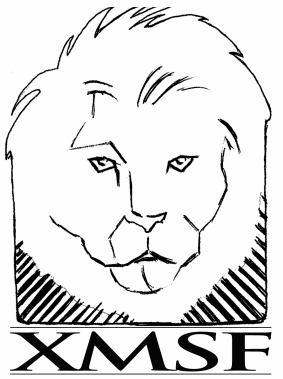
Extensible Modeling and Simulation Framework (XMSF) Challenges for Web-Based Modeling and Simulation

TECHNICAL CHALLENGES WORKSHOP – INTERIM REPORT

4 SEPTEMBER 2002



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EXTENSIBLE MODELING AND SIMULATION FRAMEWORK (XMSF)
TECHNICAL CHALLENGES WORKSHOP REPORT
EXECUTIVE SUMMARY

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 warfighters. The only software systems that composably scale to worldwide scope utilize the World Wide Web. Therefore, it is evident that an extensible Web-based framework offers great 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.

To meet the DoD M&S transformation challenge, government, academic, and industry experts under the leadership of representatives from the Naval Postgraduate School, George Mason University, and SAIC are defining an Extensible Modeling and Simulation Framework (XMSF) to exploit Web-based technologies. This white paper describes the basis and initial requirements for such transformational interoperability through development of the Extensible Modeling and Simulation Framework (XMSF). The precepts of XMSF are:

- Web-based technologies applied within an extensible framework will enable a new generation of modeling & simulation (M&S) applications to emerge, develop and interoperate.
- Support for operational tactical systems is a missing but essential requirement for such M&S applications frameworks.
- An extensible framework of XML-based languages can provide a bridge between forthcoming M&S requirements and open/commercial Web standards, while continuing to support existing M&S technologies.
- Compatible and complementary technical approaches are now possible for model definition, simulation execution, network-based education and training, network scalability, and 2D/3D graphics presentations.
- Web approaches for technology, software tools, content production and broad use provides best business cases from an enterprise-wide (i.e. world wide) perspective.

This version of the White Paper includes key findings from a Technical Challenges Workshop conducted at the Naval Postgraduate School, Monterey California on 19-20 August 2002. Participants in this workshop presented point papers and discussed issues in three focus areas:

- Web Technologies and the Extensible Markup Language (XML)
- Internet/networking
- Modeling and simulation (M&S)

Each group of experts worked to reach consensus on areas of agreement, identify areas of controversy, and highlight any critical actions needed to move these concepts forward.

In plenary session, attendees at the XMSF Technical Challenges Workshop concluded:

- There must continue to be a close working relationship across the three component areas (Web Technologies / XML, Networking, and M&S) to benefit from broad technical insights and interrelated goals and concerns.
- The XMSF concept must continue to be refined from a high-level concept to definitive technical recommendations, practices, and applications.
- A set of exemplar applications need to be identified and initiated that can collectively and clearly demonstrate the application potential of XMSF concepts. A number of existing and emerging programs were discussed as possible contexts for the exemplars.
- Web Services appear to be a promising area for focusing future work.
- Security concerns are cross-cutting for all areas and must be addressed throughout any design process.

Major milestones in the continuing effort to establish XMSF concepts include:

- A Strategic Opportunities Symposium at George Mason University on 6 September 2002, presenting technical workshop issues and results. By engaging senior leadership from DoD in a dialog with technical experts, we hope to set the stage for further exploration of these concepts. Follow-on work is needed to establish the business case for application of Web technologies to military M&S.
- A series of prototype demonstrations at the Interservice/Industry Training, Simulation, and Education Conference (IITSEC) in Orlando Florida from 3-6 December 2002 will expose a series of XMSF-related applications to the M&S community at large.

This edition of the XMSF white paper serves as a report of XMSF Technical Challenges Workshop, provided as part of presentations at the September 2002 XMSF Strategic Opportunities Symposium. Attendee reactions and additional presentations from the Symposium will then be incorporated to produce the final version of this report.

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1.1 Purpose

As the Department of Defense (DoD) is engaged in both warfighting and institutional transformation for the new millennium, DoD Modeling & Simulation (M&S) similarly needs to identify and adopt transformational technologies which provide direct tactical relevance to warfighters. Today the only software systems that can composably scale to worldwide scope utilize World Wide Web technologies. It appears that an extensible Web-based framework shows great promise to scale up the capabilities of M&S systems to meet the needs of training, analysis, system acquisition and tactical preview needed by operational warfighters.

Defense M&S includes a large and diverse set of applications which individually provide advanced computing capabilities. Embracing commercial web technologies as a shared-communications platform and a ubiquitous-delivery framework will enable current M&S to fully leverage mainstream practices for large-scale software development. Similarly, providing Web interoperability for general M&S applications can provide broad new classes of capability to commercial, educational and scientific applications.

1.2 Scope

Web-based technologies have the capability to support interoperability of the spectrum of DoD models and simulations including constructive, virtual, and live as well as integrating legacy simulation frameworks and the increasingly important distance-learning technologies. This report describes the basis and initial requirements for such transformational interoperability, through development of the Extensible Modeling and Simulation Framework (XMSF).

The precepts of XMSF are:

- Web-based technologies applied within an extensible framework will enable a new generation of modeling & simulation (M&S) applications to emerge, develop and interoperate.
- Support for operational tactical systems is a missing but essential requirement for defense M&S application frameworks.
- An extensible framework of XML-based languages can provide a bridge between diverse M&S requirements and open/commercial Web standards, while continuing to support existing M&S technologies.
- Compatible and complementary technical approaches are now possible for model definition, simulation execution, network-based education and training, network scalability. and distributed animation of 2D/3D graphics presentations.
- Web approaches for technology, software tools, content production and broad usage provide best business cases from an enterprise-wide (i.e. worldwide) perspective.

1.3 Current Shortcomings

Unfortunately a number of severe gating problems are evident in the current generation of defense-related modeling and simulation systems. Hundreds of active legacy applications have limited commonality, mixed levels of support and stove-piped interoperability. Despite the best efforts of numerous programs, the difficulties inherent in current M&S strategies have thwarted the deployment of tactically useful systems into the hands of warfighters. Interoperable software, networking and message semantics are needed at all levels of activity.

This need for scalable interoperability is growing faster than ever before, as nearly all operations become coordinated joint/coalition efforts, and diverse new agencies for homeland defense and peacekeeping operations become critical partners.

Current common shortcomings include:

- Few current applications successfully leverage commercial software imperatives. Interoperable reuse is essential for feasibility, life-cycle supportability, fundability and product flexibility.
- Modeling and simulation is not a significant day-to-day asset for U.S. operating forces.
- A spectrum of operational goals needs to be met: direct warfighting, homeland defense and coalition peacekeeping operations. Tactical needs are broad, immediate and interrelated, thus approaches must be scalable and take a global scope.
- Technical limitations are evident in current software. New capabilities are needed that still work correctly in small scale but can also grow/aggregate into much larger scales.
- Current DoD software strategies do not leverage commercial-sector investments in interoperable Web technology, so planned improvements perpetuate this disconnected state of affairs.
- Distance-learning technologies (e.g. audio/video/whiteboard/documents/ADL/SCORM/etc.) are not compatibly augmenting or utilizing simulation technology.

Clearly many strong motivations for significant progress exist.

1.4 Status of this Report

Most material in this report was presented as an advance White Paper for the XMSF Technical Challenges Workshop held 19–20 August 2002, in conjunction with the NPS MOVES Open House. The initial version provided a detailed backdrop for participants to produce point papers detailing their conclusions, concerns and recommendations over an impressively wide range of experience.

The report has been updated to include Workshop results. Specifically each topic-area section now includes “triage” findings on each complex subject: areas of consensus agreement, areas of controversy, and recommended issues for future work. The Strategic Considerations section has been expanded to address strategic considerations identified by all the subgroups and agreed to in plenary sessions.

This report will now be used as the basis for reporting workshop results at the XMSF Strategic Opportunities Symposium, to be held 6 September 2002 at George Mason University (GMU) in Fairfax Virginia. The Symposium agenda is included as an appendix in this document. Symposium presentations and attendee comments will then be integrated to produce a final version of this Report.

2 XMSF Postulates, Preconditions for Success, Challenges and Definition

2.1 Postulates

XMSF has several high-level requirements derived from years of experience with M&S frameworks, and the challenges of their effective deployment across diverse networks and systems. XMSF must enable simulations to interact directly and scalably over a highly distributed network, achieved through compatibility between a Web framework and networking technologies. XMSF must be equally usable by human and software agents. Clearly XMSF must support composable, reusable model components. XMSF use cannot be constrained by proprietary technology or legally encumbering patents which might discourage the free, open, *ad hoc* development of interconnected tactical models and simulations.

For these reasons, the Extensible Markup Language (XML) is the technology of choice for the syntax and representation of root data structures. Similarly, Semantic Web efforts regarding Resource Description Framework (RDF) and ontology tagsets provide corresponding support for semantics. XML also enables equivalent model representations to be described, validated (and even autogenerated) in a variety of human and programming languages. Thus XML, along with the large family of XML languages for Web use, provides a rich and already well-developed set of technologies suitable as an available basis to begin achieving XMSF goals.

2.2 Preconditions for Success

While working to clearly identify, elaborate and correlate the many required technologies involved in modeling and simulation using Web-based technologies, the investigators found that three technical areas can effectively group together a wide variety of related technologies. These three key areas of endeavor are:

- Web and XML
- Internet and Networking
- Modeling and Simulation (M&S)

Of course tremendous overlaps occur for each area, but workshop participants agreed that this is an effective portioning of both technical topics and human talent. These three topic areas provide the primary reporting structure for technical material in this report.

Looking ahead, workshop representatives mostly agreed that three such groups will be an effective way to divide diverse challenges across groups of committed participants. This will likely enable focused and effective application of expert knowledge to solve component problems. However, such groups will still have to work closely together on strategy and cross-cutting issues to ensure global success.

Participants and investigators felt strongly that representative leaders and workers from industry, academia and government must work together as coordinated teams for each of the three major technical areas: Web/XML, Internet/Networking, and Modeling & Simulation. The biggest challenges likely require effective organization more than new technology. These three groups and the forthcoming XMSF community will need:

- Effective human interfaces among all three areas
- Avoid "throw it over the wall" from one group to another, rather work on joint strategies
- Solutions that are end-to-end, likely driven by cornerstone exemplar demonstrations

2.3 Key Challenges for XMSF

Many issues and goals have been identified. Top-level XMSF challenges include:

a. Utilize Web-based technologies for more powerful and cost-effective government-wide networking, serving, client-side rendering and user interaction.

b. Provide open, affordable, extensible modeling and simulation capabilities for tactical scenarios of direct use to participants engaged in conflict and peace operations.

c. Employ mainstream practices of enterprise-wide software development.

d. Improve ease of use for developers and users, fueling rapid growth of interoperable simulations.

e. Provide support for all types and domains of M&S: constructive human-in-the-loop, live, virtual, and analytical.

f. Models of interest reflect reality. Simulations and tactical engagements are each the behavior of models over time. Models and simulations need to match tactical requirements for rehearsal, reality and replay to meet operational needs.

Each key challenge will help guide emerging technical and programmatic strategies for XMSF.

2.4 XMSF Definition

The Extensible Modeling and Simulation Framework (XMSF) is defined as a set of Web-based technologies, 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.

Details for each workshop area – Web/XML, Internet/networking and M&S – are presented in the next three sections.

3 Web and XML Considerations

3.1 Overview

The ambitious nature of these many requirements and challenges requires aggressive reliance on standardized, openly available, legally unencumbered, commercially available technologies. Sufficient support for DoD M&S needs will require active engagement with standards development groups such as IEEE, IETF, ISO, OASIS, W3C and Web3D.

The diversity of defense, government, public, scientific and international needs for M&S means that cross-platform capabilities are a given. No single operating system or monolithic hardware architecture can possibly be forced upon so many existing and legacy systems. Such cross-platform data interoperability is critically important when considering the plethora of customized tactical systems connecting to worldwide tactical networks.

A particular strength of a XMSF approach based on Web technologies is that the most difficult interoperability challenges are already resolved (or else are being solved) by the development of tightly interdependent and highly complementary Web standards. The World Wide Web Consortium (W3C) and the Internet Engineering Task Force (IETF) are the lead drivers in these efforts. Thus it appears that this Web-technology strategy for XMSF can provide the most technically robust solutions, with the most reliable future-growth processes and best-case business practices. This is clearly evident when seen from an enterprise-wide (i.e. DoD-wide and coalition-wide) perspective.

To meet these requirements, XMSF will employ object-oriented programs and validatable structured data in a language-independent and object-system-independent manner. Design patterns will unambiguously define language bindings by mapping representations and component models from root XML schemas to multiple programming languages and application programming interface (API) bindings, including the Interface Description Language (IDL). Software component functionality and interactions will be further documented using the Unified Modeling Language (UML).

XMSF will have a modular framework with kernel plug-ins to support extensions and modifications to framework layers as low as the network layer. Design patterns for modular extensibility are needed at all levels and across system lifecycles, in order to support future growth and backwards compatibility as well as multiple-system interoperability.

To support real-world military secure communications systems XMSF must be compatible with currently fielded wireless, radio and wire military technologies to include SINGARS, UHF/VHF radios and Digital Subscriber Network (DSN). Diverse network channels and transport mechanisms will thus drive some application-level design decisions when applying various Web technologies.

3.2 Functional Requirements

Many of the functional requirements described below overlap, complement or build on one another. The crux of these requirements is that they are considered the key properties that a framework should have in order for it to be platform-independent, flexible, extensible, secure, distributed and dynamically reconfigurable.

a. Data Representations

Data is defined as any information of interest that is to be exchanged between two systems. XMSF will need to be able to represent exchangeable data in a language-independent manner. For troubleshooting and confidence, data must be readable both by humans and by a complete variety of

computer languages, e.g. Ada, C++, Java, Perl, Prolog, etc. Such data interchange is typically addressed by using structured text-based standards.

The logical implication of data being machine readable is that the data representation will need to be structured and self-defining. For future capabilities, most data representations need to allow for facile extension of the represented data.

Given the verbose nature of most text-based representations, data representations will also need to support compression schemes, applicable both to documents and streams equally. Default (i.e. run-time replaceable) compression algorithms must be offered, probably as a code component. Of particular note is that compression is closely interrelated to encryption, authentication, composition, key management, and completeness of delivery.

The current state of standards evolution already accounts well for most of these requirements. XML is the preferred structured-data standard for platform-independent representation that, when carefully applied, can meet most of these requirements.

b. Security Considerations

Security is defined to encompass identification, authentication, authorization and encryption. Access restrictions (i.e. permissions) can be the responsibility of the application, or the application environment.

It is desirable for a framework such as the XMSF to offer utilities (probably through a code component) that included one or more default encryption algorithms. This can allow applications to interact in a commonly acceptable way if they did not need a specific encryption implementation.

The framework should also provide a standard for signing messages and documents. Note that the signature itself does not provide authentication, but rather associates an identity with data.

Following on from identification, the framework should define a standard for authentication. As for encryption, it would be preferable that a pre-existing mechanism (outside applications) be made available to provide authentication services. This could take the form of an authentication server.

A novel requirement that follows from the nature of dynamic reconfiguration is that there needs to be a mechanism for defining groups and group membership. Additionally, the membership of those groups needs to be dynamic. A further consideration is that the groups should be definable in such a way as to apply to either a single service, or span multiple services (as in the case of a distributed multi-application simulation).

The increasing focus on security means that XMSF must be underpinned by the strongest and most current web security technologies. These are seen as additional capabilities which can augment military-grade security for unclassified and administrative networked systems. Furthermore, security is cross-cutting issue that must work sufficiently and simultaneously across all three areas (Web/XML, Internet/network and M&S) or new vulnerabilities will result.

c. Service Descriptions

A (web) service is defined as a logically coherent set of functions offered for invocation by a code component. A code component may expose more than one service.

As for data, the functionality offered by a code component will need to be represented in a computer language independent manner. This means that irrespective of the programming language (e.g. C++, Java, Fortran) used to develop the code component, and the platform on which it is

deployed, common-denominator representations of the exposed functions and the parameters of those functions will need to be consistently represented.

The implication of the preceding paragraph is that the service description needs to be binding independent. The corollary of that implication is that the service description will need to define a binding specification.

If the underlying mechanism employed is the same as for data representation (e.g., XML), then many of the issues of platform independence will have been addressed already.

d. Graphical User Interface (GUI) Descriptions

A Graphical User Interface (GUI) is defined as a man-machine interface of a graphical (as opposed to a textual) nature. Typically these are things like windows, toolbars and dialogs, but 3D virtual environments are also encompassed.

In a similar manner to Service Descriptions, a GUI description will need to represent user interface elements in a computer-independent (language and platform) manner. Further, the GUI description will need to not only define the appearance of graphical elements, but also their behavior. In this case behavior is the component's response to user stimulus.

The aim of a GUI description is to define a consistent look and feel across operating systems.

e. State Transition Description

State transition is defined as the progression of a system through its logical states. In effect this will translate to the allowable sequences of messages.

Since we are now dealing with the logical domain rather than the physical domain, there are fewer issues of representation. If we consider the workflow representation to simply be data we wish to exchange between systems, then it suffices to use a computer-independent data representation to address platform independence issues. All that then remains is for syntax to be developed for the workflow representation.

One key requirement is that even though a set of logical state transitions may be published, these should not reveal the internal logic (or internal state transitions) of the code component. What to publish should be at the discretion of the developing entity, and will very likely be a subset of the actual state transitions of the system.

f. Transactions

A transaction is defined as a logical set of changes that must be made as a single activity, e.g. a funds transfer from one account to another must debit the source account and credit the destination account as a single atomic action.

A common paradigm in use for some time is a 2-phase commit. Unfortunately, this approach can suffer from latency and heavy resource utilization when applied to the Internet.

An alternative approach is that of undo operations. The idea is that certain (simpler) actions can be reversed by another action, e.g. the request to be added to a mailing list can be undone by a request to be removed from the mailing list.

A requirement for the M&S framework is that a transaction pattern (that may encompass more than one application paradigm) needs to be defined and supported. Supported approaches need to allow for both simple request-response situations that do not require the overhead of a 2-phase commit, and also more complex situations that do require a 2-phase commit procedure.

g. Ontologies

An ontology is defined as a basis of meaning. This is a fundamentally difficult area which has seen much research progress in recent few years as part of the W3C's Semantic Web.

The first requirement in the area of ontologies is to allow definition and approval of complementary taxonomies that can be applied across multiple XMSF application domains. If nothing else this will allow for the consistent classification of data and services via precise vocabularies. XML Schema and XML Namespaces are the primary mechanisms for defining and referring to such vocabularies.

A subsequent requirement is to establish consensual common meaning. It does not suffice for there to be agreed meaning within a group, but to be truly useful, there needs to be a mechanism for defining the equivalence of terms between groups. This will allow for both extensibility and for interoperability. XML Schema annotations and XML Internationalization (i18n) / XML Localization (l18n) provide the mechanisms for recording and translating accepted meanings in a reviewable fashion.

An open issue is the establishment of schema and ontology repositories for common service representations. The following semantic representations are expected to be of particular interest.

- Resource Description Framework (RDF)
- DARPA agent modeling language (DAML) and Ontology Integration Language (OIL)
- NATO-developed Generic Hub information-exchange data model for tactical operations

It will be particularly interesting to consider the implications of ontologies like Generic Hub that help to establish commonalities between services and coalition partners. Development of operations orders (which contain tactical versions of who, what, when, where and how) is an identified application area deserving dedicated further work.

h. Repositories

A repository is defined as a logically related collection of information. XMSF applications will need numerous repositories across different levels of abstraction, presumably exposed via Web services. Work is needed to identify potential libraries of components which can be made available to support reusability, encourage interoperability, and reduce user learning curves. Example application-level repositories are likely to include:

- 3D models
- Portable computational models
- Software-agent templates with requested capabilities
- Stream-specific adaptors/components
- Exercise simulation management
- Operational recording
- Order of battle (inventories and functional characteristics of friendly and opposing forces)

It appears likely that each level of a "Web services stack" will have one or more associated repositories. For the purposes of this whitepaper, the requirement for repositories will be assumed to be an implicit requirement of each of the preceding areas discussed.

A shared requirement necessary for the effective use of repositories is that common interfaces are defined that allows consistent access to contained information by search engines and other interested applications. UDDI fulfills this need for Web services.

i. Search Engines

A search engine is defined as a code component that extracts information matching a specified set of criteria from one or more repositories.

One of the great challenges of the Internet has been locating information. In order for the XMSF to not fall prey to the same shortcomings it will be necessary for the framework to provide a capable search engine.

The areas discussed in preceding sections are a good starting point for search topics in the various repositories. Hence common search criteria will likely include topics such as Provider, Type of Service, Name, Quality of Service (QoS) or other constraints, Security, etc. It is likely that typical e-commerce web-service descriptions will need to be augmented to fully describe needed functionality pertaining to distributed M&S applications.

j. Composability

Run-time composition of new components and existing components is a long-running area of research that finally appears to be ready for widespread practical application. Both backwards compatibility (for legacy applications) and forwards compatibility (with as-yet unknown applications) can be enabled through composable software. A Defense Modeling and Simulation Office (DMSO) workshop on Software Components held July 2002 explored these topics in some detail, with further work to follow. [reference needed]

It is interesting to consider that the platform-independent techniques of Web Services can significantly reduce the amount of software components which need to be directly composable. Exposing object-method functionality via XML-based remote procedure calls (e.g. XML-RPC, SOAP) can provide lightweight access to heavyweight capabilities.

3.3 Web Services Overview

Web Services has been an active area of work for several years. While there is no fixed definition or locked-down architecture, certain capabilities appear to be common. A summary table follows.

Table 1. Multiple layers of functionality are composed to provide accessible Web Services. Adapted from [Cerami 2002].

Repositories Locations for providing approved (or ad hoc) Web services.	**Administrative** Exemplar: DoD XML Registry http://diides.ncr.disa.mil/xmlreg/user/namespace_list.cfm
Services Discovery Centralized access via repositories is made accessible to Web-based applications via service publish and search capabilities	**UDDI, LDAP** Universal Description, Discovery and Integration, Lightweight Directory Access Protocol OASIS: http://www.uddi.org IETF: http://www.ietf.org/rfc/rfc2251.txt
Services Description Describing the detailed methods and parameter signatures of each service	**WSDL** Web Services Description Language W3C: http://www.w3.org/2002/ws
XML Messaging Express messages in common XML formats for simple encoding/decoding	**XML-RPC, SOAP, XMLP** Remote Procedure Calls, Simple Object Access Protocol http://www.xmlrpc.org , http://www.w3.org/2000/xp/Group
Service Transport Transporting messages between applications. Typically requires reliable (i.e. guaranteed) delivery	**HTTP, SMTP, FTP, BEEP** Hypertext Transfer Protocol, Simple Mail Transfer Protocol, File Transfer Protocol, Blocks Extensible Exchange Protocol

Rob Glidden's presentation on the Seven Successful Habits of Web Services sparked a particularly interesting discussion. Key points follow.

- **Enablement of developer community**. Supporting developers drives overall success.
- **Services are not equal to applications**. Rethinking and restructuring the architecture.
- **Incrementalism: results are greater than effort**. True and measurable benefits occur.
- **Federation: accept political uncertainties and interests**. Many sizes fit all, not one size.
- **Assembly → combining**. Assembling applications becomes combining web services.
- **Virtualization → distillation.** Exposing functionality requires distilling key capabilities.
- **System stability: equilibrium or dynamic change**. Adaptable systems are most robust.

3.4 Web Languages

The following table of XML languages and protocols, with corresponding definitions and resources, can provide an initial set of functionality for the Extensible Modeling and Simulation Framework (XMSF). Language descriptions are grouped by the following categories:

- Core XML Functionality
- Presentation Languages
- Web Services
- Transport Protocols

Table 2. Web language descriptions and key references, grouped by categories.

Categories and Languages	Descriptions
Core XML Functionality	Fundamental languages for XML documents, linking, etc.
XML Extensible Markup Language	Extensible Markup Language (XML) is the universal format for structured documents and data on the Web. http://www.w3.org/XML/1999/XML-in-10-points http://www.w3.org/TR/2000/REC-xml-20001006
XML Namespaces	XML Namespaces qualify element (i.e. tag) and attribute names used in XML documents through URI reference associations. http://www.w3.org/TR/1999/REC-xml-names-19990114
XML Schema	XML Schemas express shared vocabularies and can define the structure, content and semantics of XML documents. http://www.w3.org/XML/Schema
XLink	XLink allows elements to be inserted into XML documents in order to create and describe links between resources. http://www.w3.org/TR/2001/REC-xlink-20010627
XPointer	XPointer defines a fragment identifier for any URI-reference that locates an XML resource. http://www.w3.org/TR/xptr
URL, URI, URN	Uniform Resource Locations, Identifiers, Names http://www.ietf.org/rfc/rfc2396.txt section 1.2 http://www.w3.org/Addressing
Web Architecture	Architectural Principles of the World Wide Web (working draft) http://www.w3.org/TR/2002/WD-webarch-20020830
DOM Document Object Model	DOM is a platform- and language-neutral interface that allows programs and scripts to dynamically access and update the content, structure and style of documents. http://www.w3.org/DOM

RDF Resource Description Framework	The RDF specifications provide a lightweight ontology system to support the exchange of knowledge on the Web. http://www.w3.org/RDF
XSLT XSL for Transformations	A language for transforming XML documents into other XML documents. http://www.w3.org/TR/xslt
XPath XML Path Language	XPath is an expression language used by XSLT and XLink to access or refer to parts of an XML document. http://www.w3.org/TR/xpath
XML Query	Provide flexible query facilities to extract data from real and virtual Web documents, providing needed interaction between the Web and databases. http://www.w3.org/XML/Query
Presentation Languages	Hypermedia, multimedia, 2D, 3D, etc.
XHTML Extensible Hypertext Markup Language	HTML is the lingua franca for publishing hypertext on the World Wide Web. http://www.w3.org/MarkUp
MathML Mathematics Markup Language	MathML describes mathematics as a basis for machine-to-machine communication, providing a foundation for use of mathematical expressions in Web pages. http://www.w3.org/Math
PNG Portable Networked Graphics	PNG is an extensible file format for the lossless, portable, well-compressed storage of raster images. PNG provides a patent-free replacement for GIF. http://www.w3.org/Graphics/PNG
SMIL (pronounced “smile”) Synchronized Multimedia Integration Language	SMIL enables simple authoring of interactive audiovisual presentations, typically used for "rich media"/multimedia presentations which integrate streaming audio and video with images, text or any other media type. http://www.w3.org/AudioVideo
SVG Scalable Vector Graphics	SVG describes two-dimensional (2D) graphics in XML. Includes three types of graphic objects: vector graphic shapes (e.g. paths consisting of straight lines and curves), images, and text. http://www.w3.org/Graphics/SVG
X3D Extensible 3D Graphics	Third-generation ISO standard for three-dimensional (3D) Web graphics. Includes Virtual Reality Modeling Language (VRML) and XML encodings, plus Scene Authoring Interface (SAI). http://www.web3D.org/x3d.html

Web Services	Provide Web capabilities for easy access by humans and systems.
Web Services Architecture Requirements	Describes a set of requirements for a standard reference architecture for Web services. Defines Web Services as "a software application identified by a URI, whose interfaces and bindings are capable of being defined, described, and discovered as XML artifacts. A Web service supports direct interactions with other software agents using XML based messages exchanged via internet-based protocols." http://www.w3.org/TR/wsa-reqs
Web Services Architecture Usage Scenarios	A collection of usage scenarios and use cases which illustrate the use of Web services, used to generate requirements for the Web services architecture, and also to evaluate existing technologies. http://www.w3.org/TR/2002/WD-ws-arch-scenarios-20020730
WSDL Web Services Description Language	An XML language for describing Web services, based on an abstract model of what the service offers. http://www.w3.org/TR/wsdl12 http://www.w3.org/TR/wsdl12-bindings
XML-RPC XML Remote Procedure Calls	A specification to allow software running on disparate operating systems and different environments to make procedure calls over the Internet. XML-RPC uses HTTP transport and XML encoding. *http://www.xmlrpc.org*
SOAP	SOAP is a lightweight protocol intended for exchanging structured information in a decentralized, distributed environment. http://www.w3.org/2000/xp/Group
XMLP XML Protocol	XML Protocol requirements document: emerging work. Envelope and serialization mechanisms will not preclude any programming model nor assume any particular mode of communication between peers. http://www.w3.org/TR/xmlp-reqs
UDDI Universal Description, Discovery and Integration	A platform-independent open framework for describing services, discovering businesses, and integrating services using the Internet via an operational registry. OASIS: http://www.uddi.org
LDAP Lightweight Directory Access Protocol	Protocol to provide read/write interactive access to directories, specifically targeted at management and browser applications. IETF: http://www.ietf.org/rfc/rfc2251.txt

XML Security	Security mechanisms for XML documents and protocols.
XML Encryption	Processes for encrypting/decrypting digital content (including XML documents and portions thereof). Includes XML syntax used to represent the (1) encrypted content and (2) information that enables an intended recipient to decrypt it. http://www.w3.org/Encryption/2001
XML Signature	XML compliant syntax used for representing the signature of Web resources and portions of protocol messages, plus procedures for computing and verifying such signatures. Signatures provide data integrity, authentication, and/or non-repudiatability. http://www.w3.org/Signature (joint effort by W3C, IETF)
XKMS XML Key Management Specification	Specification of XML application/protocol that allows a simple client to obtain key information (values, certificates, management or trust data) from a web service. http://www.w3.org/2001/XKMS

3.5 Workshop Findings and Issues (further writing needed)

Recognizing XML's verbosity, how do we minimize impact on bandwidth? Consider compression standard(s).

Consider the implications for ontologies to establish commonalities between services. Identify areas where standards don't yet exist.

Discuss push vs. pull architectural models.

Discuss agent frameworks: RDF, DAML, partnerships with other projects (e.g. CoABS Grid), etc.

Discuss unambiguous autogeneration of behaviors in multiple languages.

Given that many of the standards that are required are still nascent or not even defined, how do we minimize the impact of changing standards? Actually most are now defined, ongoing involvement needed.

Discuss XML-based over-the-network protocols with a view to allowing run-time extensibility.[1]

Identify technology availability: immediate, near-term (1-2 years), likely (3-5 years), problematic.

[1] Some issues were identified as spanning multiple topic areas. These issues are indicated by italics.

4 Networking, Streaming & Multimedia Considerations

Over-the-network protocols will be defined unambiguously and flexibly in XML to allow rapid definition of application-specific data streaming formats that include run-time extensibility, portability and semantic interoperability, e.g. the NPS Dynamic Behavior Protocol. While the expectation is that users will have fast workstations (running any major operating system), XMSF will support a scaled list of capabilities to support users with a wide range of network bandwidths from modems through ADSL through gigabit networks.

4.1 Basic Assumptions

These core assumptions provide a baseline to consider the network services required to support XMSF objectives:

- The XMSF environment will not be confined to individual networks. Key objectives of XMSF are to expand the customer base, enable a new generation of modeling and simulation applications, and jointly accrue benefits with commercial industry. The implication is that XMSF must reach beyond individual private networks or individual Internet Service Provider (ISP) networks. XMSF must be able to run across the public Internet. Otherwise, it will not provide the benefits needed by commercial industry, upon which we plan to capitalize for Defense purposes.
- XMSF applications should not be network media-aware. Web services are designed to be extremely flexible and are most effective when independent of supporting services such as network media. Therefore, XMSF applications should not be dependent on specific network media.
- Scalability and resilience are essential in XMSF. XMSF applications, middleware and networks must not only be scalable and resilient in the sense of supporting a large number of users, but also from the perspective of being responsive to unpredictable demands from various interoperating processes as a result of the unpredictable nature of the simulations involved. Without the ability to adapt to fluctuating demands and network services, the goals of XMSF will not be achievable.

4.2 Network Service Requirements

While the basic functional requirements for network services have been defined, the Modeling and Simulation community needs to characterize network requirements in a way that can be measured and understood. This includes an understanding of the impact if the requirements cannot be met. Key network service requirements that warrant special consideration include:

- Network Quality of Service (QoS). QoS must meet a specified or negotiated standard for end-to-end capacity, latency, jitter, and packet loss in a statistical sense. If the approach is a negotiated solution, then a mechanism(s) for negotiation is required with possibly different solutions for global and local negotiation. Today, QoS can be specified or negotiated within private networks or individual ISP networks, but not across the Internet. For Internet wide QoS negotiation, no known strategy exists, nor is one expected in the next decade. QoS requirements include the consistency needs of applications and translation to network capabilities. For example, does the application need to know the order of message sending? Achieving certain QoS objectives also implies tradeoff. For example, two very important parameters to XMSF are reliability and latency. Unfortunately, these parameters work hand in hand as increased reliability implies greater latency.

- Multicast. XMSF requires many-to-many multicast (group communication) among instances of distributed applications. The current trend is away from providing this as a network layer service because the business model for the Internet doesn't support the service. One-to-many multicast may become available from individual service providers, but probably will not be available end-to-end across the Internet. This implies that many-to-many multicast must be provided in an overlay/middleware solution by the XMSF community, using a non-multicast network layer. Implicit in the approach is a requirement for an ability to identify and respond to congestion, because multicast networks are very susceptible to congestion. Reliability is also a major concern for multicast networks, as it is impossible to have fully reliable/real-time multicast. This implies a need to specify an XMSF requirement for reliability in the form of a selectively reliable/real-time and fully reliable/non-real-time capability.
- End-to-end network status and performance monitoring. A mechanism must be defined and implemented to provide real-time end-to-end network status and performance monitoring. This information is necessary to the application or middleware for use in adapting to changing network conditions, specifically capacity availability, information loss, and congestion.
- Management of policy-based filtering technology. When considering communications across multiple management domains or Autonomous Systems, routing policies, firewalls, and Network Address Translation (NAT) generally prevent straight forward any-to-any communications. Therefore, a mechanism for dealing with policy-based filtering technology that will be encountered in the Internet is required.
- Security. XMSF network security requirements must be defined to include authentication, denial of service protection, confidentiality, auditing, and integrity.
- Multi-sensor systems. XMSF must support multi-sensor systems, and thus needs the ability to manage streaming data with low buffering latency and also coordinate groups of sources.
- Middleware requirements. There are critical middleware functions that must be included above the network. These include:
    - real-time object request broker
    - authentication/authorization services
    - real-time directory services
    - group coordination/synchronization
    - session coordination provided by the Session Initiation Protocol (SIP) with addition of an automated setup/teardown capability
    - XML requires network transfer mechanisms such as XML-RPC or SOAP
- Network timing. NTP and /or GPS are required to provide synchronized network time for XMSF. GPS is more accurate and can be used to synchronize a local NTP master service.
- Over-the-net protocols. Standardizing on over-the-net protocols is a key requirement for success. Riding over standard Internet protocols is a proven basis for enabling interoperability.
- Grid and cluster network computing. Grid and cluster style network computing will accommodate XMSF without modifications as long as network capacity is sufficient.
- Test environment. A dedicated and monitorable test environment would accelerate development of an XMSF community. This might be accomplished using Next Generation Internet (NGI) networks such as Abilene and the Defense Research and Engineering Network (DREN). To be useful, a test environment must be stable and therefore must be adequately funded for operation at two or more locations.

4.3 Protocol Summary

Current networking protocols of primary interest include the following.

Network Protocols	Descriptions and primary references.
http Hypertext Transfer Protocol	An application-level protocol for distributed, collaborative, hypermedia information systems. It is a generic, stateless, protocol which can be used for many tasks beyond its use for hypertext, such as name servers and distributed object management systems. http://www.ietf.org/rfc/rfc2616.txt http://www.w3.org/Protocols
ftp File Transfer Protocol	An application-level protocol to promote sharing of files, to encourage use of remote computers, to shield users from variations in file storage systems among hosts, and to transfer data reliably and efficiently. ftp://ftp.isi.edu/in-notes/std/std9.txt
SMTP Simple Mail Transfer Protocol	SMTP is a protocol to transfer electronic mail reliably and efficiently. SMTP is independent of the particular transmission subsystem and requires only a reliable ordered data stream channel. ftp://ftp.isi.edu/in-notes/std/std10.txt
RTP Real-time Transport Protocol	RTP provides end-to-end network transport functions suitable for applications transmitting real-time data, such as audio, video or simulation data, over multicast or unicast network services. RTP does not address resource reservation and does not guarantee quality-of-service for real-time services. The data transport is augmented by a control protocol (RTCP) to allow monitoring of the data delivery in a manner scalable to large multicast networks, and to provide minimal control and identification functionality. RTP and RTCP are designed to be independent of the underlying transport and network layers. http://www.ietf.org/rfc/rfc1889.txt http://www.ietf.org/html.charters/avt-charter.html
Beep Blocks Extensible Exchange Protocol	A standard application layer that supports dynamic, pluggable application "profiles" (protocols). Includes peer-to-peer, client-server, or server-to-server capabilities, multiple channels over a single authenticated session, and support for arbitrary MIME payloads including XML. http://www.beepcore.org
SRMP Selectively Reliable Multicast Protocol	SRMP is a selectively reliable transport protocol for real-time, multicast distributed applications such as Distributed Interactive Simulation (DIS). SRMP applications need multicast communication with low latency and reliable transmission of some, but not all, data. http://netlab.gmu.edu/srmp

DIS Distributed Interactive Simulation Protocol	State- and entity-based multiplayer updates, with extensive support for diverse physics-based interactions and military applications. Example open implementation: http://www.web3d.org/WorkingGroups/vrtp/dis-java-vrml

4.4 Network Services Available Today

QoS and multicast services can be provided today on private networks, including the NGI. In some cases, individual ISP's are capable and willing to provide guaranteed levels of QoS, but make no guarantees for traffic that leaves their managed network. Performance that might be expected in this environment includes:

- Individual path flows to ~100 Mbps.
- Latency under 100 ms round-trip in North America
- Jitter is manageable by buffering but has a latency penalty of ~10% or more; with fiber networks overall latency generally can be held to 100 ms round-trip.
- Packet loss guarantees in a private or single source network are easily attainable at <1%
- High performance end-to-end with instant startup is practical as long as reliable delivery is not needed. Reliable delivery via TCP is available up to ~100 Mb/s; TCP flow control does not scale well to wide-area flows above this.
- Good global time synchronization can be made available with NTP/GPS. Review of requirements for secure NTP for special applications is still required.

4.5 Network Services Achievable in Three to Five Years

The Internet is a continuously changing environment with a number of on-going initiatives that will offer new services and improved guarantees of QoS. In addition, there are alternative approaches that can be considered by the XMSF that will provide an improved XMSF network environment. Below is a brief summary of key capabilities that are achievable:

- QoS on a multi-network basis seems likely, though not Internet wide. This is not a technology issue, rather one of a business case for ISP's. Individual ISP's are likely to form agreements that would allow QoS policy transfer across network interfaces.
- Multicast can be accomplished through applying overlay networks. This can be done using Virtual Private Networks (VPN) or through a middleware that provides application-transparent multicast. Both of these approaches require adequate capacity, but available capacity is not expected to be a problem.
- Significant advances in dynamic caching based on products that are available today, can significantly enhance performance for digital libraries. It is possible to provide individual data flows of ~1 Gbps by localizing access. This approach doesn't apply to dynamic data exchanged by simulations, but has the effect of relieving competition for network services demanded by the large file transfers associated with the digital libraries.
- Reliable multicast for non real time bulk data transfer.

4.6 Recommendations for Early Work Projects

While there are many technical requirements to be addressed, a smaller set of fundamental initiatives is required to lay the foundation for providing a successful networking environment for XMSF. These early initiatives include definitional work and development of mechanisms supporting unique XMSF requirements. The definitional work is needed to develop a clear characterization of M&S network requirements, with well-defined metrics:

- Develop workable definitions of the consistency needs of applications. This is a key aspect that will allow translation from applications requirements to network capabilities.
- Define acceptable tradeoff between reliability and latency in a parameterized form. There must be agreement between M&S and networking on definition and measurement of acceptable reliability and latency.
- Define requirements for reliability in multicast (group communication), such as selectively reliable/real-time, fully reliable/non-real-time.

The work on mechanisms for support of XMSF includes:

- Develop mechanisms that will allow XMSF to function in the presence of policy based filtering technologies, such as firewalls, NATs, and policy-based routing.
- Provide mechanisms for application or middleware processes to be aware of available network capacity.
- Develop a strategy/capability to support Modeling and Simulation needs for networked group communications over non-multicast network layer as an overlay network.
- Develop mechanisms for end-to-end network status and performance monitoring

5 Modeling & Simulation Considerations

5.1 Overview

[broader lead-in needed]

XMSF has a further critical requirement to integrate with tactical systems to augment the joint common operational picture. XMSF should be supported by a public library of useful reusable components and that provide rendering support and architectural hooks for visual simulations.

XMSF will incorporate time services for the support of discrete-event simulations, wide-area routing, and exercise/operations recording/playback. All XMSF services will be represented transparently as first-class objects in the framework, meaning that discovery mechanisms enable run-time extensibility even for future plug-in components.

5.2 Functional Requirements

a. *Backward Compatibility*. Backward compatibility with existing protocols such as DIS, ALSP, and HLA will enable XMSF to deliver existing M&S capabilities to new constituencies via the web.

b. *Authoritative Representations.* XMSF will provide mechanisms and formats for mapping existing authoritative representations between existing formats. The goal of this effort is not to develop authoritative representations, but rather to identify existing data formats and ensure the ability to map them.

c. *Composability*. XMSF must support multiple levels of model and component composability including enabling reasoning about the suitability of components for composition. This effort may initiate a longer term effort to develop ontologies for composability as the semantics of composition is outside the scope of XMSF itself.

d. *Multi-resolution modeling.* One of the challenges with model integration in general and composability in specific is identifying appropriate levels of model resolution for desired simulation. XMSF will need to provide mechanisms for labeling model resolution and reasoning about integration suitability based on these labels. This effort may initiate a longer term effort to develop ontologies for the labels as the semantics of these labels is outside the scope of XMSF itself.

e. *Tactical System Integration.* Sim-to-C4I integration is an ongoing issue of interest. XMSF will need to address this issue in addition to identifying other tactical systems whose integration with M&S will benefit the warfighter.

f. *Simulation Support Services: Time Management.* XMSF will support real time, scaled real time, time stepped discrete event, and event driven discrete event simulations. Doing so will require time management services which scale across a highly distributed, dynamic environment.

g. *Simulation Support Services: Logging and Playback.* The highly distributed, dynamic nature of XMSF will exacerbate the already challenging problem of consistent, complete logging and playback in existing distributed simulation environments. Addressing this issue may entail defining an initial set of scenarios which drive logging and playback requirements.

5.3 Issues

- Discuss the shared goal of bringing working M&S applications matching real world problems into tactical use.
- Discuss approaches for backwards compatibility to HLA/RTI and DIS technologies which don't constrain emergence of new capabilities. Explore specific bridging approaches for HLA/RTI and DIS over web channels.
- Discuss compatibility with the Joint Technical Architecture (JTA), http://www-jta.itsi.disa.mil.
- Explore integration with C4I systems to augment joint common operational picture.
- Discuss approaches for playback capture.
- *Identify technology availability: immediate, near-term (1-2 years), likely (3-5 years), problematic.*

5.4 Workshop Findings

The M&S subgroup began its session by reviewing the initial requirements and issues. There was universal agreement on both requirements and issues. The general consensus was that XMSF has the potential to support the needs of the broader M&S community, extend current standards, and to address some remaining shortcomings. There are already XML-based standards such as X3D which very successfully support 3D graphics via the Internet, and which should be incorporated into XMSF. There is also some work in progress for support of sound and haptics. Specific standards for inclusion include SCORM, XML, X3D, SEDRIS, H-Anim, and metadata standards. Further definition of XMSF must be based on focus on extensibility and composability.

[Insert table on M&S standards, similar to tables in previous sections]

Based on this agreement, the M&S subgroup focused on refining the technical issues which must be resolved and defining use cases which incrementally test the reach of XMSF. Both issues and use cases were ranked according to estimated time to resolution. Near term is defined as 1 – 2 years. Two general classes of issues fall into this category. The first is simply technical issues we believe can be solved in the short term. The second is process, policy, and standards issues which *must* be solved in the short term for substantial progress to be made. Mid term is 3 – 5 years; long term is greater than 5 years.

The following tables summarize open issues over the near-, mid- and long-term future.

Table 5-1. Open Issues

Near-Term Open Issues

- What are performance and computation issues, particularly scalability including level of service for varying platforms and graceful degradation? Will XML always be used for data representation or is it better used for just meta-data representation? Definition of compressed streaming file formats may be in order
- There is a need to reduce the cost of authoring and automatically converting between formats, e.g. XML scenario information to specific X3D scene renderings. Related to this is the need to convert between more disparate data standards. Support is needed for correlation of 2D and 3D models, e.g. georeferencing.
- How will branding, licensing, and security of data be handled? This issue is of interest both from a confidentiality perspective and from the perspective of protection of data rights, i.e. protection of commercial investment in the development of expensive content. Black boxing may be considered for this issue.

Mid-Term Open Issues

- How do we do time management in a highly dynamic environment including both scheduling and synchronization? This may require definition of new time management paradigms and mechanisms. It will certainly require automated means for reasoning about and integrating simulations with different time management mechanisms.
- How do we compose, display, and interpret multi namespace documents?
- How do we *rapidly and repeatably* integrate hardware-in-the-loop devices and live components?
- We need to define metadata standards to support systems engineering, valuation of data, and dynamic data acquisition. Valuation of data in this context means the goodness or certainty of correctness of the data, not its cost. Dynamic data acquisition is the process of automatically tagging data acquired from (possibly) non-simulation sources for rapid inclusion in the simulation environment.

XMSF requires mechanisms for supporting need-to-know for purposes of security and perception-based modeling. This is probably an application of interest management.

Long-Term Open Issues

- We need to define metadata standards to support VV&A. What is the process for VV&A of extensions to security mechanisms?
- How are aggregation and composability supported, including authoring, archiving, selection (searching, directories, repositories), and traceability and maintenance of a simulation's constituent components? This last item is configuration management complicated by the distributed maintenance of components, i.e. the simulation's engineer may not "own" all the components or even have a copy.
- How do we integrate non-simulation functionality, e.g. network optimization? This will probably require definition of a simulation control API, support for results analysis, and mechanisms for compensating for missing data.
- How much of a development environment can we define interfaces to support? How can this environment provide debugging support for developers?

6 Strategic Considerations

In addition to specific technical considerations, XMSF's highly distributed and collaborative nature further requires addressing several logistic and business challenges.

6.1 Workshop Findings

The following are strategic considerations identified by all the subgroups and agreed to in plenary sessions:

- We need to actively engage developers and users from commercial, industrial, and government organizations.
- We need to select and develop standards that meet the needs of consumers, government and industry, recognizing that each of these groups have different priorities for scalability, return on investment, ease of use, and security.

6.2 Symposium Findings

This section will be completed after the 6 September Symposium.

6.3 Issues

- *Discuss establishment of 24 x 7 x 365 networked virtual worlds over DREN/Abilene/Web between a set of research partners to show accessible/growing exemplars with network monitoring.*
- Identify approaches for gaining support of various service operational commanders plus OSD C4I and transformation agents as top-level sponsors.
- Discuss business model and logistics of open-source implementations.
- Identify models/scenarios for bottom-up demonstration of capabilities using scenarios of increasing sophistication and interoperability.
- List contrary technical attributes/conflicts which ought to be avoided.

7 Exemplar Demonstrations

Our choice of driving exemplars is very important. We want to demonstrate the ability to work on essential problems challenging U.S. and coalition defense forces

7.1 Vision Vignettes: Defense Scenarios

We have considered a large number of example defense scenarios that might show the potential breadth and depth provided by XMSF capabilities. The following "vision vignettes" are candidate demonstration

- Coalition hostage rescue from terrorists holding one hundred ambassadors at a United Nations (UN) conference situated on a coastal city in the Middle East.
- Multiple U.S. agency bio-terror response to simultaneous epidemic outbreaks centered at Dulles and San Francisco International Airports.
- Conventional forces with complex real-time targeting problem, small scenario. Possible candidate as Future Combat System (FCS) or Joint Synthetic Battlespace (JSB) scenario.

7.2 Technical Attributes of Tactical Exemplars

Diverse individual systems for communication, command and operations must support diverse organizational entities. Modeling and simulation capabilities must be demonstrated in the small (on a system-by-system basis) and also in the large (within a scalable non-stove-piped framework). In some respects, even individual systems can't be effectively modeled in isolation – they are deployed in concert on coordinated problems.

Exemplar demonstrations tackling visionary defense scenarios must work across this range of scalable interoperability. Specific technical issues for scenario development follow.

Table 7-1. Technical Goals for Tactical Scenario Development

Develop simple, compelling, cross-cutting scenarios demonstrating the vision

- Joint/coalition, overseas warfare, coalition peace keeping, amphibious raid for hostage rescue demonstrating diverse physics, perimeter defense
- Homeland defense against bio-terror: how to connect disparate inputs and provide a framework for successful cooperation despite systemic challenges
- Joint targeting problem, tracking with real-time updates in a dynamic conventional environment, include possible FCS/JSB and future Aviation (e.g., Multi-Mission Aircraft).

Vignettes provide back story for exemplar software-capabilities demonstrations; when carefully chosen, these provide precise technical requirements for tactical capabilities

Describe exemplar or validating scenarios showing goal capabilities 2-5 years

- Command & control applications; decision support tools
- Need high flexibility due to diverse legacy mission-critical systems
- Ability to interoperate with commercial tools and databases
- Virtual worlds connect diverse models, datasets, data streams
- Virtual environments for diverse interaction modes, palm-PC-Cave

- Vignette tasks drive technical needs for low latency, high throughput, ability to control sockets down to the network layer, etc.
- Must not look like a toy problem
- Must not look like "science fiction" since results have to appear broadly achievable
- Keep message simple: connect existing technologies of immediate value to warfighter capabilities

Show systems operating across 3-part spectrum: rehearsal using simulation, real for operations conduct, replay for training/critique.

7.3 Use Cases to Drive Requirements

The M&S subgroup sketched the following use cases as potential tests of incrementally available XMSF capability. The suggestions identify some existing programs and planned exercises. This does not imply any commitment from these programs and exercises to participate in the XMSF development.

- The near term use case focuses on dynamically updating behaviors and data models at run time, demonstrating the capability of a simulation to be "always on." The simulation would be a small server based simulation, i.e. fewer than 60 entities, running on NPSNET V.
- The mid term use case seeks to demonstrate extension of metadata standards and mapping between existing data standards, including producing multiple output formats from a single source and 2D to 3D correlation. The scenario is target acquisition sensor to shooter pairing modeling probability of hit/probability of kill. The scenario should also model logistics and communications in order to demonstrate integration of multiple types of models. Several existing and/or planned simulations are potential bases including OTB, JSAF, VR Forces and Combat XXI.
- A significant long-term use case intended to demonstrate the viability of XMSF is the support of major joint/coalition military exercises. Recognizing that XMSF is several years from this level of capability, the suggestion is to work in parallel with a major joint exercise that is already planned. Unified Endeavor 2004 is a candidate which has the added benefit and challenge of being a coalition exercise. The goal is to integrate virtual, live, and constructive elements using XMSF services in less than one year, while spending less than half of the system-by-system simulation-integration costs of Millennium Challenge 2002.

The networking group proposed a "Hello HLA" initial use case for XMSF, intended to combine a demonstration of working Internet connectivity with current M&S technologies and XML:

- Distribute a Java-based HLA simulation over the Web. Human interfaces and setup/scenario coordination would use Web technologies. Connectivity would be via open Internet technologies with work-around for barriers such as firewalls. The simulation would run at government, industry and academic sites and would be demonstrated at a highly visible event. The components would then be made available openly for community experimentation.

8 Determining The Path Forward

For XMSF strategies to succeed, supported applications must succeed broadly, and thus successful development must be enabled for many participants through a sustainable business model. The minimal framework will be a royalty-free open source implementation, but interoperable commercial implementations are equally important to sustainability. This business model engages successful business models for both military simulation and the Web, enabling more sponsors to participate and also enabling diverse simulations, models, and applications to survive despite intermittent funding profiles. The model also makes it possible for programmers and managers to develop transferable, career-building skills and reusable experience, reinforced despite any employer flip-flops, through the availability of open-source example implementations.

8.1 Partnerships

Where's the market for industrial partners? In many ways it is the same market we have today. There will still be a need for expert support, development of proprietary models and tools, consulting and integration, and maintenance. For DoD partners, the use of commercial and transportable technology is crucial. With shrinking budgets and expanding requirements, spending too much for unique, proprietary or perishable technology is no longer a sustainable option. DoD can benefit most by slipstreaming with Web-wide standards and industry best practices. The following table provides a simple overview summary of relationships necessary for broad success.

Table 8-1. Liaison Relationships Needed for XMSF-related Standards

Consortia and Standards Bodies

- World Wide Web Consortium
- Web3D Consortium
- OASIS
- ISO
- IEEE
- IETF
- SISO
- Others

Service M&S Management Offices

- DMSO
- NAVMSMO
- AMSO
- AFAMS
- MCMSMO

SECDEF Initiatives

- NATO Generic Hub (Trilogy) C^4I Tagset Semantic Interoperability
- Future: inevitable need to find web-based interoperability solutions

Navy Initiatives

- Task Force Web
- IT21, NMCI, portals
- DON CIO XML Working Group
- NUWC submarine/shipboard combat control systems

Army Initiatives

- SMART
- Joint Virtual Battlespace (JVB) for Future Combat Support
- Army Data portal

Air Force Initiatives

- Joint Battle Infosphere (JBI)
- Joint Synthetic Battlespace (JSB)
- [list additional initiatives, add links]

8.2 Future Architectures

Mapping to diverse architectures, past present and future: principles in Andreas Tolk's *Model Driven Architecture* submission appear to have broad applicability and can guide a remapping of diverse capabilities to Web-based interoperability, and perhaps Web services restructuring.

Need to examine results of recent DMSO Workshop on Component Architectures and determine next steps. Best way to get visible and measurable architectural comparisons might be development of a remapping of RTI Services to Web services.

8.3 Advanced Distributed Learning (ADL)

[Section on advanced distributed learning technologies and how they are integral.]

Additional issues [further editing]

Broad suite of open and commercial-grade tool support

E-business, U.S. government, DoD and service: registries and repositories for XML

Web Services – furious activity underway (SOAP, registries, etc.)

Dynamic Behavior Protocol: XML-defined packet payloads providing extensible/discoverable/validatable protocols customized for diverse applications

XML data interchange standards

Network Time Protocol (NTP) and GPS plugins for globally networked time

Virtual reality transfer protocol (vrtp) to provide integrated suite and URL accessibility for content-author use of these diverse network protocols

ADL/SCORM for integration of instruction with simulation (and vice versa) for the purposes of training to employ simulations, interacting with story-engine and game-play simulations as instructional content, etc.

Make deployment and duplication easily repeatable: Web-browser plugins, installers, updaters, server builders as extensible one-click/automatic utilities

Real-time Transport Protocol (RTP) header mechanisms for diverse behavior-based streams to maximize WAN routability as unicast, multicast

Making reliable multicast protocols available

Lightweight Directory Access Protocol (LDAP) capabilities within a Web framework and possible suitability for broad and diverse shared-state-consistency support

Session Announcement Protocol (SAP) and Lightweight Directory Access Protocol (LDAP) suitability for advertising arrival of entities and availability of services for large-scale widespread distributed simulations/operations

Availability of multicast fabric despite long-standing delays in deployment, possible benefits for bandwidth-constrained tactical networks, and whether new approaches such as Java JXTA or Cisco routers provide new capabilities (or at least address long-standing barriers to deployment)

Extreme programming: design patterns and team practices for effective cross-platform, cross-technology software integration and life-cycle sustainability

NPS-directed SIGGRAPH 2001 Online project. http://cave.cs.nps.navy.mil/contents.html

9 Glossary

ADL	Advanced Distributed Learning
ADSL	Advanced Digital Subscriber Line
AFAMS	Air Force Agency for Modeling and Simulation
AFIT/ENG	Air Force Institute of Technology/ ??
AMG	(HLA) Architecture Management Group
AMSAA	Army Materiel Systems Analysis Agency
AMSO	Army Modeling and Simulation Office
AOIM	Area of Interest Management
API	Application Programming Interface
BDA	Battle Damage Assessment
CAD/CAM	Computer Aided Design / Computer Aided Manufacturing
CIO	Chief Information Officer
CMM	Capability Maturity Model
CoABS	Control of Agent-Based Systems
CORBA	Common Object Request Broker Architecture
DAML	DARPA Agent Markup Language
DBP	Dynamic Behavior Protocol
DIS	Distributed Interactive Simulation
DMSO	Defense Modeling and Simulation Office
DOM	Document Object Model
DON	Department of the Navy
DREN	Defense Research & Engineering Network
DSN	Digital Subscriber Network
ESG	Expeditionary Sensor Grid
FCS	Future Combat System
GCCS	Global Command and Control System
GIF	Graphics Interchange Format
GMU	George Mason University
GPS	Global Positional System
HLA	High Level Architecture
IDA	Institute for Defense Analysis
IDL	Interface Description Language
IEEE	Institute of Electrical and Electronics Engineers
IESG	Internet Engineering Steering Group
IETF	Internet Engineering Task Force
I/ITSEC	Interservice/Industry Training, Simulation & Education Conference
ISO	International Standards Organization
ISP	Internet Service Provider
ITEM	Integrated Theater Engagement Model
ISO	International Standards Organization
IT21	Information Technology for the 21st Century
JSAF	Joint Semi-Automated Forces
JBI	Joint Battle Infosphere
JSB	Joint Synthetic Battlespace
JTA	Joint Technical Architecture
JXTA	"Juxtapose" – Next Generation Jini

LDAP	Lightweight Directory Access Protocol
MAGTF	Marine Air-Ground Task Force
MCMSMO	Marine Corps Modeling and Simulation Management Office
M&S	Modeling and Simulation
MEDAL	Mine-warfare Environmental Data Analysis Laboratory
MMA	Multi-Mission Aircraft
MOVES	Modeling, Virtual Environments, and Simulation
MTF	Message Text Format
MTWS	MAGTF Tactical Warfare Simulation
NAT	Network Address Translation
NAVMSMO	Navy Modeling and Simulation Management Office
NEW	Network Education Ware
NGI	Next Generation Internet
NGIC	U.S. Army's National Ground Intelligence Center
NMCI	Navy Marine Corps Internet
NIMA	National Imagery and Mapping Agency
NPS	Naval Postgraduate School
NPSNET	NPS Network
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSS	Naval Simulation System
NTP	Network Time Protocol
NUWC	Naval Undersea Warfare Center
OASIS	Organization for the Advancement of Structured Information Standards
ODU	Old Dominion University
OSD	Office of the Secretary of Defense
OTB	OneSAF Test Bed
PNG	Portable Networked Graphics
QoS	Quality of Service
RDF	Resource Description Framework
RTI	(HLA) Run Time Infrastructure
RTP	Real-time Transport Protocol
SAF	Semi-Automated Forces
SAIC	Science Applications International Corporation
SAP	Session Announcement Protocol
SAVAGE	Scenario Authoring and Visualization for Advanced Graphics Environments
SCORM	Sharable Content Object Reference Model
SEDRIS	Synthetic Environment Data Representation Interchange Standard
SEI	Software Engineering Institute
SIGGRAPH	(Associate for Computing Machinery) Special Interest Group on Graphics
SINGARS	
SIP	Session Initiation Protocol
SISO	Simulation Interoperability Standards Organization
SIW	Simulation Interoperability Workshop
SMART	(Army) Simulation Modeling Acquisition Requirements & Training
SMIL	Synchronized Multimedia Integration Language
SNMP	Simple Network Management Protocol
SOAP	(originally) Simple Object Access Protocol, now simply SOAP

SVG	Scalable Vector Graphics
TCP	Transport Control Protocol
TRAC	(Army) Training & Doctrine Command Analysis Center
UAV	Unmanned Aerial Vehicle
UDDI	Universal Description, Discovery and Integration
UHF	Ultra High Frequency
UML	Unified Modeling Language
URI	Universal Resource Identifier
URL	Universal Resource Locator
URN	Universal Resource Name
UUV	Unmanned Underwater Vehicle
VHF	Very High Frequency
VPN	Virtual Private Network
VR	Virtual Reality
vrtp	virtual reality transfer protocol
W3C	World Wide Web Consortium
WSDL	Web Services Description Language
X3D	Extensible 3D Graphics
XHTML	Extensible HyperText Markup Language
Xj3D	Extensible Java 3D Graphics
XML	Extensible Markup Language
XMSF	Extensible Modeling and Simulation Framework
XSL	Extensible Stylesheet Language
XSLT	XSL for Transformations

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IEEE Standard 1516.2 ³Standard for Modeling and Simulation High Level Architecture - Federate Interface Specification,² September 2000.

Defense Modeling and Simulation Office (1998) ³Department of Defense High Level Architecture, Version 1.3,² April 2 1998, online document at http://www.dmso.mil

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Numerous further references to be provided. Recommendations welcome.

Appendix A. XMSF Technical Challenges Workshop Attendees, Point Papers

Point papers available via http://www.MovesInstitute.org/xmsf/workshop

Point paper	Invitees, listed by Areas of Interest	Affiliation	Area of Expertise
Web and XML Languages Chair: Dr. Don Brutzman. NPS			
	Erik Chaum	NUWC	Submarine, shipboard combat control systems
	Steven Fouskarinis	SAIC	XML/legacy integration, Web services
	Rob Glidden	Sun	Web & Broadband Services Architecture
	Jack Jackson	TRAC-Monterey	Analytic simulation, Web Simulation Description Language
	Dr. David Kwak	MITRE	Chief Scientist for M&S
	Dr. Francisco Loaiza	IDA	Databases, schema, Generic Hub
	Dr. Edward Sims	Vcom3D	Humanoid animation, SEDRIS, ADL SCORM
	Dr. Chenghui Luo	Fraunhofer CRCG	Security, encryption, authentication
	Dr. Andreas Tolk	ODU	Object designs, XML architectures
	Phil Zimmerman	DMSO	Composable environments
	Justin Couch	Yumetech	3D graphics, open source, specifications
Networking and Internet Chair: Dr. Mark Pullen, GMU			
	Dr. Rusty Baldwin, Maj USAF	AFIT/ENG	Communication systems modeling
	Scott Bradner	Internet IESG, Harvard University	Internet Protocol, transport, IETF
	Dr. Suleyman Guleyupoglu	NRL	CEEs, works with Henry Ng
	Dr. Norbert Schiffner	Fraunhofer CRCG	Secure distributed networking, 3D graphics
	Dr. Marcelo Zuffo	University of São Paulo - Brazil	Cluster computing
	Dr. Sue Numrich	DMSO	Environmental representations and systems composition

Modeling and Simulation Chair: Dr. Katherine Morse, SAIC			
	Dr. Mike Bailey	USMC Modeling & Simulation Office	Discrete event simulation, tactical systems
	Dr. Steve Carson	GSC Associates	ISO, SEDRIS
	Dr. Paul Diefenbach	OpenWorlds Inc.	Advanced 3D graphics rendering
	Dr. Niki Deliman Goerger	USA ERDC (Engineering Research Development Center)	Terrain and land environmental databases. Liaison to TRAC-Monterey
	Alan Hudson	Yumetech Inc.	Real-time 3D Graphics, open source
	Kalyan S. Perumalla	Georgia Institute of Technology	Time mechanisms and services
	Dr. Dick Puk	Intelligraphics	SEDRIS, ISO
	Dr. Cristina Russo dos Santos	Eurecom, University Toulon	3D scientific visualization, network monitoring
	Dr. Andreas Tolk	ODU	HLA/RTI and Web follow-ons
	Dr. Sanjeev Trika	Intel	Geometric reasoning, VR for CAD, CAD/CAM integration
	Dr. Bowen Loftin	ODU	Virtual and collaborative environments
	CAPT Erik Jilson USMC	MCMSMO	
	Matt Beitler	University of Penn.	Humanoid animation
	Ph.D. students		Active research, observers/assistants
	Curt Blais Andrzej Kapolka Don McGregor Simon Goerger Joerg Wellbrink	MOVES	Autoconstructing large-scale virtual worlds Dynamic component architectures Large-scale networking Human and Organizational Behavior Performance and vigilance
	Matt Beitler	Univ. Pennsylvania	Humanoid animation
39	**Total attendees**		
	Additional support staff		
	Cecelia Childers	1.831.656.3818	Travel
	Jeff Weekley	1.831.656.2809	Logistics
	Barb Helfer		Video preparations for open house

APPENDIX B. TECHNICAL CHALLENGES WORKSHOP AGENDA

Monday 19 August 2002

0815 Welcome
Don Brutzman, Mark Pullen, Katherine Morse, Mike Zyda
Workshop goals, agenda and outcomes. MOVES Open House.

0830 XMSF and Technical Workshop Overview.
Motivation, milestones and goal outcomes.
White paper review and lookahead.
Challenges: can we do all modeling and simulation over Web?

0930 Workshop tasks: triage consensus on the XMSF challenges.
- what do we agree on
- what do we disagree on
- what areas most deserve immediate work
Review whitepaper list of overarching issues for all groups, and names in each group

1030 Three work groups meet in separate meeting rooms:
- Web/XML, Don Brutzman
- Networking, Mark Pullen
- Modeling & Simulation, Katherine Morse
Rapid 10-minute point-paper briefings by participants

1200 Lunch break on the quadrangle
1300 Workgroups

1530 Working groups determine consensus on triage questions

1700 Plenary progress quicklook: 5 minutes per group
Determine tasks for evening, morning sessions
1830 Break

Tuesday 20 August 2002

0815 Working groups resume and complete

1030 Plenary results session
- 20-minute group reports

1130 Final discussion
- Consensus conclusions, disagreements, go-forward steps
- Participant updates to point papers and reading references
- XMSF Strategic Opportunities Symposium, Friday 6 SEP, GMU

1200 Workshop complete

APPENDIX C. STRATEGIC OPPORTUNITIES SYMPOSIUM AGENDA

http://netlab.gmu.edu/xmsf

0800 Registration Opens
0830 Welcome to GMU
Dr Lloyd Griffiths, Dean
GMU College of Information Technology & Engineering

0835 Keynote: M&S Technologies and the Web
Dr. Anita Jones
University of Virginia (UVA) Dept of Computer Science
(former Director, Defense Research and Engineering)

0900 XMSF Workshop Results
(Chair: Dr. Don Brutzman, NPS)
Web Technologies: Dr. Don Brutzman, NPS
Internet Technologies: Dr. Mark Pullen, GMU
M&S Technologies: Dr. Katherine Morse, SAIC
Defense Impact: Dr. Mike Zyda, NPS

1030 Technologists' Perspectives on XMSF
(Chair: Dr. Katherine Morse, SAIC)
Commercial M&S Web Technologies: Rob Glidden, Sun Microsystems
Commercial CAD-to-Web efforts: (Intel invitee)
ADL & Web-Based M&S: Dr. Philip Dodds, Advanced Distributed Learning
DoD's Homeland Defense Role and Web-Based M&S: Walt Zimmers, DTRA

1145 Lunch

1245 Supporting the Tactical Warfighter - Perspective on XMSF
(chair: Dr. Dennis McBride, Potomac Institute)
USMC: Dr. Mike Bailey, USMC Combat Development Command
USAF: JSB uniformed leader? POC David Kwak Mitre
J7/J9 (POC Bowen Loftin)
Katherine invite ForceNet M+S Ray Coutley; alt TF Web

1400 Programmatic Pespective on XMSF
(chair Dr. Mike Zyda, NPS)
Dr. Sue Numrich, DMSO
MAJ David Laflam USA, AMSO
Steve Swenson, NAVMSMO
Mr. Alan Murashige, HQ USAF XIW (invitee)

1515 Open-Mike Session (Chair: Dr. Mark Pullen, GMU)
ground rule: form a queue; one slide/3 minutes max
each time you come to front of the queue

1630 Reception