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Extensible Modeling and Simulation Framework (XMSF) challenges for web-based modeling and simulation

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FINDINGS AND RECOMMENDATIONS REPORT:

TECHNICAL CHALLENGES WORKSHOP, STRATEGIC OPPORTUNITIES SYMPOSIUM

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EXTENSIBLE MODELING AND SIMULATION FRAMEWORK (XMSF)

FINDINGS AND RECOMMENDATIONS REPORT 2002

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 World Wide Web technologies. 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.

In order to carefully consider these DoD transformation challenges for M&S, we are defining an Extensible Modeling and Simulation Framework (XMSF) to exploit web-based technologies. An exceptional group of government, academic, and industry experts worked together under the leadership of investigators from the Naval Postgraduate School, George Mason University, and SAIC for an exploratory workshop and a public symposium. This report describes the basis and initial requirements to achieve such transformational interoperability, through community development of the Extensible Modeling and Simulation Framework (XMSF).

The Extensible Modeling and Simulation Framework (XMSF) is defined as a composable set of standards, profiles and recommended practices for web-based modeling & simulation (M&S). XML-based markup languages, Internet technologies and Web Services will enable a new generation of distributed M&S applications to emerge, develop and interoperate.

XMSF integrates 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 must not be constrained by proprietary technology or legally encumbering patents, since such barriers discourage the free, open, *ad hoc* development of interconnected tactical models and simulations.

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 Extensible Markup Language (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, network scalability, and 2D/3D graphics views.
- 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 final version of the report includes key findings from the XMSF Technical Challenges Workshop conducted at the Naval Postgraduate School, Monterey California on 19-20 August 2002, plus considerations and recommendations from the XMSF Strategic Opportunities Symposium held at George Mason University, Fairfax Virginia on 6 September 2002. Key points emerging from both the Workshop and the Symposium include the following findings.

- The XMSF concept must continue to be refined from a high-level concept to definitive technical recommendations, practices, and applications tailored for the M&S domain.
- 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 are examined as possible exemplars.
- Web Services appear to be a promising application of technology for focusing future work.
- Security concerns are cross-cutting for all areas and must be addressed throughout any design process (i.e. built in from the outset).

Frequently asked question #1*: what does XMSF look like?*

- Web, internet and XML technologies for open interoperability in M&S
- Data and metadata standards for semantic consistency among systems
- Profile specifications, associated with standards, to define common capability levels needed for user requirements and application support
    - Specification of mandatory (and optional) standards and recommended practices
    - Recommendations and guidelines for implementation (e.g. composability requirements, recommended technologies, application guidelines, recommended hardware configuration)
    - Implementation and evaluation metrics to measure conformance and capabilities

Frequently asked question #2*: what doesn't XMSF look like?*

- A single, exclusive, tightly coupled architecture
- Proprietary technologies which require licenses or royalties for use

The next major milestone for XMSF is a series of prototype demonstrations at the Interservice /Industry Training, Simulation, and Education Conference (I/ITSEC) in Orlando Florida, 2-5 December 2002 showing prototype XMSF-related applications to the M&S community.

The foundation for XMSF's future success is based on multiple strategies. Viewed from an enterprise perspective, commitments to open standards processes are the most cost effective approach over the long-term lifecycle of technology development and deployment. It is also important to have common business models for delivering expert services and developing compatible domain-specific applications. Partnerships with commercial industry can leverage technology opportunities to improve interoperability and achieve greater defense capabilities. Many incentives exist to begin demonstrating XMSF capabilities immediately as a prelude to transformational change.

The primary next-step activities for 2003 are establishing partnerships among implementers, sponsors, industry supporters and standards organizations. This report and the numerous accompanying XMSF contributions serve as the technical basis for that next round of activity.

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1 Introduction: Purpose, Scope, Shortcomings and Status

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 is evident 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 industry practices for large-scale software development. Similarly, providing web interoperability to general M&S applications can provide broad new classes of capability for 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 systems. Web-based technologies can integrate legacy simulation frameworks, tactical systems 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-based 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

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 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/Advanced Distributed Learning (ADL)/Sharable Content Object Reference Model (SCORM)/etc. - are not compatibly augmenting or utilizing available simulation technology.

Clearly many strong motivations exist for significant progress and transformational change.

1.4 Report Status

Much of the material in this report was presented as an advance whitepaper for the XMSF Technical Challenges Workshop held 19–20 August 2002, in conjunction with the annual 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 in three focus areas:

- Web technologies and 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.

The initial version of the XMSF whitepaper was updated to include Workshop results. Specifically each topic-area section gained "triage" findings on each complex subject: areas of consensus agreement, areas of controversy, and recommended issues for future work. The Strategic Considerations section was expanded, to address issues identified by all the subgroups which were later agreed upon in plenary sessions.

The resulting intermediate version of the whitepaper was then used as the basis for reporting Workshop results at the XMSF Strategic Opportunities Symposium, held 6 September 2002 at George Mason University (GMU) in Fairfax Virginia. The Symposium agenda is included as Appendix D in this document. Symposium presentations and attendee comments were broadly favorable to the concepts put forward at the XMSF Workshop, and have been integrated to produce this final version of the report.

This completed report documents the integrated results of these two major efforts, and reflects the considered consensus of the project investigators. The XMSF website further includes over 40 detailed contributions to the XMSF Workshop and XMSF Symposium which provide essential amplifying material. Appendices C and D list all of the participating experts.

We thank our colleagues for their invaluable contributions and sage insight. We also thank staff members and participating doctoral students at NPS and GMU for superlative support. Finally we wish to express our particular appreciation for technical feedback and advice from Dr. Sue Numrich and Ms. Phil Zimmerman of the Defense Modeling and Simulation Office (DMSO).

2 XMSF Postulates, Preconditions for Success, Challenges and Definition

2.1 Postulates

XMSF has several high-level requirements for success, 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. XMSF must support composable, reusable model components. XMSF use cannot be constrained by proprietary technology, restrictive licenses or legally encumbering patents which might discourage the free, open, *ad hoc* development of interconnected tactical models and simulations.

For these and other 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 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 technologies and XML
- Internet and networking
- Modeling and Simulation (M&S)

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 agreed that three such groups will be an effective way to divide diverse challenges across groups of committed participants. 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 of collaborative efforts just as much as effect use of new technology. These three groups and the forthcoming XMSF community will need:

- Effective human interfaces among all three areas: Web/XML, Internet/Networking, M&S
- 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:

- Utilize web-based technologies for more powerful and cost-effective government-wide networking, serving, client-side rendering and user interaction.
- Provide open, affordable, extensible modeling and simulation capabilities for tactical scenarios of direct use to participants engaged in conflict and peace operations.
- Employ mainstream practices of enterprise-wide software development.
- Improve ease of use for developers and users, fueling rapid growth of interoperable simulations.
- Provide support for all types and domains of M&S: constructive, analytical, live, virtual, playback-driven, agent-based, human-in-the-loop, heterogeneously distributed, logistical, and others.
- Models of interest reflect reality. Both simulations and tactical exercises are 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 composable set of standards, profiles and recommended practices for web-based modeling & simulation (M&S). XML-based markup languages, Internet technologies and Web Services will enable a new generation of distributed M&S applications to emerge, develop and interoperate.

An important finding from the workshop and subsequent investigations was that 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 focus area – Web/XML, Internet/Networking and M&S – are presented in the next three report sections.

3 <u>Web and XML Considerations</u>

3.1 Overview

The ambitious nature of the many requirements and challenges of defense M&S 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 Institute of Electrical and Electronics Engineers (IEEE), Internet Engineering Task Force (IETF), International Standards Organization (ISO), Organization for Advancement of Structured Information Standards (OASIS), the Simulation Interoperability Standards Organization (SISO), the World Wide Web Consortium (W3C), and the Web3D Consortium.

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

A particular strength of an 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 W3C and the IETF are the leading 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 particularly important when viewed from an enterprise-wide (i.e. DoD-wide and coalition-wide) perspective.

To meet these larger requirements, XMSF systems will employ object-oriented paradigms and validatable structured data in a language-independent and object-system-independent manner. Design patterns will unambiguously define programming-language bindings by mapping representations and component models from root XML schemas to multiple programming languages and application programming interface (API) bindings. The Interface Description Language (IDL) provides further good capabilities in this area. 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 data/voice Single Channel Ground and Airborne Radio System (SINCGARS), Ultra High Frequency (UHF)/Very High Frequency (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 must 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

XMSF security will encompass identification, authentication, authorization and encryption. Functional access restrictions (e.g. role-based permissions) are considered to 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 include one or more default encryption algorithms. This can allow applications to interact in a commonly acceptable way if they do not need a specific encryption implementation.

The framework must also select a standard for signing messages and documents. The existing XML Digital Signature (DS) specification (RFCs 3076 and 3275) is a likely candidate. The signature itself does not provide authentication, but rather associates an identity with data. Developments of related interest include industry efforts such as the Liberty Alliance project (http://www.projectliberty.org) and Passport (http://www.passport.com).

Following on from identification, the framework must define standards for authentication. As is the case for encryption, it appears preferable that a pre-existing mechanism (outside applications) be made available to provide authentication services. This might be implemented via authentication servers.

A 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 must 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 additional capabilities that can augment military-grade security for classified, unclassified and administrative networked systems. Security is cross-cutting issue that must work sufficiently and simultaneously across all three areas (Web/XML, Internet/networking and M&S) or new vulnerabilities will result.

Classified information security systems remain responsible for meeting military security requirements. Web-based content does not replace or jeopardize any of those existing, externally controlled techniques.

c. Service Descriptions and Bindings

Web services typically include a logically coherent set of functions offered for discovery and remote invocation across the internet by a code component. A code component may use many such services.

The functionality offered by a code component will need to be represented in a language-independent manner. This means that for the various programming languages of interest (e.g. C++, Java, Fortran, etc.) used to develop the code component, and for the platforms on which the code is deployed, common-denominator representations of the exposed functions and the parameters of those functions (i.e. the interface) will need to be represented consistently. Thus the service description needs to be binding independent. The corollary of that implication is that the service description needs to employ a common binding specification.

If the underlying mechanism employed for defining API binding mechanisms is the same as for data representation (e.g. XML), then many of the issues relating to platform independence are resolved.

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 define not only 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 a set of logical states. In effect this can translate to allowable sequences of messages. Some simulation applications may need to share state-transition definitions in order to effectively model certain shared processes.

Since state transitions deal with the logical domain rather than the physical domain, there are fewer issues of representation. If a workflow representation is simply exchangable 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 interesting requirement is that even though a set of logical state transitions may be published, these do not necessarily reveal the actual internal logic (or internal state transitions) of the implementing code component. Published state transitions are the basis for functional interoperability among participating entities, and may be a critical subset of the actual state transitions in each 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 both debit the source account and also credit the destination account, all as a single atomic action.

A common pattern for such transactions is a 2-phase commit procedure. Unfortunately, this approach can suffer from latency and heavy resource utilization when implemented across the Internet.

An alternative approach to 2-phase committal is that of adding undo operations to individual atomic actions. 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 more sophisticated 2-phase commit procedures.

g. Ontologies

An ontology is defined as a basis of meaning. This is a fundamentally difficult area that 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. 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 (L10N) provide the mechanisms for recording and translating accepted meanings in a reviewable fashion.

An open issue is the establishment of XML 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 effective ontologies for military operations orders (which contain tactical versions of who, what, when, where and how) is a strategically important application area deserving dedicated further work.

h. Repositories

A repository is defined as a logically related collection of information, accessible through a common point of reference. 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 that 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, such as physics of entity and sensor interactions
- Software-agent templates with requested capabilities
- Stream-specific adaptors/components
- Exercise simulation management
- Operational recording of simulated or actual interactions
- Order of battle (inventories and functional characteristics of friendly and opposing forces)

It appears likely that each logical level of a "XMSF stack" (probably corresponding to an augmented Web Services stack) may have one or more associated repositories. For the purposes of this report, the requirement for repositories will be assumed to be an implicit requirement for each of the preceding areas discussed.

A shared requirement necessary for the effective use of repositories is that common interfaces are defined to allow consistent access to contained information by search engines and other interested applications. Universal Description, Discovery and Integration (UDDI) fulfills this need for Web Services, and may be sufficient for XMSF. Registry functionality is intrinsic to the usefulness and growth capabilities of repositories.

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 is locating information. In order for XMSF to not fall prey to the same shortcomings it is important to provide sufficient support for capable search engines.

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), Security and other constraints. 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

Composability is defined for XMSF as the ability to select and combine components in various combinations to create new functionality which satisfies specific user requirements across a variety of application domains. This applies both during design and implementation, and during runtime. Automated, tool-based support is a composability goal.

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 [DMSO 2002].

It is interesting to consider that the platform-independent techniques used by Web Services can significantly reduce the number 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 client-side access to heavyweight server-side 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 which presents a possible XMSF Stack for Web Services, adapted from [Cerami 2002].

Table 3-1. Multiple Layers of Functionality, Composed to Provide Accessible Web Services.

Repositories Locations for providing approved (or ad hoc) Web Services with integrated registry services.	**Administrative** Exemplars: DoD XML Registry, XML.Gov http://diides.ncr.disa.mil/xmlreg/user/index.cfm http://xml.gov/efforts.htm
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 Describe 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 and decoding	**XML-RPC, SOAP, XMLP** Remote Procedure Calls, SOAP, XML 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 several interesting discussions and is summarized below. Further details appear in his Symposium slideset.

- **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.

An important further resource is the W3C Workshop on Web Services, held 11-12 April 2001 in San Jose California. Online at http://www.w3.org/2001/01/WSWS

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
- XML Security

Table 3-2. 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 Uniform Resource Identifier (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 Locators, 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
XSLT Extensible Stylesheet Language 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
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
DAML DARPA Agent Markup Language	An extension to XML and RDF, to create ontologies and markup information to become machine readable and understandable. http://www.daml.org
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 Graphics Interchange Format (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) 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

Numerous capabilities were examined that show web functionality for modeling and simulation provides rich support. The primary difficulty was not a lack of capabilities, but rather how to coherently integrate these many technologies for broad M&S use.

Some additional issues were identified that deserve further examination.

- Recognizing XML's verbosity, how do we minimize impact on bandwidth? Consider compression standards. This area has not yet been formally addressed by W3C efforts.
- Consider the implications for ontologies to establish commonalities between services. Identify areas where standards don't yet exist.
- Further investigate push vs. pull architectural models. Crucial design questions for most web applications are centered on where to put computational and data resources: on the client, on the server, in mobile code, change the balance dynamically, etc. Design patterns are needed for clarity, showing which common practices are best suited for various collaborative interactions.
- Further investigate agent frameworks: RDF, DAML, partnerships with other projects (e.g. Control of Agent-Based Systems (CoABS) Grid), etc. Numerous agent frameworks with similar functionality but differing syntax do not improve interoperability.
- Examine unambiguous autogeneration of scripting behaviors in multiple programming languages.
- Internationalization (I18N) of interfaces, and perhaps large portions of data, is essential. XML has good support for I18N. However, most developers are not familiar with the topic and broadly accepted design practices are not yet commonplace.
- XML-based network protocols for rapid code generation with consistent over-the-wire serialization can accelerate our abilities to achieve run-time extensibility across different operating platforms and programming languages.
- Given that many of the required standards continue to evolve, how do we minimize the impact of changing standards? Coherent evaluation and improvement planning across multiple technologies with ongoing long-term involvement by coordinated XMSF architects will be needed.

4 Internet/Networking

While a common 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 capabilities from wireless access and modems through Advanced Digital Subscriber Line (ADSL) and upward 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.
- In keeping with the layered abstraction approach, 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. This implies support mechanisms for fault tolerance, but not direct implementation of fault tolerance, which is application specific.
- Over-the-network message formats for corresponding network protocols will be defined unambiguously. Interestingly, such payload definitions can be flexibly represented in XML to allow rapid definition of application-specific data streaming formats that include run-time extensibility, portability and semantic interoperability. For example, the NPS Cross-Format Schema Protocol (XFSP) provides a dynamic behavior protocol capability, using XML-defined packet payloads that provide extensible/discoverable/validatable protocols customized for diverse applications.

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 a shared application-level 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 inversely 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 under the IETF's source-specific multicast (SSM) protocol, 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.
- Reliable Multicast Transport. Internet unicast achieves ordered, reliable transmission using Transport Control Protocol (TCP). Reliability is also a major concern for multicast networks, as it is impossible to have fully reliable, order-preserving real-time multicast comparable to TCP in unicast. The IETF is developing reliable bulk-transfer multicast protocols, but these by their nature will not support real-time requirements. An application that needs to know the order of sending must deal with the problem itself by including sequence numbers in its messages. This implies a need to specify XMSF requirements for reliability in the format of a selectively reliable/real-time and fully reliable/non-real-time capability.
- Graceful startup. In the Internet, transmissions are expected to be "TCP friendly" in the sense that they ramp up their sending rate using a "slow start." The IETF currently is considering proposals that will allow TCP to scale better at higher data rates; however the requirement for graceful startup will remain, thus instant startup will be available only in private networks.
- 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 of 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 straightforward 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. See section 6.3 for more information.
- Multi-sensor systems. XMSF must support multi-sensor systems, and thus needs the ability to manage streaming data with low buffering latency and also the ability to 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), or a similar protocol, with addition of an automated setup/teardown capability
  - XML requires network transfer mechanisms such as XML-RPC or SOAP
- Network timing. Network Time Protocol (NTP) and /or Global Positioning System (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 will 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

Table 4-1. Current Networking Protocols of Primary Interest

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 the Real-time 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) and High Level Architecture (HLA). SRMP applications need multicast communication with low latency and reliable transmission of some, but not all, data. http://netlab.gmu.edu/srmp

4.4 Network Services Available Today

QoS and multicast services can be provided today on private networks, including the NGI. In some cases, individual ISPs 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 Mbps; TCP flow control does not scale well to wide-area flows above this.
- Instant startup of high-performance flows is available on private networks only.
- 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 ISPs. Individual ISPs are likely to form agreements that will 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.
- Develop guidelines for effective management of distributed XMSF simulation including session initiation, network monitoring, and authentication procedures for participants, key distribution, software version control, etc.

4.6 Recommendations for Early-Work Networking 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 following 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 proper network 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 M&S needs for networked group communications over a non-multicast network layer as an overlay network.
- Develop mechanisms for end-to-end network status and performance monitoring

These networking efforts should not be pursued in isolation, but rather in cooperation with applications development for XMSF exemplars.

5 Modeling & Simulation Considerations

5.1 Overview

XMSF faces both old and new challenges in the area of M&S. Reasoning about and automated support of composability remain ongoing issues for M&S which XMSF will attempt to improve. Many of the new challenges will include supporting existing technologies in a loosely coupled, distributed environment which doesn't lend itself easily to capabilities we have come to expect in standalone and/or tightly coupled, distributed environments such as time management.

XMSF has an additional critical requirement to integrate with tactical systems to augment the joint common operational picture. XMSF needs to be supported by a public library of useful reusable components, and 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, Aggregate Level Simulation Protocol (ALSP), and HLA will enable XMSF to deliver existing M&S capabilities to new constituencies via web technologies.

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, since the semantics of composition are likely to be outside the scope of XMSF itself. This implies some means of evaluating the suitability of a component for a particular application is required. This applies both for functional matching (e.g. "will this model suffice for my needs?") and for substitution (e.g. "can this model be used in place of the one already in use?").

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 (Command, Control, Communications, Computers and Intelligence) 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. Time Services

XMSF will support real time, scaled real time, time-stepped discrete event, and event-driven discrete-event simulations. Doing so will require time 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

- Bringing working M&S applications matching real-world problems into tactical use.
- Backwards compatibility to HLA Runtime Infrastructure (RTI) and DIS technologies which will not constrain emergence of new capabilities. Explore specific bridging approaches for HLA RTI and DIS over web channels.
- Compatibility with the Joint Technical Architecture (JTA), http://www-jta.itsi.disa.mil.
- Integration of C4I systems to augment joint common operational picture.
- Approaches for distributed-event capture and playback.
- Predicting technology availability: immediate, near-term (1-2 years), likely (3-5 years), and 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 may be incorporated into XMSF. OpenWorlds and Vcom3D are already partly addressing the need for native, small, fast import and export of XML-X3D. XSLT is the candidate technology for conversion of individual content sources into multiple output formats purposed for different user requirements. There is also some work in progress for support of sound and haptics. Specific standards for inclusion include SCORM, XML, X3D, Synthetic Environment Data Representation Interchange Specification (SEDRIS), H-Anim, Computer Aided Design (CAD), and metadata standards.

Further definition of XMSF must be based on focus on extensibility and composability, where composability is defined as the capability to select and assemble simulation components in various combinations into simulation systems to satisfy specific user requirements [Petty 2002]. Two forms of composability are of interest: syntactic and semantic [Pratt 1999, Ceranowicz 2002]. Syntactic composability, meaning compatibility of parameter passing and interface mechanisms, is a capability well within the scope of XMSF. Current research indicates that XMSF might also support semantic composability, in which simulation questions and answers can be meaningfully addressed through consistent use of semantically significant information when integrating simulations.

Table 5-1 lists existing M&S technologies targeted for integration with XMSF.

Table 5-1. Existing M&S Technologies

M&S Technology	Description and Primary References
ALSP Aggregate Level Simulation Protocol	A protocol and architecture for modeling aggregated military entities in constructive simulations. http://alsp.ie.org/alsp
DIS Distributed Interactive Simulation	A real time, entity level, UDP based protocol for simulation of military specific entities on local area networks. State- and entity-based multiplayer updates, with extensive support for diverse physics-based interactions and military applications. http://www.ieee.org IEEE 1278 Example open implementation: http://www.web3d.org/WorkingGroups/vrtp/dis-java-vrml
HLA High Level Architecture	An architecture for interoperability of simulations, both real time and time managed, on LANs and WANs. http://www.dmso.mil, http://www.ieee.org IEEE 1516
SEDRIS Synthetic Environment Data Representation Interchange Specification	A standard for converting environmental representation data between various other standards and formats. http://www.sedris.org

Based on this agreement, the M&S subgroup focused on refining the technical issues to 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. For these purposes, 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.

Table 5-2. Open M&S Issues

Near-Term M&S 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 metadata 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. between different Computer Aided Design (CAD) system file formats. Related to this is the need to map common transformations 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 from a confidentiality perspective and also 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 M&S Issues
• How do we do time management in a highly dynamic environment including both scheduling and synchronization? Wide-area network link latency, highly dynamic joins and leaves, and the persistent nature of presence and access contribute to this challenge. This may require definition of new time management paradigms and mechanisms, e.g. time-to-live on time stamped events. 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 M&S 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 Technical Challenges 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. This effort will require developing communication mechanisms with different constituencies.
- We need to select and develop standards that meet the needs of consumers, government and industry, recognizing that each of these groups has different priorities for scalability, return on investment, ease of use, and security.
- We need to identify and leverage other related efforts, such as the Object Modeling Group (OMG)'s Model Driven Architecture (MDA).
- Security is a cross-cutting concern. An overview of key issues is provided in Section 6.3.

6.2 Strategic Opportunities Symposium Findings

Symposium speakers had a week to consider the draft XMSF whitepaper, and then present their reactions from their perspectives as industry, tactical or programmatic leaders. A diverse group of practitioners and leaders examined XMSF concepts from a variety of perspectives. Symposium presentations were consistently supportive of XMSF goals, often enthusiastically requesting such capabilities as part of their respective programs. This was very encouraging feedback. Discussions were similarly spirited. Much important future work awaits us.

Keynote speaker Dr. Anita Jones posed numerous important questions and ideas, drawing on both successes and lessons learned from previous major M&S efforts such as DIS and HLA. She challenged attendees to consider M&S as the next "killer app" for the web.

Strategic Opportunities Symposium speaker presentations are available on the XMSF website. http://www.MovesInstitute.org/xmsf

6.3 Security Considerations

There are three well-discussed attributes of security: confidentiality, integrity, and availability. Confidentiality is the protection of proprietary or classified information from being accessed (read) by an unauthorized party. Preserving integrity implies that unauthorized users must not be able to modify data or processes without detection. Preserving availability is usually associated with the prevention of denial-of-service attacks or other destructive intrusions. Another security attribute of system design is that of military data aggregation. Based on the type, classification, and amount of data, aggregated data can increase in classification, and/or become designated to a need-to-know security category. Finally, to properly (securely) handle some data requires tracking what its original owner requires for the handling of that data. An example is a copyrighted digital image, which must not be duplicated and distributed, even by a party who bought a copy of the image from the original owner.

The composition of independently secure systems is not necessarily secure because the system has functionality *in toto* that it doesn't have within the constituent components. In particular, the process of joining a distributed simulation has new security implications because the federation needs to know who is joining and whether they're authorized to join. Thus, security must be built into the simulation management protocols.

If the constituent components are secure, they must each have an associated security policy. The security policy for each secure system is only to protect that system, and probably not any other system which interacts with it. This implies that security analysis needs to be performed across the entire composed system. Security analysis traditionally involves verification of interfaces that protect information as it enters and leaves a trusted boundary. Those boundaries are usually defined by the accessibility of the interfaces. Integrating such systems requires reconciling their security policies. In the context of XMSF, this implies that there will be automated, tool-based support for the reconciliation. The security certification and accreditation community is not currently prepared to accept security composability of this type.

Applying the paradigm of defining a framework for XMSF, there is an opportunity to define an XML framework for acceptable security architectures for the individual components of a distributed simulation. The XML framework can define the security profile and metadata standards that allow components to be connected. This can reduce the ambiguity of employing less formally descriptive documents, and permit the descriptive formalization of the security architectures of existing components. This formalized security architecture description can be used in a running system as an authenticated security pass-phase, allowing the system to communicate with the understanding of how metadata is to be exchanged from a security perspective. Ultimately making such an approach work requires constructively engaging the security certification and accreditation authorities who must agree that the approach produces secure systems.

6.4 Additional Issues

Numerous additional topics will merit further examination.

- Determine and list contrary/conflicting technical attributes which ought to be avoided.
- Identify approaches for gaining support of various service operational commanders plus Office of the Secretary of Defense (OSD) C4I and transformation agents as top-level sponsors.
- Provide market analysis of business model and logistics for open-source implementations.
- E-business, U.S. government, DoD and service: registries and repositories for XML.
- 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 by defining common practices for configuration and update. Resources include web-browser plug-ins, installers, updaters, server builders as extensible one-click/automatic utilities, etc.
- Session Announcement Protocol (SAP) and 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 might provide new capabilities (or at least address long-standing barriers to deployment).
- Characterize shared value of "extreme programming" using design patterns and team practices for effective cross-platform, cross-technology software integration and life-cycle sustainability, particularly when employed by teams working across multiple cooperating organizations.

7 Exemplar Demonstrations

Our choice of driving exemplars for XMSF is very important. These must 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 candidates for demonstration:

- Coalition hostage rescue from terrorists holding one hundred ambassadors at a United Nations 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, at first in a 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
- Must support integration of existing technologies/protocols

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 list does not imply any commitment from the named programs and exercises to participate in 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 will 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 may 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 OneSAF Test Bed (OTB), Joint Semi-Automated Forces (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 ultimate 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 can use web technologies with connectivity via open internet technologies with work-around for barriers such as firewalls. The simulation can run at government, industry and academic sites and demonstrated at a highly visible event. The components will then be made available openly for community experimentation.

8 Determining The Path Forward

8.1 Business Model

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.

8.2 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 desirable for broad success.

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

Consortia and Standards Bodies

- World Wide Web Consortium http://www.w3.org
- Web3D Consortium http://www.web3D.org
- Organization for Advancement of Structured Information Standards (OASIS) http://www.oasis-open.org
- International Standards Organization (ISO) http://www.iso.ch
- Institute for Electrical and Electronic Engineers (IEEE) http://www.ieee.org
- Internet Engineering Task Force (IETF) http://www.ietf.org
- Simulation Interoperability Standards Organization (SISO) http://www.siso-stds.org
- Object Management Group http://www.omg.org

Service M&S Management Offices

- DMSO – Defense Modeling & Simulation Office https://www.dmso.mil
- NAVMSMO – Navy Modeling & Simulation Management Office http://navmsmo.hq.navy.mil
- AMSO – Army Modeling & Simulation Office http://www.amso.army.mil
- AFAMS – Air Force Agency for Modeling & Simulation http://www.afams.af.mil
- MCMSMO – Marine Corps Modeling & Simulation Management Office http://www.tecom.usmc.mil/tesb/mcmsmo.htm

SECDEF and Joint Initiatives

- NATO Generic Hub (Trilogy) C4I Tagset Semantic Interoperability
- Defense Information Infrastructure (DII) Common Operating Environment (COE) "plug and play" open architecture with client/server design basis http://diicoe.disa.mil/coe
- DII COE Shared Data Engineering (SHADE) services infrastructure http://diides.ncr.disa.mil/shade
- Future: inevitable need to find web-based interoperability solutions

Navy Initiatives

- Task Force Web https://ucso2.hq.navy.mil
- Information Technology for 21st Century (IT21) http://www.hq.navy.mil/it-21
- Navy Marine Corps Internet (NMCI) https://nmci.spawar.navy.mil
- DON CIO XML Working Group https://quickplace.hq.navy.mil then select ***navyxml***
- Naval Undersea Warfare Center (NUWC) submarine/shipboard combat control systems

Army Initiatives

- Simulation Modeling Acquisition Requirements & Training (SMART) http://www.amso.army.mil/smart
- Joint Virtual Battlespace (JVB) for Future Combat Support http://www.jpsd.org/jvb
- Army Data Portal http://www.us.army.mil

Air Force Initiatives

- Joint Battle Infosphere (JBI)
- Joint Synthetic Battlespace (JSB) http://www.afams.af.mil/programs/projects/jsb.htm

8.3 Diverse Software Architectures

Mapping to diverse architectures, past present and future: the principles presented in Andreas Tolk's contribution regarding the Object Management Group (OMG)'s *Model Driven Architecture* appear to have broad applicability, and may guide a remapping of diverse capabilities to web-based interoperability and Web Services restructuring.

XMSF participants need to examine results of ongoing DMSO workshops on Component Architectures and determine a path for integration with those activities. One approach to getting visible and measurable architectural comparisons might be to develop a mapping of HLA-based RTI Services to Web Services.

8.4 Advanced Distributed Learning (ADL)

The DoD education and training community recognizes that the use of simulations can significantly enhance the student's educational experience. There are many examples of curricula employing stand-alone simulations. There is a lack of standard construction techniques that tie specific skills and competencies to assessed simulation-based learning experiences.

XMSF will allow the modeling and simulation community to connect models and simulations, and live entities (C^4I devices and range interfaces), using web-based standards. The DoD ADL SCORM defines a web-based learning content aggregation model and runtime environment for learning objects. At its simplest, it is a model that references a set of interrelated technical specifications and guidelines designed to meet DoD's high-level requirements for web-based learning content. XMSF must provide a compatible approach for interfacing such learning content and simulation together. XMSF can also benefit from effectively supporting both live and recorded distributed-group communications. Such capabilities are based on the same technologies as real-time distributed virtual simulation and can be applied to education, training and coordination in the networked simulation environment.

8.5 Partnership Strategies for 2003

In summary, XMSF presents numerous transformational opportunities and a comprehensive set of achievable technical challenges. Multiple coordinated strategies are needed for such broad work to proceed. Our partnership strategies for 2003 follow.

- Implementation and development partners. Loosely coupled work on complementary XMSF exemplars will demonstrate the feasibility of various proposed Web, Internet and M&S technologies.
- Shared strategies for sponsoring agencies. Partnered XMSF implementation and development efforts can reduce risk and increase payoffs for individual sponsors. We will explore whether a joint strategic partnership among sponsors can lead to greater global progress.
- Industry partners for common hardware/software resources. Industry players have a strong vested interest in seeing how Web Services applied to XMSF exemplars can resolve long-standing disconnects across the spectrum of defense tactical and M&S applications. We will offer opportunities to contribute hardware, software or programming-team resources for exemplar development by partnered implementers.
- Shared standardization efforts in Web3D Consortium and SISO. Open forums for long-term development of specifications, recommended practices and reference implementations are crucial for repeatable, sustainable success. We expect to propose tandem activities in Web3D and SISO to organize these many efforts.

We are grateful for the work of many contributors as integrated in this report. We look forward to continued focused effort and joint partnerships on these key challenges.

9 <u>Glossary</u>

ADL	Advanced Distributed Learning
ADSL	Advanced Digital Subscriber Line
AFAMS	Air Force Agency for Modeling and Simulation
AFIT/ENG	Air Force Institute of Technology/Engineering
ALSP	Aggregate Level Simulation Protocol
AMSO	Army Modeling and Simulation Office
API	Application Programming Interface
BEEP	Blocks Extensible Exchange Protocol
CAD/CAM	Computer Aided Design / Computer Aided Manufacturing
C4I	Command, Control, Communications, Computers and Intelligence
CIO	Chief Information Officer
CoABS	Control of Agent-Based Systems
DAML	DARPA Agent Markup Language
DIS	Distributed Interactive Simulation
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
DOM	Document Object Model
DON	Department of the Navy
DREN	Defense Research & Engineering Network
DSN	Digital Subscriber Network
FCS	Future Combat System
FTP	File Transfer Protocol
GIF	Graphics Interchange Format
GMU	George Mason University
GPS	Global Positioning System
GUI	Graphical User Interface
HLA	High Level Architecture
HTTP	Hyper Text Transfer Protocol
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” advanced Java network transport
LDAP	Lightweight Directory Access Protocol
MathML	Mathematics Markup Language
MCMSMO	Marine Corps Modeling and Simulation Management Office

MDA	Model Driven Architecture
M&S	Modeling and Simulation
MOVES	Modeling, Virtual Environments, and Simulation
NAT	Network Address Translation
NATO	North Atlantic Treaty Organization
NAVMSMO	Navy Modeling and Simulation Management Office
NGI	Next Generation Internet
NMCI	Navy Marine Corps Internet
NPS	Naval Postgraduate School
NPSNET	NPS Network
NRL	Naval Research Laboratory
NTP	Network Time Protocol
NUWC	Naval Undersea Warfare Center
OASIS	Organization for the Advancement of Structured Information Standards
ODU	Old Dominion University
OIL	Ontology Integration Language
OMG	Object Modeling Group
OSD	Office of the Secretary of Defense
OTB	OneSAF Test Bed
PNG	Portable Networked Graphics
QoS	Quality of Service
RDF	Resource Description Framework
RPC	Remote Procedure Call
RTI	(HLA) Run Time Infrastructure
RTCP	Real-time Control Protocol
RTP	Real-time Transport Protocol
SAF	Semi-Automated Forces
SAI	Scene Authoring Interface
SAIC	Science Applications International Corporation
SAP	Session Announcement Protocol
SCORM	Sharable Content Object Reference Model
SEDRIS	Synthetic Environment Data Representation Interchange Standard
SIGGRAPH	(Association for Computing Machinery) Special Interest Group on Graphics
SINCGARS	Single Channel Ground and Airborne Radio System
SIP	Session Initiation Protocol
SISO	Simulation Interoperability Standards Organization
SMART	(Army) Simulation Modeling Acquisition Requirements & Training
SMIL	Synchronized Multimedia Integration Language
SMTP	Simple Mail Transfer Protocol
SOAP	(originally) Simple Object Access Protocol, now simply SOAP
SRMP	Selectively Reliable Multicast Protocol
SSM	Source-Specific Multicast
SVG	Scalable Vector Graphics
TCP	Transport Control Protocol
TRAC	(Army) Training & Doctrine Command Analysis Center
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
VHF	Very High Frequency
VPN	Virtual Private Network
W3C	World Wide Web Consortium
WSDL	Web Services Description Language
X3D	Extensible 3D Graphics
XHTML	Extensible HyperText Markup Language
XKMS	XML Key Management Specification
XML	Extensible Markup Language
XMLP	XML Protocol
XMSF	Extensible Modeling and Simulation Framework
XSLT	Extensible Stylesheet Language for Transformations

10 References

Numerous references of direct interest are included on the XMSF website, contributed as point papers and presentations during the XMSF Workshop and XMSF Symposium. These resources are primary references for further information on XMSF design issues.

Appendices C and D list individual contributors and their corresponding subject areas of interest. http://www.MovesInstitute.org/xmsf

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Table 10-1. IEEE DIS and HLA References

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IEEE Standard 1278.4-1997, Trial-Use Recommended Practice for Distributed Interactive Simulation--Verification, Validation, and Accreditation, 1997.
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APPENDIX A. TECHNICAL CHALLENGES WORKSHOP ATTENDEES

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

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
Philomena 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. Steve Carson	GSC Associates	Systems engineering, communications engineering, SEDRIS and ISO
Dr. Suleyman Guleyupoglu	NRL	CEEs, works with Henry Ng
MAJ Dave Laflam USA	AMSO	Communications, signals modeling
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 L. 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, virtual reality 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
Dennis Moen	GMU	Multicast and distributed networking
Matt Beitler	Univ. Pennsylvania	Humanoid animation
Total attendees - 39		
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 L. Morse, Mike Zyda
Workshop goals, agenda and outcomes. MOVES Open House.

0830 XMSF and Technical Workshop Overview.
Motivation, milestones and goal outcomes.
Whitepaper 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 L. 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 September, GMU

1200 Workshop complete

APPENDIX C. TECHNICAL CHALLENGES WORKSHOP POINT PAPERS

http://www.MovesInstitute.org/xmsf/xmsf.html#Workshop

Speakers	Point Paper Contributions
Don Brutzman, NPS	NPS Workshop welcome, plan of action
Web/XML Group	
Don Brutzman, NPS	Moderator: Group discussion report
Mike Bailey, TECOM/MCMSMO	Marine Corps Modeling & Simulation Issues
Erik Chaum, NUWC	NATO Trilogy: Shared Operational Context brief and Transformation Cornerstone: Operational Context paper
Justin Couch, Yumetech	Interoperable Media Player Toolkit (IMP)
Rob Glidden, Sun Microsystems	Web Services
David Kwak, MITRE	IT/Web Technologies integration to DOD M&S, and Its Future Direction
Francisco Loaiza, IDA	Web-Based Simulation
Chenghui Luo, Fraunhofer CRCG	XMSF Security: XML and DRM Issues
Ed Sims, VCom3D	Humanoid animation, SEDRIS, ADL SCORM, and Speech Application Programmer's Interface XML (SAPI-XML) Markup,
Andreas Tolk, ODU	Avoiding another Green Elephant – A Proposal for the Next Generation HLA based on the Model Driven Architecture
Phil Zimmerman, DMSO	GameBoy Composability
Internet/Networking Group	
Mark Pullen, GMU	Moderator: Group discussion report
Rusty Baldwin, AFIT/ENG	Communication systems modeling
Scott Bradner, Harvard	IP transport
Suleyman Guleyupoglu, NRL	Collaborative Engineering Enterprise
MAJ Dave Laflam USA, AMSO	Networking needs for Army knowledge portal
Sue Numrich, DMSO	Large-scale M&S network strategies
Norbert Schiffner, Fraunhofer CRCG	Communication Framework for XMSF
Marcello Zuffo, University of São Paulo, Brazil	Cluster and grid computing

Modeling & Simulation (M&S) Group	
Katherine L. Morse, SAIC	Moderator: Group discussion report
Steve Carson, GSC Associates	ISO, SEDRIS position paper on key challenges
Paul Diefenbach, OpenWorlds	Advanced 3D graphics rendering
Niki Deliman Goerger, TRAC/ERDC	Terrain and land environmental databases
Alan Hudson, Yumetech	Interoperable Media Player Toolkit (IMP)
Cristina Russo Dos Santos, Eurecom and University of Toulon, France	Networked 3D Visualization Requirements
Kalyan S. Perumalla, Georgia Tech	Time mechanisms and services
Mikel D. Petty, ODU (unable to attend)	Semantic Composability and XMSF
Dick Puk, Intelligraphics Inc	Expanding the Role of Simulation
Sanjeev Trika, Intel	Key Opportunities for Web-based Modeling and Simulation

APPENDIX D. STRATEGIC OPPORTUNITIES SYMPOSIUM AGENDA

http://www.MovesInstitute.org/xmsf/xmsf.html#Symposium

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, 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 L. Morse, SAIC
Defense Impact: Dr. Mike Zyda, NPS

1030 Technologists' Perspectives on XMSF
(Chair: Dr. Katherine L. Morse, SAIC)
Commercial M&S Web Technologies: Rob Glidden, Sun Microsystems
Commercial CAD-to-Web efforts: Sanjeev Trika, Intel
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)
U.S. Marine Corps: Dr. Mike Bailey, USMC Combat Development Command, MCMSMO
U.S. Navy: Dana Paterson, FORCENet
Joint: Phil Zimmerman, DMSO

1400 Programmatic Perspective on XMSF
(Chair Dr. Mike Zyda, NPS)
MAJ David Laflam U.S. Army, AMSO
Ms. Phil Zimmerman, DMSO
Mr. Steve Swenson, NAVMSMO
Mr. Alan Murashige, HQ U.S. Air Force XIW (invitee)

1515 Open-Mike Session (Chair: Dr. Mark Pullen, GMU)

APPENDIX E. CONTACT INFORMATION

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