A Common Framework for Military M&S and C4I Systems

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ABSTRACT: *Despite the presence of technical solutions such as the Joint Technical Architecture (JTA) and the Common Operating Environment (COE), and despite the political will manifested in form of mandates by the superior leadership to use respective common frameworks, the story of common projects of the Modeling & Simulations (M&S) Community and the Command, Control, Communications, Computers, and Intelligence (C4I) Systems Community is more or less limited to a story of building interfaces. This may change in the near future.*

Both communities are within something that can become a paradigm shift. While the technical and architectural solutions of the past were system focused, the new emerging solutions are looking at distributed, composable functionality connected by a common infosphere. The system-of-systems approach places the information into the center. Distributed components deliver necessary functionality to manipulate and analyze the information to increase the efficiency of the Warfighter. The Internet and web-based services are becoming the new way to think about information technology applications.

Within the C4I community, the Defense Information Systems Agency is working on solutions to ensure Information Superiority in Network Centric Warfare scenarios. The use of web-services will help to transform the system centric Common Operating Environment into Net Centric Enterprise Services (NCES) as a new backbone for future C4I systems. Within the M&S community, various efforts are looking at similar solutions. Only recently, the Extensible Modeling & Simulation Framework (XMSF) team articulated the idea to use open standards such as web-services, the Extensible Mark-up Language (XML), and the Simple Object Access Protocol (SOAP) to create a framework for future M&S applications.

This paper summarizes ongoing related efforts and articulates, that a common framework is not only technically feasible, but necessary to increase the efficiency of the Warfighter for future military operations.

1 Introduction

Since the early days of the Simulation Interoperability Workshops (SIW) in 1997, papers are presented in the Command, Control, Communications, Computers, and Intelligence (C4I) Forum dealing with the challenge to couple simulation systems and C4I systems. The roots go back even to similar forums within the Distributed Interactive Simulation (DIS) Workshops.

The scope of application of respective solutions, however, changed over the last years. While the early papers were nearly exclusively focused on the aspects of training, i.e., how to integrate operational C4I systems effectively and efficiently into Computer Assisted Exercise (CAX) environments, nowadays the operational use of modeling and simulation (M&S) functionality is the issue, such as alternative courses of action analysis in the headquarters based on the perception and situational awareness obtainable via the operational C4I systems. Furthermore, the Warfighter requires real "embedded" training solutions. To fulfill such requirements, interface driven solutions fall short.

Integrated solutions are necessary to enable software solutions beyond the stove-piped era of military information systems.

Another aspect is that the necessity to look for a new generation of information systems supporting the Warfighter is no longer driven by the Department of Defense only. Future military operations require inter-agency interoperability to enable cooperation of various national and international partners. Future military operations will be conducted in joint and combined environments and often in tight collaboration with non-military and non-governmental organizations. As it is very unlikely that these organizations and international partners will use U.S. DoD standards to implement their information systems, built-in ways are needed to insure information exchange with such systems. The only way to cope with these challenges seems to be to integrate open standards into the systems. These open standards can be used to integrate other open information systems in case of need. One of the most promising approaches is the Model Driven Architecture (MDA) proposed by the Object Management Group (OMG). This relatively young standard merges promising and matured integration technologies to new system engineering standards, which are supported by a large commercial community.

Respective ideas did lead to the development of the idea to use web technologies to create an Extensible M&S Framework (XMSF) only recently. XMSF doesn't want to replace standards like the High Level Architecture (HLA). XMSF wants to broaden the basis of applicable standards by using web technologies such as web services, the Extensible Markup Language (XML), and the Simple Object Access Protocol (SOAP) to enable distributed M&S applications. Therefore, XMSF can be seen as an evolutionary step within the domain of Advanced Distributed Simulation.

The C4I community is following a similar pathway. Only very recently, the Office of the Secretary of Defense (OSD) decided to refocus the work for C4I system architectures from the system centric view to a network centric view. The Common Operating Environment (COE), which is developed and improved under aegis of the Defense Information System Agency (DISA) and which use is mandatory for operational information systems, will evolve into the new architecture referred to as Net Centric Enterprise Services (NCES). As XMSF, the NCES community is still in the process of defining a common vision, but the use of the MDA, XML, and SOAP is under strong consideration. The neighborhood of XMSF and NCES is obvious and these new approaches seem to be able to become a backbone for common integrated solutions.

The best framework, however, is useless without the respective applications. In the context of this paper, two programs are worth analyzing more closely, both of them related to the idea of using components sitting atop a common framework like NCES/XMSF delivering the functionality derived from operational requirements. The development of a theory of composability aims at the establishment of a sound mathematical concept enabling a scientific approach to the challenge of composing a new system using various legacy components. That technical interoperability is not sufficient is well known, but so far, a theory has been lacking to deal with this issue. The gap will be closed by the results of this ongoing effort. Additionally, the work on Base Object Models deals with the practical side of the problem. After a common vision could be established over the recent workshops, the ideas are now mature enough to establish a standardization effort in form of a Simulation Interoperability Standards Organization (SISO) Product Development Group. The Base Object Model (BOM) Specification is likely to be standardized in the near future. BOMs lying in the overlapping domain of interest for NCES and XMSF, e.g., embedded training, after action review, mission rehearsal, and many more, can be standardized in a common approach of NCES and XMSF engineers and – which is even more important – respective system users.

To summarize this introductory overview, various very valuable contributions are under development right now. If we succeed in harmonizing the respective program in sufficient detail, we have a real chance to reach domain overarching interoperability based on component based systems in a network centric environment using a common framework.

In the following sections of this paper, various exemplifying programs are described. This list of programs is neither exclusive nor complete and the reader is invited to participate in the harmonization with applicable projects to insure the overall success to enhance the capabilities, effectiveness, and efficiency of our armed forces.

2 Model Driven Architecture

Until recently, open standards were not too well structured and it was hard to find a way to access them in an organized manner. Organizations like the Object Management Group (OMG) tried to bring some

structure to this world by overarching architectures. Starting with the Common Object Request Broker Architecture (CORBA), the OMG started to organize several well-accepted and evolutionary developed and evolving standards around general principles. The latest project of this kind is the Model Driven Architecture (MDA).

The MDA is based on this idea of meta-modeling, which means that instead of approaching a given problem directly with a programmed or coded solution, a conceptual model solving the general underlying problem in form of a "Meta Model" is established first. The MDA merges different OMG standards having been developed and used separately so far into a common view by applying common meta models. The kernel idea is to use a common stable model, which is language-, vendor- and middleware-neutral. This model must be a meta-model of the concept. The MDA offers concepts for such a model. With such a model in the center, users having adopted the MDA gain the ability to derive code for various sub-levels. Even if the underlying infrastructure shifts over time, the meta-model remains stable and can be ported to various middleware implementations as well as platforms, etc.

The MDA comprises standards to address the various facets of interoperability. The main kernel standards are

- The Unified Modeling Language (UML) to cope mainly with the harmonization of processes and interfaces,
- The Common Warehouse Metamodel (CWM) to cope with data modeling, object modeling, repositories, and data transformation and data mediation, and
- The Meta Object Facility (MOF) to store all the necessary information and meta information needed for continuously interoperable heterogeneous and shared – and preferably component based – software solutions.

These kernel standards of the MDA are needed to formulate and document the conceptual model of the distributed solution in a standardized and reproducible manner easily to be shared between software architects who are respectively educated. The conceptual model in form of the common meta model is described in form of the Platform Independent Model (PIM). Using standardized procedures, the PIM is then transformed into a programmed solution in form of the Platform Specific Model (PSM). For one PIM, several different PSM can exists, e.g., for different platform as well as for different middleware solutions, such as CORBA, the Runtime Infrastructure (RTI) of the HLA, or the Internet.[1]

As can be seen when analyzing the application examples on the OMG website, the ideas of the MDA are gaining ground. Possible applications in the M&S domain in general have been presented during the Fall 2002 Simulation Interoperability Workshop within the paper [7]. This paper raised a lot of discussion and feedback. Among others, the feedback led to the engagement in the three programs XMSF, NCES, and BOM all of which can be seen as potential application domains of the ideas of using conceptual meta models to assure interoperability of derived software implementations.

3 From HLA to XMSF

The title of this section should not imply that the Extensible M&S Framework (XMSF) has been developed to replace the High Level Architecture (HLA). The core architects of the XMSF had another motivation, namely the application of open standards and open sources to increase the efficiency and applicability of distributed simulation systems. XMSF doesn't replace but completes the HLA concept. In summary, XMSF can be described as an evolutionary step toward advanced distributed simulation using open standards –in particular standards related to the web – complementary to the HLA to reach the next level of this domain of distributed computing.

In the end of 2001, chief architects for M&S applications of the Modeling, Virtual Environments and Simulation (MOVES) Institute of the Naval Postgraduate School in Monterey, CA, the George Mason University in Fairfax, VA, and the SAIC in San Diego, CA, started to harmonize their efforts to apply commercially viable integration efforts to distributed M&S challenges. In late 2002, the Virginia Modeling, Analysis, and Simulation Center (VMASC) of the Old Dominion University in Suffolk, VA, joined the circle of the XMSF core architects to tighten the relations between the M&S and the C4I community using similar technical solutions for establishing their future system architecture frameworks. The most recent

[1] The most efficient translation from the PIM to a PSM is a niche still to be filled by software developers. Although first solutions are already entering the market, there is much room for improvement. The website of the OMG is a good source to start respective research on existing as well as needed solutions.

report with the latest findings [10] can be downloaded from the XMSF website at the MOVES Institute.

3.1 Background

The Department of Defense (DoD) is engaged in warfighting and institutional transformation for the new millennium. In parallel, DoD Modeling & Simulation (M&S) needs to identify and adopt transformational technologies providing direct tactical relevance to the Warfighter. XMSF is intended to contribute to the transformation of the armed forces by contributing to fulfill the requirements for software system support derived from future military operations.

In the eyes of XMSF core architects, the only software systems that composably scale to worldwide scope utilize Internet and web technologies. The XMSF Technical Challenges and Strategic Opportunities Report presents the consensus integration of extensive inputs by four-dozen experts. It is now evident that an extensible web-based framework offers immediate promise to scale up the capabilities of M&S systems to meet the needs of training, analysis, acquisition, and the operational Warfighter. By embracing commercial web technologies as a shared-communications platform and a ubiquitous-delivery framework, DoD M&S can fully leverage mainstream practices for enterprise-wide software development. The use of open web-based standards and technologies doesn't imply that XMSF is limited to the public Internet. To fulfill the requirements for military operations, security is an important issue that has been addressed and integrated since the first workshops.

The actual Working Definition for XMSF hence is:

"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.
Current work in Web Services appears to be an appropriate basis for organizing and composing the many necessary capabilities of Web/XML and Internet/networking needed for M&S applications."

Therefore, XMSF is defined as a composable set of standards, profiles and recommended practices for Web-based modeling and simulation. XML-based markup languages, Internet technologies, and Web Services will enable a new generation of distributed M&S applications to emerge, develop, and interoperate. The XMSF program kicked off in August 2002 with a Technical Challenges Workshop in Monterey California, followed by a Strategic Opportunities Symposium at George Mason University and technical interactions at the Simulation Interoperability Workshop, Orlando Florida, in September 2002. These meetings are documented in the XMSF Challenges for Web-Based Modeling and Simulation Report.

Web-based technologies applied within an extensible execution framework are enabling a new generation of modeling and simulation applications to emerge, develop, and interoperate in the commercial world. A bridge is needed between these emerging commercial technologies/standards and defense systems. Support for defense systems at all levels currently is a missing but nevertheless essential requirement for such application frameworks. An extensible XML-based framework can provide a bridge between forthcoming modeling and simulation requirements and open/commercial Web standards. A Web approach for technology, software tools, content production and broad use makes great sense technically, and furthermore provides best business cases from an enterprise-wide perspective.

In the light of the MDA described in the last section, XMSF can be interpreted as a web-based, and hence platform specific solution with the objective to identify the necessary basic functionality for distributed M&S applications. The framework established by the HLA is a tremendously valuable start set of requirements, but it is already clear that the operational view on the XMSF will not be limited to the already defined functions of the Runtime Infrastructure (RTI). Therefore, to talk about XMSF as the "webization" of the RTI would shoot too short, although this is an important aspect of the project and a necessary step.

In addition, as will be elaborated in the next section of this paper, the C4ISR community is evaluating similar approaches for their future systems as well. Thus tremendous potential to merge XMSF components and future C4ISR applications to enable embedded training as well as integrated decision support – like online alternative courses of action analyses – becomes feasible based on a harmonized web-based architectural approach.

3.2 First Results and XMSF Prototypes

It should be clear by now that XMSF is not an application, but a set of standards for technical solutions as well as building processes for distributed solutions establishing a technical framework and an engineering process for M&S applications utilizing

web services and technologies. Consequently, there are many potential domains interested in the efforts.

Four technical core areas have been defined that have to be dealt with in XMSF. Projects should be tied to one of these core areas, but they are not limited to them:

- Web-services and related standards, such as the Simple Object Access Protocol (SOAP) and the Extensible Mark-Up Language (XML);
- Internet-technologies and network protocols; technical networking issues;
- M&S applications, migration concepts for legacy systems (such as HLA-compliant federations);
- Integration of M&S components into operational systems, i.e., the use of M&S functionality to enhance operational effectiveness and efficiency.

The following bullet points can summarize the results of two workshops conducted in 2002; a significant level of agreement and the establishment of consensus on principles can characterize both of them:

- The application of actually available web services and technologies for networked M&S appeared to be feasible and useful to all participants (industry, government, military, and academia); in particular, open standards and open sources have been proven to be of value even to the military community.
- In order to benefit from broad technical insights and to harmonize interrelated goals and concern efficiently in time, a close working relationship across all four technical core areas of XMSF must be established, respectively continued. Liaisons to the various communities and organizations are essential, such as the World Wide Web Consortium (W3C), the Object Management Group (OMG), standardization bodies like the IEEE or and Simulation Interoperability Organization (SISO), and many more.
- To reach a broader community, the XMSF approach must be further refined from the actual high-level concept to definitive technical recommendations, practices, and applications. The core architects will do this by guiding participating projects into the XMSF direction. First exemplar applications are identified and initiated, and some tentative findings will follow in the next paragraphs of this section.
- Security must be a concern from the first moment on. It doesn't make any sense to deal with security as an add-on, like unfortunately done with HLA. Concepts for multi-level security, handling of unclassified and classified data in the same environment, and many issues more have to be dealt with from the beginning. In particular, in the light of the objective to integrate M&S functionality into operational systems, a common understanding and a common set of solutions must be agreed upon as early as possible. On the other side, ready to use solutions applicable to "for office use only" security problems shouldn't be excluded by these requirements.

These findings were presented and agreed on during the Strategic Opportunities Workshop (September 2002, Fairfax, VA) as well as by the presentation and discussion during the Fall Simulation Interoperability Workshop (September 2002, Orlando, FL) and during the I/ITSEC (December 2002, Orlando, FL).

As a first feasibility proof, some ideas already have been implemented using the XMSF ideas. SAIC used the XML/SOAP protocols to demonstrate the possibility to integrate HLA-compliant federates in a way that they may be used in DoD's Advanced Distributed Learning (ADL) program using the Shareable Content Object Reference Model (SCORM). Although the federate was very simple, the proof of concept was given by this presentation. Furthermore, first step to "webizise" were made. Both prototypes are described in more detail in parallel papers contributing to this conference.

The work of XMSF lies in the mainstream of actual developments. The U.S. Joint Forces Command (JFCOM), for example, continues to evaluate web-based tools and federates to increase the efficiency of large distributed computer-aided command post/field exercises supporting the training events of the Joint Warfighting Center (JWFC), as well as the experimentation events of the Joint Futures Laboratory (JFL). More connections are derived in subsection 4.3 of this paper.

It is furthermore worthwhile to mention that in the international arena similar efforts are going on. The Society for Modeling & Simulation International (SCS) has organized several workshops explicitly dealing with web-based simulation. The Swedish Defense Research Agency (FOI) is working on adapting HLA federates to the web in order to achieve

distributed, component-based, and platform independent simulations.

Although XMSF has never been intended to replace the HLA, the author of this paper is convinced that it has the potential to be a logical next step in the evolution of Advanced Distributed Simulation Frameworks. In this sense, it evolves from the HLA, making the necessary steps towards a broader community and a commercially supported environment. Hence, XMSF and MDA are complementing efforts.

4 From COE to NCES

Many papers presented during the recent SIW within the C4I forum dealt with the necessity to align architectures of M&S systems and C4I systems, both intended to support the Warfighter; a sort of a summary of the discussion is given in [11]. Until recently, the Common Operating Environment (COE) was the architecture of choice for C4I systems. However, in fall 2002, Assistant Secretary for Defense (ASD) for Command, Control, Communications, and Intelligence (C3I), Mr. Stenbit, declared COE legacy. As a result, the Defense Information Systems Agency (DISA) will maintain the COE through 4.7; and in the COE parallel transform into a new concept, called Net Centric Enterprise Services (NCES).[2] Officially, NCES starts as a program in FY04, but DISA will position programs in FY03 to align with the NCES vision.

This section gives a very rough overview of the kernel concepts. The content is based on the official NCES brief [9] as well as on discussions with the NCES architecture team. The main objective is to show the neighborhood of NCES and XMSF and the potential of early harmonization, based on the common conceptual concepts of MDA and the implementation ideas using XML and SOAP.

4.1 Network Centric Warfare and the Global Information Grid

NCES is the logical follow-on to the Common Operating Environment (COE) concept in the era of Network Centric Warfare (NCW). While COA was system centric, NCES will be network centric. As NCES is designed to enable NCW by supporting the Global Information Grid (GIG) idea, it is essential to know the basics of NCW and GIG first before dealing with NCES itself.

Network Centric Warfare is about networking, not about technical networks, i.e., NCW doesn't focus on technologies but on organizations and organizational behavior. The development of doctrines and guidance for operations using NCW is part of the institutional transformation for the new millennium. Concerning Alberts et al. [1], NCW is actually more a state of mind than a concrete reality. Anyhow, it is well accepted that respective NCW doctrines will support gaining and maintaining the necessary information superiority, i.e., full spectrum dominance by the ability to collect, process, and disseminate an uninterrupted flow of information while exploiting and/or denying an adversary's ability to do the same. The technical vehicle will be the GIG.

The **Global Information Grid** is defined in DODD 8100.1 [6]. The GIG will be 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 includes all owned and leased communications and computing systems and services, software (including applications), data, security services, and other associated services necessary to achieve Information Superiority.

In various other publications, the GIG concept is also referred to as "Infosphere" or information centric warfare. In the light of Homeland Security it should furthermore be mentioned explicitly, that beyond DoD agencies the GIG will support all National Security communities and the related Intel communities and must comprise interfaces to coalition, allied, and other non-DoD but operationally relevant communities.

NCW doctrine transforms organizations and changes working procedures in a way that shared information can be used in efficient joint and combined operations. The GIG is the technical vehicle. As shown in [9], a key point of the GIG definition is that it will provide services necessary to achieve Information Superiority. NCES will provide Enterprise Services that will enable the GIG to achieve these Information Superiority goals.

4.2 Development of NCES

Based on the idea that NCES will provide services enabling Information Superiority, the Warfighters – as edge users of the implied system – see NCES as a collection of networked capabilities organized as Core

[2] The importance of the definition of NCES can be judged by the fact, that the program manager of the COE is tasked to be responsible for the definition, leaving the daily COE business to his deputy.

Enterprise Services and Community-of-Interest Capabilities. These services provide the basic ability to search the enterprise for desired information and services, and then establish a connection to the producer for the desired service/data. Capabilities are organized around communities of interest such as C2, Intelligence, Logistics, and Personnel.

Beside these user driven requirements, additional three main drivers had to be taken into account. NCES must

- Provide publish/subscribe services that allow Warfighters to pull whatever information is required from any available network sources, at any time, with minimal latency, and from any workstation;
- Maximize the usage of COTS products, services, technologies, and standards. Develop DoD-unique products, services, and standards only when there is no suitable commercial alternative;
- Make maximum reuse of software, processes, and procedures to minimize costs and increase supportability, maintainability, agility, and scalability.

Within a first study, DISA evaluated four alternatives to reach the objectives and fulfill the requirements. All alternatives as well as the measures used for the evaluation are given in [9]. The recommended solution is, that NCES will be realized as a set of Core Enterprise Services (CES) plus Community of Interest (COI) capabilities, which means that DISA integrates, tests, & deploys CES products, provides CES publication and subscription interface definitions and pays license costs associated with CES. The following set of Core Enterprise Services (CES) is identified in the report:

- **Enterprise Systems Management** (ESM) provides end-to-end GIG performance monitoring, configuration management, and problem detection and resolution as well as enterprise information technology (IT) resource accounting and addressing (e.g., for users, systems, devices, etc.).
- **Messaging** is the ability to exchange information among users or applications on the enterprise infrastructure (e.g., Email, DMS, VMF, USMTF, TADIL, OTH, Message Oriented Middleware, AOL instant messenger, Wireless Services, Alert Services).
- **Discovery Services** comprise the processes for obtaining information content or services that exploit metadata descriptions of enterprise IT resources stored in Directories, Registries, and Catalogs. Search engines are a subset of these services.
- **Mediation Services** are services that help disseminating, translating, aggregating, fusing, or integrating data and associated metadata.
- **Collaboration Services** allows users to work together and jointly use selected capabilities on the network (i.e., chat, online meetings, work group software etc.).
- **User Assistants Services** are facilitators in form of automated "helper" capabilities that reduce effort required to perform manpower intensive tasks. They are not essential for the task to perform, but increase the efficiency.
- **Security Services** comprises capabilities that address vulnerabilities in networks, services, capabilities, or systems.
- **Storage Services** means physical and virtual places to host data on the network with varying degrees of persistence (e.g., archiving, COOP, content staging).
- **Application Services** is the overarching term for an infrastructure to host and organize distributed on-line processing capabilities.

A lot of the work on data alignment, data management, and integration of components like the Common Message Processor (CMP) into M&S solutions can be reused in the ongoing feasibility studies.

In addition to being responsible for these CES, DISA also will provide an initial set of Command, Control, and Intelligence COI capabilities. However, because the solution itself is extensible, additional COI-capabilities can be added in case of need. The business model for such extensions is, that DISA will support the kernel and the framework while Component Commanders, Services, and Agencies will pay license costs associated with additional COI-capabilities, which are added due to their requirements and under their own responsibility, including technical responsibility for providing and realizing the necessary interfaces.

4.3 The NCES Pilot

The recommendations briefed in [9] comprise an NCES Pilot. This prototype will comprise a set of COI capabilities for the Command and Control and the Intelligence communities. The initial set of COI

capabilities piloted will include tools and components for a first set of basic COI capabilities. It is planed that these COI capabilities will provide Joint Command and Control services that support Information Operations/ Information Warfare (IO/IW) Visualization tools, Moving Target Indicator (MTI) track management, and battle space targeting decision support tools for the accelerated integration and fielding of high-priority situational awareness services.

The NCES Pilot will not be a pure technical solution and the product of a technical feasibility study. It is much more intended to implement the initial COI capabilities to fulfill a Joint Force Commanders' Command, Control, and Intelligence needs for air-, land-, and sea-based operations. It will be integrated into the material solution for Standing Joint Force Headquarters (SJFHQ). This capability supports the Quadrennial Defense Report requirement for strengthening joint operations through SJFHQ and improved joint Command and Control.

Technically, the results of the pilot will determine the feasibility and scalability of expanding COI capabilities across the DoD. If the framework is flexible enough to cope with the requirements of SJFHQ – including the ad-hoc integration of additional components delivering necessary functionality to the Warfighter via the NCES framework – it is more than likely that the solution will become the backbone of future C4I systems. It is very likely that XML and SOAP will be applied in this context for the first iterations of the NCES Pilot.

Although this section is much to short to pay tribute to all necessary aspects of the NCES approach, the proximity to XMSF should be obvious. Consequently, in particular as both program are still in their infancy, harmonization efforts are necessary to avoid divergent solutions that will be limited to gateways and interfaces instead of converging early to a common approach usable for XMSF as well as NCES.

5 Composability and BOMs

Component based software development is a well-established paradigm in the commercial software development community. A very good overview of related methods and applicable procedures can be found in [2]. There are several papers of recent SIW dealing with the applications of this domain to benefit the ADS community. Two of the emerged ideas are described in detail in the next two subsections, and several additional ideas are mentioned in subsection 5.3.

5.1 Base Object Models

To increase simulation interoperability by developing a component reuse methodology, several international experts are working on the concept of Base Object Models. Most of these efforts have been conducted in preparation for or during several recent SIW supported by SISO. Actually, a Product Development Group is launched to standardize the results. The main ideas are best described in the overview paper of Paul Gustavson et al. [3, 14].[3]

A Base Object Model (BOM) is defined as a simulation component representing a single aspect of federation interplay that can be used as a building block of Federation Object Models (FOM) and Simulation Object Models (SOM). It is documented as a set of data elements as required by the High Level Architecture standard IEEE P1516.2-2000 (Object Model Template (OMT)) augmented with additional meta-data such as requirements, conceptual model data, development and use history, and other aspects facilitating the exploitation of its potential for reuse.

Whereas a FOM generally deals with the multiple object model set, a BOM focuses on a single, ideally atomic aspect. The general idea is that this will facilitate the composition of necessary interplays. To this end, the BOM must be a complete model of the simulation interplay activity, covering all aspects of systems' interoperability (including timing, internal effects, etc.)

Consequently, there are two types of BOMs, namely Trigger BOMs and Interaction BOMs. While Trigger BOMs deal with interplays that will change the internal representation of the systems' state (i.e. the updates of attributes), the interaction BOMs deal with effects in the simulated space that will influence one or more objects in this space.[4]

Derived from these ideas, two categories of BOMs are derived. Interface (IF) BOMs embrace the concept of

[3] It is assumed that the reader is familiar with the ideas of the High Level Architecture, in particular the principles of the Object Model Template (OMT), the Federation Object Model (FOM), and the Federation Development and Execution Process (FEDEP).

[4] Within HLA, such events are modelled as Interactions, i.e. events that are not bound to a simulated object but that occur as independent events, such as the impact of a missile, which itself is not modelled. This is necessary if the source of the event (the missile) is not part of the model (to reduce complexity), but the effect (the explosion) is needed anyhow.

patterns.[5] They are closely related to interactions. Encapsulated (ECAP) BOMs are directly representing components and their behavior. Steven Reichenthal [8] presented a very promising approach using XML to describe configurable behavior for BOMs during the last workshop.

The BOM methodology provides an appropriate building block mechanism useful for advanced distributed simulations as well as advanced distance learning and other distributed applications using M&S functionality. The main idea is to set up a set of BOMs describing the functionality to be integrated. As this includes meta data needed by search engines and web services, the approach is useful for XMSF as well as NCES. Both communities are in the focus of the BOM experts, and applications can be launched soon.

5.2 A Theory on Composability

Composability, as generally used, refers to the ability to compose, or select and assemble from a set of available components, a specific simulation application suited to the user's purpose. The library of components might include multiple network interfaces, different user interfaces, a range of classes of implemented entity models, a variety of implemented physical models at different levels of fidelity, and so on. The essential aspect of composability is that different simulation systems that can be composed at configuration time in a variety of ways, each suited to some distinct purpose, and all of the different possible compositions, will operate correctly.

The general idea of composability is that a system that can be composed at configuration time in a variety of ways, each suited to some distinct purpose, and all of the different possible compositions will operate correctly. Thus, composability is both a software engineering problem and a modeling problem. From the software engineering point of view, composability requires that the different software modules that embody the different composable units of the simulation system be constructed so that their parameter passing mechanisms, external data accesses, and timing assumptions are compatible under all of the different configurations that might be composed. However, composability adds difficulty from a modeling point of view as well. For example, when two models are composed so that the second model takes as input the output of the first model, it is necessary that the range of output of the first model fall into domain of valid input for the second model. Incompatibilities can produce useless results. These incompatibilities are difficult to resolve if the models represent the system at different levels. While the domain problem is already difficult to handle, the problem of harmonizing the interior processes – often only observable by state changes of visible or public attributes of the system – is even more demanding.

On behalf of the Office for Naval Research (ONR) and the Defense Modeling & Simulation Office (DMSO), VMASC is working on the development of a mathematically sound theory of composability of simulation systems. This theory will be applicable to M&S components. First results are presented in [12]. It is possible that it can be also applied to C4ISR components as well. In addition to the theoretical work, the practical application of the theory using the BOM results as a test bed is planned. The application of the resulting theory to C4ISR components used within XMSF or NCES is desirable.

5.3 Ongoing Common Ontology Efforts

Another aspect that has to be addressed in this context is the topic of talking a common language and understanding the data coming from other modules. Based on the recommendations formulated in recent studies – many of them presented and discussed in and some even initiated by Simulation Interoperability Workshops – a lot of work on finding a common ontology is going on. Outside the U.S., more and more programs are using the long year experience of the NATO data modeling groups having let to the formulation of the Land Command and Control Information Exchange Data Model (LC2IEDM), former also known as the Army/Allied Tactical Command and Control Information System (ATCCIS) Data Model. As this a very mature data model, in particular the new partners of NATO as well as the Partnership for Peace nations are interested in using these efforts to improve their development of NATO standard compliant systems. But also in the U.S. work is going on in this domain, some based on LC2IEDM, some based on major U.S. Command and Control Data Models; and data alignment studies of the past have proven that a lot of these efforts can be applied to U.S. as well as LC2IEDM solutions. The important fact is that all of these efforts are trying to use C4ISR hubs as kernels for M&S interoperability solutions. Although the project is still going on, the C4I-M&S Reference Object Model (C-ROM) will be used as an example how future projects can benefit from respective common ontology efforts. An overview of first results is given in [13].

[5] A pattern is an idea that has been useful in one practical context and will probably be useful in others.

Similar efforts are going on in Germany as well. These efforts even started before the once referenced above. Starting with a pre-feasibility study for NATO on a kernel application for an Allied Command Europe (ACE) integrated database, presented during the Joint Warrior Interoperability Demonstration (JWID) 1999, the Data Mediation Team of the *"Industrieanlagen-betriebsgesellschaft mbH"* (IABG) started to use the ATCCIS data model to harmonize various data models in order to derive standardized shared data elements (SDE). Since 1999, in addition to the Link 1, Link 11, and Link 16 messages, the Over-the-Horizon (OTH) Gold messages and the Allied Data Publications (ADatP) of the German Navy were mapped to the Shared Data Model to instantiate the Core Data Model of the German Navy. Furthermore, various models developed under the responsibility of the German Army Office (*"Heeresamt"*) with various resolution and aggregation levels were mapped to the model as well. Unfortunately, the results are not published and spread widely enough to show the applicability of respective recommendations.

Within the United Kingdom, the Ministry of Defense set up the UK MOD Central Data Management Authority (CDMA).[6] This is a tri-service /civil service organization responsible for ensuring data is defined consistently across the MOD to enable information systems interoperability. The main task of the CDMA is data management, i.e., conducting the process leading to agreed data definitions for information elements stored in a common Data Defense Repository (DDR). The CDMA results from a study on the "Way Forward for Defense Data Management" conducted on behalf of the UK MOD were presented and published in August 2000.

In addition to these national efforts, the NATO Data Administration Group (NDAG) has to be mentioned. Although their focus is the domain of NATO C4ISR systems, their activities may expand to cover M&S systems in the future as well.

6 Talking to the Warfighter: BML

The last topic is dealing with the problem of unambiguous communication between the system and the Warfighter to be supported. An entity based ontology like the a common set of Standard Data Element based on common shared data models like the LC2IEDM or the JCDB (see section 5.3) are only contributing to a possible solution. What is needed on the long term is an efficient way to share information between Warfighters, not only their machines.

Originally derived from the necessity to increase the interoperability requirements for C4I systems and simulation systems in the domain of training and education, i.e., the necessity to improve the automatic data exchange of the systems to decrease the number of personnel needed to support a computer assisted exercise (CAX), a common way to communicate between Warfighters, C4I systems, simulation systems, and robotic forces has been proposed in form of a common Battle Management Language (BML), mainly in the paper [4] and [5]. Within these papers, BML is defined 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."

In addition to this definition, the following four principles are characterizing the BML approach as well:

- BML must be unambiguous.
- BML must not constrain the full expression of the commander's intend (complete within the military operational domain).
- BML must use the existing C4ISR data representations when possible (avoiding double work, fostering reuse, built in interoperability).
- BML must allow all elements (i.e., systems and participants) to communicate information pertaining themselves (status, perceptions, plans), their mission, and their environment in order to create situational awareness and a shared, common operational picture (operational relevance).

Another aspect was very important for the definition phase of BML, namely the vocabulary and graphics defined by the doctrinal manuals, such as the Field Manual FM 1-02. Looking at C4I messages of today, such as ADatP-3, OTH Gold, or USMTF, one of the most used options for efficient information sharing is the use of free text, hopefully on the basis of doctrinal unambiguous vocabularies of the manuals. Unfortunately, the "natural" battle management language used in operational orders and messages of today, is everything but unambiguous. It is dependent of the sender, the receiver, the operational context, the service, and branch, and last but not least the individuals. While humans can handle such ambiguity,

[6] Very valuable information can be found on the website of the CDMA at http://www.cdma.mod.uk.

information systems are not capable to cope with such unstructured and context dependent information elements. Hence, the full range of automation as envisioned by the Joint Vision 2010 and 2020 cannot be supported.

The U.S. Army is actually supporting a program dealing with the feasibility of the BML approach. Only very recently, a first prototype has been presented. The kernel idea of the BML is to fuse tactical C4ISR data models with the content of doctrinal manuals (hence adding semantics in form of standardized glossaries and relations). An XML Repository captures these harmonized results of the process and can be used to check the consistency of messages, orders, courses of action, scenarios, and many context sensitive military information. Together with a respective easy to handle and easy to interpret graphical user interface, the requirement for an efficient communication with the Warfighter based on his preferred methods of communication becomes feasible.

In the light of the common infrastructure, the BML is the hottest candidate for the common interface from the systems to the Warfighters (as well as between the Warfighters). BML can check the consistency of a perceived situation being used to initialize a simulation for decision support as well as the recommended course of action derived from a set of simulation runs in the actual operational context.

To summarize it, it can be stated that the BML efforts – when elevated from the actual Army centric prototype to a joint program – is the common interfaces to all users of the common infrastructure.

7 Bringing it all together

Concerning the author, it is not only possible and desirable but essential to bring all these different programs together to increase the efficiency of the Warfighter supported by new information systems comprising elements of all necessary operational domains.

- NCES and XMSF will distribute the necessary information between various components of the distributed system. If NCES and XMSF will be two different approaches harmonized in the overlapping domains of interest or if one common approach will be chosen has to be evaluated in the near future.
- The components of the M&S domain will be supported by the results of the BOM efforts and the application of theory of composability. Information passed between the components will be structured due to the findings of the common ontology approaches.
- BML will be used as the common interface to C4I as well as M&S components automatically checking the doctrinal soundness and consistency of the information passed to and between the systems.
- PIMs can be used as the hub for common conceptual models because they document solutions in a common way [7]. In addition, PIMs can facilitate the integration of other systems using the standards embraced by the MDA, like the Test and Training Enabling Architecture (TENA).
- While the MDA will help to deal with the general concepts by defining PIMs of general solutions, XML/SOAP etc. will help to initiate efficient web-based solutions using commercially viable and supported standards.

In summary, we are standing on the threshold to a new paradigm useful to C4I system as well as M&S system developers.

8 Summary

In the historic context it is understandable that the M&S community developed a framework focusing on their original needs first. The High Level Architecture was a tremendous success. Within only a couple of years the HLA was brought from a prototypical idea to a software implementation and a standard family recognized, accepted, and applied worldwide. The level of maturity was proven in the event "Millennium Challenge 2002 (MC02)" in which live, virtual, and constructive simulations were coupled among each other as well as with real systems, command and control environments, and training ranges.

The same argument is applicable to the actual C4ISR architecture, the COE. It was necessary to reach the appropriate level of maturity on the system level first before ideas of system of systems and network centric approaches could be applied on the technical level efficiently. A new level of interoperability will be reached with the NCES effort, embracing new domains like (embedded) training, (online) decision support, and operational support by applied methods of military operations research.

However, with this reorientation of both communities towards the same set of open standards, a new level of

build-in interoperability becomes possible which goes far beyond the interface driven solutions of past stove-pipe system collaboration. First discussions already have been initiated, more events like common workshops, common exercises, common technical coordination meetings, and common procurement projects must follow. A lot of the projects and programs discussed in this paper are on the right track, but even on the right track you can be run over if you don't move or you move into the wrong direction. Therefore, early harmonization and awareness is essential and common decision must be made directing all influencing communities.

We are standing on the edge of a new era of integrated support by network centric information systems. It is the role of standardization bodies like SISO to path the common way by respective works, and we are doing this with ongoing study and product development groups like XMSF, BOMs, and many more.

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REMARK:

The DoD Net-Centric Data Strategy (May 9, 2003) replaces the term *Net Centric Enterprise Services (NCES)* used here with the new term ***Global Information Grid (GIG) Enterprise Services (GES)***. The content of this paper is not affected by this decision. *A. Tolk, Norfolk, May 20, 2003*