ABSTRACT

The Air Force envisions an integrated, common modeling and simulation (M&S) environment that will be accessed by analysts, warfighters, developers, and testers supporting the range of Air Force tasks, from determining requirements through conducting operations. This paper summarizes trends in the new vision for M&S and in the simulation technology that can be employed to implement the simulation systems of the future. Joint M&S standards will provide key advanced technologies for future simulation applications. The Joint Modeling and Simulation System (J-MASS) is a key ingredient in these new technologies and is envisioned as the modeling system for the development, acquisition, and test and evaluation process.

THE NEW M&S VISION

M&S is already an integral part of the way the Air Force conducts business. It is spread throughout the Air Force enterprise from research and development, acquisition, and sustainment, to training and operations.

Throughout the rest of the decade, the use of M&S will increase throughout all functional areas in the Department of Defense (DoD). Because of increased technical capability and increased fiscal constraint, M&S utilization will continue to expand as other budgets are reduced. M&S allows DoD organizations to do things that would otherwise be unaffordable (i.e., thousands of parametric sensitivity tests on new systems) or physically difficult to accomplish (military worth studies on proposed force structures against threat command and control systems). The importance of M&S has resulted in a DoD Directive on "DoD Modeling and Simulation Management," that provides for a DoD M&S Master Plan. The Master Plan was signed by Paul Kaminski, Under Secretary of Defense for Acquisition and Technology, in October 1995 and is approved for public release through the National Technical Information Service. As part of the Master Plan, DoD intends to establish a common high-level simulation architecture to assure
the appropriate interoperability of simulations, and their interface with command, control, communications, computers and intelligence systems. The goals of the HLA include: interoperability, reuse, portability, distributed operation, legacy operation, scalability, broad applicability, technological evolvability, and maximum feasible use of commercial off-the-shelf (COTS) and government off-the-shelf (GOTS) products.

Today's simulations are narrowly focused, stove-piped developments for each user community. They do not fully meet joint needs; take too long to build; cost too much to build and operate; have not been verified, validated and accredited; are not interoperable with other M&S assets; and are not easily maintainable or extensible. There is high level DoD and Air Force consensus on the need to interoperate and reuse models, simulations, and related products across Service lines, across traditional communities (e.g., linking models and simulations to C4I systems), across functions (e.g., sharing capabilities between operations and acquisition), and across classes of models and simulations (e.g., linking live, virtual, and constructive simulations). The effective use of models and simulations across DoD requires a common technical framework for M&S in order to insure interoperability and reuse. The technical framework will consist of a common high-level architecture (HLA) to which models and simulations must conform; conceptual models of the mission space (CMMS) to provide a basis for the development of consistent and authoritative simulation representations; and data standards to provide common representations of data across models, simulations, and C4I systems.

There is general agreement that no single model or simulation system can satisfy all uses and users. Further definition and detailed implementation of the specific simulation system architectures, which will be HLA compliant, will remain the responsibility of the developing Service or Agency. The HLA will specify only the minimum definition required to facilitate interoperability and reuse. The primary components of the HLA include:

- **Functional Definition** -- a set of rules that describe the functions of simulations and the services provided by the runtime infrastructure in a HLA federation (a set of interacting simulations)
- **Interface Specification** -- simulations interact with a runtime infrastructure to establish and maintain a federation and to
enhance information exchange among simulations.

- **Object Model Template** -- each federation has an object model describing the entities represented in the simulations and across the federation.

The DoD High Level Architecture is central to the M&S Master Plan. One way to view this simulation High Level Architecture is to think of a city planner or architect. A building is compliant as long as you get the right permits and follow the building codes and standards. Similarly, new models would be required to follow specific standards to fit within a certain general architecture. The DoD M&S Master Plan requires a review and oversight of all ongoing DoD M&S projects and programs for feasibility of adoption and compliance with the HLA. Each program must establish a date by which it can comply with the HLA.

A NEW VECTOR FOR AIR FORCE M&S

Consistent with the DoD vision, the Air Force envisions an integrated, common M&S environment accessed by analysts, warfighters, developers, and testers and supporting the range of Air Force tasks, from determining requirements through conducting operations. An Air Force Four Star M&S Summit was convened 9 June 1995 to create an M&S roadmap. The roadmap defines a future vision for Air Force simulation and describes near-term and midterm goals that move the Air Force closer to this vision and also a consistent representation of aerospace forces for Joint use. The key concept in the Air Force M&S vision is the Joint Synthetic Battlespace -- an integrated M&S environment, connecting analysis and training and tying together many types of simulation. The simulations extend from high level aggregate models to detailed engineering models, from pilots in live aircraft and simulators to hardware components and laboratory test beds.

![Figure 3. The Air Force M&S Architecture](image)

The AF M&S Infrastructure focuses on three key initiatives:

- **Joint M&S Integration Program (JMSIP)** - a coordinated approach to improving air and space representation in our legacy models and simulations while consolidating into fewer models that meet the requirements of many

- **Joint Standards** -- a commitment to Joint M&S developments with supporting Air Force initiatives

- **Advanced Distributed Simulation** Leveraging -- programs to provide high-speed connectivity between Air Force installations, multiple networked air combat training simulators for each wing in the Air Force, and a synthetic
battlespace for Joint Force Air Component Commanders.

In the near-term, JMSIP will address both the need to corporately address M&S improvements and the need to encourage consolidation. It will serve as a leveraging fund, allocating funds in a manner that maximizes common efforts and targets improvements based on a corporate assessment of their importance and urgency.

For the mid-term and in accordance with overall DoD direction, the Air Force will implement simulation standards through defined architectures and simulation systems that support them. Standards will generate greatly improved simulation interoperability, allowing the Air Force to leverage simulation investments. Three major simulation standards efforts are targeted in the roadmap for high-level Air Force oversight and investment. All will participate and adhere to the DoD High-Level Simulation Architecture initiatives being directed by DDR&E and managed by the Defense Modeling and Simulation Office. The Joint Simulation System (JSIMS) is a distributed, object-oriented simulation architecture and system focused on the operational level of war (campaign and mission level simulation). The Joint Warfare Simulation (JWARS) is focused on Joint campaign analysis. The Joint Modeling and Simulation System (J-MASS) is an Air Force-directed program to develop and deliver a distributed, object-oriented simulation architecture and system focused on the tactical level of war (mission and engagement simulations.)

These Joint standards and the systems that support them will enable interoperability and reusability of Air Force M&S tools across key communities and processes. These Joint standards serve as GOTS frameworks for the addition of third party applications. These initiatives, coupled with ongoing improvements and standards will bring the Air Force measurably closer to the objective of a common, integrated M&S system.

COMPUTER & SIMULATION TECHNOLOGY TRENDS

The above changes and resultant revision in the DoD and Air Force M&S visions have been motivated by changes in computer and simulation technology. Computer hardware technology has improved several orders of magnitude in the past decade: microprocessor speed alone has increased about 100 fold. The overwhelming trend is faster, smaller, and cheaper. This reduction in cost and size coupled with the increase in speed and capacity has resulted in a massive increase in simulation capability. Computational power continues to increase as prices decrease. As the decade moves on, a multiprocessor on the desktop will be commonplace for simulation and analysis. It will be accompanied by the continued decentralization away from the central site to distributed computing -- personal processors close to the user mixed with computationally intensive servers on a heterogeneous network.

Object-oriented (OO) software technology is having a major impact on simulation technology as it is on software in general. OO software addresses three major problems for software developers: iterative development, reuse, and maintenance. Since upfront requirements definition is difficult, many successful OO projects have employed an evolutionary, iterative process for development. Object-orientation can also promote reuse through a library of reusable objects. OO technology when combined with reuse and visual programming can increase productivity and therefore lower cost and decrease time for software development. Software development has been historically labor intensive. To date, even computer aided software engineering (CASE) tools have not dramatically increased productivity. A major paradigm shift is required to produce the needed improvement. OO technologies combined with visual approaches and an engineering discipline to software development via a software structural model methodology can finally bring the needed breakthrough. OO technology will allow implementation of component based software as the construct for software reuse. By employing component base design, users can be divided into four roles:

- **Appliers** -- who configure input data and execute existing simulations
- **Assemblers** -- who establish connections among component parts found in a reuse library to build simple custom applications or models without professional programming assistance
- **Power Assemblers** -- who go beyond piecing component parts together by implementing more complex logic
• Fabricators -- who can build new component parts

Advanced User Interfaces will extend the now common Graphical User Interface (GUI) into an agent-based multi-sensor user interface that will incorporate features such as voice synthesis and voice recognition. Future computer software architectures will incorporate Manager-Agent and Remote Programming -- the client computer sends an object that the server executes. The object is called an agent because it acts on behalf of the sending computer. In Remote Programming, the client and server can interact independently of the network once it has been transported between them. These intelligent agents act like assistants rather than tools: they will show more initiative, assume responsibility for larger subtasks, and take appropriate risks (rather than confirming every detail with the user).

As computer and software technologies advanced, they have changed the face of modeling and simulation. Simulation technology has evolved from standalone models to model hierarchies to an integrated modeling system.

Future advanced modeling systems will include the following characteristics:

• Open systems architecture supporting applications conforming to commercial and industry standards
• Visual paradigm -- visual programming, visual assembly, visualization of output results
• Object based to allow component reuse
• Extensible architecture for future software concepts
• Execution on distributed heterogeneous network of workstations and upscale PCs
• Tools to support development of model components
• Multiple language support -- the user can specify the target source language (C, C++, Objective C, Ada83, Ada95, VHDL, etc.)
• Object oriented database
• Tools and models support a “Plug and Play” concept
• Supports “distributed model development” by the domain experts as opposed to central model development by software experts
• Provide a repository of models and their components
• Documentation designed to support software reuse
• Verification, Validation, and Accreditation (VV&A) integral to the software development
• Ability to interface to IEEE Distributed Interactive Simulation (DIS) standard
• Compliant with the DoD High Level M&S Architecture

J-MASS TECHNOLOGY
An increasingly important component of the M&S Vision is Joint models, simulations, and M&S standards. The Air Force is committed to supporting these Joint M&S developments with supporting Air Force initiatives. The Joint Modeling and Simulation System (J-MASS) is an Air Force-directed program to develop and deliver a distributed, object-oriented simulation modeling system focused on mission and engagement simulations.

Table 1. Future M&S Characteristics & J-MASS Technology

<table>
<thead>
<tr>
<th>M&amp;S Characteristics</th>
<th>J-MASS Rel 3.0/a</th>
<th>Future Release</th>
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<tbody>
<tr>
<td>Open Systems Architecture</td>
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<tr>
<td>Visual Paradigm</td>
<td>X</td>
<td>Enhancements</td>
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<tr>
<td>Object based for component reuse</td>
<td>X</td>
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<tr>
<td>Extensible Architecture</td>
<td>X</td>
<td>Enhancements</td>
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<tr>
<td>Distributed Heterogeneous Network</td>
<td>X</td>
<td>Enhancements</td>
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<tr>
<td>Tool for Model Development</td>
<td>X</td>
<td>Enhancements</td>
</tr>
<tr>
<td>Multiple Language Support</td>
<td>C++, Ada83</td>
<td></td>
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<tr>
<td>Object Oriented Database</td>
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<tr>
<td>Plug &amp; Play</td>
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<td>X</td>
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<tr>
<td>Distributed Model Development</td>
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<td>X</td>
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<tr>
<td>Model Repository</td>
<td>X</td>
<td>Enhancements</td>
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<td>Model Documentation Supports</td>
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<tr>
<td>Reuse</td>
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<tr>
<td>Integral VV&amp;A Process</td>
<td>In Progress</td>
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<tr>
<td>DIS Support</td>
<td></td>
<td>X</td>
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<tr>
<td>HLA Compliant</td>
<td>In Progress</td>
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J-MASS will provide a common environment for tactical modeling across the requirements, development, acquisition, and test process. Coordinated efforts are currently underway to populate the system with authoritative representations of Air Force and threat systems (e.g., surface-to-air missiles, aircraft, etc.) that interoperate and comply with J-MASS standards. J-MASS is an Air Force advanced simulation technology program that already has many of the above characteristics for future M&S systems as shown in Table 1. Considering user requirements, future J-MASS releases will move into other advanced technology areas.

SUMMARY:

The future vision for Air Force simulation is a flexible, integrated simulation environment that supports the full range of Air Force activities. Revolutionary and evolutionary advances in computer and software technology provide significant opportunities to implement this modeling and simulation vision. The new M&S technologies will permit the creation of simulations tailored to the user's need, at a greatly reduced cost in both time and money, and with elements of proven quality. Patience, perseverance, and significant investment are required to overcome many challenging problems, but the potential payoff is extremely high.