DEVELOPMENT AND APPLICATION OF AN ACADEMIC BATTLE LAB

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ABSTRACT

The Virginia Modeling, Analysis and Simulation Center (VMASC) at Old Dominion University is developing an academic battle lab facility. The battle lab is a highly sophisticated computer simulation laboratory that integrates constructive, virtual and live simulations with intelligent decision support and collaboration tools to create an environment in which to evaluate new ideas and concepts. The military uses battle labs to conduct simulation-based experimentation and training. Government and industry may one day use the battle lab as an enterprise decision support laboratory. In an academic setting, the battle lab is a place to use methods of war fighting as an application area in which to investigate the frontiers of modeling and simulation. The purpose of this paper is to describe the VMASC Battle Lab and to discuss how the battle lab supports the University's modeling and simulation research and graduate programs. The important characteristics and requirements of a battle lab are identified and the design of the VMASC Battle Lab is presented. Then, research areas supported by the battle lab are identified and several current and potential research projects are described. Finally, the integration of the battle lab with the graduate modeling and simulation programs is explained.

AUTHORS

Roland R. Mielke earned BS, MS, and PhD degrees, all in electrical engineering, from the University of Wisconsin – Madison. Since 1975 he has been on the faculty of Old Dominion University where he is currently Professor of Electrical and Computer Engineering and holds the designation University Professor. Dr. Mielke also serves as Technical Director for the Virginia Modeling, Analysis and Simulation Center. His research interests are in the areas of systems theory and simulation and include simulation methodologies, system modeling, composability theory, discrete event simulation, and the application of simulation to the development of enterprise decision support tools. Dr. Mielke is the author of more than fifty-five technical publications and holds one patent. His research has been funded by agencies that include NASA, DoD, NSF, and numerous industries.

Mark A. Phillips earned the BE degree in electrical engineering at the University of New South Wales and currently is completing the MS degree in Modeling and Simulation at Old Dominion University. He has 20 years experience in the Australian Regular Army where he served as a logistician and engineer. In 1998, Mr. Phillips was appointed the Technology Development Officer for Headquarters Training Command – Army responsible for the design and development of training systems and the development of the Tactical Training Simulation Capability, a network of battle simulation centers. Currently, Mr. Phillips is a Research Scientist at the Virginia Modeling, Analysis and Simulation Center and serves as the VMASC Battle Lab Director. Mr. Phillips' research interests include military modeling, modeling of large-scale synthetic environments, and distributed and collaborative simulated environments.

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INTRODUCTION

The Virginia Modeling, Analysis and Simulation Center (VMASC) at Old Dominion University is developing the VMASC Battle Lab Facility. The Battle Lab is a highly sophisticated computer simulation laboratory that integrates constructive, virtual and live simulations with intelligent decision support and collaboration tools to create an environment in which to evaluate new ideas and concepts. The military uses the battle lab concept for training and experimentation. The non-military application of the battle lab is as an enterprise decision support laboratory. At VMASC, the battle lab establishes the infrastructure required for conducting research, graduate education, and economic development in computer modeling, simulation, and visualization.

The purpose of this paper is to describe the VMASC Battle Lab and then to discuss how the battle lab supports the University's modeling and simulation (M&S) research and graduate programs. First, background concerning VMASC is presented to establish a context for the battle lab development. Second, the battle lab concept is introduced. The importance of the battle lab for military and non-military applications is explained. Third, the design of the battle lab is described. The desirable characteristics of a battle lab are listed and the actual implementation of the VMASC Battle Lab is explained. Then, the research areas that are supported by the battle lab are discussed and several current and future research projects are identified. In addition, the integration of the battle lab with the graduate programs in modeling and simulation is described.

BACKGROUND

Without a great deal of attention or fanfare, Hampton Roads, Virginia has become this nation's center for the military application of modeling and simulation. Hampton Roads is home to the Joint War Fighting Center (JWFC) and the Joint Battle Center (JBC), co-located in the US Joint Forces Command's Joint Training, Analysis and Simulation Center (JTASC) located in Suffolk. The US Army's Training and Doctrine Command (TRADOC) and the Military Traffic Management Command – Transportation Engineering Agency (MTMCTEA) are located in Newport News, and the Joint Forces Staff College is located in Norfolk. In addition, numerous US Navy operational commands are present including the Commander Operational Test and Evaluation Force (COMOPTEVFOR) located in Norfolk, the Naval Sea Systems Command – Dam Neck (NAVSEA-Dam Neck) located in Virginia Beach, and the Space and Naval Warfare Center – Little Creek (SPAWAR-Little Creek) located in Norfolk. These military commands utilize modeling and simulation extensively to develop doctrine, test and evaluate doctrine and equipment, and train military personnel. A host of companies and businesses operate offices and laboratory facilities in southeastern Virginia to support the military's requirements for modeling and simulation. In calendar year 2002, the economic value of modeling and simulation related business activity in Hampton Roads was estimated to be over $700M. The modeling and simulation activity occurring in Hampton Roads is one of the key components leading to the identification of information technology as a Virginia strategic technology.

Recognizing the significance of the modeling and simulation enterprise in Hampton Roads and the need to provide an academic infrastructure to support this activity, Old Dominion University began to plan and solicit support for research and graduate programs in modeling and simulation during spring 1995. In October 1996, Old Dominion University entered into a Cooperative Research and Development Agreement (CRADA) with the US Joint Forces Command. This CRADA, coupled with special funding from the Commonwealth of Virginia, facilitated the establishment of the Virginia Modeling, Analysis and Simulation Center (VMASC) on July 1, 1997. This was followed quickly by the development of formal degree programs in modeling and simulation (M&S), a master's degree program in fall 1998 and a doctoral degree program in spring 2000

VMASC

VMASC is organized as a research and development center within the College of Engineering and Technology at Old Dominion University. VMASC has the goal of promoting Hampton Roads and Virginia as a recognized center for modeling and simulation. The Center actively

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seeks collaboration and partnership with other organizations representing academia, government and industry through VMASC membership. VMASC members include all doctoral-granting universities in Virginia, organizations representing all branches of the military, state and local economic development agencies, and 90 dues-paying industrial members. The mission of VMASC has four components: research, to develop new knowledge and technologies for modeling, simulation, and visualization; economic development, to expand modeling and simulation business activity in Virginia; education, to increase the number of qualified modeling and simulation professionals available in the workforce; and technical support, to assist the military and industry in the application of modeling and simulation technology. The main VMASC facility is located on the Campus of Tidewater Community College - Portsmouth. This location was selected because of its close proximity to the Joint Training, Analysis and Simulation Center. The 24,000 square foot facility includes simulation development laboratories, a multimedia-equipped conference room, administrative and staff offices, and the VMASC Battle Lab. VMASC also operates a Visualization Laboratory and CAVE facility located on Old Dominion University's Norfolk Campus. These facilities soon will be relocated to the new Engineering and Computational Sciences Building now under construction.

The research activities of VMASC are focused on the areas of modeling, simulation, and visualization. Research interests and capabilities of VMASC include simulation methodologies, mathematical modeling, verification and validation, distributed simulation, computer visualization, immersive virtual environments, human-machine interfaces, human behavior modeling, intelligent systems, decision support and collaboration methodologies, and M&S systems integration. These capabilities are applied to problems in diverse application domains including business and manufacturing, training and education, transportation, medicine, and urban planning. The Center's primary research customer is the United States Department of Defense that supports research projects in war- gaming, simulation-based training, information systems, and simulation-based testing, evaluation and analysis. The economic development activities of VMASC are directed at expanding the application of modeling and simulation; we are especially cognizant of opportunities to transfer modeling and simulation technology and know-how between the military and commercial sectors. Our primary approach has been to conduct technology demonstration projects. During the past five years, VMASC has conducted over forty such demonstration projects, often with the participation and financial assistance of Virginia's Center for Innovative Technology and Old Dominion University's Technology Application Center.

M&S Graduate Programs

VMASC also functions as the administrative home of Old Dominion University's new graduate programs in modeling and simulation. The Master's Degree Program in Modeling and Simulation is a multidisciplinary program offered jointly by five academic departments: the Department of Electrical and Computer Engineering and the Department of Engineering Management from the College of Engineering and Technology; the Department of Computer Science and the Department of Psychology from the College of Sciences; and the Department of Occupational and Technical Education from the College of Education. The program is offered with a thesis option (Master of Science) and a non-thesis option (Master of Engineering). There is a core course requirement of five courses that includes the topic areas of probability and statistics, discrete event simulation, systems modeling, project management, and human-computer interaction. Electives may be selected from four focus areas: simulation-based instruction; analysis and decision making; simulation development; and human-in-the-loop simulation interaction.

During fall 2000, Old Dominion University introduced a new Doctoral Program in Modeling and Simulation. This was the first such degree program at a public university in the United States. The program is offered within the College of Engineering and Technology and leads to the award of the degree Doctor of Engineering with concentration in Modeling and Simulation. The program focuses on developing the necessary skills and knowledge to conduct and evaluate independent original research in an area of modeling and simulation. The goal is to prepare students for careers in teaching and research at academic institutions as well as in public, private and military organizations characterized by innovation and research in modeling and simulation. The program requirements include course work beyond the master's degree and dissertation research. There is a core course requirement of four courses: Advanced Discrete Systems Simulation; Foundations for Continuous and Real-Time Simulation; Simulation Modeling Theory and Formalisms; and Ph.D. Seminar - Advanced Simulation Systems. Additional course work is selected from one of two focus areas, Large-scale Systems Experimentation and Analysis or Experimental Environments.

The Large-scale Systems Experimentation and Analysis area addresses issues surrounding the development and use of models representative of large, complex systems for the purpose of evaluation of policies, technology, tactics, doctrine, strategies, and operations. Some

underlying issues include experimentation, aggregation/de-aggregation of models, model granularity, the appropriate levels of abstraction, complexity, and modeling of decision processes. The Experiential Environments area addresses the issues and technology surrounding war gaming, training, education, and artificial environments for experimentation and discovery. The focus is on principles and technology of providing environments for individuals and teams to achieve training, learning, and discovery of knowledge through direct experience and experimentation in artificial, simulation-based environments. A strong emphasis is placed on visualization. The selection of these initial focus areas clearly is influenced heavily by our partnerships and close working relationships with local military commands.

BATTLE LAB REQUIREMENTS

The battle lab establishes the infrastructure required at VMASC for conducting research and graduate education in computer modeling, simulation and visualization. The laboratory is designed specifically to position VMASC to better support the many military commands that utilize simulation for experimentation and training. In addition, the battle lab enhances VMASC's ability to transfer this technology for use by government and industry. In this section, the military and non-military applications for the battle lab are described. These applications in turn determine functionality requirements for the battle lab. Military M&S requirements for experimentation and training are addressed first, and then the utilization of the lab for non-military enterprise simulation is presented.

Military M&S Requirements

Transformation is the process of changing the structure of our military forces, the military culture and doctrine supporting those forces, and streamlining our war fighting functions and technologies to more effectively meet the new threats challenging our nation. The objectives for a transformed military include development of the capability to: (1) protect the US homeland and forces overseas; (2) project and sustain power in distant theaters; (3) deny our enemies sanctuary; (4) protect our information networks from attack; (5) use information technology to link different US forces so they can fight jointly; and (6) maintain unhindered access to space and protect our space capabilities from attack [1].

The mission to build jointness in our military forces is the responsibility of the US Joint Forces Command (USJFCOM). USJFCOM is the transformation laboratory for the Department of Defense. Two key activities, joint experimentation and joint training, are essential to the accomplishment of this mission. Joint experimentation refers to experimentation necessary to ensure that our forces are more effectively used through improvements in doctrine, interoperability, and integration. Joint training refers to the joint task force training required for our forces to utilize the improved doctrine and technologies realized through transformation. Modeling and simulation is used extensively to develop realistic computer-generated battlefield models, and other types of simulations, that support experimentation and training. Simulation-based experimentation uses M&S to develop and evaluate new concepts and technologies much faster and more economically than by more conventional approaches. Simulation-based training uses M&S to practice the movement or coordination of forces by providing an operational background to a staff exercise, or by augmenting live forces to simulate a larger operational environment. These two activities are described in more detail in the following.

Experimentation. A battle lab is a computer simulation laboratory specially designed as a place in which to test new methods of war fighting. The word 'methods' is used broadly to include the three primary components of war fighting: technology, such as weapons and sensors; doctrine, such as tactics and battle drills; and organizations, such as force structures and command and control hierarchies. Functionally, battle lab is as much a process as it is a facility or system. If we wish to analyze or evaluate a new war fighting concept, then we 'battle lab' that concept to obtain the desired information. The military community has embraced the battle lab approach to investigating and evaluating methods of war fighting. This has occurred because the battle lab approach often has many advantages compared to the alternative, live simulation. Conducting live military exercises is very expensive, hazardous to personnel and equipment, difficult to control fully, and often limited by location and weather.

The battle lab approach to concept development is shown in Figure 1. A new concept is modeled and then tested and evaluated in the battle lab environment using constructive and/or virtual simulation. The information derived from these tests is used to revise and improve the initial concept, and an iterative process of revise and then test is followed until satisfactory results are obtained. Only when desired model performance is achieved is it necessary to conduct live simulated testing. This battle lab process is almost always much faster and more economical than the use of live simulation only.

Training. The goal of constructing and maintaining a joint training capability is to improve the ability of the US forces to fight effectively as a joint team. Secretary of Defense Donald Rumsfeld spoke to this point recently

while addressing an audience at the National Defense University [2]:

> "The lessons of this war [Afghanistan] is that effectiveness in combat will depend heavily on jointness, how well the different branches of the military can communicate and coordinate their efforts on the battlefield, and achieving jointness in wartime requires building that jointness in peacetime."

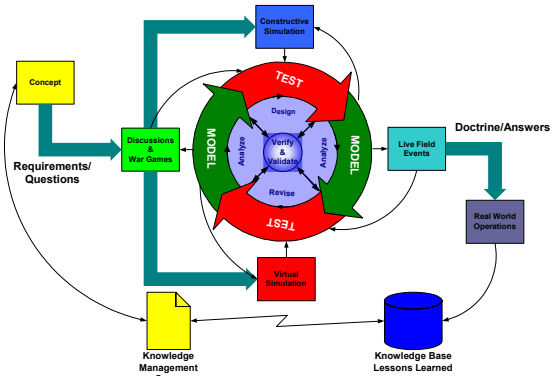

Figure 1. Battle Lab Integrated Experimentation Model

In order to support this new mission, a transformation in joint training is required. However, the ability to transform joint training is encumbered by the disparity between how US forces fight and train. The majority of military training occurs at the tactical level and is conducted primarily by the individual services. Most of the fighting is planned and controlled at the operational level by the Secretary of Defense and a CINC with support from other government agencies. This disparity between training and fighting forms the "seams" of the jointness problem and erodes the military's ability to conduct operations.

The Joint Training Manual describes six levels of training [3]. Two of these levels, Joint Training and Joint Interoperability Training, are included here because they utilize heavily M&S and thus help define the requirements of a battle lab. Joint training is defined as military training based on joint doctrine or joint tactics, techniques, and procedures to prepare joint forces to respond to strategic and operational requirements deemed necessary to execute their assigned missions. Joint training involves forces of two or more military departments interacting with a combatant commander and is conducted using joint doctrine or joint tactics, techniques and procedures. At the joint training level, the training audience is principally a headquarters staff (CINC, JTF, or component staff) that can best be trained in a computer-assisted exercise. Joint interoperability training is defined as interoperability training during joint training events. It is the synthesis of joint doctrine and joint tactics, techniques, and procedures, and service systems and personnel. At the joint interoperability training level, tactical forces work together to execute joint interoperability tasks under the direction of a joint force commander. As the training audience moves from the operational to tactical-level, there is a tendency to rely more on live training and less on computer-assisted training. Thus, interoperability exercises involve extensive live play to ensure the forces are interoperable augmented by a mix of virtual and constructive forces.

Non-Military M&S Requirements

The non-military equivalent of the battle lab might be called the enterprise decision support lab. An enterprise decision support lab is a computer simulation laboratory specially designed as place where new methods of conducting business can be evaluated. Once again, the word 'methods' is used broadly to include the primary components of conducting business. For a manufacturing industry, these components might include: technology, such as computer-aided design tools and numerically-controlled milling machines; build strategy, such as just-in-time inventory and component assembly; and organizations, such as divisions/departments/shops and component process lines. With the exception of several large corporations, the enterprise decision support lab approach to investigating new business methods in the non-military sector is still only a novel idea. Most companies have neither the expertise nor the financial resources to conduct enterprise simulation experiments. However, as simulation technology and techniques continue to improve and decrease in cost, it is likely that an entire new business area devoted to providing enterprise decision support lab services will develop and flourish.

Enterprise simulation refers to a dynamic model or simulation that is constructed with a top-down perspective and is intended to provide an overall conceptual view of the workings of a system [4]. Systems that lend themselves to enterprise simulation frequently are comprised of a collection of entities interacting with one another in some context or environment according to a physical or behavioral set of accepted rules. In this case, the enterprise simulation is most easily viewed as the aggregation of the behaviors of the entities as they interact with each other and with their environment. Most often such systems are complex systems that have emergent behavioral properties; therefore, it is imperative in enterprise simulations to accurately represent both the effects of the environment and the behavior of the individual entities.

A common characteristic of enterprise simulations is that they are developed to support human decision-making. They directly support the decision maker resulting in decisions which are either easier to make or are better informed. When confronted with the management of complex systems, humans conceptually build mental models of the system. A properly constructed enterprise simulation should present to the user an externalization of his mental model. Enterprise simulation allows the user to ask 'what if' questions about the enterprise. The simulation computes the probable system response to management decisions and policies so that managers can observe and better understand the cause and effect relationships between their decisions and system performance. Enterprise simulation provides the decision maker with a virtual environment in which to quickly, economically, and safely test and improve understanding and knowledge about the enterprise.

The use of an enterprise simulation is different from the way most simulation technology has been used in the past. Simulation has long been a tool the analyst used to evaluate potential solutions to a specific management problem they were assigned to help solve. The analyst's role was to derive a recommended point solution for management. This process might be called problem-centric simulation. Enterprise simulation, on the other hand, is used directly by decision makers to observe the dynamics of a system as it responds to stimuli introduced by the user. Notionally, the role of the analyst as a middleman in decision-making is eliminated; in actuality, the role of the analyst changes to one of simulation developer and validator only. Problem-centric modeling and simulation still has its place and continues to be a topic for research into improved methods. It is important to understand enterprise simulation as a different perspective on the use of simulation technology that may require some unique tools and capabilities. It is a decision support tool, not a solution generator.

The battle lab facility provides an ideal environment for the development and implementation of the enterprise simulation concept. The facility supports a number of different modeling methodologies. This is extremely important because different components of a business enterprise require different modeling and simulation approaches. The facility must then have the capability to integrate the set of heterogeneous component simulations to realize the entire enterprise simulation. The ability to integrate geographically distant simulation components using distributed computing resources also is required to insure that model ownership remains with those individuals who operate and manage the various enterprise components. And of course, advanced data visualization techniques, intelligent decision support strategies, and new methodologies for collaboration, areas the battle lab is especially designed to explore, are at the very heart of business management. This exciting commercial application of the VMASC Battle Lab will be promoted through the development of several demonstration projects with VMASC industrial members. The demonstration projects will be used to prove the value and return on investment that is possible through enterprise simulation.

BATTLE LAB DESIGN

In this section, the design and organization of an academic battle lab is described. It is important to observe that in a military setting, a battle lab is a place to use simulation to investigate methods of war fighting. In a university setting, a battle lab becomes a place to use methods of war fighting as an application area in which to investigate the frontiers of simulation.

Lab Characteristics and Capabilities

Just as there is no single way to utilize a battle lab, there is no single hardware and software configuration for a battle lab. The hardware and software must be selected and integrated to support the many possible objectives and demands of potential customers. However, there is a set of characteristics and/or capabilities that are desirable descriptors of a well-designed facility. These characteristics are identified in the following.

Flexibility – The battle lab system must be capable of performing a large number of different functions, not all of which can be predicted at design. Therefore, the lab must have the flexibility to be reconfigured rapidly to meet changing uses and requirements. This can be achieved by developing the facility as a cluster of complementary laboratories, each designed for a specific purpose, whose interconnection can be quickly reconfigured electronically.

Scalability – The laboratory system must be able to expand to address increasingly complex situations and greater service demands. Thus, computational resources must be organized so that they can be easily reconfigured and so that additional resources can be added transparently.

Supportability – The system should be based on commercial-off-the-shelf (COTS) technology that is readily maintainable, supportable, and expandable.

Open – The value of a battle lab is enhanced greatly when that facility has the capability of functioning as a component of a larger distributed system of battle labs. Therefore, the laboratory system must have the capability

to communicate over local and long haul networks with other labs that may utilize dissimilar hardware systems.

Multi-Modal – The system must be able to exploit new and emerging technologies developed to reduce the barrier between human operator and machine through multi-modal display and interaction techniques and technologies. Input formats might include keyboard, joystick, pointer, voice, and feature recognition; output formats might include auditory, 2D and 3D visual representations, and perhaps even haptic and motion displays.

Interactive – The system should be capable of testing 'what if' scenarios through a combination of human-in-the-loop, semi-automated, and fully automated components.

Thus, the battle lab should be a scalable, reconfigurable system built upon an open communications architecture. This will facilitate both distributed simulation and distributed experimentation as well as provide a framework for extending and linking to other academic, government, and eventually commercial battle lab facilities.

Lab Implementation

The VMASC Battle Lab consists of five interconnected research laboratories. These laboratories, as well as the shared infrastructure, are described in the remainder of this section.

Operations Research and Analysis Laboratory. The Operations Research and Analysis Laboratory is designed to host real-time collaborative analysis and design activities. The facility is configured as a medium-sized conference room with seating for up to 35-40 people. The front wall consists of three six feet by eight feet rear-projected display screens; these displays can be connected to any video source in the battle lab via an electronically controllable matrix switch. The room is equipped to support video teleconferences over ISDN or IP; this capability is enriched by the addition of special software tools to facilitate collaboration and interactive decision-making. The Operations Research and Analysis Laboratory is used for planning and design meetings, formal presentations, teleconferences, collaborative meetings with external groups, project demonstrations and reviews, and after-action reviews. This room serves as the heart of the entire battle lab facility.

Constructive Modeling Laboratory. The Constructive Modeling Laboratory is designed to host model design and simulation code development activities and to host simulation exercises. The facility is configured as a medium-sized computer laboratory containing approximately 40 workstations. Each workstation is mounted to a computer desk with casters so that the room can be easily reconfigured. A combination of wired network ports and power access points are distributed throughout the lab; in addition, a wireless RF local area network is installed. The room is large enough and shaped so that several groupings of workstations can be formed and isolated from one another. The lab also contains a ceiling-mounted data projector and large screen to create a computer classroom environment when needed. The Constructive Modeling Lab hosts a number of military models, such as Joint Semi-Automated Forces (JSAF), and model design and programming tools including Visual Studio and Rational Rose. A number of small office areas and a small conference room surround the lab and provide spaces where small groups can hold discussions without disturbing people working in the main lab area.

Human Factors Engineering Laboratory. The Human Factors Engineering Laboratory is designed to host human-computer interface and human behavior modeling activities. The lab consists of two smaller isolated work areas that can provide a controlled quiet environment for testing human subjects, and a larger open laboratory area for other activities. The lab is instrumented to monitor and record the interface activities that occur between a human subject and a simulation exercise; this equipment also supports post-experiment playback and analysis of this interaction. The laboratory also is equipped with several other interactive display tools including 3D interactive displays and haptic devices.

Virtual Simulation Laboratory. The Virtual Simulation Laboratory is designed to host simulators for conducting human-in-the-loop virtual simulation activities. The lab is configured for housing up to four simulators. Presently, it contains a single F/A-18 cockpit flight simulator. As more funding becomes available, additional simulators will be added. The virtual simulation lab is linked via the Internet to a driving simulator located on the main Old Dominion University campus. The laboratory facilitates investigations and experiments in which constructive, virtual, and live simulation components are integrated into a common simulation exercise.

Database Laboratory. The Database Laboratory is designed to host modeling tools and GIS tools for developing graphical and terrain databases. The lab contains several workstations to support model development using tools like Maya, 3D Studio Max, and MultiGen, GIS data manipulation using tools like ArcInfo, and terrain database generation using tools like Terra Vista. The Database Laboratory also contains a

large table-sized digitizer and a wide-carriage color printer.

Other Common Laboratory Infrastructure. The battle lab contains a number of additional hardware and software components that support the common operation of the five main laboratory areas. The major infrastructure components include: (1) a 32-node PC cluster to provide scalable computational power for intensive numerical computations; (2) a high-speed, switched TCP/IP Ethernet local area network to interconnect the various laboratory areas and the equipment within each laboratory area; (3) middleware software, including HLA and DIS, to provide interoperability among heterogeneous applications, protocols and databases; (4) an expandable network area storage system with several terabytes of storage capacity for data storage; and (5) a secure interface to external clients and users via a web-enabled application server.

External Laboratory Interfaces. The battle lab is connected to several additional laboratory facilities located on the Norfolk Campus of Old Dominion University. These facilities include VMASC's Virtual Environments Laboratory, the High-Speed Networks Laboratory, the Human Factors Lab, and the University's supercomputer facility. The Virtual Environments Laboratory includes a Virtual Reality Lab, a CAVE facility, a 74-seat multimedia theater, and a second 32-node PC cluster.

A system diagram showing how these components are interconnected to form the VMASC Battle Lab is displayed in Figure 2.

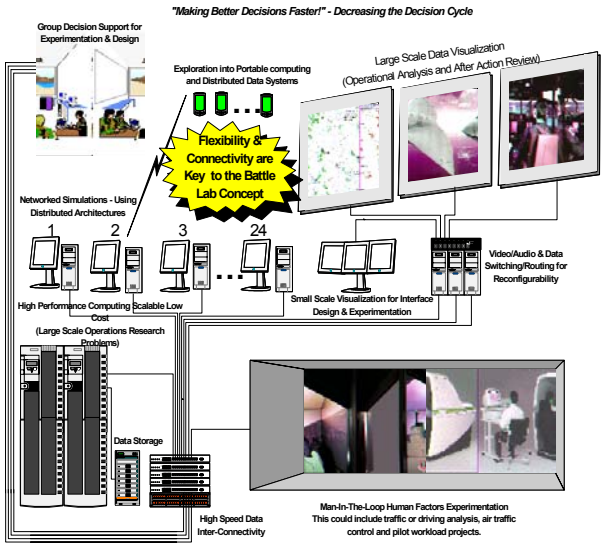

Figure 2. Battle Lab Architecture

RESEARCH AGENDA

The VMASC Battle Lab is being developed to expand and enhance VMASC's research activities with Department of Defense agencies and military commands. By constructing a facility similar to the simulation laboratories that the military uses for training, experimentation, and test and evaluation, VMASC scientists and engineers will be able to conduct basic and applied research having direct benefit to these organizations. However, the research issues of importance to the military are the very same challenges that are of importance to the entire modeling and simulation community. The same theories, techniques and technologies that enable the military to rehearse the response to an impending world military crisis also enable a company to model its supply chain or a community to plan a response to a natural or man-made disaster. The application domains may be very different, but the fundamental modeling, simulation and visualization research issues are the same. In this section, some of the more significant research activities facilitated by the development of the VMASC Battle Lab are described. First, activities already underway are identified and then several potential project opportunities are presented.

Current Research Activity

A number of fundamental M&S research problems arise as attempts are made to enhance and expand the capabilities of computer-generated battlefield simulations that are used extensively by the military for training and experimentation. Several of these research problems are listed here.

Larger and More Complex Simulations. Current distributed battlefield simulations may involve on the order of tens or hundreds of federates and may simulate tens- or hundreds-of-thousands of battlefield entities. There is a desire to increase the size and complexity of simulations, so that thousands of federates may simulate millions of entities. Increasing the number of federates in a federation and the number of entities being simulated often increases by many times the computational power and the communication capacity required. Thus, the ability to simulate larger and more complex systems requires advances in computer architectures and computer networking strategies. By linking the PC cluster in the VMASC Battle Lab with the PC cluster located in the Virtual Environments Lab, we have the ability to investigate strategies for using networked PC clusters to scale available computational power. By combining the resources of the High-Speed Networks Lab with the Battle Lab, new networking strategies for achieving guaranteed quality of service levels are being investigated.

Reduced Cost and Development Time. The development time for a major simulation-based training exercise like Millennium Challenge-02 is measured in months and the cost is measured in millions of dollars. If war-games are to be used successfully for crisis rehearsal and preparation for specific missions, then development time must be reduced to days or even hours. If this technology is going to be used routinely for missions other than war, then the cost of simulation also must be reduced dramatically. One of the most obvious ways for reducing development time and cost is to improve the ability to reuse software components. It would be desirable if large, complex simulations could be composed quickly from a library of already validated simulation components with the assurance that the composition also is valid. Researchers within the VMASC Battle Lab are developing a theory to support simulation composition [5]. If successful, this research may lead to new methodologies for simulation composition that significantly reduce development time and cost.

The Human Component. The ability to model human behavior is becoming increasingly important in battlefield simulations. This is occurring for two reasons. First, humans often are essential components in complex systems. In order to simulate the system, it is necessary to simulate the behavior of the human components. Second, the conduct of a battlefield simulation often requires large numbers of people to conduct and control the exercise and to play the role of the opposing forces. Thus, an enhanced ability to model human behavior may lead to better simulation models for complex systems with embedded human components. In addition, it may be possible to reduce the number of exercise support personnel by replacing some of the live decision-making with constructive human behavior models designed to make the required decisions. The Human Factors Engineering Lab presently is conducting two research efforts. In the first, a model of the decision-making of the joint force commander has been developed and successfully implemented [6]. In the second, research is being conducted to characterize crowd behavior. If successful, this research may lead to the development of a federate that provides the ability to add civilian crowds to battlefield models for urban operations.

Potential Research Opportunities

There are two important areas, the Joint National Training Capability and Homeland Security, where VMASC sees significant research potential. The VMASC Battle Lab was designed and implemented to help position VMASC to better respond to these opportunities. Both research areas are described briefly in this section.

Joint National Training Capability. The US Joint Forces Command has been directed to develop the Joint National Training Capability (JNTC). The JNTC vision is to create a persistent, global training system that brings the benefits of live, virtual, and constructive simulation to the user [7]. The JNTC will establish a joint training network that will digitally link ranges and simulation centers around the world. The goal of establishing a joint training capability is to improve the ability of the US forces to fight effectively as a joint team. The development efforts to establish the JNTC are directed from the Joint Warfighting Center in Suffolk, Virginia. There are a number of research and development issues that must be solved in order to realize this complex system over the next four years. In addition, once the system is established, there will be continuing opportunities to help develop the next generation of M&S technologies needed to continued to expand and enhance JNTC capabilities. VMASC is hopeful that the availability of the VMASC Battle Lab will uniquely position the Center to assist with the development of the JNTC.

Homeland Security. Homeland security has become one of the dominant concerns of federal, state, and local governments. The initial focus has been to quickly develop the infrastructure required so that our first line defenders have the tools to identify threats and to respond to potential crises. As this infrastructure is developed, the focus will gradually shift to the development of tools for training first line defenders and for experimentally evaluating the potential value of proposed strategies and technologies prior to purchase. It is clear that the same technologies and tools being developed to establish the JNTC are potentially useful for training and experimentation in the context of Homeland Security. VMASC would like to play a leading role in transferring the M&S technology developed by the military for JNTC to the Homeland Security efforts. The VMASC Battle Lab will be an important research infrastructure for this activity.

Integration With M&S Graduate Programs

The battle lab establishes the infrastructure required to conduct thesis and dissertation M&S research that involves an experimental component. In fact, each of the research projects described in this section includes one or more students completing research requirements for their degrees. An important by-product of the availability of the battle lab has accrued to students employed in the local M&S community. In many cases, they now have the capability of conducting research related to their work assignments.

We also are integrating the battle lab directly into some of our M&S courses. During spring 2003, we developed a course entitled "Introduction to Combat Modeling". This course is an introduction to basic modeling and simulation concepts essential to modeling different aspects of military operations and to implementing combat simulations. During fall 2003, we will offer a follow-on course entitled "Developing and Applying Combat Models" [8]. This course will deal with the practical application of the codes of best practice for combat models. It will be based on the NATO Code of Best Practice for Command and Control Assessment and the Code of Best Practice for Experimentation. This will be a "hands-on" course taught in the battle lab; each topic will be accompanied by an actual implementation exercise. The main course topics include: design of a simulation study plan; scenario development and set-up; component based implementation of a simulation federate; application of the federation development and execution plan; measure of merits definition and evaluation; evaluation and visualization of study results; and integration of operational software.

CONCLUSION

This paper has described the development and application of an academic battle lab at the Virginia Modeling, Analysis and Simulation Center. Although the facility just recently opened and is not yet complete, already it is apparent the battle lab is an important asset to all segments of the Center's constituency. Center faculty and research staff now have an M&S laboratory infrastructure that supports leading-edge research in an environment that is similar to that of their primary research sponsor. M&S graduate students, many employed by military organizations or support contractors, are able to conduct thesis and dissertation research that is of immediate relevance and importance to their employers and their employer's customers. The Center's military research sponsors view the battle lab as a convenient location to develop and evaluate new technologies without having to compromise the hectic exercise schedule of their own simulation facilities. The Center's industry members are beginning to recognize the battle lab as an extension and enhancement of their own simulation facilities; the battle lab is creating new reasons for industry and academia to form constructive partnerships that ultimately provide better service to the customer.

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