of federated databases, shown in figure 3.

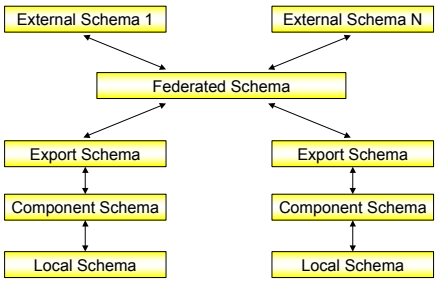

Figure 3: *Notional Schema of Federated Databases*

The five level schema for federated databases starts with the legacy applications:

- The local schemas describe the data of the legacy data source in a form used for the legacy database. In the M&S High Level Architecture (HLA) world, this is comparable to the data or object models used in the federates.
- The component schema transforms the description into a "common" language, such as XML. This provides a common access to the various data formats. This is comparable to writing a Simulation Object Model (SOM).
- The export schema defines which parts of the components will participate in the federation. Not all data need to be exchanged, so this is a subset.[4] This is comparable to the part of the SOM that contributes to the Federation Object Model (FOM) of the current federation.
- The federated schema is the logical or conceptual data model of the federation. It unambiguously defines the data elements to be used to exchange information between the participating partners. This is comparable to the FOM.
- The external schemas are applications working on the federated information space, such as a common operational picture or a data logger. This is comparable to HLA tools using the FOM information, such as After Action Review (AAR) tools or federation and stealth viewers.

As a general principle, information exchange should be performed based on the logical (conceptual, federated) data model, which involves at least three level schemas. Two level schemas will not be sufficient for general solutions but will always be limited to specialized peer-to-peer connections. In addition, there are three guiding principles developed over the decades of logical data modeling:

- **Resolution**: the resolution of the logical schema must be at least as high as the highest resolution of the participating local schemas.
- **Composition**: there must be well-defined rules to compose elements of the logical schema resulting in elements of the local schemas and vice versa.[5]
- **Normalization**: the logical schema must be normalized to avoid ambiguities, in particular those caused by redundant data.

In summary, decades of computer science and information theory point to the use of normalized logical data for unambiguous information exchange between heterogeneous systems. The data elements used for information exchange are independent from

[4] Many practical implementations exchange the order of export schema and component schema and transform only those elements into the common language that participate in the current federation.

[5] This is the objective of aggregation and disaggregation. It is worth mentioning that whenever the resolutions of two models differ, ambiguity is introduced automatically: aggregation is always connected with the loss of information. If this information is not captured somewhere, there will be more than one way to restore the data; hence, we have ambiguity.

the implementation; in other words, the data schema used for information exchange can be independent from the data schema used for internal data (as the data used in federates generally differs from the data described by the FOM).

In the next section, these principles are applied to the ideas of BML.

3 Battle Management Language

Battle Management Language (BML) is defined as an unambiguous language to command and control forces and equipment conducting military operations and to provide for situational awareness and a shared, common operational picture. BML is being designed as a standard representation of a "digitized commander's intent" to be used for real troops, for simulated troops, and for future robotic forces.[6]

BML has not yet been formally specified. Within the Simulation Interoperability Standards Organization (SISO) study group on Coalition BML, such a formal specification will be produced. So far, three views have been identified that must be included in such a definition: the doctrine view, the representation view, and the protocol view. We describe and discuss these three views in detail in the following subsections.

3.1 BML – Doctrine View

Every term used within BML must be unambiguously defined and must be rooted in doctrine. In other words, *the doctrine view must be a glossary* comprising each term and its unambiguous definition as well as the source of this definition.

The glossary must be aligned with other SISO efforts to create a standard dictionary for use within M&S solutions (e.g., the RPR FOM definitions of the FOM/SOM lexicon) and respective command and control efforts. Furthermore, the glossary must be aligned with the manuals and handbooks used to describe doctrines for the warfighter. A starting point can be Joint Publication 1.01.[7]

A misperception often surfacing in discussions is that the doctrine view implements only a single doctrine. This is not the case. The view provides unambiguous definition of a doctrine, but allows different doctrinal viewpoints of services or nations to be defined. The BML doctrine view – once it is standardized – helps to describe different doctrines in a common form. Therefore, it actually will help show different partner viewpoints regarding doctrine.

In particular, the groundbreaking work done for the US Army is documented in the reports referenced in detail in [1,2]. Setting up an ontology for command and control is not a trivial task and should not be underestimated. That we are not there yet does not mean that the work done so far is not useful. The contrary is the case: this is the basis to work on standard recommendations and show methods and procedures to be followed by future BML group. Nonetheless, no generally accepted standard not even to cope with ontologies in general is established yet, which leads to the recommendation to keep the recommended standards to the minimum (as we have no alternatives yet), but to encourage more research on this topic, as currently initiated with studies on BML for Air Operations and Naval Warfare.

It has been discussed to what extent ontological layers – as recommend by Jens Pohl in [6] – will be necessary to express doctrine. The authors are convinced that we will need to extend the standard from the currently recommended glossary approach to a more semantically rich ontology approach, but there is no solution accepted by all target domains of BML that is applicable today. Therefore, the glossary approach is the best we can do currently, but the study group report should point to the fact that future work is necessary. The glossary is a first step leaving future options open.

3.2 BML – Representation View

The representation view structures and relates the terms defined in the doctrinal view in such a way that they result in the description of *executable missions and tasks*. A mission is defined by a sequence of tasks that must be executed in an orchestrated manner. The representation must not only allow description of the various tasks but also composition and orchestration of these tasks into missions. Furthermore, the representation must comprise military means, which can be units or platforms or simulated entities. Being able to cope with causalities and temporal relationships

[6] "Digitized commander's intent" in this sense goes beyond the paragraph defined in the operational order of armies. It comprises everything that is needed to describe to an executing system (C2, simulation system, or robotics) to understand what the commander wants, which includes traditional orders.

[7] It is worth mentioning that each attribute in the C2IEDM has a mandatory field providing the meaning of this attribute. This field also has a pointer to the source of the definition. This can be compared to the FOM Lexicon specified in the HLA standard.

in terms used by the warfighter is required and connects the representation view to the doctrine view.

In earlier phases of the US prototype development for BML, the use of the C2IEDM was evaluated, recommended, and implemented. However, as various doctrines may require tasks and missions outside the current scope of C2IEDM, extensions and enhancements must be defined and consistently applied. Current discussions evolve around the question of whether BML data elements should be based on the C2IEDM or if something new is needed, such as BML data elements defined by the BML Web Service Description Language (WSDL) used in the recent US prototype demonstrated during the 2004 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC).

C2IEDM fulfills the needs of the conceptual schema for information exchange as described in section 2 of this paper. The logical recommendation therefore is that the study group should analyze (a) if the C2IEDM is generally applicable to cope with these issues or if there are counterexamples, and (b) what extension rules need to be captured and standardized in order to ensure consistency between separately developed extensions and enhancements.

Many organizations are already using the C2IEDM, so we hope that we can evaluate their rules to determine if they are a good basis for standardization. In particular, the Multinational Interoperability Programme (MIP) group is of interest as well as the former NATO Data Administration Group. In particular, the US and a number of other member nations of the MIP are initiating a Coalition Secure Management and Operations System (COSMOS) Advanced Concept Technology Demonstration (ACTD) to explore transformational information exchange capabilities in Coalition operations. Among the proposed objectives of the ACTD is demonstration of interoperability among US and other nations' equivalent echelon applications within a consolidated network environment using data modeling and exchange mechanisms compliant with MIP specifications [7].

In short, the C2IEDM is the core representation to be exploited for information exchange in this ACTD. Execution of this ACTD program will provide valuable insights into the power and readiness of the C2IEDM for widespread coalition adoption to improve interoperability and warfighting capability. Furthermore, commercial solutions, such as data federation or data migration services, may comprise valuable algorithms and rules applicable to BML challenges as well.

The representation view is academically interesting and challenging and the study group should make this clear in discussions of possible alternatives. There are several expert opinions concerning the applicability of data models to cope with ontological challenges. Additional ideas and future model-driven solutions are welcome to be discussed. One possibility is the use of Artificial Intelligence (AI) approaches, such as the Knowledge Interchange Format (KIF), to support the structuring process by (semi-) automatic tools. Linguistic approaches and methods used for knowledge sharing between intelligent software agents seem to be valuable. However, in conjunction with the recommendation at the end of section 3.1, there are no current solutions applicable to all three target domains of BML besides the C2IEDM, so our recommendation is to standardize the use of the C2IEDM and additionally discuss other ongoing efforts.

3.3 BML – Protocol View

In order to communicate necessary initialization data into BML and the resulting executable missions and tasks from the BML to the executing system, communication protocols are needed. The protocol view standardizes the way the description of the executable tasks and assigned executing military means is *transported from the BML implementation to the target system*, be it a Command and Control device, a simulation system, or a robot.

The use of XML to describe the information exchange requirements is fundamental, as XML is the only standard for data description accepted by the Command and Control community, the simulation community, and the robotic community. Within the Extensible BML (XBML) project and follow-on efforts, the use of http-based web services was chosen. Based on results in ongoing work of the XMSF team, as well as other interested experts in the domain of application of web services within computer grids, solutions that are more general may be needed in the international domain, which further point to XML.

Grid services are one example for alternative future research. Although they follow the same principles for data exchange and invocation, these services allow more alternatives within applicable protocols for web communication.

Based on the actual web service solution, the study group should analyze advantages and disadvantages of alternatives and point to connected effects within the community. However, our recommendation is to start with standardizing XML as the initial means to be used for the protocol view, as XML is the only standard

accepted by all three target domains as the necessary component schema on which the export schema can be based.

3.4 Summary of Immediate Short-term BML Recommendations

There are without doubt many alternatives worthy of detailed evaluation. However, given the short time available to the study group and the necessity to come up with an initial specification before implementations become too diversified in lieu of standards, we recommend the following:

1. BML should initially focus on the **exchange of military command and control data**, in particular the unambiguous description of executable tasks, their composition into missions, and – where applicable – the assignment of executing military means.
2. The C2IEDM to comprise the necessary elements to describe tasks, compose them to missions, and to assign executing organizations down to single weapon systems, platforms, or persons. This **subset of C2IEDM** should be standardized as the **initial representation view** of BML.
3. As every data element already is documented in detail, including the source of the definition used, the subset already builds a core for the glossary to become the **initial doctrine view** of BML.
4. An XML tag set extracted from that used for the coalition namespace of the **US DoD XML** Repository for use as the **initial protocol view** for BML. In addition, more work is needed to evaluate or define applicable standards coping with ontology specifications in support of describing doctrines for BML.
5. Alternatives and extensions should be discussed in subsections of the final study group report of the Coalition BML study group, but they should not be part of the first standard approach if they are not proven to be applied in all three target domains of BML: Command and Control devices, military simulation systems, and military robots.

This set of recommendations is a preliminary set based on the experience of VMASC and MOVES employees and students and must be enriched by alternatives. However, we see them as a good starting point.

4 BML in the Context of Complementary Solutions

This section discusses alternatives and related projects and programs that must be evaluated by the Coalition BML study group. While section 3 dealt with the initial core views, this section broadens the view to show what must be aligned in order to result in a broadly applicable standard. This enumeration is neither complete nor exclusive and needs to be discussed in the study group. Following the idea of different views, this section is divided into two different views as well. We start with operationally motivated efforts, and then look at technically motivated projects and efforts.

4.1 Operationally Motivated Efforts

BML is embedded into several operational concepts, some of which will be evaluated in this section.

ONA/PMESII

The acronym PMESII stands for Political, Military, Economic, Social, Infrastructure, and Information. These summarize the vulnerabilities identified by the Operational Net Assessment (ONA) in the strategic and tactical decision process of a Joint Task Force (JTF) commander [8]. The vulnerabilities are researched as "system of systems" networks that can be exploited by effects-based operations to affect an adversary's war-making/warfighting will and capability. This includes actions against supporters of terrorism, alliance partners who do not engage in shooting conflicts but support hostile activities with other means, etc.

ONA and PMESII result in evaluated actions conducted by operational entities, such as military elements from the organization level down to single platforms or persons conducting an assigned task. If these operational entities are military means, they should be part of the overarching architecture, which is described in the next subsection.

In summary, ONA and PMESII build the highest research framework in which military operations – or activities and effect-based operations with strong connections to military operations – can be evaluated.

DoDAF

Generally, architectures provide a mechanism for understanding and managing complexity. The purpose of the Department of Defense Architecture Framework (DoDAF) is to improve capabilities by enabling the quick synthesis of "go-to-war" requirements with

sound investments leading to the rapid employment of improved operational capabilities, and enabling the efficient engineering of systems supporting the warfighter [9]. The ability to compare, analyze, and integrate architectures developed by the geographical and functional unified Commands, Military Services, and Defense Agencies from a cross-organizational perspective is critical to achieving these objectives.

In DoDAF, three major views logically combine to specify an architecture:

- The **Operational View** (OV) is a description of the tasks and activities, operational elements, and information flows required to accomplish or support a military operation.
- The **Systems View** (SV) is a description, including graphics, of systems and inter-connections providing for, or supporting, warfighting functions. These views potentially will close the conceptual gap between what has to be modeled and why (operational view) and how this is done (technical view).
- The **Technical View** (TV) is the minimal set of rules governing the arrangement, interaction, and interdependence of system parts or elements, whose purpose is to ensure that a conformant system satisfies a specified set of requirements.

In summary, the operational view is the view of the warfighter, the systems view is the view of the system designer or technical supporter, and the technical view is the set of necessary standards and alternative technical solutions enabling composition of the system level to deliver the functionality needed on the operational level.

While PMESII structures the general application domain, DoDAF focuses mainly, although not exclusively, on the military domain. Whenever a military operation has to be accomplished, the DoDAF should be applicable to identify the operational components, the system components, and the necessary technical standards to enable collaboration of systems to fulfill the operational requirements. The described system is not limited to information technology. DoDAF has been designed to describe military systems, such as architectures that enable capabilities such as theatre ballistic missile defense.

BML is therefore connected to the DoDAF, in particular as an applicable potential standard to be described in the technical views as well as an enabler to facilitate information exchange as described in the various system-to-system interfaces. DoDAF and BML support each other; while DoDAF can help to formulate standardization requirements for BML (in all three views of BML), BML can facilitate the implementation of DoDAF based on real operational systems.

UJTL

When something has to be accomplished within military operations, normally an order is given or a task is assigned to one of the available organizations. The Universal Joint Task List (UJTL) structures military tasks into sub-tasks and shows how these tasks are interdependent. The UJTL provides a common language for describing capabilities of the US Armed Forces [10]. UJTL v4.2 is the current UJTL baseline.

The UJTL is designed as a common reference system for joint force commanders, combat support agencies, operational planners, combat system developers, and trainers to communicate mission requirements. It is the basic language for development of a joint mission essential task list (JMETL) or agency mission essential task list (AMETL) that identifies required capabilities for mission success. When augmented with the Service task lists, UJTL becomes a comprehensive integrated menu of functional tasks, conditions, measures, and criteria supporting all levels of the Department of Defense in executing the National Military Strategy.

This is directly applicable to BML, in particular when considering the currently missing bridge between the doctrine view and the representation view. The use of UJTL-like structures seems to be a good way to move from the pure glossary based solution to a structure that will allow machine interpretable storage of doctrine descriptions.[8]

If a task makes sense in the context of DoDAF to support an operation as defined in PMESII, the task should be found in the UJTL, or should be described in a form that can be integrated later (e.g., in the context of transformation experiments, where new and innovative concepts not yet in the UJTL are evaluated).

MMF

The Military Missions and Means Framework (MMF) originated from the observation that certain DoD

[8] When trying to map UJTL (US), CJTL (Canadian Joint Task List), ASJETS (Australian Joint Essential Tasks) and METL (Mission Essential Task Lists of the UK) it was observed that a "clean translation" is not easily possible, as the underlying doctrines differ. This leads to the idea that different dialects may be necessary, but this is not the topic of this paper, but should be a topic of the study group.

transformation initiatives today focus largely on the materiel side (the physical means needed for successful military operations) without adequate consideration for (or linkage to) the missions, or those end actions that must be accomplished to meet objectives. In other words, the technical and systems architecture describing the materiel are not following functions defined by the operational architecture. To enable DoD transformations, from concept through actual combat, a framework is needed to help the warfighter, engineer, and comptroller specify a common understanding of military operations, systems, and information, and to provide quantitative mission assessment of alternative solutions [11].

MMF tries to close this gap by defining levels and operators in the form of a framework. The seven levels are:

- Level-7: Purpose, Mission
- Level-6: Context, Environment
- Level-5: Index, Location/Time
- Level-4: Tasks, Operations
- Level-3: Functions, Capabilities
- Level-2: Components, Forces
- Level-1: Interactions, Effects

To support the user navigating between the levels and for mapping related concepts to each other, four transformation operators are defined:

- Interaction specifications into component states (level 1 to level 2)
- Component states into functional performance (level 2 to level 3)
- Functional performance into task effectiveness (level 3 to level 4)
- Task sequences into interaction conditions (level 4 to level 1)

By doing so, MMF allows the layered decomposition of tasks from the highest operational levels to actions to be taken by platforms and persons on the battlefield. The tasks- and operations-level is directly connected to the UJTL discussed in the previous subsection, and the connection to DoDAF becomes obvious from the motivation of MMF.

So far, MMF is a concept and a paper-based framework. However, it seems to be obvious that BML can be directly integrated into this framework. MMF sets up a framework to break down organizations and tasks on the different levels and connects them respectively by generating the five W's well known from the BML concepts: WHO (the military means) is doing WHAT, WHERE, and WHEN (describing the military mission) and WHY (part of the breakdown of MMF). If the BML glossary as recommended in 3.1 comprises the UJTL task definitions, and if the BML model extends the C2IEDM task domain as recommended in 3.2, then the UJTL can be broken down from operational organization tasks to platform level tasks. As the same is true for the structure of the military means (starting from operational organizations and going down to platforms and persons acting on the battlefield), BML holds the structures to capture the results of MMF in the form of executable tasks for Command and Control devices, simulation systems, and robotic systems.

MSDL

The last project to be presented in the context of BML is the Military Scenario Definition Language (MSDL), which in some presentations is also referred to as the Military Scenario Development Language [12]. Although MSDL was developed for the US Army, in particular for the simulation system OneSAF Objective System (OOS), it must be seen in a wider context. MSDL is being developed by OOS – but not exclusively for OOS – to generally provide simulations with a mechanism for loading military scenarios. The intent is to define scenarios independently of the application within a special simulation system. To that end, MSDL is an XML based data interchange format that enables C2 planning applications to interchange the military portions of scenarios with simulations and other applications.

There is obviously an overlap between BML and MSDL interests. However, while BML focuses on the description of executable tasks and assigned military entities, MSDL targets the initialization of simulation (and potentially also C2) systems with military scenarios, which consist of a description of the initial state of a military situation including planned actions (e.g., planned air missions, fire missions, ship-to-shore movement, etc.).

Furthermore, BML is applicable to all military C2 levels up to the strategic levels needed by coalition operations, while the focus of MSDL is currently the tactical and the operational levels simulated by OOS, even if the concepts are generally applicable.

Nonetheless, MSDL and BML should be developed for mutual benefit. BML clearly focuses on C2 issues. As such, BML should be embedded into an approach describing the related information elements consistently, and MSDL has the potential to become such an approach.

Our recommendation is to use BML structures – enriched by the current findings of MSDL research as described in [12] – for C2 initialization and exchange and to evolve the MSDL situation components into the broader framework targeted by the MSDL project.

4.2 Technically Motivated Solutions

In this subsection, additional technically motivated solutions are mentioned. However, evaluation of the projects is not limited to technical aspects only, as some political factors have to be taken into account as well, in particular when discussing C2IEDM, HLA, and alternatives.

C2IEDM/MIP

As previously recommended, common data engineering using XML is seen as a necessary – but not sufficient – first step. A common reference model defining the XML tag sets and the structure is needed to ensure meaningful interoperability [13].

For military operations, the C2IEDM has the potential to become (and in fact is becoming) such a reference model. Applicability in the BML context has already been shown in the last section. However, as the operational use is also part of the C2IEDM agreements, even higher levels of interoperability can be reached; the C2IEDM may become an ontological layer for the GIG [6].

In early 1980, the Army Tactical Command and Control Information System (ATCCIS) Permanent Working Group (APWG) was established by NATO to deal with the challenge of future Command and Control information systems. The ATCCIS approach was designed to be an overall concept for future command and control systems of the participating nations. In 1999, ATCCIS became a NATO standard with the new name Land Command and Control Information Exchange Data Model (LC2IEDM). By 2002, the activities of LC2IEDM and the Multilateral Interoperability Program (MIP) – another NATO effort to make fielded operational C2 systems interoperable – were very close, expertise was shared, and specifications and technology were almost common. The merger of ATCCIS and MIP was a natural step. LC2IEDM became the data model of MIP, enabling data sharing between fielded C2 systems of Canada, France, Germany, Italy, the United Kingdom, and the United States. Finally, in 2003 the name was changed to Command and Control Information Exchange Data Model (C2IEDM).

Currently, C2IEDM comprises data elements describing a common vocabulary consisting of 176 information categories that include over 1500 content elements. C2IEDM is divided into a Generic Hub comprising the core of the data identified for exchange across multiple functional areas. Special functional areas extending the Generic Hub fall under national responsibility to cope with information exchange needs of national concern. C2IEDM lays down a common approach to describe the information to be exchanged and is not limited to a special level of command, force category, etc.

In general, C2IEDM describes all objects of interest on the battlefield; e.g., organizations, persons, equipment, facilities, geographic features, weather phenomena, and military control measures such as boundaries. Besides the technical maturity of this data model, the recommendation to use C2IEDM as the reference model for military information exchange is driven by the fact that all participating MIP nations already agreed that the information exchange captured in C2IEDM is operationally relevant and sufficient for allied operations. Military and technical experts from 10 full member nations (Canada, Denmark, France, Germany, Italy, The Netherlands, Norway, Spain, The United Kingdom, and The United States) as well as 14 associate member nations agree that C2IEDM is an adequate and operationally meaningful way to exchange information about military operations, including new tasks like anti-terrorism operations.

That C2IEDM is not only a theoretic or technical approach is documented by many ongoing discussions concerning its use within the US Armed Forces. TRADOC as an organization is supporting the Army/DoD/JFCOM in a number of venues recommending using a common data standard for all C2 systems and C2 feeder systems. The C2IEDM is seen to be best available start point for this standard. The C2IEDM should be expeditiously completed (in a consensus manner) as a joint model. TRADOC is heavily committed to core MIP developments, but the C2IEDM use is not limited to this international program [15].

In the summer of 2003, the US Department of Defense (DOD) Joint Staff, Force Structure Directorate (J8) and the readiness portion of the Office of the Under-Secretary of Defense for Personnel and Readiness (USD(P&R)) established a Community of Interest for Global Force Management (GFM-COI) to tackle the challenges imposed by the Net-Centric Data Strategy [16]. This group identified the C2IEDM as a kernel for the modeling activities. Although many national extensions are necessary, the principles of C2IEDM, as recommended in various papers on this topic, proofed to be applicable to use the model as the core for national extensions.

In summary, speaking C2IEDM means speaking in agreed operational terms to 24 nations using a NATO standard. Therefore, it makes operational, technical, and political sense to base the definition of BML on these efforts. In addition, under the aegis of MIP, the C2IEDM is currently evolving into the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM). Beside a broader consensus based vocabulary, XML interfaces, and XML Schema Documents will be standardized as well.

HLA/OMT

As summarized in a tutorial given during the 2004 I/ITSEC, the High Level Architecture is currently evolving into a more open, standards-based concept [14]. The IEEE 1516 HLA standard is currently under review to identify necessary improvements. The advent of the Global Information Grid (GIG) will influence the evaluation of web-based standards and how they will play with the HLA as it evolves. Of particular interest is making HLA concepts generally available to GIG users interested in distributed simulation applications. To this end, a web-based version of HLA software products, in particular the Runtime Infrastructure (RTI), in the Core Enterprise Service domain is an option currently considered. The current IEEE 1516 standard already supports XML as the standard for information exchange. The Object Model Template (OMT) as defined in IEEE 1516.1 may evolve into an XML schema in the mid term, and the Lexicon Tables already being mandated for Simulation and Federation Object Models (SOM/FOM) is a natural connection to the glossary and/or data element definitions needed for the BML.

Technically, the gaps are already closed, and it is now a question of community interest to merge this effort. One recommendation is that the next generation of IEEE 1516 should use a community-accepted glossary as the general basis for definitions used in the semantics column of the SOM/FOM Lexica.

MDA-based Approaches

Since its introduction by the Object Management Group (OMG), several research projects have evaluated the applicability of the concepts of the Model Driven Architecture (MDA) for the development of simulation systems.[9] Several of these were presented to SISO; however, it is beyond the scope of this paper to reiterate the discussion. The applicability of MDA to develop simulation software has been shown and commercial products are available, including but not limited to HLA implementations. Furthermore, recent studies [17] have motivated the use of MDA to manage heterogeneous simulation systems.

Of particular interest for BML are current studies on the applicability of MDA to describe ontologies in a software friendly way [18]. Although currently in their infancy, such efforts may become promising integration solutions in the future. The Coalition BML study group of SISO should observe and evaluate their potential for use in the BML doctrine view domain.

RDF, OWL, and the Semantic Web

This paragraph points to current research on semantic web ontology languages, including the Web Ontology Language (OWL) rooted in the Resource Description Framework (RDF). Their relation to XML is shown in the following figure. Refer to [19] for additional detail and links to online resources.

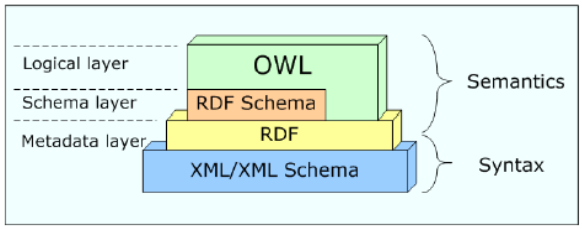

Figure 4: *OWL, RDF, and XML* [13]

The vision of the Semantic Web is creating "an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation" [20]. Semantic Web researchers are defining XML-based languages for expressing higher order semantics in a so-called Semantic Web Stack, partially shown in figure 4. As developers use emerging standards farther up the stack, systematic logic about a domain can be constructed to better enable software to reason about the data automatically.

Understand that the level of semantic content contained in a representation is dependent on the representation scheme itself. For example, OWL enables expression of stronger semantics (formal logic) than, say, the entity-relation description of the C2IEDM. Taking an operational example, the C2IEDM provides the constructs for defining military plans, but does not inherently contain the logic to define what is meant by planning conflicts, whether logical, spatial, or temporal. Additional information about the logical, spatial, and temporal semantics need to be encoded to enhance the automated processing capabilities of a

[9] See http://www.omg.org/mda for current documentation and examples.

system using the C2IEDM as its core data model. Such rules constitute business processes that are established across communities of interest in the warfighting domain. The same community consensus process that removed process, service, and other logical layers of information to achieve the core C2IEDM will be needed to add such layers back onto the model to achieve automation that is more powerful. An exploration into such an activity has been proposed as part of the COSMOS ACTD introduced earlier.

Thus, even when not following the recommendations given in [18] to utilize MDA/UML to capture the results in a more software friendly way, the BML doctrine view needs an ontological component. If C2IEDM will be the basis, as recommended in [6] and elsewhere, or if alternative ontologies developed by the Services will be the initial hub, does not matter. It is important that BML can be aligned with these efforts; therefore, analysis and evaluation are necessary.

4.3 Mapping to Supported Levels of Conceptual Interoperability

The Levels of Conceptual Interoperability Model (LCIM) was introduced in [21] and slightly modified by several authors making use of this concept. The following table shows the different levels and which standards support this level.

Table 1: *LCIM and Supporting Standards*

LCIM Level	Definition	Supporting Standards
Conceptual	Derived from same concept	DoDAF? MMF? MDA/UML?
Dynamic	Harmonized and aligned state changes	Ontology for Services
Pragmatic	Aligned use of information in the system	Taxonomy, Ontology
Semantic	Unambiguous definition of terms	C2IEDM Dictionary, Glossary
Syntactical	Aligned common protocols	XML
Technical	Exchange of Bits and Bytes	HTTP

The ultimate goal must be to reach common concept to derive the information. If DoDAF is the right choice is an open question. Methods like MMF are needed to connect these concepts with executable solutions.

New techniques, such as Ontology for services, will help to align the dynamic interoperability, the harmonized execution in different environments. Ontologies as they are support only the pragmatic aspect of the use of information. Taxonomies are supporting, but not sufficient. Reference models, such as the C2IEDM, comprise more info than Dictionaries and Glossaries, but they all are only sufficient to define the information elements unambiguously. XML is only applicable on the syntactical level, but when the tag sets are managed with C2IEDM (or alternatives), the semantic level gets a strong foundation.

4.4 Summary of Mid- and Long-term BML Recommendations

While section 3.4 summarized immediate actions and decisions concerning the Coalition BML study group, this section looked at domains of importance. The set of domains is neither complete nor exclusive. To pursue this evaluation, the following subgroups should be established within the Coalition BML study group:

1. Improving the C2IEDM: While the C2IEDM is considered the best initial information hub currently available, it has to be improved. Studies described in [1, 2, 12] show that the resolution needs of simulation systems are not met in all areas.
2. Establishing a BML ontology: In alignment with the other ontology efforts described in this section, a subgroup has to work on recommendations on how to extend the BML doctrine view beyond the glossary. In addition, the ontology must bridge the current gap between the BML representation view and the BML doctrine view. A better way than a glossary to represent doctrine is needed.
3. Evaluation of related standards: While XML enables separation of data definition and data content, it doesn't ensure that data exchanged is interpreted correctly by the receiving system. Other standards may be needed that are able to ensure correct application. The study group must evaluate such standards for future extension.

In summary, we see several research tasks that are likely not to reach the levels of maturity necessary for standards in the short term. Nonetheless, collaboration must be encouraged and established as soon as possible.

5 Summary and Recommendations

The statement of work for the Coalition BML study group identifies the following tasks:

1. Conduct a **Paper Survey** comprising as many international contributions applicable to the

Coalition Battle Management Language effort as possible.

2. Develop **a Plan** of how these various efforts identified in task 1 can contribute to a common Coalition BML standard or to a standard framework.
3. Formulate a set of **Recommendations** on how to proceed toward a Coalition BML product development group.

The products resulting from the establishment and execution of these tasks shall include, but not be limited to, a literature survey summarizing the results of task 1 and a final report summarizing the results of tasks 2 and 3.

The recommendations given in more detail in sections 3.4 and 4.4 of this paper directly contribute to the study group plan; hence, they are intended to contribute to the final report, if accepted by the study group. In summary, we recommend (1) XML, C2IEDM, and the glossary of used terms as the initial set of standards for Coalition BML and (2) establishment of subgroups addressing the challenges of extending the C2IEDM, establishing a Coalition BML ontology, and evaluating additional standards applicable to all three Coalition BML domains of Command and Control Devices, Simulation Systems, and Robotic Systems. In order to do this, an analysis of the embedding and related works described in section 4 must be evaluated in detail. This project overview is currently limited to US efforts, which means, that similar international efforts should be brought to the attention of the Study Group and must be included in the evaluation as well to ensure the same degree of applicability of BML in coalitions, as originally targeted by the study group.

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