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EXECUTING THE MODELING AND SIMULATION STRATEGY MAKING SIMULATION SYSTEMS OF SYSTEMS A REALITY

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ABSTRACT

The widespread use of advanced modeling and simulation (M&S) is necessary if the Department of Defense (DoD) is to cost-effectively maintain readiness, accomplish its operational missions, make optimal investment decisions, and achieve dramatic acquisition savings. To this end, the DoD has established a strategy to foster simulation interoperability and reuse, calling for them to work together as a community, in systems of systems. The "city planning" strategy calls for the establishment of a common technical framework (CTF), to which simulations must conform, and the sharing of common services needed by each developer and user.

1 INTRODUCTION

In the late 1980s and early 1990s, the DoD and Congress began to comprehend the vast potential of advanced modeling and simulation to revolutionize the way the Department makes decisions and conducts its operations. DoD has used M&S in many diverse ways through most of its history, but advances in information technology capabilities and the advent of the distributed interactive simulation concept, evidenced by projects such as Defense Advanced Project Agency's (DARPA) Simulation Network (SIMNET), clearly signaled that major increases in simulation capabilities were possible.

Further encouraged by several Defense Science Board studies pointing to the potential benefits, the Department decided it should make the use of advanced simulation a corporate priority. Thus in the summer of 1991, the Deputy Secretary of Defense put a single individual, the Under Secretary of Defense for Acquisition (now Under Secretary of Defense for Acquisition and Technology (USD(A&T)), in charge of the Department's simulation efforts. At the same time the USD(A&T) established a flag-level Executive Council on Modeling and Simulation (EXCIMS) and stood up the Defense Modeling and Simulation Office (DMSO) as a new organization within the Office of the Director of Defense Research and Engineering (DDR&E). The DMSO was designated the focal point for M&S matters across the department. This management structure was subsequently codified in DoD Directive 5000.59, "DoD Modeling and Simulation (M&S) Management", of January 4, 1994.

In March of 1992, the EXCIMS, chaired by the DDR&E, crafted a vision for DoD M&S. While there were and continue to be many individual requirements documents for simulation developments, DoD needed a capstone requirement -- a statement of its overall goal for this new simulation initiative. The EXCIMS crafted a DoD M&S vision calling for the establishment of readily-available, operationally-valid synthetic environments to support a full range of application areas (e.g., joint training and doctrine development, formulation and assessment of operational plans, and support of the acquisition process and force structuring). Importantly, the vision also says these environments will be constructed from affordable, reusable components interoperating through an open systems architecture.

Achieving this DoD M&S vision requires an extraordinary DoD-wide cooperative effort. Operating under the guidance of the DDR&E and the EXCIMS, DMSO's mission is to perform those key corporate-level functions necessary to foster cooperation, synergism, and cost-effectiveness among the M&S activities of the DoD Components, such that together they optimally contribute to realizing the vision.

The vision called for achieving interoperability and reuse as a fundamental strategy to satisfy DoD's simulation needs. Clearly it was not possible to build just a few simulations to satisfy the broad needs of DoD. Any simulation would be an abstraction of the real-world, driven by the goals of its sponsor. Thus there would need to be many different simulations which certainly could not be individually planned and controlled by one central office. However, at the other

extreme, the cost of building narrowly-focused, "stove-piped" simulations to satisfy each of the ever-expanding simulation requirements would be too high. Reuse needed to be fostered wherever possible.

The DoD M&S community appreciated that cost, time, and risk benefits would come from reusing existing simulations to address new requirements, flexibly connecting existing representations together to create new simulation environments. Demands for the reuse of simulations came soon and frequently, often even before their development was complete, but it proved difficult to achieve the necessary interoperability. Thus the key technical question was how to facilitate interoperability and reuse. The Distributed Interactive Simulation (DIS) and Aggregate Level Simulation Protocol (ALSP) interoperability standards, which had emerged in the early 1990s, represented major advances in achieving interoperability, but each applied to only a particular application domain, had significant technical limitations, and could not satisfy the broad simulation interoperability and reuse goals of the DoD. A new approach was required.

As these lessons were learned, DoD, led by the DDR&E, then Dr. Anita Jones, established a new, more comprehensive strategy to foster broad interoperability and reuse. The analogy was drawn to planning a city, calling for simulations to work together as a community, in systems of systems. To build and operate an efficient city, a governing framework (e.g., street plans, building codes, ordinances) is laid out and certain basic services (e.g., utilities, schools, fire protection) are provided. Beyond that the residents are generally left to their own discretion as to what type of home or business they build, who they interact with in the city, etc. To foster a community of simulations capable of being composed into federations to address whatever requirements emerge, likewise requires a common technical framework and a set of common services. This concept is communicated in the following figure.

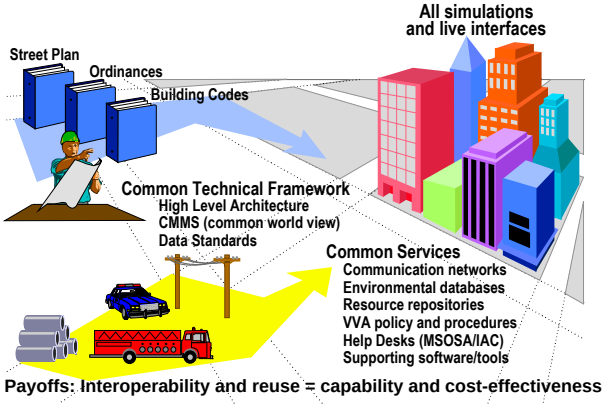

Figure 1: DoD M&S Strategy - An Analogy to City Planning

This "city planning" strategy is captured in the first DoD-wide M&S Master Plan, DoD 5000.59-P, which was signed in October 1995 after formal coordination across all DoD Components. The M&S Master Plan (MSMP) identified six objectives necessary to achieve DoD's M&S vision. The first, and most important, of these objectives calls for the establishment of a common technical framework (CTF), to which individual simulation developments must conform. The MSMP also calls for the sharing of common services among simulation developers and users. By this strategy DoD expects to foster interoperability, reusability, cost-effectiveness, and greater capability.

2 COMMON TECHNICAL FRAMEWORK

The CTF consists of three parts, the most important of which - the CTF cornerstone - is the high-level architecture (HLA). An "architecture" defines the major functional components, design rules, and interfaces for a computer-based simulation system. It specifies (conceptually) how they hook together and work together as a whole. It is of course distinct from the software which is required to implement it.

The other two legs of the common technical framework are a common understanding of the real-world (termed a conceptual model of the mission space, or CMMS) and data standards.

2.1 High Level Architecture:

The HLA has been developed, tested, and established as the standard technical architecture for all DoD simulations. DoD policy now requires all simulations, byOctober 1, 2000, to comply with the HLA, be retired, or obtain a waiver from the USD(A&T). As of August 1, 1997, approximately 403 simulations have committed to HLA compliance.

The HLA was developed by an EXCIMS-chartered, DMSO-led consortium of major simulation programs, supported by government, academic, and commercial representatives. In taking this approach, DoD emulated the commercial industry standards development processes. This was a significant innovation for the Department and one of the major ingredients for the success of the HLA enterprise. It allowed broad community participation in the HLA development process, fostered ownership of the HLA, and expanded the technical experience base. The forum for this development effort is called the Architecture Management Group (AMG). AMG members built multiple prototypes to investigate technical approaches in various applications (e.g., training, analysis, engineering). The AMG still meets regularly to guide the evolution of the HLA.

The HLA is not software but a set of rules and specifications that prescribe how simulations, live systems (e.g., command and control systems, weapon systems on instrumented ranges), and supporting utilities such as data collectors and wide-area viewers will work together as a federation. The HLA separates the representations, provided by simulations or live systems, from the general interconnection services, provided by a Runtime Infrastructure (RTI).

The HLA is defined by three things: rules, an interface specification, and an object model template. The ten HLA Rules establish the requirements for federation components (termed federates) and the federation as a whole. The HLA Object Model Template (OMT) specifies a standard form in which federates and federations must be described. Finally the HLA Interface Specification describes the ways simulations interact with the supporting RTI software during a federation operation.

The RTI, which can be thought of as a special-purpose distributed operating system, provides a set of management services to the federation. These include federation management, declaration management, object management, ownership management, time management, and data distribution management. The HLA does not specify a particular software implementation, just that there will be a RTI. However, to facilitate cost-effective implementation of the HLA, DMSO is developing an initial suite of HLA supporting software. This software is openly distributed in the public domain through the DMSO homepage (http://www.dmso.mil). Open access to the various specifications (e.g., OMT data interchange format) is available through the same source. This is intended to facilitate broad adoption of the HLA and development of commercial software tools to support HLA implementation.

The HLA is garnering much international and commercial interest. The North Atlantic Treaty Organization (NATO) has established a high-level steering group on M&S which is evaluating the HLA as a potential NATO Standard to facilitate simulation interoperability and reuse. The Simulation Interoperability and Standards Organization (SISO) has begun the process of establishing the HLA as an Institute of Electrical and Electronics Engineers (IEEE) standard. The DARPA Synthetic Theater of War (STOW), with United Kingdom participation, is using the HLA and pushing technology boundaries in a number of important areas, including scaleability, command and control representation, and representations of the natural environment. Many foreign nations have begun HLA-based simulation developments.

2.2 Conceptual Models of the Mission Space:

Conceptual Models of the Mission Space (CMMS) are a first abstraction of the real world activities associated with a particular mission area. Such conceptual models provide an entities, actions, tasks, and interactions (EATI) representation of the military mission space which is independent of any specific computer-aided software engineering (CASE) tool or utility employed to capture it. These functional descriptions are intended to serve as a representational resource, capturing information about various military operations, to be used by simulation developers and others. This information will be derived from authoritative sources, described using common syntax and semantics, and independent of any particular simulation implementation.

Development and sharing of the CMMS is a responsibility shared among various organizations in the DoD. Warfighters act as the authoritative source for how the world works, specifying mission-essential task lists and doctrine. Simulation developers cooperatively perform the knowledge acquisition. DMSO is developing the database management system, providing knowledge acquisition teams with technical support (e.g. common semantics and syntax, data interchange formats), registering the resulting CMMS data provided by the simulation developers, and allowing wide access to the CMMS database as it is filled.

Other related DMSO efforts such as the Modeling and Simulation Resource Repository (MSRR) and the Data Standards work will provide the infrastructure and technologies needed to support CMMS. The MSRR will provide CMMS access to simulation developers, doctrine developers, trainers, and other interested parties. The CMMS database management software

will support a variety of structured views for the display and manipulation of these conceptual models. A Data Interchange Format (DIF) standard has also been developed for the conversion, integration, storage, and extraction of these conceptual models.

The CMMS is a work in progress. The initial focus of the CMMS effort is on the military operational mission space. It is now beginning to be populated and several evaluation experiments are being conducted.

2.3 Data Standards

DMSO is leading an effort to develop M&S data standards as directed by the DoD MSMP. DMSO has also been delegated the M&S Functional Data Administrator (FDAd) mission and authority. As a result, our Data Standards activities are coherent with the execution of the larger DoD Data Administration Program promulgated under DoD Directive 8320.1. DMSO's data engineering efforts have four thrusts. The first is the development of Common Semantics and Syntax (CSS) and associated DIFs. CSS are the logical structure and content (meaning) of any specific model or data element. DIFs are the physical representation (e.g., Backus-Naur Form, Structured Query Language, bits and bytes) of data which programmers employ to interchange complex data fields

The second thrust of the data standards effort is the identification of authoritative data sources (ADS). An ADS tells developers and users where to go for the best data. Each military service is identifying the appropriate ADS associated with its varied responsibilities (e.g., weapon system characteristics and performance, order of battle) and providing that information to DMSO for incorporation in the MSRR. A total of 161 authoritative data sources have been designated as of August 1, 1997.

The third thrust is the establishment of standard Data Quality practices to provide a means to ensure databases are complete and coherent. The fourth thrust is the establishment of Data Security practices (DS) to guide the sensitive matter of data access and release.

Data standards are intended to facilitate the creation, management, and exchange of information data sources, simulation developers, and simulation users for all phases of simulation operations -- development, initialization, runtime interchange, and post-execution review. They will be employed in the drafting of HLA Simulation Object Models (SOMs) and Federation Object Models (FOMs), CMMS, and in the authoritative representation of the natural environment, units, systems, and human behavior.

Some of data standards efforts have been delegated to agents other than DMSO. For instance, data standards for the natural environment are managed under the leadership of the DoD M&S Executive Agents for the Natural Environment (see below). Their key data standards project is the Synthetic Environments Data Representation Interchange Specification (SEDRIS).

3 COMMON SERVICES

A broad range of common services are being developed to support both users and developers of M&S.

3.1 Modeling and Simulation Executive Agents:

To provide focus, coordination, centers of excellence, cost avoidance, and broad support to the M&S community in common and general use areas, the DoD has designated four M&S Executive Agents (MSEAs) to serve the broad M&S community. They represent the domain areas of the natural environment (terrain, oceans, aerospace) and foreign forces and joint and national intelligence processes. They are cooperatively attacking the tough technical problems and speeding the development and delivery of authoritative representations for their respective domains.

3.1.1 Natural Environments

The second major objective of the DoD M&S Master Plan (MSMP) is to provide timely and authoritative representations of the natural environment, which are subdivided into the terrain, ocean, atmosphere, and space domains.

In April, 1995, the USD(A&T) designated the Director, Defense Mapping Agency (DMA) as the DoD MSEA for Authoritative Representation of the Terrain Natural Environment. DMA established a Terrain Modeling Project Office (TMPO) to execute its MSEA responsibilities. This MSEA designation is now part of the National Imagery and Mapping Agency (NIMA) which has continued to execute through the TMPO.

The Secretary of the Navy and the Secretary of the Air Force were designated MSEAs for the Ocean and Air and Space Natural Environments respectively in April, 1996. Within the Navy, authority to execute MSEA responsibilities was passed to the Oceanographer of the Navy who established an Ocean Executive Agent (OEA) Office, currently located at the Naval Research Laboratory in Washington, DC. MSEA execution authority within the Air Force was passed through the Director of Weather to the Commander, Air

Force Combat Climatology Center (AFCCC), located at Scott Air Force Base, Illinois.

The MSEAs for the natural environment work closely together and have generated a Joint Strategic Plan. This plan is designed to coordinate MSEA activities in all environmental domains and provide a consolidated view of MSEA operations to the M&S Community. It fully supports the joint MSEA mission of enabling developers and users to represent the natural environment rapidly, thoroughly, authoritatively, and consistently in a manner that promotes cost-effectiveness, ready access, interoperability, re-use, and confidence. The document is available for review through the following environmental MSEA homepages:

- Air and Space: http://thunder.safb.af.mil/html/msea
- Ocean: http://rsd-www.nrl.navy.mil/OceanEA
- Terrain: http://www.tmpo.nima.mil

Two key accomplishments of the Environmental EAs have been the development of SEDRIS, a fully-attributed data standard, to facilitate the rapid, cost-effective production and interchange of natural environment data, and a Master Environmental Library (MEL), to improve the sharing of existing environmental databases. SEDRIS is successor to the Simulator Interchange Format (SIF). MEL has been established to provide ready, on-line access to a wide range of natural environment databases. MEL is available as a resource within the Modeling and Simulation Resource Repository described later in this paper.

3.1.2 Foreign Forces and US National and Joint Intelligence Processes

The Director of the Defense Intelligence Agency (DIA). is the MSEA for the Representation of Foreign Forces and US National and Joint Intelligence.

DIA's MSEA responsibilities for authoritative representation of foreign forces and the US National and Joint intelligence processes support Objectives one, three, and four of the DoD MSMP. The term "foreign forces" includes foreign military forces, systems, behaviors and capabilities.

Some key customers served by the Intelligence MSEA include the program managers for the Joint Simulation System (JSIMS), the Joint Warfighting System (JWARS), the Joint Modeling and Simulation System (JMASS), and the Directors of Intelligence, or J-2s, for the warfighting Commanders-in-Chief (CINCs).

The development of data to support M&S efforts with more robust representation of foreign forces is based on intelligence programs already under way by DIA and the other Military Intelligence Board (MIB) components. MIB components are assigned intelligence production tasks based on their Service or CINC Area of Operation responsibilities. Intelligence data for both M&S and other applications will be made available via the Modernized Integrated Data Base (MIDB) for general military intelligence and the Military Equipment Parameters Data Base (MEPED) for technical aspects of foreign weapons and systems.

3.2 Communication Services

Although most simulation executions may take place within a single facility or involve only limited point-to-point wide area communications, others require comprehensive wide-area communications support among multiple sites. Additionally these distributed simulations may require multi-cast and bandwidth reservation services which are not generally available within either commercial or defense communication networks. Beginning with establishment of the Defense Simulation Internet (DSI) and now migrating to Enhanced Internet Protocol (IP) services within the Defense Information Services Network (DISN), DARPA and the Defense Information Systems Agency (DISA) have cooperatively put in place the necessary communication capabilities required to support such simulation activities. These include multicast and bandwidth reservation services to maximize efficiency and reliability for large-scale applications.

3.3 Verification, Validation, and Accreditation

Verification, Validation, and Accreditation (VV&A) supports establishing the credibility of models and simulations. It also helps reduce risk by identifying potential problems and errors early in the development cycle. Verification is a determination of whether a model meets the developer’s conceptual description. Validation determines whether a model or simulation is an accurate representation of the real world from the perspective of its intended use. Accreditation is an official certification that a model or simulation is acceptable for a specific purpose.

As the employment of simulation plays an increasingly important role within DoD, the importance of VV&A is being likewise recognized as more critical. Developers and sponsors are struggling with how to perform these tasks in the most cost-effective manner. DMSO sponsors a VV&A Technical Working Group to provide an M&S community forum for addressing VV&A issues.

An important first step in addressing VV&A issues was the approval of a DoD policy instruction, DODI

5000.61, DoD Modeling and Simulation (M&S) Verification, Validation and Accreditation (VV&A)", April 29, 1996. It established VV&A roles and responsibilities, and defines common terminology. A DoD VV&A Recommended Practices Guide has also been developed as a community effort and published in late 1996 to delineate an underlying philosophy and principles, and to provide a generic process for VV&A. It will be evaluated, refined, and evolved to help guide developers and users in this important, complex area. We envision evolution of the Recommended Practices Guide into a set of accepted DoD-wide policies, including the establishment of a common template for documenting a model, simulation, or federation VV&A history.

3.4 Modeling and Simulation Resource Repository

The Modeling and Simulation Resource Repository (MSRR) is a set of resources, stored on a distributed network of computers, and linked by special applications software and world-wide web (WWW) protocols. The purpose is to catalogue information and provide a means for identifying and distributing reusable resources. Resources stored in the MSRR system will include models, simulations, metadata, databases, CMMS, VV&A histories, simulation and federation object models, standards, and supporting software and tools. An example of a resource found through in the MSRR would be the MEL discussed earlier. Resources are not shipped anywhere. They stay on their owners computers, which are integrated into the MSRR system.

The MSRR is designed to serve developers, users, operators and managers. It will provide access and security controls, as well as, efficient and flexible search mechanisms. Contents will be registered and configuration managed, but the individual resource elements will be maintained by their respective owners. Access to unclassified resources will be via the internet, with access to classified information via Secure IP Router Network (SIPRNet). DMSO is developing the necessary software and providing management oversight. The whole M&S community will populate the MSRR with the resources they wish to share. There are problems associated with persuading organizations to disclose and share their M&S-related activities As a result, the MSRR effort involves interesting social and policy issues in addition to the technical challenges.

3.5 Information Resources

There are two human-in-the-loop information resources, "help desks," available to the DoD M&S community. The first, the Defense Modeling, Simulation, and Tactical Technology Information Analysis Center (DMSTTIAC) is a classic, government-funded IAC providing scientific and technical information and analysis services. The DMSTTIAC operates under the auspices of the Defense Technical Information Center (DTIC) and serves multiple communities: M&S, Special Operations, test and evaluation, and tactical warfare.

The second resource, the Modeling and Simulation Operational Support Activity (MSOSA) is a contractor-staffed activity operating under the direction of the DMSO. Its mission is to assist DoD activities in meeting their M&S needs by providing operational advice and facilitating access to M&S information and assets.

The MSOSA staff is comprised of subject-matter experts who collectively have expertise in the operational and technical aspects of M&S. They serve as information facilitators who direct users of M&S to people, assets, and information and also provide advice on the operational employment of M&S in the following areas:

- Models and Simulations
- Joint/Combined Operations
- Operations Other Than War
- High Level Architecture
- Conceptual Models of the Mission Space
- Data Standardization
- C4I Systems
- Databases
- M&S Security Operations

The MSOSA Homepage is accessible through the DMSO Homepage (www.dmso.mil) or directly at http://www.msosa.mil.inter.net.

4 SUMMARY

A revolution is occurring in the way DoD builds and employs models and simulations. A corporate vision for the use of M&S has been put forth, an innovative strategy has been developed, an appropriate organizational structure has been established, and a comprehensive master plan for achieving DoD's vision has been crafted. As a result, a wide range of DoD-wide actions are underway and reaching fruition. When matched with the aggressive set of simulation developments and simulation modifications currently underway, DoD expects to more aggressively, capably and cost-effectively employ M&S in all phases of Department operations.

ACKNOWLEDGMENTS

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AUTHOR BIOGRAPHIES

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