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TECHNOLOGY TRENDS IN MILITARY SIMULATION

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ABSTRACT

Technologies being developed to address military simulation requirements vary from advanced software and computer aided system engineering tools to hardware improvements and new interface designs. This paper presents the technologies critical to military simulation, summarizes their status, proposes a concept of what technologies are likely to be applied in future military simulations, and concludes with a review of two current simulation architectures - SIMOBJECT and J-MASS.

1 INTRODUCTION

The military simulation community, in seeking to meet the increasing demands of its customers, often looks to technology to help in attaining its goals. Although there continues to be many challenges, there is also reason for optimism that increased flexibility, reuse, and functionality in the modeling of modern combat will be made possible by technology.

Advances in technology are being driven by fundamental requirements within the military simulation community. At the top of these requirements is the need for simulations to represent the increased complexity of modern combat. Modeling the intricacies of maneuver warfare, combined and joint operations, command and control / information warfare, and advanced weapons systems is critical for effective training, analysis, and system evaluation. It is also important, in this era of reduced budgets, that training and mission rehearsal be conducted without using expensive operational equipment. Additionally technological sophistication is required to represent the very complex threat environment that underlies effective mission planning systems. Finally, in stimulating state-of-the-art deployed systems such as Aegis, technology must allow the effective generation, manipulation, and management of complex sensor inputs.

Technologies that help meet these military simulation requirements include advanced software and computer aided system engineering tools, hardware improvements, and interface designs. This paper summarizes the technologies critical to military simulation, summarizes their status, discusses current initiatives, postulates what technologies future military simulations will employ, and concludes with a discussion of two current architectural initiatives being applied in the military simulation community - SIMOBJECT and J-MASS.

2 MILITARY M&S TECHNOLOGIES

There are many organizations and perspectives relevant to defining critical technologies. However, the Defense Technology Plan is an excellent source of guidance, as are reports by the National Research Science Council. Although both present approximately twenty technology areas for investment, a listing of their findings relative to modeling and simulation is summarized in Table 1.

Table 1: Identified M&S Technologies

Defense Technology Plan, DDR&E, 1994
Modeling and Simulation
Architectures (Software, DB methods, interfaces)
Environmental Representations (terrain, ...)
Computer Generated Forces (systems, human, ..)
National Research Council, STAR 21
Battle Management Decision Aids
System Design Language
Computer Aided Software Engineering
Simulation and Rapid Prototyping

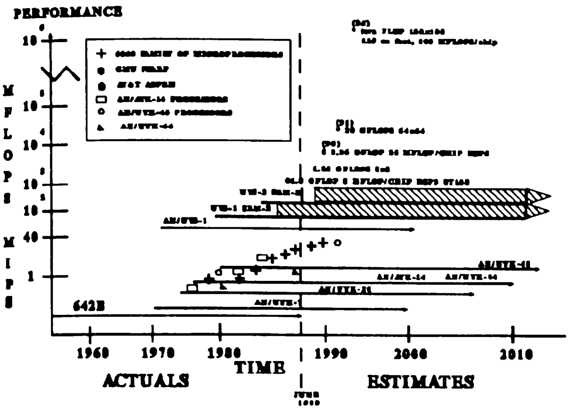

Figure 1: Computer Generations

The importance and power of architectures is a common theme throughout the modeling literature. Having a means to link dissimilar distributed simulations is critical to developing a robust modeling capability that can meet a variety of demands. Following DDR&E's technology plan, which cites the Multi-Warfare Analysis and Research System (MARS) and the Joint Modeling and Simulation System (J-MASS) as significant architectural efforts, this paper will discuss both in some detail in Section 5.

Representing the physical environment and opposing forces is critical to having effective military simulations. The environment must include features such as weather, terrain, and an air / space / sea media through which combat is conducted. In a similar way, hostile forces (computer generated forces (CGF), semi-automated forces (SAF), modular SAF (MODSAF), etc.) provide opposition to a military action. Providing a means to effectively generate these units, each of which must act in a reasonable manner, is critical to large-scale simulations, which cannot afford to have all units controlled by human players.

The STAR report emphasizes the importance of terrain and architectures, but also highlights the need for object-oriented frameworks, both for software development and as a way to allow heterogeneous data constructs.

3 HARDWARE, SOFTWARE, DISPLAY, & DIS

Computers are an integral part of the vast majority of military simulations. Whether it be producing a visual scene for a simulator, a target as part of a stimulator, or a combat group for a simulation, computers provide the processing horsepower for environment representation, unit movement, and combat adjudication. As warfare increases in complexity, so must the technology that processes its representation. Fortunately, as shown in Figure 1, computer generations are rapidly advancing.

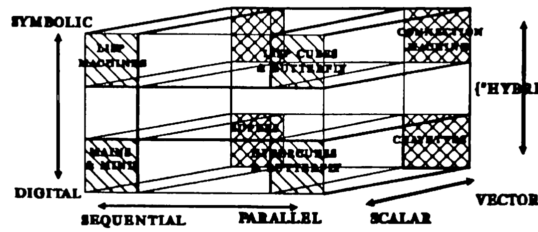

Figure 2: Types of Computer Processing

A massively parallel super-computer from Thinking Machines Corporation, for instance, combines single-instruction multiple-data (SIMD) and multiple-instruction multiple-data (MIMD) and can reach peak speeds of trillions of floating-point operations per second (teraflops). Reduced instruction set computing (RISC) systems are also improving processing times. Mirrored or reflective memory, which allows data to be simultaneously shared and eliminates the switching-associated delays inherent in shared memory systems, is also improving processing times. Some of the differing types of hardware advancements are presented in Figure 2.

Perhaps a larger challenge for the military simulation community is leveraging the hardware now available. Writing simulation software that takes advantage of parallel architectures for instance is not a simple task. However, there are many techniques that are improving software design and application. One of the most discussed, object oriented programming (OOP), uses information hiding, data abstraction, dynamic binding, and inheritance to make software development faster and simpler, and to increase code reusability. Fourth-generation languages also improve software development by allowing computer instructions to be written at a higher level than traditional high-level programming languages.

The interfaces, through which operators interact with simulations, are being significantly improved to allow for more intuitive analysis and realistic education and training. For instance, three dimensional representations of information, which have long been used in high-end training systems, are now being applied to tactical mission planning, command and control, and war gaming. The Army's Force Command Automated Intelligence System (FAIS) uses software that combines digital data with raster graphics to allow an intelligence analyst to examine battlefield situations in three dimensions.

Taking this one step further, as an example of futuristic imaging, Texas Instrument's OmniView system - a part of the DoD's Visualization of Intelligence Supporting Three-dimensional Analysis (VISTA) program - can project objects in three dimensions to allow a user to view the display from any angle. Visual systems can present images of external scenes set in day, twilight, or night through an aircraft canopy or on a heads-up display using computer generated color images. Digital photographic scenes can be projected in real-time, with very large scale integrated technology and artificial intelligence software providing increasingly accurate displays. Aircraft cockpit simulation systems also benefit from improved performance through the use of micro- and parallel-processing. Parallel processing allows accurate integration of separate components, provides real-time fidelity, provides visual scene updating in real-time and at frame update rates fast enough to avoid flicker.

Virtual reality, as an environment where users enter a computer based reality and interact with it in real time, uses one of the computer's strengths, its ability to precisely control synchronization and timing, to integrate video and audio inputs. Flight simulators have long been required to simulate aerodynamic characteristics in real-time, however, in virtual environments objects routinely interact (e.g., touch or overlap). One way to visualize three important dimensions, that can be used to evaluate the degree to which a system possess characteristics of virtual reality, has been developed by Richard Thurman of the Aircrew Training Research Division. It is a cube, presented in Figure 3, where the three axes represent *verity* or the degree that the simulation represents the way things really exist, *interface* or the means by which the user interacts with the system, and *inclusion* or how much the user is a part of the simulated world. The ability of a particular simulation to provide an effective synthetic environment can be assessed by applying this framework.

There are many programs currently underway that seek to extend the networking capabilities available for military simulation. The Defense Simulation Internet (DSI), originally sponsored by DARPA, allows the linking of simulations for exercise support. The Distributed Interactive Simulation (DIS) architecture provides a paradigm for interoperability between heterogeneous simulators and operational systems from

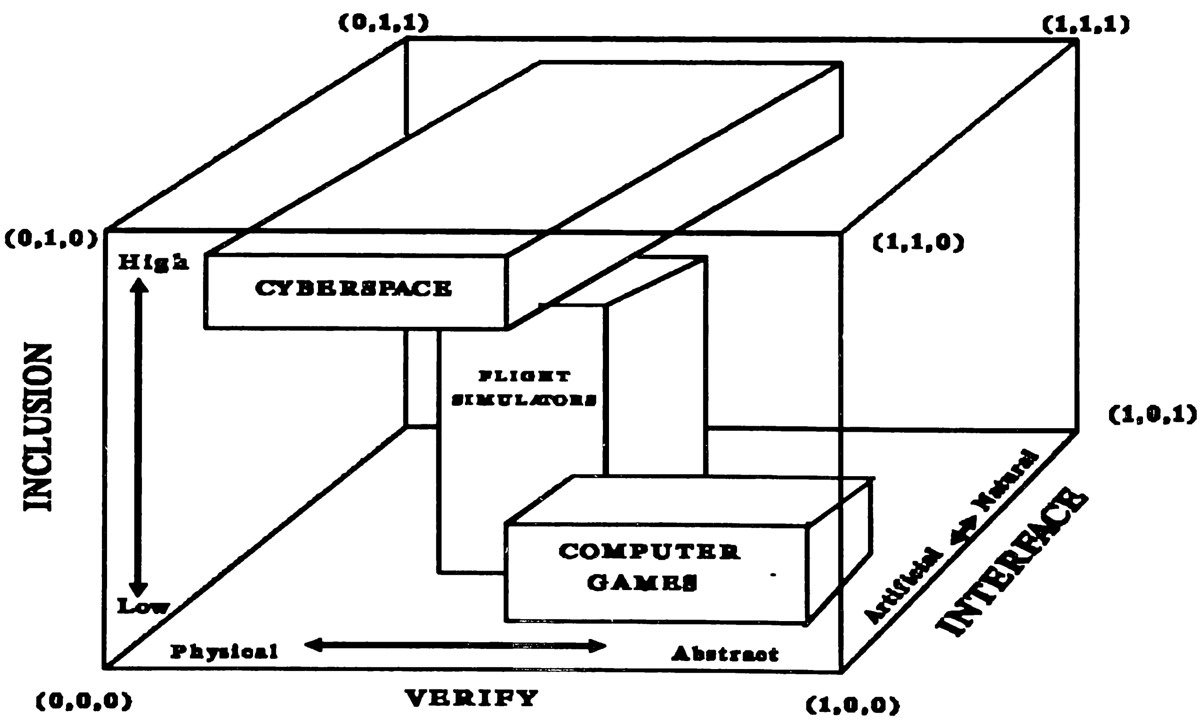

Figure 3: Three Dimensions of Virtual Reality

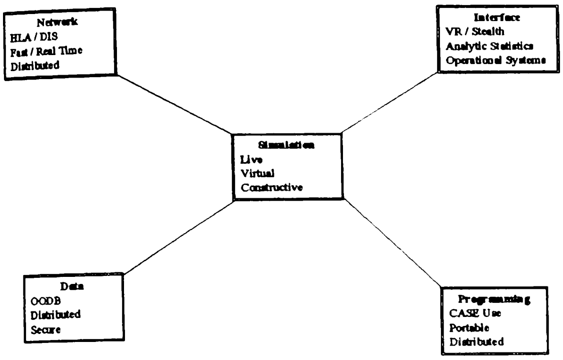

Figure 4: Simulation Technology Forecast

differing services. DIS, sponsored by ARPA, STRICOM, DMSO, DISA, and STRICOM, provides a three-dimensional battlespace, free play capabilities, intelligent adversaries (either a human in another simulator or a semi-automated force simulation), and operates at the human perception level (100ms time frame). The evolution of DIS - from the prior SIMNET system - continues to develop based on the principles that no central computer schedules events, that each node would transmit ground truth, that receiving computers calculate the local effects of ground truth, and similar constructs. The Defense Modeling and Simulation Office's High Level Architecture (HLA) is leveraging these ideas to forge ahead with a new simulation interface to allow model interoperability.

4 TECHNOLOGY FORECAST

Given this discussion of technology trends in simulation, it is useful to postulate what technologies military simulations will employ in the near future. This can provide a way to measure current system performance as well as establishing a frame of reference for the next section, which discusses two current initiatives. A summary is provided in Figure 4.

Increasingly, simulations will be required to interact in support of live exercises, to provide an environment for analytic assessments, and to operate in virtual or DIS exercises. The underlying simulation must be flexible enough to run in both fast time and real time, efficiently interface to DIS/HLA compliant simulations, and produce outputs that can be rendered in a very high fidelity mode when required. Distributed and parallel processing of simulation functionality is likely to be an increased requirement as complex models represent many more aspects of a combat environment. The underlying language of implementation will increasingly need to be high level - to allow maintenance - but also it will need to be portable across platforms and well supported by CASE tools. Finally, data will need to be used in a standard, flexible, and secure manner as variable resolution is increasingly required.

5 TWO SIMULATION ARCHITECTURES

Since architectures consistently rank at the top of any military M&S technology prioritization list, it is appropriate to conclude with a review two current initiatives.

The first, SIMOBJECT is a portable model-building and execution architecture that facilitates rapid prototyping of simulation systems. The user can evolve these prototypes into detailed, domain-specific simulation models at a fraction of the time and cost that would be required if starting from scratch. At each step in the model evolution, the developer is able to provide the model user with the capability to graphically configure a hierarchical model, see an animated picture of the system in operation, interrupt the simulation to change parameters, and obtain graphical and printed summary reports at the conclusion of the simulation.

With SIMOBJECT, new model development starts with the robust high-level model that is provided. Its component objects can then be customized and extended to build an application. Through object-oriented technology, a new object can be created which inherits all of the characteristics and capabilities of its ancestors but which may be given additional or modified functionality. It can be given new data fields and new logic to manipulate them.

The inheritance mechanism constrains changes so that they conform to the original interface specification. This preserves the interchangeability of object components and enforces consistent design. Thus, objects with the same functional interface, although differing in their implementations, can be substituted for each other without disturbing the rest of the model. Object-oriented databases may provide an effective match to the object oriented programming approach.

Two examples of SIMOBJECT's use are COMNET III and SIMPROCESS III. COMNET III (communications network simulation) and soon to be released SIMPROCESS III (business process simulation environment) are both analytic tools that use the power of SIMOBJECT as an simulation architecture. This is demonstrated by the fact that seventy percent of the code in COMNET and SIMPROCESS is common SIMOBJECT code.

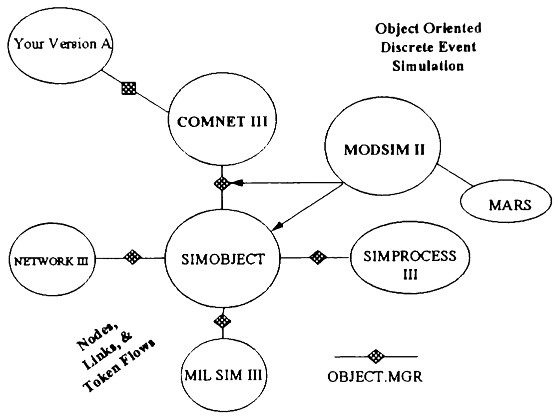

Figure 5: The SIMOBJECT Architecture

CACI is actively seeking to establish a partnership with a military simulation development activity to produce MIL SIM III - a state-of-the-art simulation development environment for combat modeling applications, leveraging the existing SIMOBJECT development environment. This would combine the requirements definition of a military organization with the software development skills and military modeling knowledge of CACI to produce a superior combat modeling environment. A summary of this initiative, and how it relates to MARS, SIMOBJECT, and CACI's other simulation development environments is summarized in Figure 5.

In more detail, SIMOBJECT is an off-the-shelf framework for developers of simulation models. It consists of a graphical editor and a simulation engine. When specialized behavior is needed, the developer can replace existing behavior of any object in SIMOBJECT with his or her own custom MODSIM III code. Thus, the developer only writes code for specialized behavior since "standard" simulation and graphical behaviors are already built-in. With SIMOBJECT, one can provide model users with a commercial quality, easy-to-use modeling environment in a fraction of the time previously required.

SIMOBJECT is built on the MODSIM III object-oriented simulation programming language. MODSIM III is an environment for building advanced models that is specialized for the successful development of visual, interactive, and hierarchical models. This specialization is achieved by combining the benefits of object-oriented development with the knowledge gained during thirty-two years of experience with all aspects of simulation.

MODSIM III has the language constructs for describing system components that have both concurrent and interacting behaviors in simulation time. Consequently, each model reads like a description of the system being modeled, and the volume of code is greatly reduced. This helps both model development and subsequent evolutionary changes. It helps developers build advanced models that are visual, allowing model users to set up a scenario through the popular icon drag and drop technique; interactive, allowing model users to monitor the simulation and interrupt it to change parameters; and hierarchical, allowing model users to select the level of simulation detail desired.

Importantly, given the rapid changes in computing technology, MODSIM III models, and hence SIMOBJECT models, are completely portable across all major platforms—UNIX workstations, and PC's running Windows, Windows NT, and OS/2. A model can be provided to all interested users regardless of the computing environment they use. Furthermore, there are no delays or development costs when changing to a new computing environment.

The SIMOBJECT graphical editor provides a rich collection of integrated tools to build and manage a graphical user interface. SIMOBJECT supports user interaction through a palette bar, menus, and dialog boxes. Developers have complete access to all aspects of the editor so that it can be customized to the requirements of the application being built. This enhances the developer's ability to provide the end user with a powerful, domain-specific graphical editor to build and modify models.

The Joint Modeling and Simulation System (J-MASS) is the second architectural initiative to be discussed. J-MASS is a US Air Force program to develop a standard simulation architecture and development support system for use in simulating weapon system effectiveness and in the acquisition and test process. The primary focus of J-MASS has been supporting the very detailed research and development

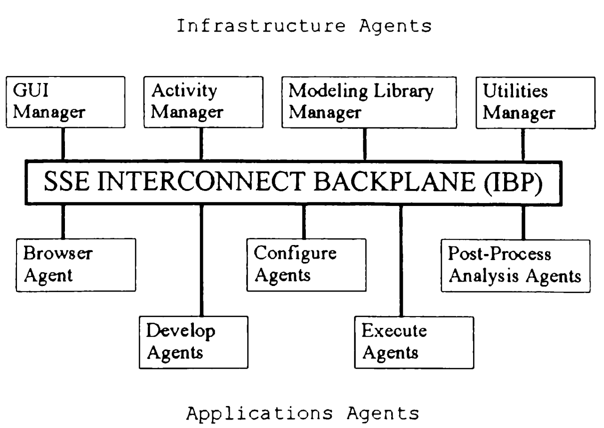

Figure 6: The J-MASS 2.0 SSE Architecture

models of threat analysis. However, the J-MASS architecture has the potential to support concept development, training, and test and evaluation activities. J-MASS provides users with a full set of tools to build, execute, and post process simulations. The J-MASS architecture contains five major modes of operation: the develop mode, assemble mode, configure mode (for models and simulations), execute mode, and post processing mode. These modes and an assortment of tools provide model developers and analysts with the ability to use one architecture for all phases of modeling and simulation.

The building block of the J-MASS simulation support environment (SSE) architecture, shown in Figure 6, is the Interconnect backplane (IBP) which provides the conduit through which various tools communicate and are controlled. The SSE IBP was designed to support J-MASS operations over multiple distributed nodes and to allow for the integration of new tools. A modeling library manager, with its supporting browser tools, provides access to a centralized repository of data. J-MASS also employs a simulation runtime agent (SRA) architecture to support the execution of autonomous entities in a distributed environment.

The design of the J-MASS architecture makes it it flexible and extensible - a result of its use of an object-based modular design, adherence to the Open Systems Interconnect model to the maximum extent possible, and by providing well defined interfaces between the runtime architecture and the populating models. J-MASS supports interoperability at several levels in that it can execute over a distributed heterogeneous network of workstations, has a standard user interface, and will accept models that are written in C++, Ada, MODSIM III, and similar languages. Finally, J-MASS fosters reusability of compliant models, third party tools, and components of its design and development architecture.

6 CONCLUSIONS

Technology is allowing increased complexity in military simulation. Everything from raw computational power to user interface capabilities and display techniques are improving. This trend is matched on the architectural side, where SIMNET has evolved into DIS and HLA and environments such as SIMOBJECT and J-MASS now exist - thus allowing interconnectivity that was not possible a few years ago. These capabilities, however, bring with them a challenge: to usefully employ the technologies to meet defined goals. Although technology is improving, it is critical to be careful when, for instance, one uses the outputs of a high fidelity model to drive another model with greater scope, or when warfare is modeled in a new way. Advances in technology do not mitigate the need for thorough design and thoughtful implementation - military simulation still combines science and art.

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