

The 2004 Command and Control Research and Technology Symposium
The Power of Information Age Concepts and Technologies

Coronado Bay Resort
San Diego, California

June 15-17, 2004

**Extensible Battle Management Language (XBML): A Methodology for
Web Enabling Command and Control for Network Centric Warfare**

Michael R. Hieb, Ph.D.

Alion S & T
1901 N. Beauregard St.
Alexandria, VA 22311-1705
(703) 933-3376
Michael.R.Hieb@us.army.mil

Andreas Tolk, Ph.D.

VMASC
Old Dominion University
Norfolk, VA 23529
(757) 686-6203
atolk@odu.edu

William P. Sudnikovich

Atlantic Consulting Services, Inc.
167 Avenue at the Common
Shrewsbury, NJ 07702
(732) 460-9416
wsudnikovich@acsinc-nj.com

J. Mark Pullen, D.Sc.

George Mason University
Computer Science/C3I MS4A5
George Mason University
Fairfax, VA 22030
(703) 993-1538
mpullen@gmu.edu

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE JUN 2004		2. REPORT TYPE		3. DATES COVERED 00-00-2004 to 00-00-2004	
4. TITLE AND SUBTITLE Extensible Battle Management Language (XBML): A Methodology for Web Enabling Command and Control for Network Centric Warfare				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Alion S & T, 1901 N. Beauregard Street, Alexandria, VA, 22311-1705				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES 44	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Extensible Battle Management Language (XBML): A Methodology for Web Enabling Command and Control for Network Centric Warfare

Michael R. Hieb, Ph.D.

Alion S & T
1901 N. Beauregard St.
Alexandria, VA 22311-1705
(703) 933-3376
Michael.R.Hieb@us.army.mil

Andreas Tolk, Ph.D.

VMASC
Old Dominion University
Norfolk, VA 23529
(757) 686-6203
atolk@odu.edu

William P. Sudnikovich

Atlantic Consulting Services, Inc.
167 Avenue at the Common
Shrewsbury, NJ 07702
(732) 460-9416
wsudnikovich@acsinc-nj.com

J. Mark Pullen, D.Sc.

George Mason University
Computer Science/C3I MS4A5
George Mason University
Fairfax, VA 22030
(703) 993-1538
mpullen@gmu.edu

Abstract

Command and Control (C2) communication in a network centric environment such as the Global Information Grid (GIG) is postulated to be data “rich”. However, our current situation is that the most critical C2 information, the commander’s intent, orders and directives, does not actually flow as data. It is often communicated as “free text”. While suitable for interpersonal communication, it is not able to support advanced automation or intelligent decision aids due to its inherent ambiguity. Battle Management Language (BML) was developed as a solution to this problem.

BML is defined as the unambiguous language used to: 1) command and control forces and equipment conducting military operations and, 2) provide for situational awareness and a shared, common operational picture. It can be seen as a representation of a digitized commander’s intent to be used for real troops, for simulated troops, and for future robotic forces.

Based on this concept, a prototype of BML was developed demonstrating an actual National Training Center (NTC) Brigade Operations Order. The United States (U.S.) Defense Modeling and Simulation Office’s (DMSO) Extensible Modeling and Simulation (M&S) Framework (XMSF) initiative is extending BML based on open, commercial Internet standards. The XMSF prototype demonstrates a web-enabled Extensible Battle Management Language (XBML).

Introduction

Recent expert evaluations have demonstrated that the way that the U.S. Army performs C2 is primarily by a loosely knit “language” tailored to interpersonal communication. Its vocabulary is found in doctrinal task lists and manuals, but it lacks clearly delineated rules governing its use (semantics and syntax). It is riddled with ambiguity and overlapping definitions. As such, it is incapable of transitioning to the full range of automation that the Department of Defense (DoD) is implementing. It will not support either “digitized” C2 or decision support based upon integrated modeling and simulation.

One of the most radical changes is the data policy in the GIG. This is based on the U.S. DoD Data Strategy that postulates all data, regardless of the final consumer, will be available to selected users (theoretically anyone, anywhere with granted access) on “publish-subscribe,” “smart-push-pull,” or query-response type mechanisms. In sharp contrast to current data this “stovepipes” have been established by Command, Control, Communications, Computers, and Intelligence (C4I) system design or by doctrine that fails to make data available until after processing by the appropriate entity, often after it is tactically useful by another community.

Communication of C2 in a network centric environment must be less interpersonal and more data oriented. The most critical C2 information, the commander’s intent, orders and directives, does not currently flow as data. It is communicated as “free text” elements within messages or as stand-alone files. While suitable for interpersonal communication, it is inadequate for use with simulations, or for the future forces that have robotic components. As commanders increase their demand to train as they fight and therefore use their C2 devices to control simulations, a solution for this “free text” problem must be found. Battle Management Language (BML) was developed as a solution to this problem.

BML is defined as the unambiguous language used to: 1) command and control forces and equipment conducting military operations and, 2) provide for situational awareness and a shared, common operational picture. It can be seen as a representation of a digitized commander’s intent to be used for real troops, for simulated troops, and for future robotic forces.

Based on this concept, a prototypical implementation of how to implement a Battle Management Language was conducted and demonstrated at the end of 2002 and in the beginning of 2003. While the first prototype was U.S. Army centric, an initiative was taken under the DMSO XMSF program to transform the BML prototype into a joint and combined solution based on open standards. The XMSF initiative has started with this BML prototype (consisting of a future U.S. Army C2 System and a U.S. Army Entity Level Simulation) and has developed a web-enabled prototype of Extensible Battle Management Language (XBML). This version will not be limited to U.S. Army constraints, and will be “extended” by applying the concepts of the XMSF. The end state for XBML will be a methodology for developing standard doctrinal terms and allowing

these to be accessed as web services. Each Service could have its own “BML” Web service, linked to a Joint overarching BML.

XMSF is evaluating the applicability of a set of web-based, open standards, developed by existing standards bodies, and methodologies focusing on – but not limited to – web-based distributed modeling and simulation. Because it is based on Web standards, it has the ability to provide simulation services to a wide class of live systems. XMSF uses open standards and open sources to increase the efficiency of development and applicability of simulation systems. Many software systems compositably scale to worldwide scope by utilizing Internet and web technologies. XMSF, by applying these web-based technologies, is an advance toward composable simulation systems. It furthermore bears the potential to migrate legacy and future M&S into web-centric components to be used in net-centric Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) environments, such as the Global Information Grid [1, 2].

The XBML approach is to adapt representations of C2 so that they are directly derived from doctrine and are expressed in a flexible syntax. This provides a means to link the BML (terminology and symbology) directly to their doctrinal source; and it allows operational forces to use their C4I systems to 1) interact with supporting simulations to conduct rigorous, realistic training and support mission rehearsals, and 2) in the future, support an expedited military decision making process.

Why BML?

The central hypothesis of Network Centric Warfare (NCW) is that a force with these capabilities can increase combat power by: better synchronizing effects in the Battlespace, achieving greater speed of command, and increasing lethality, survivability, and responsiveness.

The concept of Network Centric Operations and Warfare (NCOW) is a realization that modern warfighting efforts are a synergy of C2, enterprise business operations, both hierarchical and asymmetric networking, and advanced cognitive software applications. They impact all levels of military activity from the tactical to the strategic. In order to successfully conduct warfare the Commander must simultaneously work in the Physical, Information, and Cognitive domains maintaining optimum situational awareness in all three. This is the challenge of modern C2 in general, and in particular a challenge for the support C4ISR. The information domain must bridge the gap between the physical and the cognitive domain as much as possible.

The means for accomplishing this in the DoD is with the GIG. A globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating, and managing information on demand to Warfighters, policy makers, and support personnel.

The GIG is a key enabler of NCW and is essential for information and decision superiority. It will enable C4I integration of joint forces, improve interoperability of systems, and increase optimization of bandwidth capacity thereby dramatically improving warfighting capabilities. The GIG will enhance operational capabilities while providing a common environment for conventional and nuclear C2, combat support, combat service support, intelligence, and business functions. In particular, the GIG will support:

- Ability to operate with reduced forces at high operational tempos where dynamic planning and redirection of assets is the norm.
- Delivery of information concerning targets, movement of forces, condition of equipment, levels of supplies, and disposition of assets to joint commanders, their forces, and the National Command Authority (NCA) within specified time frames.
- Ability to obtain and use combat and administrative support information from national, allied, coalition, and other widely dispersed assets.
- Collection, processing, storage, distribution, and display of information horizontally and vertically throughout organizational structures across the Battlespace.
- Rapid and seamless flow and exchange of information around the globe, enabling collaborative mission planning and execution from widely dispersed locations and at different levels (to include strategic, operational, tactical, and business).

The GIG is a system of systems that provides a set of value-added functions operating in a global context to provide processing, storage, and transport of information; human-GIG interaction; network management; information dissemination management; and information assurance. These functions are fully interrelated, integrated, and interoperable with one another in order to achieve overall interoperability across the GIG. As a result, the GIG is an information environment comprised of interoperable computing and communication components.

As military organizations move toward operating in a network centric environment, they are relying more upon open commercial standards than previously. This is mainly due to the success of the worldwide Internet in the past 10 years. To the extent that commercial standards can be used, this is preferable to military specific standards. However, it is recognized that there are certain areas where military specific standards must be developed. One of these is security. Another is the representation of military tasks, actions and missions.

A critical deficiency in current simulation systems is the lack of a standard methodology for representing C2 information. Many advanced simulations have excellent representations of C2 internal to their simulations, but do not use this representation when dealing with other simulations or C2 systems (here we define C2 systems as the range of planning to execution systems used in military operations). See [3, 4] for related work in simulation C2 formats.

BML was developed as a common standard to represent military tasks, actions and missions, both in simulations and C2 systems. A proof of principle BML prototype was developed in the domain of ground forces (for a U.S. Army Mechanized Brigade). As BML development continues, the issue of how to address different domains is a key issue.

BML will allow a commander to develop a plan and exchange data with other organizations – the commander’s subordinates, his superiors and his equals. However, in a joint environment, this will involve different services exchanging planning information and plans with each other. In a coalition environment, one nation will exchange plans with another. Thus, BML needs to address the following dimensions:

- 1) Service
- 2) Joint
- 3) Multi-National

This is shown in Figure 1. The coalition systems may belong to different nations and be specific to particular services (e.g., ground or air). Typically, a federation of simulation systems will be employed to support the mission planning systems for training or operations. In addition, the systems involved can be highly aggregated (such as a joint logistics system tracking movement of assets or a large joint simulation system) or very detailed (platform specific systems).

The challenge for BML is to provide a common methodology, a common syntax and semantics. However, each nation and service will have different tasks unique to itself, and BML must be flexible enough to accommodate them.

Extensible Battle Management Language builds on the experience of the U.S. Army

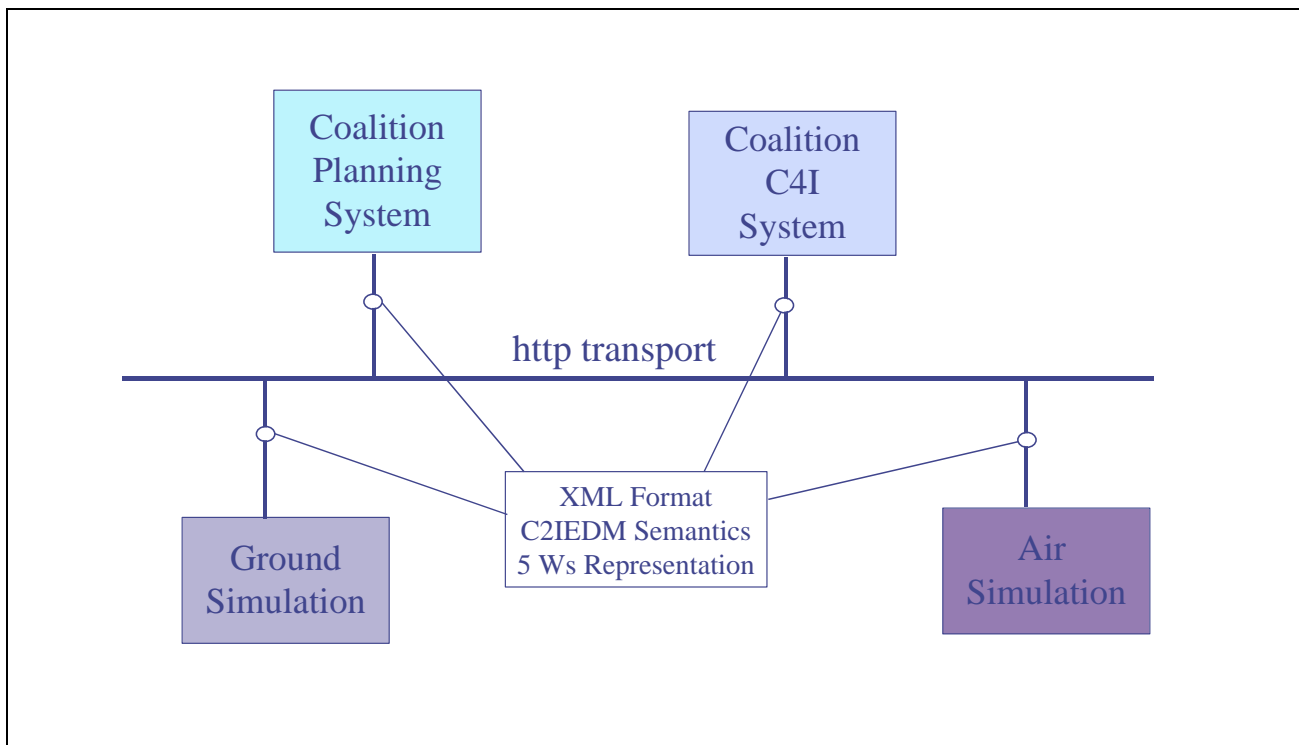


Figure 1: XBML Coalition Concept

proof of principle implementation by using Internet standards to develop web-enabled interfaces. However, while Internet and Web standards are a tremendous aid to developing flexible interfaces (addressing BML methodology and syntax), they do not address the issue of common semantics. XBML uses the Command and Control Information Exchange Data Model (C2IEDM) in order to establish a common representation for tasks, actions and missions. XBML represents mission in terms of Who, What, Where, When, Why as an organizing principle

This paper focuses on how to establish interoperability between distinctly different domains, building upon work in progress. BML is described in [5, 6] and [7] investigates the scalability of BML to coalition operations. The U.S. Army proof of principle is described [8] in detail and [9, 10] present the first phase of XBML, concentrating on applying commercial Internet standards to “open up” the specific interfaces. In addition, Tolk in [11] explains how the C2IEDM will be used for semantic interoperability for XBML as well as for M&S in general.

The remainder of this paper will describe XMSF, the current status of XBML, the applicability of XBML to coalition operations and future plans

XMSF

XMSF is a set of profiles for use of open standards, developed by existing standards bodies, and methodologies for their application, to facilitate reuse, composability, and orchestrated execution of distributed and heterogeneous M&S. Because it is based on Web standards, it has the ability to provide simulation services to a wide class of live systems. XMSF uses open standards to increase the efficiency of development and applicability of simulation systems. Many software systems that composably scale to worldwide scope utilize Internet and Web technologies. XMSF, by applying these Web-based technologies, is an advance toward composable simulation systems and is a viable technical platform to integrate live systems, such as C2 systems.

Software systems that composably scale to worldwide scope using Internet and Web technologies are strong candidates for use in composable simulations. XMSF is characterized by the application of open standards and open sources to increase the efficiency and applicability of distributed simulation systems. Therefore, XMSF is an evolutionary step toward advanced distributed simulation not necessarily limited to military standards. XMSF uses particular standards related to the Web, to reach the next level of this domain of distributed computing. By embracing commercial Web technologies as a shared-communications platform and a ubiquitous-delivery framework, military M&S can fully leverage mainstream practices for enterprise-wide software development. Its focus on open, Web-based standards and technologies doesn't imply that XMSF is limited to the public Internet; it can just as well operate on secure military networks. Two of these Web-based standards play a particular role in XBML:

- 1) The **Extensible Markup Language (XML)** is designed to improve the functionality of the Web by providing more flexible and adaptable information identification. It is a standardized file format on the basis of the Standard Generalized Markup Language (SGML) and became a wide spread standard for Web applications within the last couple of months.
- 2) The **Simple Object Access Protocol (SOAP)** is a protocol for exchange of information in a decentralized, distributed environment. It is an XML based protocol to let applications exchange information over the Hyper Text Transfer Protocol (HTTP), which is supported by all Internet browsers and servers.

Agreeing on a common tag set of underlying XML documents is the first step allowing unambiguous information exchange on the semantic level of interoperability. This tag set then can be used to define SOAP message content to be exchanged between these applications via the Internet or a Web-based military network supporting the minimal set of Internet standards and may later be used for semantically meaningful web service definition. Although in complementing papers the need for additional standards to insure meaningful interoperability is stressed [12, 13], this level is sufficient for XBML applications and the initialization of C4I systems by M&S applications.

C2 systems are of particular interest in composable simulations because they are the windows through which the warfighters see the world. There is a growing requirement to interface existing and emerging simulations to C2 systems. We believe that ultimately the best solution is to use the same underlying Information Technology (IT) infrastructure supporting M&S and C2 systems, facilitating the delivery of simulation services for operational applications as required. To do this, XMSF must be extended and integrated into emerging C2 systems and standards. Using XMSF to integrate simulations into C2 networks is discussed in [1, 2].

Given that XMSF addresses a critical technology base for simulation composability, extending XMSF to address C2 integration will bring a crucial domain as part of the overall set of candidates for composition. To date, efforts to use Simulations with C2 systems have been fragmented and “stovepiped”. XMSF provides mechanisms for addressing this issue systematically as well as providing a deeper interoperability.

Warfighters deal directly with C2 systems, but there are many barriers to integrating simulations into C2 systems. While technical solutions are necessary, experience has proven that they are not sufficient to solve integration and interoperability problems. We are including C2 in an XMSF Distributed Testbed in order to demonstrate the potential of XMSF to the C2 community and provide a basis for experimentation. Experimentation will allow us to consider the complex issues of dealing with live systems.

Once developed, this C2 XMSF testbed capability will support both simulations and C2 systems. This will allow exploration of a number of critical issues in C2/M&S interoperability that have not been addressed to date – such as time management and labelling of live vs. simulated data [14]

While XMSF provides the means for technical integration in form of a C4I testbed applicable to C4I and M&S components based on open and commercially supported standards, BML provides the means for syntactically and semantically unambiguous descriptions of C2 information, both orders and situational awareness. While we will define BML more accurately in the following sections, for now it can be best thought of as the “digitized commanders intent” to be used in C2 systems, as well as in M&S applications, that need to get orders from a user.

The project described in this paper, XBML, merges both concepts. It builds on the technical flexibility of XMSF to migrate the Army specific BML prototype into the XMSF environment. Additional components will be integrated to broaden the applicability and BML will be extended to cover other services and even to be used in combined application domains with international partners.

In the next sections we will deal with the underlying concepts in more detail before describing BML, the XBML prototype, and the XBML representation.

BML and XBML Concepts

While XMSF ensures the integration and migration of components on a technical level, BML is the foundation for a methodology for complete and unambiguous specifications of the commander’s intent.

The Battle Management Language Concept

Taking the widest possible interpretation, BML is defined [7] as follows:

BML is the unambiguous language used to command and control forces and equipment conducting military operations and to provide for situational awareness and a shared, common operational picture.

Along with this definition, there are four principles that are fundamental to BML:

- 1) BML must be unambiguous;
- 2) BML must not constrain the full expression of a commander’s intent;
- 3) BML must use the existing C2 data representations when possible; and
- 4) BML must allow all elements to communicate information pertaining to themselves, their mission and their environment in order to create situational awareness and a shared, common operational picture.

BML must contain no distinction between live or simulated forces, thus ensuring that commanders and staff can train as they fight. They will use the same BML whether they

are dealing with live subordinates, a simulation, or a semi-autonomous robotic entity as in Figure 2.

BML is more than a well-structured language. In its complete expression, BML must be a methodology that allows complete and unambiguous specification of C2 information, directly linked to doctrine. The methodology must represent doctrine, identify appropriate doctrinal sources, elaborate doctrine into a standardized authoritative representation, and specify the rules for how the representation communicates information

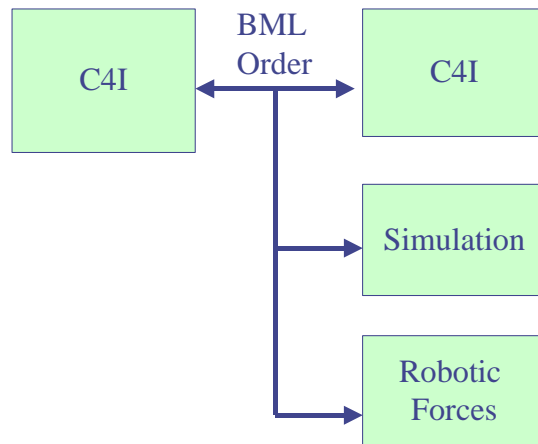


Figure 2: BML Scope

To accomplish this, the BML must incorporate doctrinal terms, graphics, tactics, etc. in a form that allows the intricate relationships of these abstract concepts to be linked to the physical aspects of the warfighter’s environment (organizations, features, persons, facilities, and materiel). The representation must include the necessary entities along with well-defined relationships. This then allows the basic vocabulary, semantics and syntax to be unambiguously defined as well as related to each other in a methodology. This implies developing structured message formats that can be parsed into existing and future operational messages as well as formats that communicate with simulations.

BML must blend structure that allows automation of the language with ease of use for the military professional. It should not be a radical change from the language the commander and staff currently use, but instead an evolution that provides a means to gain structure while remaining transparent to the user. It must be based on doctrine and linked to the doctrinal sources, both to ensure standard use/understanding, and to foster concise and precise use of the language. The technology components of BML must support the “train as you fight” concept and therefore exist in a single format, at least as far as the military professional user is concerned. The output of the automated system is dependent on whether the intended audience is a human, a software “intelligent agent” or an autonomous robot.

BML is being built based upon work that has gone before – EAGLE [3] (a U.S. Army constructive force-on-force simulation) BML, the Command and Control Simulation Interface Language (CCSIL) [4], and as a Task Decomposition Methodology [15]. Recently, an assessment [16] of the BML Prototype was performed providing a useful set of evaluation criteria.

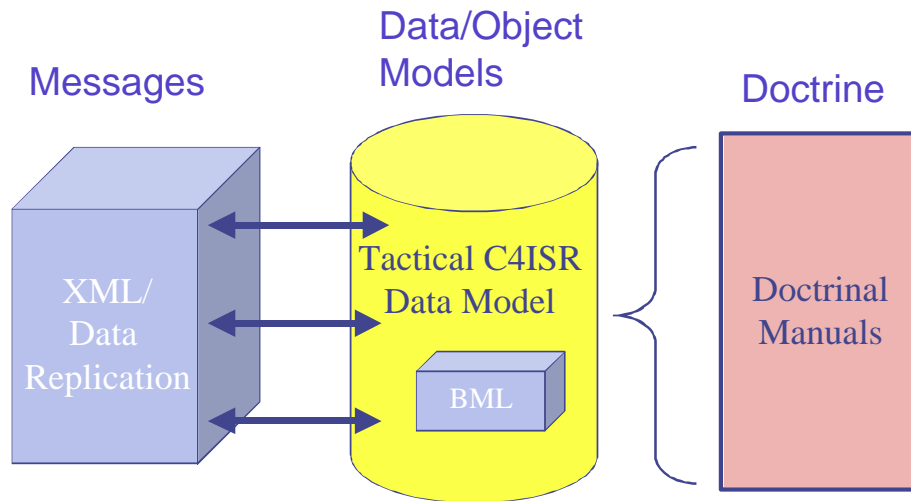


Figure 3: BML Concept

Figure 3 shows graphically our BML implementation concept. This consists of:

- A C2 Database (used by a C2 application). BML must be imbedded and integrated into the C2 Database.
- A Doctrine Repository, with doctrine accessible to the C2 application. The more strongly the BML terms are tied to how live forces are trained and employed will enable how well BML will perform.
- A technology to disseminate BML terms from the Doctrine Repository and a technology for exchanging BML messages.

Figure 4 shows the scope of the BML methodology. This paper shows how BML can be extended from a service specific implementation (Army using specific interfaces) to an approach linking coalition, joint and service elements. It is important to note that there may be different BML “dialects”. A populated BML for the Army will be different from a populated BML for the Air Force due to the difference in how they employ their forces. But the way that a BML language is constructed must be standard so BML information can be exchanged and understood.

A key aspect of BML is that with the vocabulary and its associated relationships built into a database, Graphical User Interfaces (GUI) and other applications can be constructed that allow implementation of BML.

The development of XBML is being conducted in phases. As the XMSF project looked at BML, it was fairly straightforward to determine which XMSF standards would be applied first, in order to “open up” the interfaces. Follow-on phases include migrating to

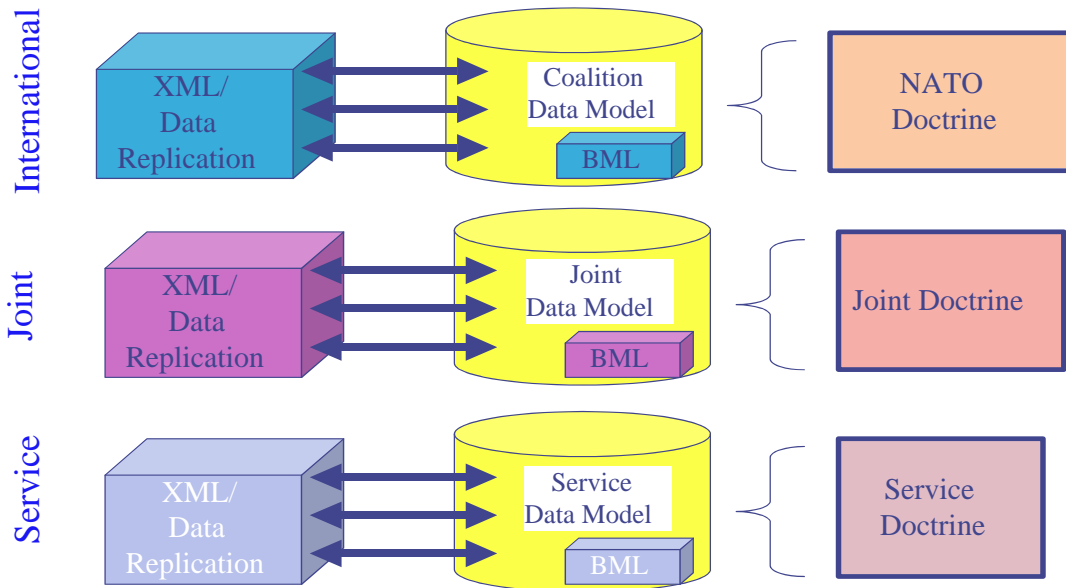


Figure 4: BML Methodology

the C2IEDM, integrating additional components, and extending the semantics of the BML vocabulary.

Development of XBML

In this section we describe what was done in Phase 1 of XBML, conducted in 2003.

The U.S. Army BML proof of principle comprises the following elements as shown in Figure 5:

- To generate orders, the **Combined Arms Planning and Execution System (CAPES)** is used. This is a prototype U.S. Army Planning System. This C2 component creates operational orders (OpOrds) that are exchanged using a proprietary tagged XML document.
- A **Multi Source Data Base (MSDB)** is based on the U.S. Army Standard data model of the Joint Common Data Base (JCDB), which has been extended by the BML development team by introducing over 100 new tables and relations. It is accessed via standardized database manipulation statements based on Open Data Base Connectivity (ODBC) or Java Data Base Connectivity (JDBC). It is implemented in open source software of the Linux environment.
- A BML Demonstrator specific **XML-BML Parser** reads the information from the XML document and generates data manipulation statements. The XML-BML Parser reads the XML document, maps the information to data elements of the MSDB, and inserts the information contained in the document into the MSDB.
- A **BML Graphical User Interface (BML-GUI)** allows data manipulation of the content of the MSDB under consideration of the semantic and syntactic constraints of the BML. The input of CAPES can be used as a basis to create

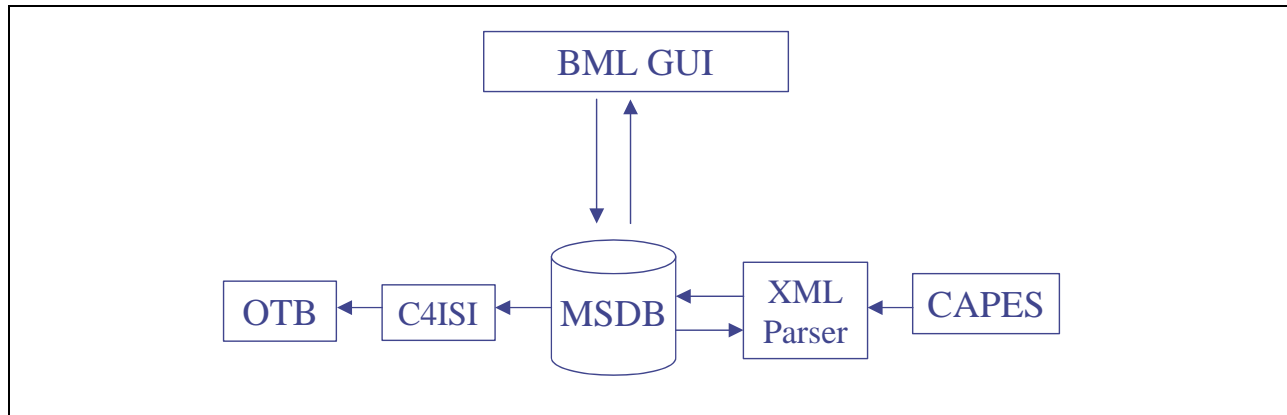


Figure 5: Army BML Proof of Principle

more detailed operational orders for the subordinated units (which are simulated using the OTB simulation system). The paradigm here is who-what-when-where-why, also called “the 5Ws.”

- The MSDB information is based on the U.S. Army doctrinal language. In order to execute such orders, this information has to be mapped from doctrinal terms to OTB interpretable terms. This is done by the **C4I Simulation Interface (C4ISI)**, which reads the MSDB and generates order files for OTB.
- Finally, the M&S component **OneSAF Testbed Baseline (OTB)** system is used to simulate the effect of the generated orders. It reads the order generated by C4ISI and executes them respectively.

Figure 5 shows a simplified version of the U.S. Army BML Proof of Principle (PoP) demonstration. Note that each element of the PoP communicates with the MSDB in a different manner, using unique interfaces and protocols. Also the components must be physically resident on a local network. The BML PoP is more fully described in [8]

It is worth mentioning that the Army BML prototype focused on the C2 application. Its objective was to proof that an unambiguous definition based on Army doctrine is possible (by defining the BML vocabulary), that C2 data can be used as a hub (by extending the JCDB), and that an application can support C4I as well as M&S components (by coupling with CAPES and OTB).

Figure 6 shows the results of the first phase of XBML. Each of the interfaces between the components comprising the original Army BML PoP demonstration environment were investigated to determine approaches to incorporate open, Web-based methods to implement the interfaces to conform with the principles of XMSF. As indicated earlier, two Web-based standards that were chosen to implement the interfaces to construct the XBML prototype were XML and SOAP. XML was used to provide a standard way to structure the data passed between the components. SOAP was used to package the ODBC and JDBC calls to the MSDB database. More details on this are given in [9, 10]

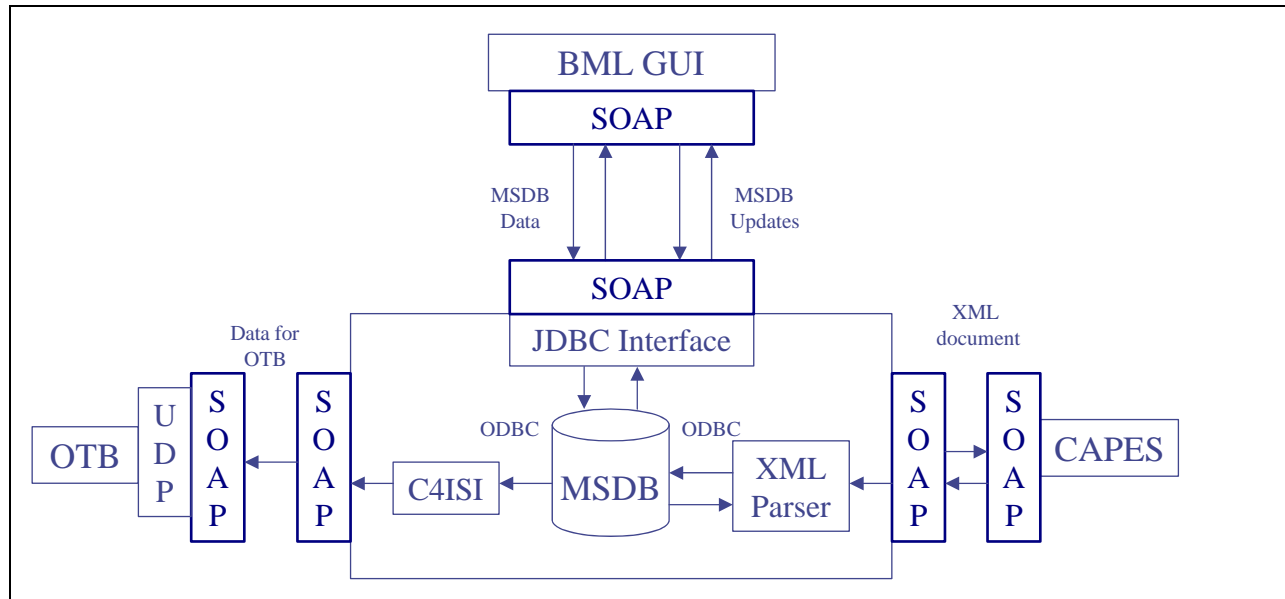


Figure 6: XBML Testbed – Distributed Interfaces

XBML Extensions

This section will address how BML can be extended to coalition members through use of the C2IEDM data structures. The foundation for this was developed in [17, 18, 19, 20].

Development of C2IEDM for Coalition Interoperability

When examining interoperability issues concerning the different Services, or between nations in a coalition, we usually consider coordination issues (e.g. how they work together). We are not immediately concerned with if their C2 systems are interoperable with simulations. Since the early 1990's the U. S. Services have undertaken an extensive revision of Service and Joint doctrine to 1) document their doctrine; and 2) standardize and align their doctrine. Both activities had the goal of improving interoperability in training and execution. This same process is occurring within formal alliances such as the North Atlantic Treaty Organization (NATO).

It is almost impossible to imagine a situation in the future when a single U. S. Service will be unilaterally employed. Because future military operations, and a significant amount of training, will be Joint in nature, it is critical that a Joint Service approach be taken to the BML development effort. The same issues that have driven the Army to embark on this program also confront the other Services as they develop both their C2 and simulation systems.

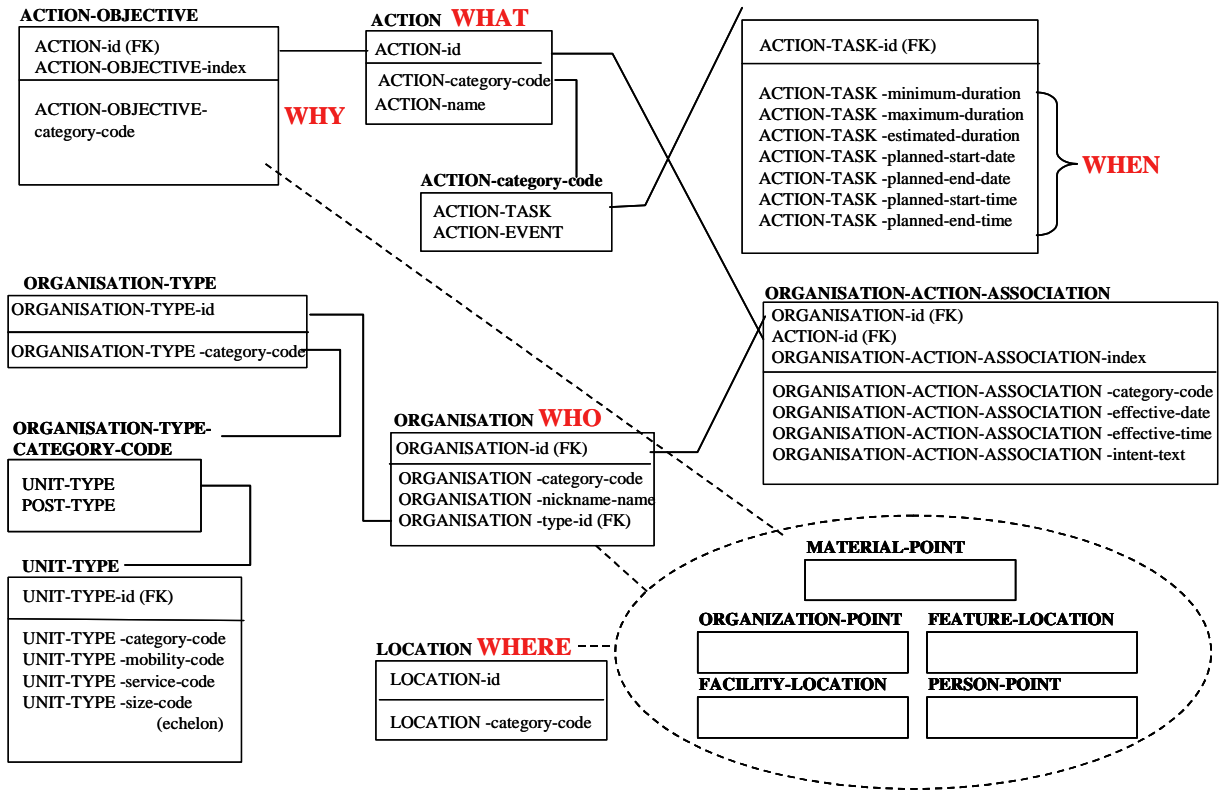


Figure 7: Subset of C2IEDM Tables showing the 5 Ws

A BML, as described in this paper, developed and applied by the other Services and by Coalition members would not only allow interoperability among their C2 systems and simulations, but also among themselves.

Just as the BML PoP implemented the 5Ws within the JCDB, Figure 7 shows similar structures within the C2IEDM. We believe that the same concept for developing BML for the U. S. Army will also work for the other Services, Joint and Combined/Coalition operations (see Figure 4) [6, 21].

Brief History of C2IEDM

To motivate why C2IEDM is our model of choice to represent BML and BML extensions, a short history should be given. More details concerning the data semantics of the C2IEDM are given in [11]. In 1978, NATO's Long-Term Defense Plan (LTDP) Task Force on C2 recommended that an analysis be undertaken to determine if the future tactical Automatic Data Processing (ADP) requirements of the Nations (including that of interoperability) could be obtained at a significantly reduced cost when compared with previous approaches. In early 1980, the then Deputy Supreme Allied Commander Europe initiated a study to investigate the possibilities of implementing the Task Force's recommendations. This resulted in the establishment of the Army Tactical Command

and Control Information System (ATCCIS) Permanent Working Group (APWG), to deal with the challenge of the future C4I systems of NATO. The technical feasibility was demonstrated several times and ATCCIS based systems were demonstrated at the annual Joint Warrior Interoperability Demonstrator (JWID) programs. Finally, the ATCCIS data model became a NATO standard (Allied Data Publication Number 32 - ADatP-32) with the new name Land Command and Control Information Exchange Data Model (LC2IEDM) adapted in 1999.

In parallel to this, the Multilateral Interoperability Program (MIP) was established by the project managers of the Army Command and Control Information Systems (C2IS) of Canada, France, Germany, Italy, the United Kingdom and the United States of America in April 1998 in Calgary, Canada. MIP replaced and enhanced two previous programs: BIP (Battlefield Interoperability Program) and QIP (Quadrilateral Interoperability Program).

By 2002, the activities of ATCCIS/LC2IEDM and MIP were very close, expertise was shared, and specifications and technology were very similar. The merger of ATCCIS and MIP was a natural and positive step and this was recognized by the almost immediate publication of a NATO policy that endorses MIP. LC2IEDM became the data model of MIP, which established the Message Exchange Mechanism (MEM) and the Data Exchange Mechanism (DEM) based on replication mechanism. In 2003, the name was changed to C2IEDM.

In summary, C2IEDM is a mature model applicable to data management as well as to information exchange and has been successfully applied in the international context within NATO.

XBML Extensions to C2IEDM

C2IEDM comprises a lot of information necessary to model the various XBML requirements. However, the new application domains are likely to contribute domain specific extensions which have to be captured by C2IEDM. To this end, the rules established by NATO will be applied. Figure 8 exemplifies how XBML will extend the basic C2IEDM structures with specific Service mission information. As with current coalition exercises using the C2IEDM, different nations and services will have to agree upon the extension to be used for a particular exercise or operation.

The key principles of C2IEDM extensions are that:

- The basic C2IEDM data representations are not changed, and
- Extensions are always done in the least obtrusive manner, i.e., (a) new information is modelled by new attribute values first. If this is not sufficient, (b) the category and subcategory codes are extended in order to generate new subtypes of existing concepts. If, and only if this is not sufficient, (c) new concepts and associations are introduced.

The applicability of these rules in the domains of BML is a current area that the XBML testbed is exploring.

It is apparent that as XBML grows, a method must be set up to “manage” the extensions used. Furthermore, the results have to be fed back to the C2IEDM community in order to have a controlled growth of the standard. Managing data within the C2IEDM is discussed extensively in [11].

Conclusion

The C2 community is shifting from the system centric view to the net centric view. While until recently this was mainly limited to the conceptual preparation of the transformation of the armed forces, the advent of the GIG and GIG Enterprise Services is now enabling the technical implementation of the underlying ideas. Net Centric Warfare [22] is finally becoming a reality. Joint Command and Control (JC2) is on its eve of implementation. Operational M&S functionality is technically ready to be integrated and operationally required to support modern military operations. We have presented a case for XBML as a necessary standardization effort to harmonize M&S standards with GIG requirements.

In summary, XMSF is a broad integration method based on open standards. BML is a collection of methods to capture C2 information in an unambiguous way. XBML merges these two concepts in a powerful manner.

There is a need for a unified BML methodology. BML is vital to achieve C2 to Simulation interoperability. It can also assist in achieving C2 interoperability within Joint and coalition environments acting as the true common language between humans, machines, Services and National militaries.

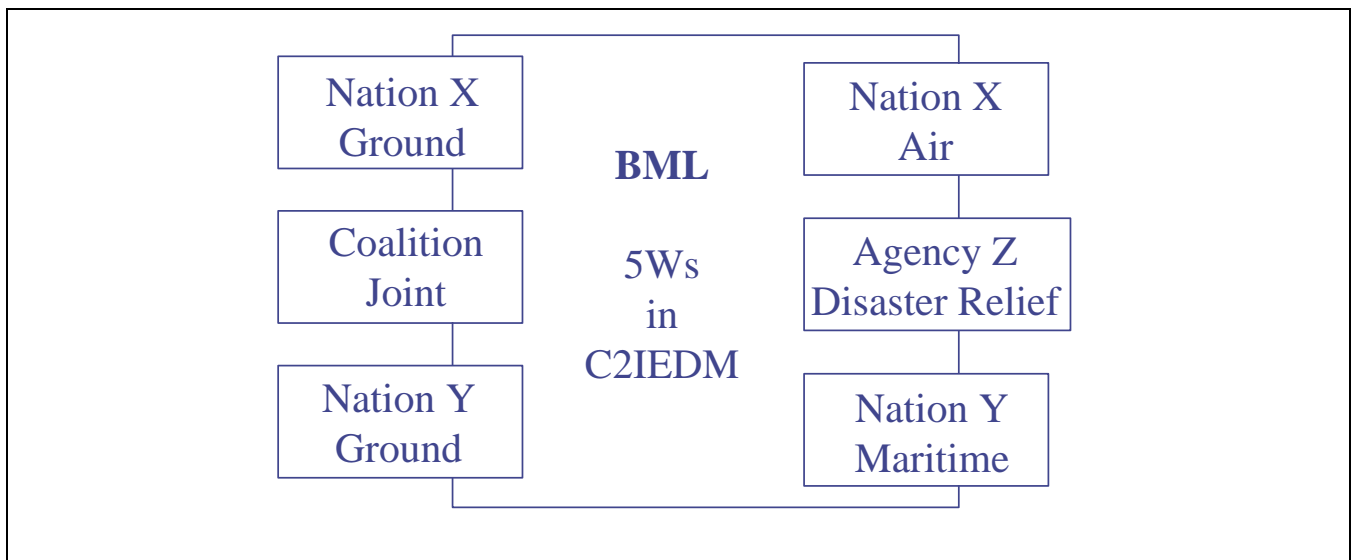


Figure 8: Notional BML Extensions to the C2IEDM 5W Core

With XBML we have demonstrated the capability of distributed, remote operation of web-enabled components. The concept of simulation applications implemented as Web services will support future network centric operational concepts. The Web based implementation facilitates the ‘smart-pull’ concept of information distribution as described in the DoD Net-Centric Data Strategy.

Acknowledgements

The authors gratefully acknowledge and support given by the DMSO for the development of XMSF and XBML. The U.S. Army Simulation-C4I Interoperability (SIMCI) Overarching Integrated Product Team (OIPT) [23] originally sponsored development of BML. The XBML work is based upon a foundation of work done by the U.S. Army and performed by Scott Carey, Martin Kleiner, Colonel Kenneth Wilson and Richard Brown. The authors received invaluable support with the C2IEDM Data Model from Dr. Francisco Loaiza, Dr. Gene Simaitis and Dr. Steven Wartik. The research work done at the Virginia Modeling, Analysis and Simulation Center (VMASC) was partially sponsored by General Dynamics – Advanced Information Systems.

References

- 1) Tolk, A. and Daly, J., “Modeling and Simulation Integration with Network-Centric Command and Control Architectures”, Paper 03F-SIW-121, 2003 Fall Simulation Interoperability Workshop, 2003.
- 2) Tolk, A. and Pullen, J.M., “Ideas for a Common Framework for Military M&S and C3I Systems”, Paper 03E-SIW-032, 2003 Euro Simulation Interoperability Workshop, 2003.
- 3) Ogren, J., and Fraka, M., “EAGLE Combat Model Battle Management Language (BML)”, Powerpoint presentation, BML Symposium at Fort Leavenworth, KS, 25 April 2001. (<http://www.simci.org/html/librsry.html> Public Folder/Meetings/Architect Meetings/Battle Management Language/BML Symposium/Eagle Presentation).
- 4) Salisbury, M., “Command and Control Simulation Interface Language (CCSIL): Status Update” MITRE Informal Report, Twelfth Workshop on Standards for the Interoperability of Defense Simulations, 1995 (<http://ms.ie.org/cfor/diswg9503/diswg9503.pdf>)
- 5) Carey, S., Kleiner, M., Hieb, M.R. and Brown, R., “Development of a C2 Standard of Task Representation for C4ISR Systems, Simulations and Robotics: Battle Management Language”, 2002 Command and Control Research Technologies Symposium, Monterey, California, 2002.
- 6) Carey, S., Kleiner, M., Hieb, M.R. and Brown, R., “Standardizing Battle Management Language –A Vital Move Towards the Army Transformation”, Paper 01F-SIW-067, Fall Simulation Interoperability Workshop, 2001.

- 7) Carey, S., Kleiner, M., Hieb, M.R. and Brown, R., "Standardizing Battle Management Language – Facilitating Coalition Interoperability", Paper 02E-SIW-005, 2002 European Simulation Interoperability Workshop, London, England, 2002.
- 8) Sudnikovich, W., Hieb, M.R., Kleiner, M. and Brown, R., "Developing the Army's Battle Management Language Prototype Environment", Paper 04S-SIW-115, 2004 Spring Simulation Interoperability Workshop, Crystal City, VA, 2004.
- 9) Hieb, M.R., Tolk, A., Sudnikovich, W., and Pullen, J.M., "Developing Battle Management Language into a Web Service", Paper 04S-SIW-113, 2004 Spring Simulation Interoperability Workshop, Crystal City, VA, 2004.
- 10) Hieb, M.R., Tolk, A., Sudnikovich, W., and Pullen, J.M., "Developing Extensible Battle Management Language to Enable Coalition Interoperability", Paper 04E-SIW-064, 2004 Euro Simulation Interoperability Workshop, Edinburgh, Scotland, 2004.
- 11) Tolk, A., "Moving towards a Lingua Franca for M&S and C3I – Developments concerning the C2IEDM", Paper 04E-SIW-016, 2004 Euro Simulation Interoperability Workshop, Edinburgh, Scotland, 2004.
- 12) Tolk, A. and Muguira, J., "The Levels of Conceptual Interoperability Model", Paper 03F-SIW-007, 2003 Fall Simulation Interoperability Workshop, 2003.
- 13) Tolk, A., "Composable Mission Spaces and M&S Repositories - Applicability of Open Standards", Paper 04S-SIW-009, 2004 Spring Simulation Interoperability Workshop, 2004.
- 14) Timian, D.H., Hieb, M.R., Lacetera, J., Tolk, A., Wertman, C., and Brandt, K., "Report Out of the C4I Study Group", Paper 00F-SIW-005, 2000 Fall Simulation Interoperability Workshop, 2000.
- 15) Kleiner, M.S., Carey, S.A., and Beach, J., "Communicating Mission-Type Orders to Virtual Commanders", Paper, Proceeding of the 1998 Winter Simulation Conference, December 1998.
- 16) Galvin, K., "Achieving C2 TO Simulation Interoperability In Support Of Training And Mission Planning/Rehearsal - A Review Of Battlespace Management Languages As A Mechanism", Masters Thesis, College Of Defence Technology, Cranfield University, August 2003.
- 17) Zimmermann, B., "Integrated Army Modelling and Simulation Data Network", NATO Conference on "C3I and M&S Interoperability", Antalya, Turkey, October 2003 (to be published in RTO-MP-123). <http://www.rta.nato.int/Abstracts.asp>
- 18) Haddix, F., Sheehan, J., Loesekann, M., and Scudder, R. "Semantics and Syntax of Mission Space Models", Paper 99F-SIW-152, Fall Simulation Interoperability Workshop, 1999.
- 19) Hieb, M.R., and Blalock, J., "Data Alignment Between Army C4I Databases and Army Simulations", Paper 99S-SIW-034, Spring Simulation Interoperability Workshop, 1999.
- 20) Wartick, S.P., Haugh, B.A., Loaiza, F., and Hieb, M.R., "Building in Interoperability: A Comparison of C4I Data Models and Simulation Object Models", Paper 01S-SIW-021, 2001 Spring Simulation Interoperability Workshop, 2001.
- 21) May, G., briefing "NATO Doctrine Development", Semi-Annual Army Doctrine Conference 14-15 November 2001, <http://doctrine.army.mil/SAADC/saad2001briefings/natodoctrine.ppt>.

- 22) David S. Alberts, John J. Garstka, Richard E. Hayes, David A. Signori:
“Understanding Information Age Warfare,” CCRP Publication Service, August 2001
- 23) SIMCI WWW Site, Army Overarching Integrated Product Team for Simulation to C2
Interoperability: <http://www.simci.org>, 2004.

Author Biographies

MICHAEL HIEB is an Assistant Vice President for C4I Programs for Alion Science and Technology. Dr. Hieb is currently an Architect for the Army SIMCI OIPT. He received his Ph.D. in Information Technology at George Mason University in 1996 and performed his doctoral research at the GMU Center for Excellence in C3I. Dr. Hieb received his MS degree in Engineering Management from George Washington University and his BS degree in Nuclear Engineering from the University of California in Santa Barbara. He has published over 50 papers in the areas of M&S integration with C4I and Machine Learning. Previously, he worked as a Nuclear Engineer for General Electric.

ANDREAS TOLK is Senior Research Scientist at the Virginia Modeling Analysis and Simulation Center (VMASC) of the Old Dominion University (ODU) of Norfolk, Virginia. He has over 12 years of international experience in the field of Applied Military Operations Research and Modeling and Simulation of and for Command and Control Systems. In addition to his research work, he gives lectures in the Modeling and Simulation program of ODU. His domain of expertise is the integration of M&S functionality into related application domains, such as C2 or web-based services, in particular based on open standards.

WILLIAM P. SUDNIKOVICH is a Project Manager for Atlantic Consulting Services in Shrewsbury, NJ and a technical architect for the Army’s SIMCI OIPT. Prior to joining ACS in 2000, Mr. Sudnikovich held various technical and management positions with the U.S. Army CECOM RDEC and was influential in establishing M&S activities there. He was an active contributor to the development of the IEEE 1278 DIS standards and is a former Chairperson of the C4I Forum of the Simulation Interoperability Standards Organization (SISO) Simulation Interoperability Workshops. Mr. Sudnikovich holds BS and MS degrees in Computer Science from Rutgers University and Fairleigh Dickinson University.

J. MARK PULLEN is Professor of Computer Science at George Mason University, where he heads the Networking and Simulation Laboratory in the C3I Center. He holds BSEE and MSEE degrees from West Virginia University, and the Doctor of Science in Computer Science from the George Washington University. He is a licensed Professional Engineer, Fellow of the IEEE, and Fellow of the ACM. Dr. Pullen teaches courses in computer networking and has active research in networking for distributed virtual simulation and networked multimedia tools for distance education.



Extensible Battle Management Language (XBML)

A Methodology for Web Enabling Command and Control for Network Centric Warfare

Michael R. Hieb, Ph.D.

Alion Science & Technology
Michael.R.Hieb@us.army.mil

Andreas Tolk, Ph.D.

VMASC - Old Dominion University
atolk@odu.edu

William P. Sudnikovich

Atlantic Consulting Services, Inc.
wsudnikovich@acsinc-nj.com

J. Mark Pullen, D.Sc.

George Mason University
mpullen@gmu.edu

George Mason
University

OLD
DOMINION
UNIVERSITY™

ALION
SCIENCE AND TECHNOLOGY

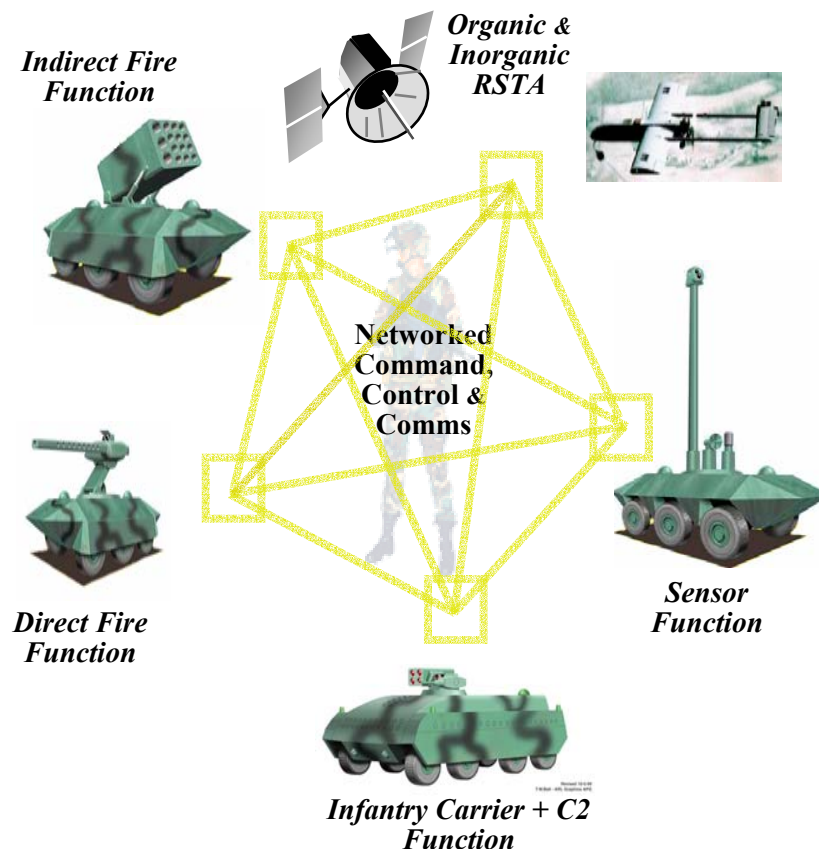
ACS
atlantic consulting services



BML as an Enabler for Network Centric Operations



- ◆ **Network Centric**
 - ✓ Know precisely, in real-time, location of all friendly and enemy forces
- ◆ **Robotics Integrated into Force**
 - ✓ Amplify capability of manned elements
 - ✓ Multi-functional (RSTA, armed, sustainment)
- ◆ **Increased Reliance on Extended Range Engagement**
 - ✓ Organic plus strategic and tactical support
 - ✓ Long range ISR and precision fires
- ◆ **Capable of Air-Mobile Operations**
 - ✓ Commercial and minimum DoD strategic and tactical lift





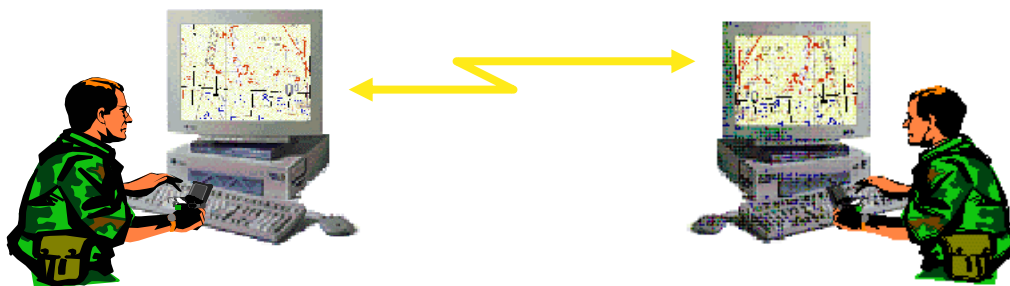
The Problem

- Current and emerging simulations do not have the capability of directly interacting with C4I systems.
 - They require the development of unique interfaces (“black boxes”) for each pairing of a simulation and a C4I system
 - They require significant non-training audience intervention in order to support digital battle staff training and they will continue to do so until a standardized Battle Management Language is developed for communicating between these systems.
 - The most difficult aspect of this problem is in communicating mission type orders from the command nodes to the supporting simulations. Generically this is known as the **“Free Text Problem.”**



Current Situation

- Our current “BML” is a loosely knit “language” tailored to interpersonal communication.
- Its vocabulary is found in Doctrinal Manuals, but it lacks clearly delineated rules governing its use (semantics and syntax).
- It is riddled with ambiguity and overlapping definitions.
- As such, it is incapable of transitioning to the full range of automation that the DoD is implementing.
- It will not support the integration of advanced modeling and simulation with “digitized” command and control.





What Is Battle Management Language (BML)?



- BML is the unambiguous language used to:
 - Command and control forces and equipment conducting military operations, and
 - To provide for situational awareness and a shared, common operational picture.

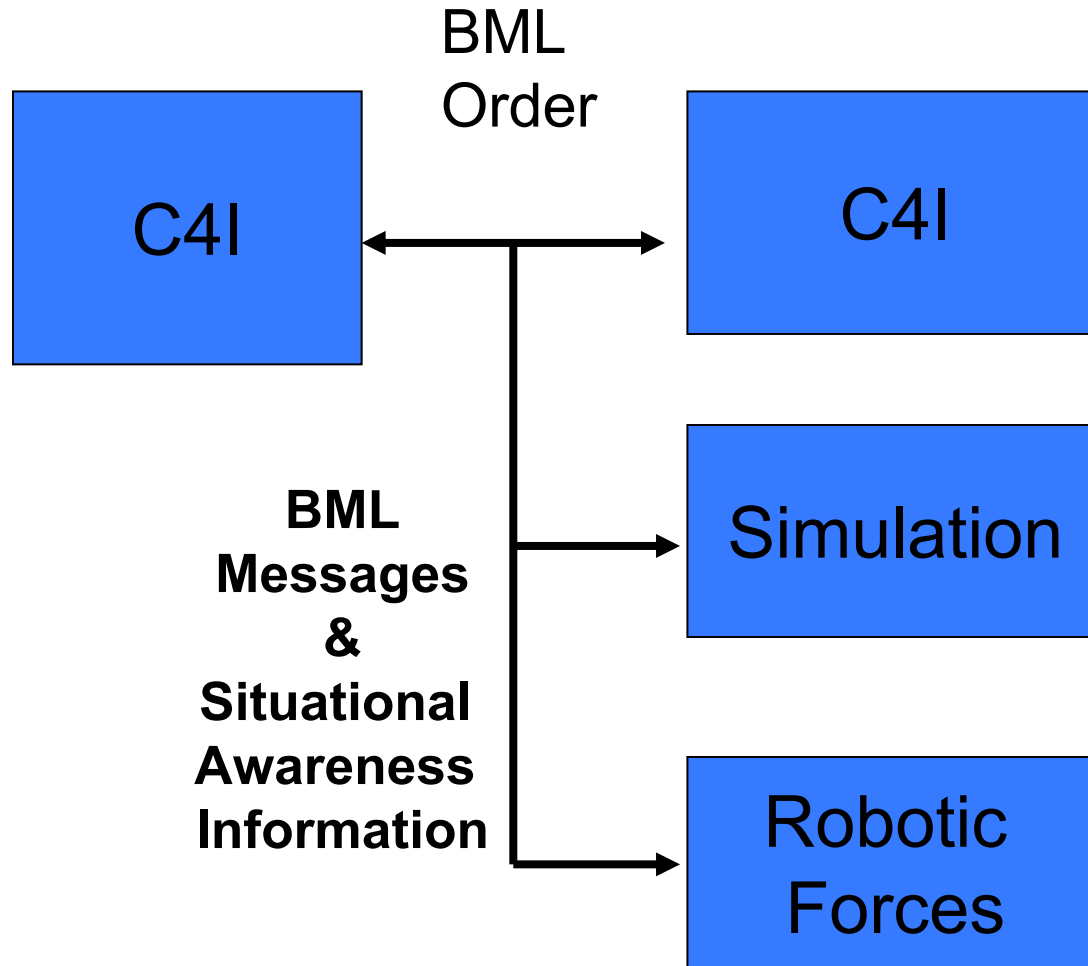


Principles of BML

- BML must be unambiguous
- BML must not constrain the expression of a commander's intent
- BML must use standardized data representations
- BML must allow forces to communicate information pertaining to their mission, their status and their environment

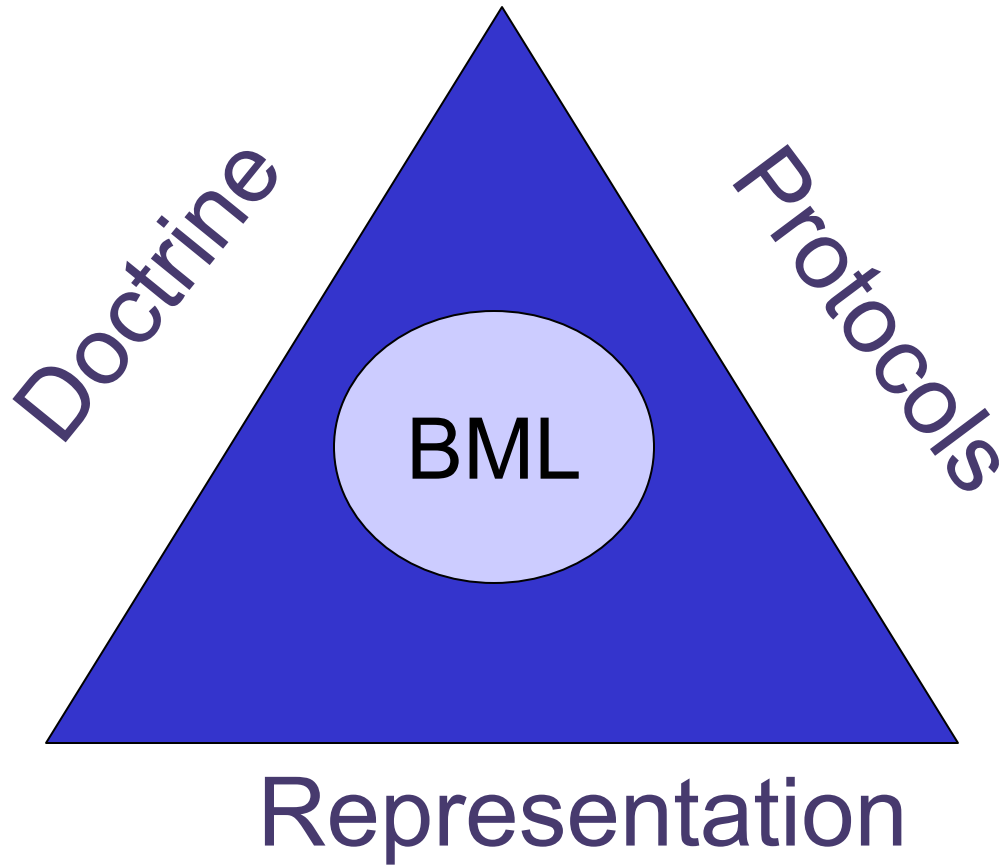


BML Scope



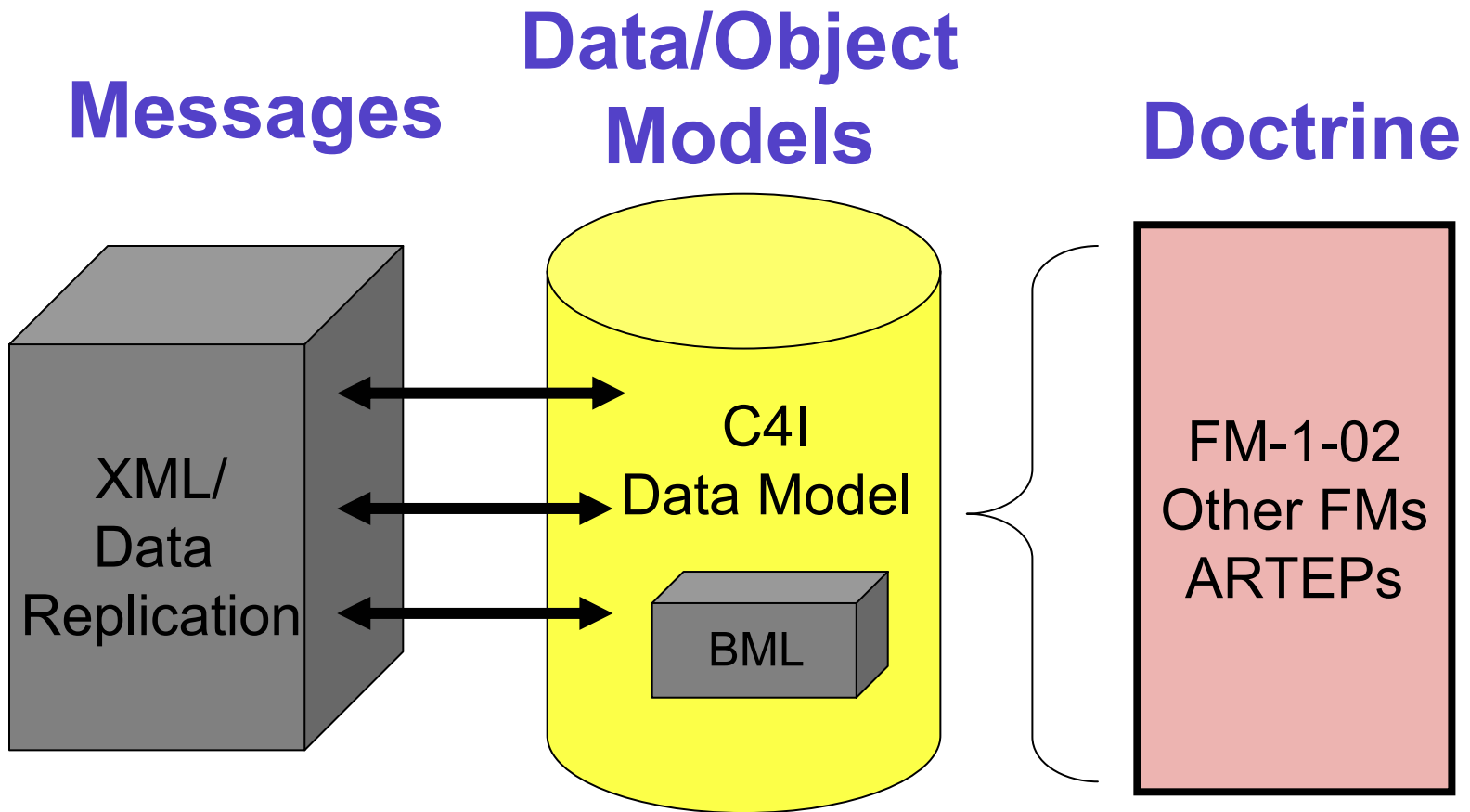


BML Views





BML Concept

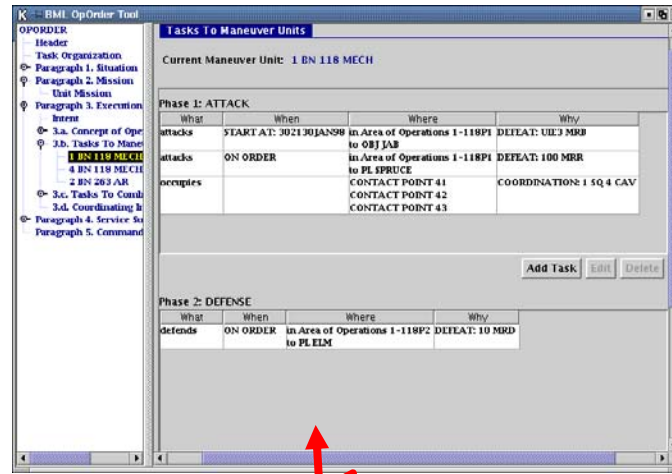




US Army BML Proof of Principle



BML GUI



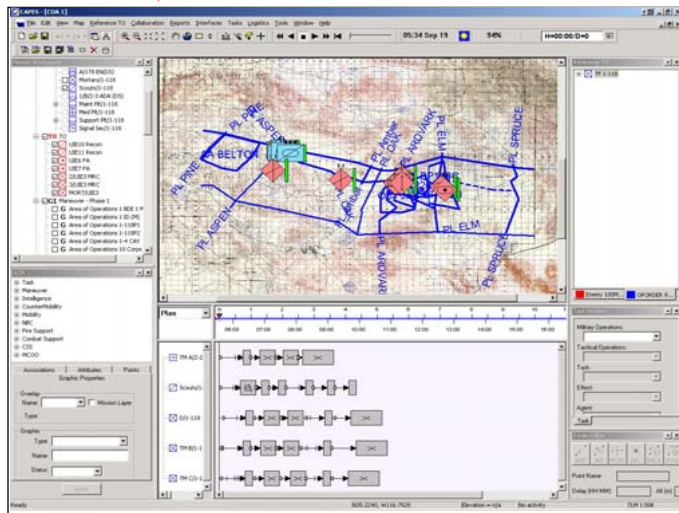
XML – BML Parser

C4ISI

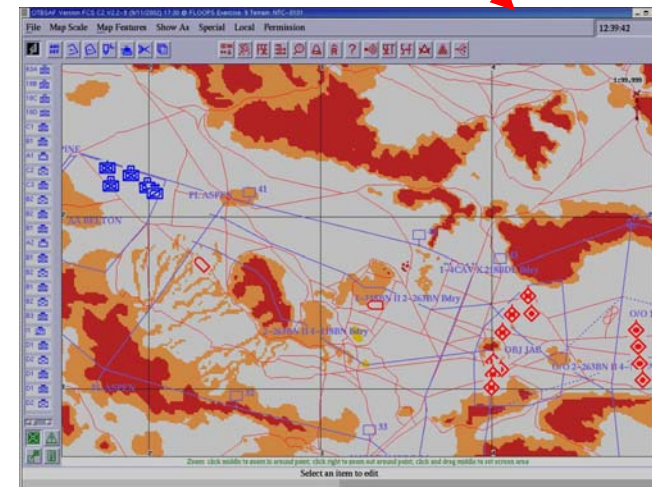
Multi-Source Database Augmented with BML

CAPES

OTB



BML acts as the common denominator

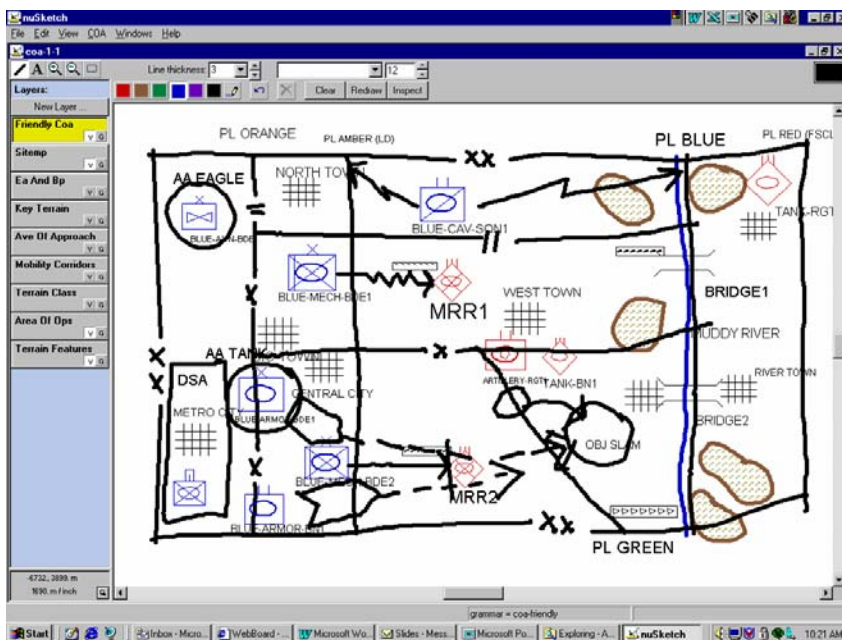




Course of Action Analysis Example



Graphics convert to BML



Division Mission

Division attacks on order in zone to seize OBJ SLAM.

Division Concept of Operations

Form of maneuver: Penetration

Main effort: BLUE-MECH-BDE2,

on order BLUE-ARMOR-BDE1

Supporting effort: BLUE-MECH-BDE1

BLUE-ARMOR-BN1

Deep: None

Reserve: BLUE-AVN-BDE1

Security: BLUE-CAV-SQN1

Tactical Combat Force: BLUE-MECH-TM1

Tasks to Subordinates

•Who	•What	•When	•Where	•Why
•BLUE-MECH-BDE1	•Attacks	•On order	•Zone	•Fix (MRR1)
•BLUE-MECH-BDE2	•Attacks	•On order	•Zone	•Penetrate (MRR2)
•BLUE-ARMOR-BDE1	•Follows and Assumes (B-M-BDE2)	•On order	•Zone	•Seize (OBJ SLAM)
•BLUE-AVN-BDE	•Occupy	•On order	•AA EAGLE	•Reserve
•BLUE-ARMOR-BN1	•Follow and Support (B-A-BDE1)	•On order	•Zone	•Support (B-A-BDE1)
•BLUE-CAV-SQN1	•Screen	•On order	•Zone (PL AMBER to PL BLUE)	•Protect (Division left flank)
•BLUE-MECH-TM1	•Tactical Combat Force	•On order	•DSA	•Protect (Division Rear Area)

Paragraph 1: Enemy Most Probable CoA

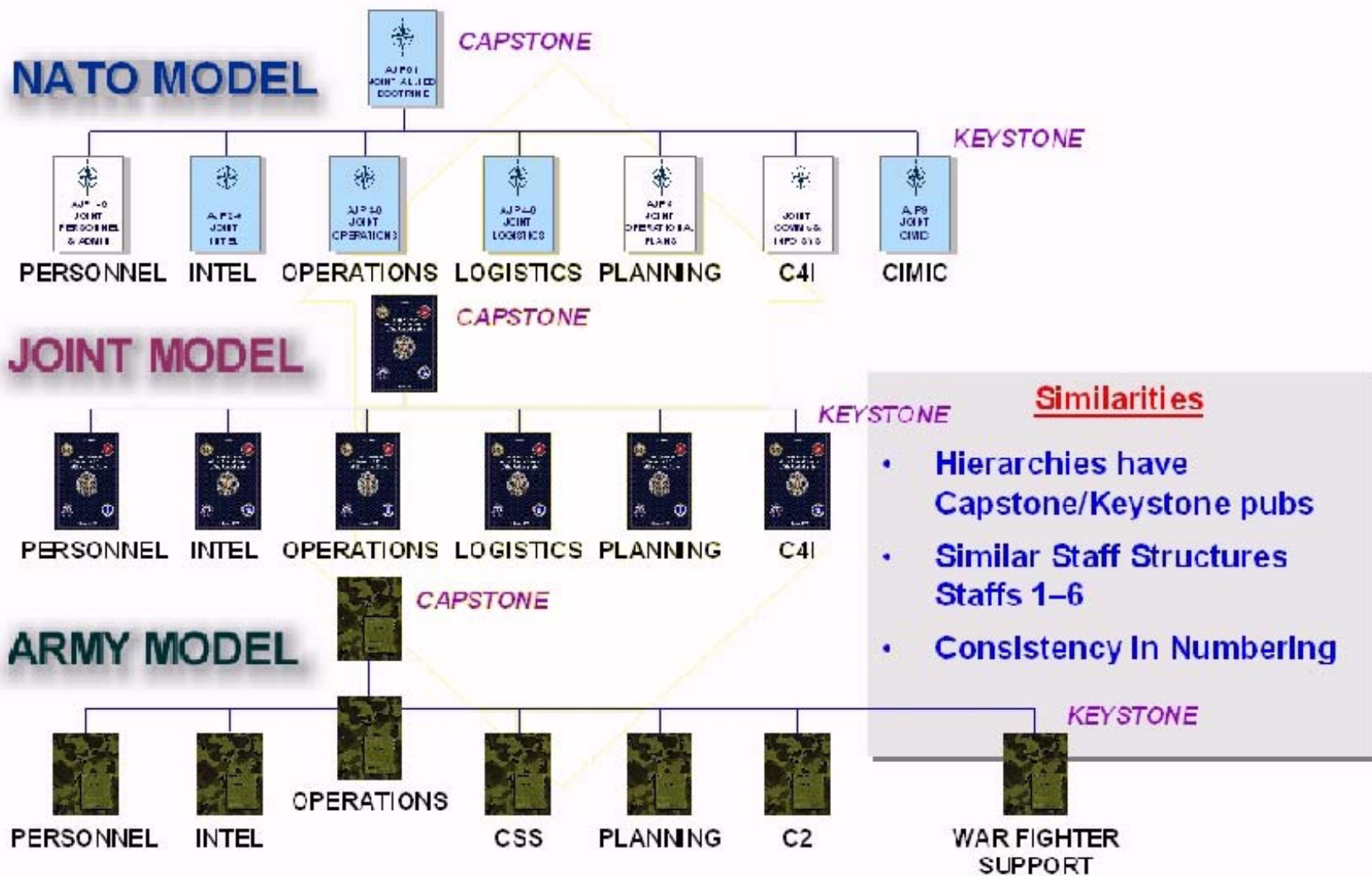
Who What When Where Why

The screenshot shows a software interface titled "BML OpOrder Tool". On the left is a tree view with "Paragraph 1. Situation" expanded to "1.b. Enemy Force", which is further expanded to "Most Probable". The main area displays a table titled "Enemy Most Probable Course Of Action". The table has five columns: Who, What, When, Where, and Why. Red arrows point from the labels "Who", "What", "When", "Where", and "Why" above the table to their respective column headers. Below the table is another section titled "Enemy Most Dangerous Course Of Action" with a similar header structure.

Who	What	When	Where	Why
10 MRD	ATTACKING	START NET: 292000JAN98 and END NLT: 011000FEB98	Area of Operations 1 ID (M)	seize: PL BALSAM
10 MRD	ATTACKING	ON ORDER	Area of Operations 1 ID (M)	seize: AA BELTON
100 MRR	DEFENDING		OBJ JAB	seize: MOUNTAIN
101 MRR	ATTACKING	START NET: 292000JAN98 and END NLT: 011000FEB98	Area of Operations 1 BDE 1 MECH DIV	seize: PL BALSAM
102 MRR	ATTACKING	START NET: 292000JAN98 and END NLT: 011000FEB98	Area of Operations 1 BDE 1 MECH DIV	support: 101 MRR
1 IMRB	ATTACKING	START NET: 292000JAN98 and END NLT: 011000FEB98	Area of Operations 1 ID (M)	support: 102 MRR
104 TR	ATTACKING	START NET: 292000JAN98	Area of Operations 1 ID (M)	seize: PL BALSAM



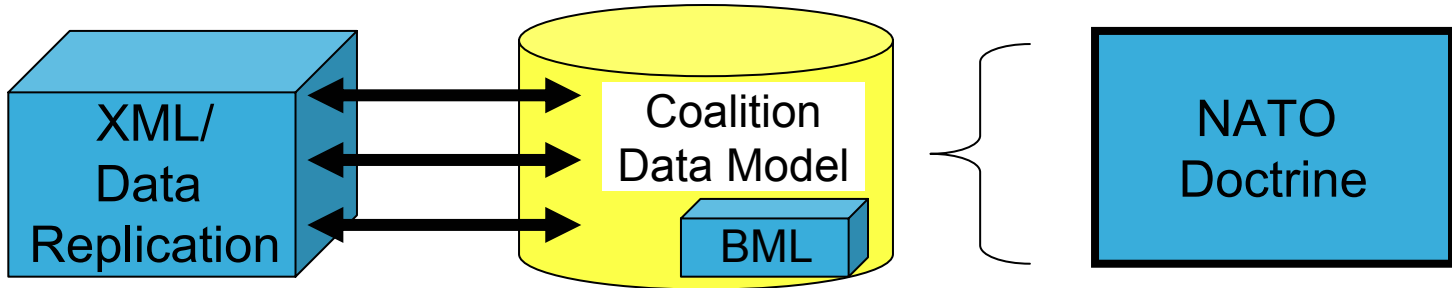
Army, Joint and NATO Doctrine Hierarchies



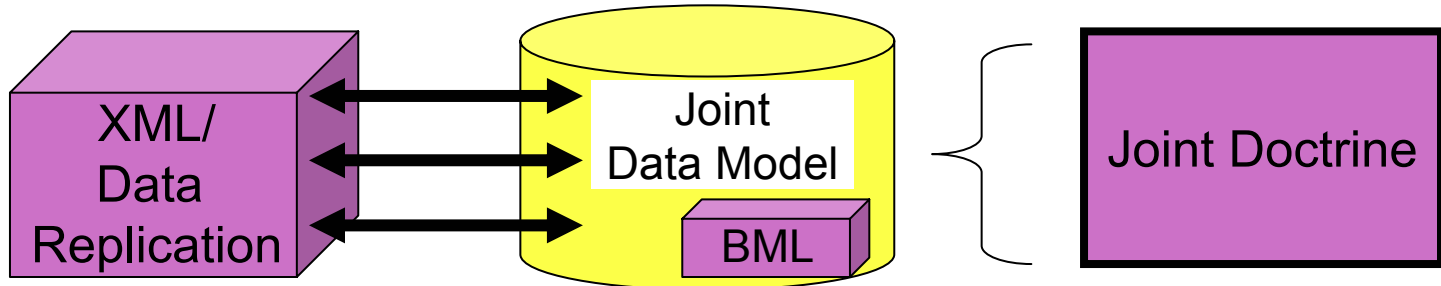


BML Scalability

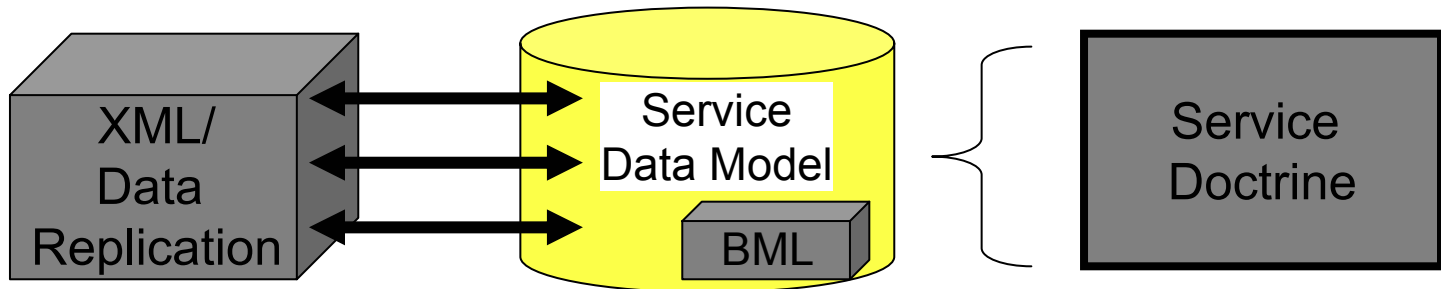
International



Joint



Service





Extensible Modeling and Simulation Framework



- **What is XMSF?**

- The Extensible Modeling and Simulation Framework (XMSF) is defined as a set of Web-based technologies and services, applied within an extensible framework, that enables a new generation of modeling & simulation (M&S) applications to emerge, develop and interoperate.

- **XMSF Precepts**

- Web-based technologies can provide an extensible modeling and simulation architecture, to support a new generation of interoperable applications
- Simulation support is needed for operational warfighting capabilities
- XML-based architecture can provide a bridge between emerging rehearsal/reality/replay requirements and open/commercial Web standards
- Web = best tech strategy + best business case



What Is XBML?

- XBML is BML provided as a Web Service
- XBML is being developed as an integral part of the Extensible Modeling and Simulation Framework



Applying XMSF Principles to BML

- BML must utilize Web Standards for Message Transmission
 - SOAP
 - XML
- BML must use a standard “vocabulary”
 - the Command and Control Information Exchange Data Model (C2IEDM)
- This results in:

- Distributed, Flexible Interfaces
- Common Syntax and Semantics between Services, and Coalition Partners
- Unambiguous terms needed for Simulation Execution

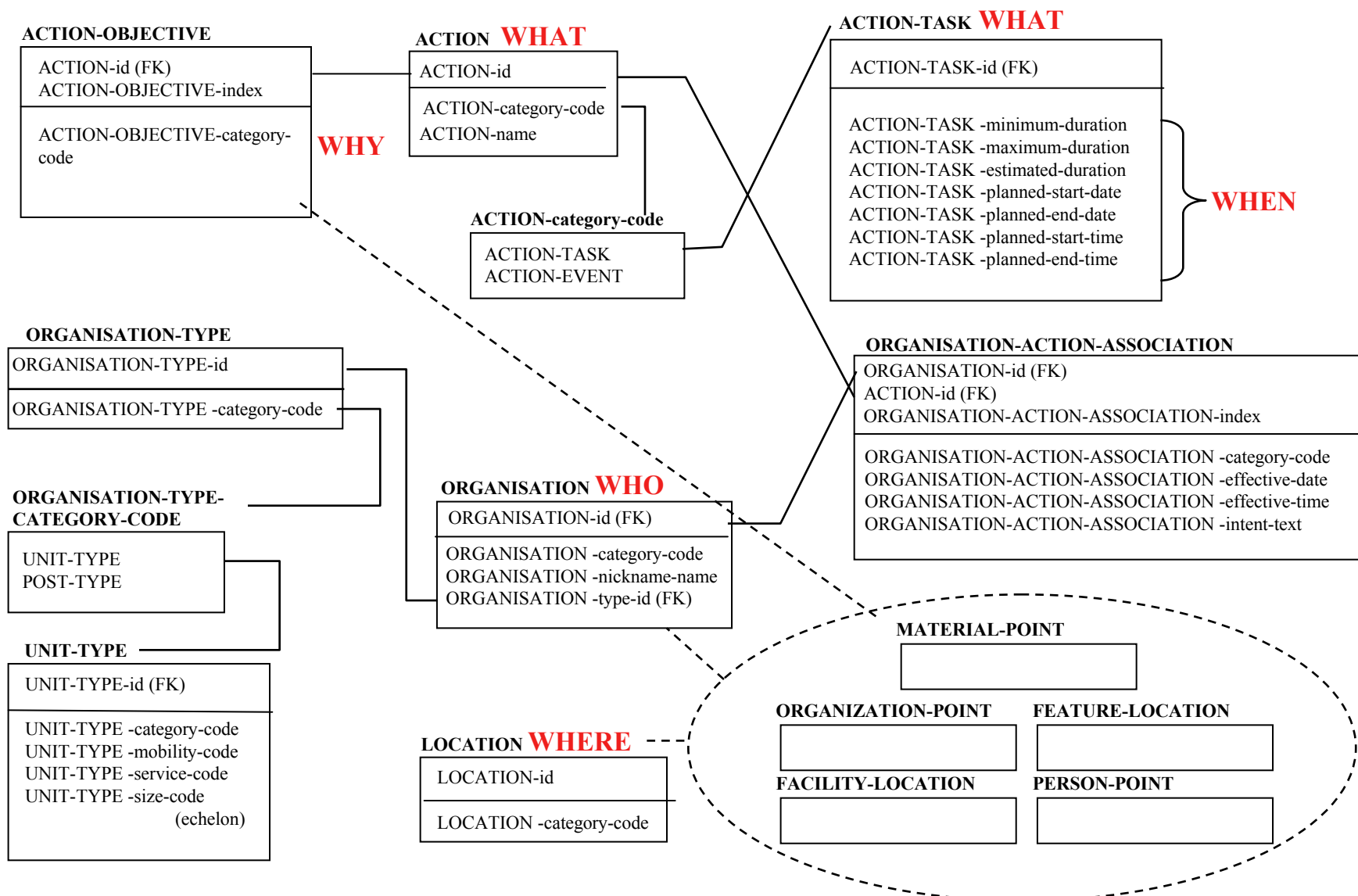


Why use the C2IEDM for XBML?

- History of C2IEDM
- Developed by NATO data modeling experts (ATCCIS Permanent Working Group)
- Based on the Information Exchange Requirements on the Battlefield
 - *Unambiguous Representation of Information*
 - *Extensible Data Model*
- NATO Standard ADatP-32
- Use by the NATO Data Administration Group
- Core Data Model for various C4I Systems
- Reference Data Model for various Simulation Systems
- Data Model for Multilateral Interoperability Program (MIP)

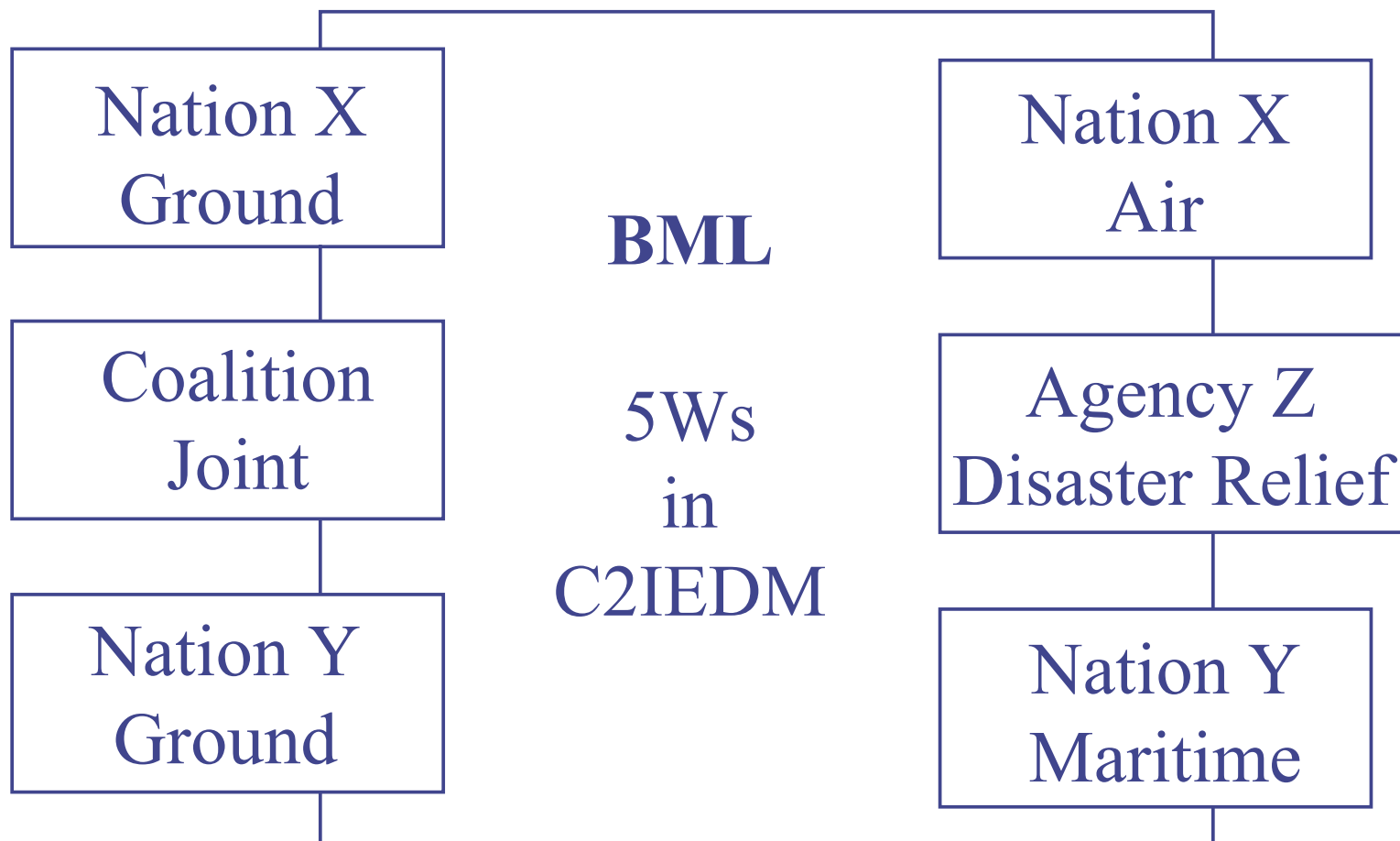


5 Ws in C2IEDM





Joint BML Implementation Concept: Extend the C2IEDM





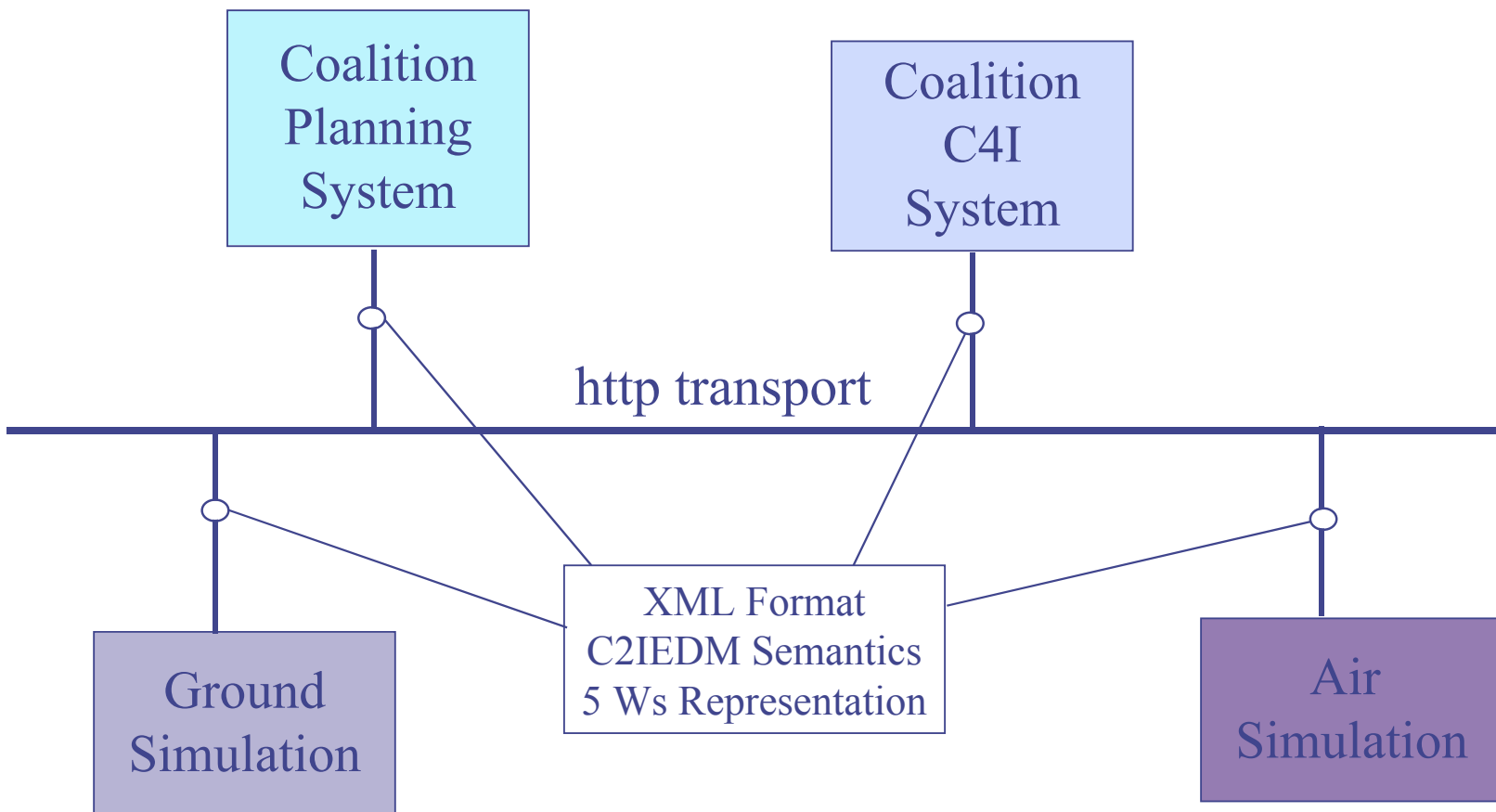
Extending the BML Vocabulary to Air Operations



- Begin with Air C2DIF (Command and Control Data Interchange Format)
 - Developed by Gestalt – AF/ESC Sponsorship (1998)
 - Vetted in over 120 Exercises/Events/Demonstrations/Tests
- Includes the Following Categories
 - Air Battle Plan
 - Air Tasking Order (ATO)
 - Airspace Control Order (ACO)
 - Special Instructions (SPINS)
 - Mission Feedback
 - Friendly Order of Battle (FRoB)
 - Scenario Data (UOB)
 - Mission Representation
 - Includes More Detailed Mission Planning Aspects of ATO Directed Missions
 - Supports the “Decrease of the Controller Footprint Goal”



XBML Coalition Concept





Conclusions

- **BML can provide a true common language between humans, machines, Services and national militaries**
 - Will enable command and control interoperability within Joint and coalition environments
- **The concept of simulation applications implemented as Web services will support future network centric operational concepts**
- **We have demonstrated the capability of distributed, remote operation of web-enabled components**