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1. Introduction

The Department of Defense (DoD) is engaged in warfighting and institutional transformation for the new millennium. In parallel, the DoD Modeling & Simulation (M&S) community is working to identify and adopt transformational technologies providing direct tactical relevance to warfighters. In 2002, the Defense Modeling and Simulation Office (DMSO) initiated the Extensible Modeling and Simulation Framework (XMSF) program to encourage application of Web technologies and open standards by military M&S planners, managers, developers, and users.

2. XMSF and XMSF Profiles

XMSF is defined as a composable set of standards, profiles and recommended practices for Web-based modeling and simulation [1]. The goal is to enable simulations to interact directly and scalably over a highly distributed network, achieved through compatibility between a web framework and networking technologies. The concept encourages (if not requires) use of standards and techniques that are enabling rapid advancement of the Internet and the World Wide Web while also creating extended opportunities for interoperability of applications with others. To do so, however, requires clear description of the XMSF "standards, profiles, and recommended practices" so that the M&S community can effectively and efficiently adopt and exploit those capabilities.

SISO established an XMSF Profiles Study Group in September 2003. The Study Group Terms of Reference document [2] states that the specification of XMSF will be in the form of a collection of profiles detailing *how to interoperate* with XMSF compliant systems. At its simplest, an XMSF Profile is an identification of Web technologies, data, and metadata standards employed in an application. Association of profiles with actual applications helps distinguish features of the applications that support greater levels of interoperability, providing both an appraisal of what an application can do now and an assessment of how it can be modified to achieve higher levels of interoperability in the future, as may be required.

3.1 Interoperability Profile

One of the fundamental defining characteristics of an application is the level of interoperability intended in the design of the application. To this end, Tolk describes a Levels of Conceptual Interoperability Model (LCIM) [3]:

- Level 0, **no connection** is established at all.
- Level 1, the **technical** level, physical connectivity is established allowing bits and bytes to be exchanged.
- Level 2, the **syntactic** level, enables data to be exchanged in standardized formats.
- Level 3, the **semantic** level, enables data with associated context (i.e., **information**) to be exchanged.
- Level 4, the **pragmatic/dynamic** level, enables information and its use and applicability (i.e., **knowledge**) to be exchanged.
- Level 5, the **conceptual** level, establishes a common view of the world through a system-of-systems wide conceptual model.

The LCIM provides a foundation for distinguishing XMSF applications and can be used to define one dimension of a profile "space." For example, we can build profiles on the basis of the levels of interoperability; e.g., for the XMSF Technical (Level 1) Profile, we identify the Web technologies, practices, and standards appropriate for connectivity; for the XMSF Syntactic (Level 2) Profile, we identify the technologies, practices, and standards appropriate for exchanging data in standardized formats.

3.2 Implementation and Security Profiles

As Web technologies mature and evolve, several characterizations from the Web community are helpful to our discovery of profiling approaches. These characterizations, presented more completely in [4], also help to provide a more explicit description of an application. In particular, consider the so-called Semantic Web Service Stack (Figure 1) and the Web Services Security Stack (Figure 2).

Semantic Web Services Stack

OWL, OWL-S, OWL-Rules	**Service Entities, Relations, Rules**
RDF/S	**Service Instances**
BPEL4WS (Business Process Execution Language for Web Services)	**Service Flow & Composition**
Trading Partner Agreement	**Service Agreement**
UDDI/WS Inspection	**Service Discovery (focused & unfocused)**
UDDI	**Service Publication**
WSDL	**Service Description**
WS Security	**Secure Messaging**
SOAP	**XML Messaging**
HTTP, FTP, SMTP, MQ, RMI over IIOP	**Transport**

Figure 1. The Semantic Web Services Stack combines knowledge representation with service representation for intelligent selection and interaction with Web services. From [5] and [6]

From the above, an initial profiling approach identifies: (1) an *Interoperability Profile*, taken as the level of interoperability according to the LCIM; (2) an *Implementation Profile* from identification of Web technologies from the Semantic Web Services Stack in Figure 1; and (3) a *Security Profile* from identification of security implementation standards from the Web Services Security Stack in Figure 2. This enables us to address, at least in an initial way, the first two parts of the XMSF Profile definition; namely (1) applicable Web technologies and protocol standards and (2) applicable data and metadata standards.

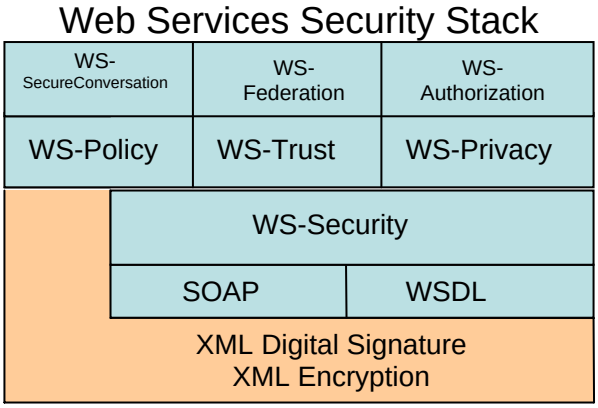

Figure 2. The Web Services Security Stack builds on the foundation of XML-Digital Signature and XML-Encryption to create levels of trusted, secure end-to-end service interactions. Adapted from [7], [8], and [9].

4. OPNAV N81 World-Class Modeling Exemplar Project

One of the principal uses of M&S in the military is to support combat analysis across the spectrum from acquisition to operations. To address new analytical modeling challenges, the Department of the Navy (OPNAV N81) recently initiated the World-Class Modeling (WCM) program consisting of a number of complementary studies and development efforts. Among these efforts, N81 tasked the Modeling, Virtual Environments and Simulation (MOVES) Institute of the Naval Postgraduate School (NPS), Monterey, California to develop and demonstrate a modeling framework using XMSF concepts to enable two disparate models, the Naval Simulation System (NSS) and the Army/Marine Corps COMBAT^{XXI}, to interoperate through a common discrete event simulation engine (Simkit).

Table 1 profiles the components after successful completion of ongoing and planned efforts to enable the systems to interact through the Simkit API implemented as a Web service.

Table 1. XMSF Profile Characterization of WCM components after current and near-term research efforts.

XMSF Profile	**Simkit**	**NSS**	**COMBAT^{XXI}**
Interoperability Profile	L4 Pragmatic /Dynamic	L2 Syntactic	L2 Syntactic
Implementation Profile - XML - SOAP - WSDL - UDDI	Modeling Messaging Service description Service registration and discovery	Data representation Messaging	Data representation Messaging
Security Profile	None	Username/password authentication to server	None

This represents a dramatic increase in LCIM level for Simkit by exposing Application Program Interface (API) calls through Web services and development of an XML Schema representation of event graph notation (see [10] and [11] for information on event graph notation). Creation of a common data interchange language provides rationale for placing NSS and COMBAT^{XXI} Interoperability Profiles at LCIM Level 2 (Syntactic). Future efforts can

examine existing standard data model formalizations, such as C2IEDM [12], to solidify the interoperability between these systems and across other systems employing that data model, moving toward LCIM Level 3 (Semantic). Unfortunately, current and immediately planned efforts do not address the Security Profile aspects of these components. This remains a significant area for further study and development in the XMSF community.

5. Flexible Asymmetric Simulation Technologies (FAST) Exemplar Project

The Military Operations Other Than War (MOOTW) Flexible Asymmetric Simulation Technologies (FAST) Toolbox (see [13] and [14]) is representative of the application of M&S to the operations end of the military analysis spectrum. The goal of the Toolbox is to provide an integrated set of combat simulations, databases, and computational tools to military analysts deploying to theater or supporting operations from a reach-back center, with primary focus on tools supporting OOTW mission planning and assessment. Components currently included in the toolbox are:

- Toolbox Controller
- Unit Order of Battle Data Access Tool (UOB DAT)
- Diplomatic and Military Operations in a Non-warfighting Domain (DIAMOND)
- Joint Conflict and Tactical Simulation (JCATS)
- Interim Static Stability Model (ISSM)
- Canadian Forces Landmine Database (CFLD)
- XML Management Tool (XMT)

Table 2 provides a characterization of the toolbox components in terms of the XMSF Profile approach described earlier. Development of the toolbox has included creation of a common data language in XML – the FAST Data Interchange Format (DIF) – being used for data interchange across the models and tools.

Table 2. XMSF Profile Characterization of FAST OOTW Toolbox components.

XMSF Profile	**Interoperability Profile**	**Implementation Profile**	**Security Profile**
Toolbox Controller	L0 No connection	None	None
UOB	L1 Technical	Client/server software product	Username/ password authentication to server
DIAMOND	L2 Syntactic	XML data representation	None
JCATS	L2 Syntactic	XML data representation	None
ISSM	L0 No connection	None	None
CFLD	L0 No connection	HTTP/HTML	None
XMT	L2 Syntactic	XML data transformations	None

The data interchange is implemented as a static data transfer prior to execution of the models. The XMT tool enables a Toolbox user to identify what files to transform from one format to another by invoking an XSLT file on the source data file. For example, UOB exports force structure data in XML format that can be transformed into a DIAMOND or JCATS XML representation to help initialize a scenario. Analysts can use the shared data representation for any number of different purposes with different software tools. Currently, the UOB tool is a client/server product. It offers a clear opportunity for implementation as a Web service to expose the UOB server functionality, thereby allowing software (and software agents) to access the force structure database services without the necessity of downloading and executing the separate client application. The ISSM product is a spreadsheet application that can potentially use data computed from execution of the other models as a way of

updating information in the spreadsheet. The CFLD tool is a hypertext application providing access to information about landmines around the world. As such, it is at the lowest level of the Implementation Profile, but offers opportunity for enhancement as a Web service in the future. As in the WCM project work described previously, implementation of Security Profile levels remains a significant challenge for future work.

Ongoing efforts involve strengthening the common XML representation of data for interchange across the models and between C4I systems and the models. Research is in progress to assess standard data models, such as the C2IEDM, for applicability as a common data exchange format across the models and between the Toolbox and C4I systems.

6. Challenges and Opportunities

This article has introduced XMSF and efforts to define XMSF profiles, with examples applied to existing analytical combat models. This work has only begun to scratch the surface in defining practical techniques for specifying XMSF profiles for existing and future applications. The SISO XMSF Profiles Study Group will evaluate the ideas expressed here as well as many others emerging from the M&S community before drafting its findings to SISO for community consideration. Other developers are encouraged to join this process through Study Group participation and through examination of particular exemplars as done here. Only through broad community involvement can we bring together policies, practices, standards, and procedures that will benefit DoD M&S development as we continue this exciting Information Technology (r)evolution exploiting Web-based technologies.

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Author Biography

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