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## This Year in the MOVES Institute

Zyda, Michael; Brutzman, Don; Darken, Rudy; Hiles, John;  
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## This Year in the MOVES Institute

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### Abstract

The MOVES Institute's mission is research, application, and education in the grand challenges of modeling, virtual environments, and simulation. Specialties are 3D visual simulation, networked virtual environments, computer-generated autonomy, human-performance engineering, immersive technologies, defense /entertainment collaboration, and evolving operational modeling.

### 1. Overview

MOVES' mission is research, application, and education in the grand challenges of modeling, virtual environments, and simulation. Our specialties are 3D visual simulation, networked virtual environments, computer-generated autonomy, human-performance engineering, immersive technologies, defense and entertainment collaboration, and evolving operational modeling.

This has been a spectacular year in all specialties:

- In 3D visual simulation and networked virtual environments, we have created the extensible modeling and simulation framework (XMSF), an effort cited as the most important strategy for connecting DoD modeling and simulation to C4I systems.
- Our terrorist behavior-modeling effort, Project IAGO, is listed among the top ten in a DTRA survey of two hundred and sixty five models.
- Our Chromakey augmented training environment has been deployed to helicopter squadron 10 (HS-10) to study its utility in flight navigation training.
- Our achievements in immersive technology include a pending patent for our inertial tracker. Sounds we and LucasFilm's Skywalker Sound recorded, of an LCAC for a Marine Corps training VE, were used for a hovercraft in the movie *Minority Report*.
- Our *America's Army* is the fastest-growing online game ever, and has won or been runner-up for several best-game-of-the-year awards. The project is cited as a transformational model for turning the PC game into a communications medium and demonstrating how innovative projects can succeed within DoD. *AA* is expected to save \$700M to \$4B annually and has inspired the CNO's strategic studies group to consider massively multi-player gaming for combat modeling; other defense

agencies are pursuing similar studies. The game is the first successful defense/entertainment collaboration, as spelled out in the National Research Council report, "Modeling and Simulation—Linking Entertainment and Defense."



**Figure 1. *America's Army: Stryker attack***

- We have applied techniques from VE and entertainment to enhance comprehension of complex tactical information in "live" command-and-control settings. We showed that radio, radar, air-traffic control, and possibly UAV communications could be improved using spatialized cues over headphones, presenting results at the ForceNet 2003 conference.

We support our students through courses and funded research directly related to our mission. Our projects provide DoD- and DoN-relevant thesis topics for officer students. Funded projects indicate serious interest in our research and educational abilities. In FY2002, MOVES had \$11.4M in reimbursable funding. As of mid-FY2003, we had some \$12M in reimbursables (forty-four accounts from thirteen sponsors).

MOVES has expanded greatly, currently employing sixty-eight faculty and staff. Students working in institute projects increased from forty to sixty-eight, hailing from twelve curricula (MOVES, CS, OR, IT, IS, NSA, IW, meteorology, ME, ECE, UW and C4I); see theses on our website.

## **2. 3D Visual Environments**

### **Technical Director, Dr. Don Brutzman**

NPS has been instrumental in standardizing the extensible 3D (X3D) graphics specification, collaborating with the Web3D Consortium, ISO, and WWW Consortium to produce a synthesis of the Virtual Reality Modeling Language (VRML) and the Extensible Markup Language (XML) to exploit X3D graphics for Web-based viewing of 3D scenes. The addition of geospatial representations, humanoid animation, DIS networking capabilities, advanced 3D rendering, computer-aided design interchange, and other capabilities makes 3D graphics and visualization broadly available on the Web.

In scenario authoring and visualization for advanced graphics environments (SAVAGE), we have built sophisticated open-license military models in X3D as part of the SAVAGE project. Dozens of students have contributed high-res models for ships, aircraft, submarines, land vehicles, robots, humanoid behaviors, environmental effects, etc. The SAVAGE archive is a multiple-CD set documenting over 700 military models, scenarios, theses, etc.

Autonomous underwater vehicle visualization is also a MOVES concern. NPS provides sophisticated capabilities in modeling and visualizing oceanographic data collected by underwater robots. With Office of Naval Research (ONR) sponsorship, we have participated in fleet battle experiments to assess minefield-clearance by robots, and translate telemetry and communicate messages to the global Command-and Control System (Maritime) mine-warfare environmental-database-analysis library.

In XML for operations orders, we can auto-generate large-scale VEs corresponding to regional (and potentially theatrical) operations. This new capability can be communicated via existing message circuits, but for actual deployment, a common vocabulary with common semantics is needed; NATO's battlespace generic hub (BGH) appears a good candidate for such a model. We are showing how BGH can be expressed in XML for modeling joint and coalition tactical scenarios. This work is seen as necessary for enabling worldwide battlespace presence, monitoring, and visualization. Applications to homeland defense and assessment of the effects of weapons of mass destruction provide further challenges.

DoD modeling and simulation (M&S) must identify and adopt transformational technologies of direct tactical relevance to warfighters. The only software systems that composably scale to worldwide scope utilize Web technologies; therefore an extensible Web-based framework offers promise in scaling up M&S systems to benefit training, analysis, acquisition, and operational warfighters. We are defining an extensible modeling and simulation framework (XMSF) to exploit Web-based technologies. Government, academic, and industrial experts are working under investigators from the Naval

Postgraduate School, George Mason University, SAIC and Old Dominion University. XMSF is a composable set of standards, profiles and recommended practices for Web-based modeling and simulation. XML-based markup languages, Internet technologies, and Web services will enable a new generation of distributed M&S applications to emerge, develop and interoperate. The precepts of XMSF are:

- Web-based technologies applied within an extensible framework will enable a new generation of M&S applications to emerge, develop and interoperate.
- Support for operational tactical systems is a missing requirement for such M&S applications frameworks.
- An extensible framework of XML-based languages can bridge forthcoming M&S requirements and open/commercial Web standards, while supporting existing M&S technologies.
- Compatible, complementary technical approaches are now possible for model definition, simulation execution, network-based education, network scalability, and 2D/3D graphics views.
- Web approaches for technology, software tools, content production and broad use provide best business cases from an enterprise-wide (worldwide) perspective.

## **3. Networked Virtual Environments**

### **Technical Director: Dr. Don Brutzman**

MOVES continues research in networked virtual environments through NPSNET-V, a platform for investigating new concepts in related design. It features composable components, and can be extended at runtime; it is graphics-standard agnostic, and can use entirely new network protocols loaded at runtime. It has been used to test new ideas in interest management, security, and dynamic extensibility.

Cross-format schema protocol (XSFP) is a technique for saving XML data in binary format. XML data can be read by many platforms, but it is verbose, storing all data as strings. XSFP uses XML in bandwidth- or storage-constrained environments, increasing processing speed in data-intensive XML documents. MOVES is developing DIS libraries in many contexts (e.g. Java, X3D, and browser plugins), and describing DIS protocol in terms of XML and XSFP.

## **4. Computer Generated Autonomy**

### **Technical Director: John Hiles**

In 2002, the MOVES Institute established the Center for the Study of Potential Outcomes to employ our connector-based, multi-agent systems (CMAS) concept and cognitive science in modeling terrorist behaviors. The first project of the center is Project IAGO.

Project IAGO (integrated, asymmetric, goal

organization) aims to develop a conceptual model and prototype implementation of a cognitive model of the decision-making and dynamic behaviors of terrorists. The object is to develop an anti-terrorist tool for intelligence analysts, enabling them to explore a complex, hyper-dimensional space of terrorist capabilities and possibilities in a social space, with potential for identifying infrastructure vulnerabilities and detection/prevention opportunities. This work also explores benefits and limitations in applying the CMAS concept, an approach conceived by MOVES professor John Hiles and inspired by the information exchange and -processing techniques that have evolved at the cellular level.

Initially, IAGO will construct a prototype cognitive model for exploring terrorist behaviors, in three phases:

- Phase 1: Demonstration Model—initial design and implementation to generate software components that capture fundamental CMAS concepts of tickets, connectors, and templates. Lessons from phase one provide the software foundation for phase-two activities.

- Phase 2: Proof-of-Concept Model. This phase produced an initial prototype implementation of mental blending, a cognitive-psychological model of creative thought in which perceptions and concepts are combined under the guidance of generic problem-solving mental spaces and goal motivations to create cognitive blends (see cognitive training agents below). Development is ongoing to yield more complex blended spaces from the initial mechanisms.

- Phase 3: Domain Demonstration. The next phase is application and demonstration of the blended-mental-space modeling approach to represent influences and dynamics in forming terrorist behaviors leading to decisions and actions and to show the potential of the approach as a useful model for analysts. Early work with experts has resulted in a characterization of decision elements influencing terrorist behaviors. This information enables formulation of initial generic spaces and goals for interplay with an information stream, to produce behaviors comparable to real-world actions.

While our funding for IAGO was small in FY2002, the project shows great promise. In 2002, the Defense Threat Reduction Agency contracted with the MIIS Center for Nonproliferation Studies for a literature review of existing terrorist-behavior models. Two-hundred-and-sixty-five models were studied, and IAGO emerged in the top ten.

Cognitive training agents are also under intensive research. In January 2003, the MOVES computer-generated autonomy team reached a milestone. Using a multi-agent system combined with CMAS technology we developed over the last three years, we demonstrated that our software could do what cognitive psychologists call cognitive blending, producing cognitive-integration networks. That is, our software was able to create new knowledge in situ based on what it was doing and what it wanted to accomplish. Until this time, advanced multi-

agent work has only been able to demonstrate the ability to adaptively explore problems with intent and purpose. Software blending means that multi-agent software can now be built to answer questions such as, “What do you know?” “How do you know that?” or (most importantly for training), “What are you doing?”

In the next year, we intend to extend these experimental results to create adjustable cognitive training agents that will add new capabilities to training. The cognition of these agents will be built-in and applicable to a range of applications. Specialization will take place outside these capabilities (for example, a specific application will require specific input and output routines (sometimes referred to as input and actuator suites), and an application-specific set of meta-data packages that we call generic spaces, which would describe the types of cognitive operations needed in that particular area).

Training software equipped with cognitive-training agents could ultimately take on the following capabilities:

- Training involving competition with virtual opponents would add adversaries that adapt, deceive, and could explain what they were doing and why.

- Training for tasks not involving problem solving could self-adjust to press students to their limits of understanding, then offer explanations of their boundaries and what additional work might expand them. In this and the following training applications, cognitive training agents guide the training software rather than act as adversary.

- Training for problem solving where innovation and discovery are demanded could continually alter the situation to keep it open and freshly challenging.

Not all training software would benefit from these properties. But important benefits can be derived from software that adapts and incorporates discoveries into knowledge that it produces as it goes.

## **5. Human-Performance Engineering Technical Director: Dr. Rudy Darken**

We find two fundamental barriers to achieving the transformation in training the CNO has called for: (1) the cost of simulation for training is too high, and (2) the development cycle from mission-need to product is too long. Low-cost simulators and the bringing training to the fleet swiftly will have an immediate impact on the individual warfighter. HPE has been focusing on these issues through the VIRTE program to develop high-fidelity deployable trainers.

Our work includes the development of a Chromakey-augmented training environment, whereby the near-field cockpit of a helicopter is captured with a camera and mixed with a simulated “out the window” view, allowing inexpensive reconfigurable training to occur. Similarly, we are developing a “suitcase” simulator for close-quarters battle for the second phase of VIRTE,

miniaturizing as many components as possible to facilitate shipboard usage. This will be integrated with our forward-observer trainer towards a full spectrum combined-arms training capability. A common theme is the use of open standards and computer gaming technologies to increase performance while driving down development costs. All simulations for training developed in our laboratory undergo thorough testing both in house and in the fleet to determine their value in transfer of training.

As a part of DARPA's augmented-cognition (Aug-Cog) program, MOVES is researching a context machine to "improve the performance of the human-machine symbiosis by an order of magnitude or greater," thereby contributing to Aug-Cog's goal of improving warrior/computer interactions, advancing systems-design methodologies, and re-engineering military decision-making at a fundamental level. MOVES is exploring the computer science behind creating a system able to determine a situation's context and thereby assist in accomplishing its goals. Using a game engine to simulate real-world inputs and provide a means of output, MOVES has built a prototype system and continues research into the artificial intelligence and other factors required to determine context and act upon it.

In addition, MOVES has evaluated the training effectiveness of a damage-control trainer built at University of Illinois, Urbana-Champaign. We evaluated the system on surface-warfare officers stationed at NPS to understand the efficacy of the system in training DCAs. We expect to present our findings at ONR Workshop in May. Funding for HPE has been provided by ONR, N61M, DARPA, and the FAA.

## **6. Immersive Technologies**

**Technical director: LCDR Russ Shilling, USN**

The immersive technologies directorate met major milestones in 2002. The goal has been not only to apply virtual environment and video-game technology to training tasks, but also bridge the gap between these technologies and the operational- warfare environment.

First, technologies were advanced for the development of a sourceless postural tracking system using magnetic and inertial sensors to accomplish full-body tracking in a virtual environment. The unique and exciting part of this technological advance centers on a tracking device only slightly larger than a quarter. Patents for this device are measured the physiological impact of VE technology and emotion/arousal on cognitive abilities in a training task.

Finally, using the student-built cave system and other visual technologies, we are combining entertainment techniques, video-game technology, and advanced display design to solve problems associated with information management in network-centric warfare tasks, especially in command and control (video games routinely use

various strategies to allow players to track and manipulate hyper-dimensional data within game play).

We will see if some of these same strategies can be applied to helping planners, analysts, and operators track multi-dimensional data sets associated with the fusion of large amounts of tactical data from different sources in a live warfare setting. At the same time, we will be examining game engines and editors to see if traditional methods of war gaming might be better implemented or improved using game-engine technology. Results of this research will be presented at ForceNet in April 2003.

## **6. Evolving Operational Modeling** **Technical director: LCDR Alex Callahan, USN (ret)**

The technical directorate for evolving operational modeling became established as the configuration manager for the naval simulation system (NSS), an analytical model with unique capabilities for representing network-centric warfare.

The directorate coordinated efforts between SPAWAR Systems Center, San Diego, developers and testing agencies to ensure the quality of delivered versions, and continued to nurture a broad base for operational analysis across government, military, and commercial interests, with NSS as the focal point.

Evolving Operational Modeling obtained tasking in several key areas of NSS employment, including analysis of alternative platforms for the multi-mission aircraft program. The directorate prepared draft curriculum materials for a new course, applied combat modeling, providing insights into the application of combat models (using NSS as the exemplar) to military operational analysis.

The directorate led a working group of faculty from operations research and MOVES to review the combat modeling curriculum at NPS. As a result of these efforts, existing combat modeling courses have been revised, greater infrastructure has been provided for the war-gaming analysis course, and a school-wide wargaming policy and advisory committee has been established to revitalize application of warfare gaming across multiple disciplines.

## **7. Defense/Entertainment Collaboration** **Creative Director: Alex Mayberry**

The MOVES Institute has been in the press continually with our *America's Army* project (see Appearances, below). *Newsweek* has toasted "the legendary Naval Postgraduate School" in the aftermath of *AA* and its success, and we will soon be in *Newsweek* again.

*AA* has engendered much faculty and master's-student interaction, yielding several completed theses this year,

and has brought NPS much positive media attention. It has inspired the CNO to task the Naval War College's strategic studies group (SSG) to perform a study on the utility of massively multi-player gaming as the basis for the development of future large-scale M&S systems. That study reports out to the CNO in July 2003. The MOVES director gave a presentation on the project to the SSG in December 2002 for that study. The last two SSG plenary meetings have discussed massively multi-player gaming.

*AA* is highly approved by the sponsor for its transformation of Army recruiting. As of the 3<sup>rd</sup> of September 2003, there were 2M+ registered players of *AA*, with 1.3M+ having completed basic combat training in the game. Over 218M+ game missions have been completed, and some 100K gaming hours per day are played.

To understand the dividends of the game from the US Army perspective, a look at traditional recruiting is in order. The army spends \$2B (two billion) per year to attract and enlist 120,000 recruits (80,000 army, 40,000 national guard). That's \$16,666 per soldier.

Twenty percent (or 24,000) of these recruits drop out during basic combat training with the excuse that the army was not what they expected and combat training was not for them. With them goes \$400M in wasted recruiting expenditure. In addition, the army has spent \$75K each for training; thus, the army's loss per annum from this dropout group is \$2.2 billion.

*America's Army* cost \$7M to build over the first twenty-four months, a tag equivalent to that of 420 recruits who wash out (if we count recruiting costs alone). If the game encourages only 120 potential waverers to stick with it, it's broken even, counting recruiting and training costs. And of course, if it attracts those who would not otherwise have considered an army career, it's worth \$92K apiece.

The Army estimates *AA* has the potential to save some \$700M-\$4B per year. With respect to recruitment, actual results won't be known for four or five years, when the current raft of thirteen- and fourteen-year olds will be old enough to join. The hope is that through realistic role playing and exploration of a soldier's job, the important work of the military will be among the options that compatible young men and women will consider when planning a career.

Improvements are continually made. By August 2003, occupations within the game will include infantry, medic, engineers, RSTA/Scouts, and Special Forces:

- Medic/91W & combat lifesaver: Four missions, from AIT at Brooke Army Medical Center through an STX under field conditions. These missions are pass-fail and enact expert information on combat lifesaving. This training conveys lifesaving information applicable to the population for homeland defense. One mission will incorporate training to recognize the symptoms of nerve agent as well as immediate self- and buddy-aid for nerve-

agent casualties (funded by FORSCOM).

- Special Forces: Several missions to replicate the Robin Sage exercise as part of SFAS with emphasis on land navigation and escape and evasion. These missions will qualify players to enter specialized S.F. training and be assigned in multiplayer S.F. missions.

New units and weapons added into *AA*:

- Stryker: the Stryker debuted in May in a transport- and support-by-fire role within a new online, multiplayer mission. Coverage of the SBCT within the Game expanded throughout the summer of 2003.

- TACOM-ARDEC is funding incorporation of the objective individual combat weapon (OICW) and the shoulder-launched multipurpose assault weapon/bunker-defeat munition (SMAW-D) into the game.

Having a successful online game inside the MOVES Institute is like having your own particle accelerator. Lots of proposed applications and interesting research are coming in the door.

Many related training applications using the *AA* code base as a starting point are being considered. We have funding from one project that's using *Operations* for treaty verification pre-planning, and an Air Force group is looking at funding a training level within the game that will deal with force protection.

Infantry soldiers at Fort Benning are using *Operations* before setting foot on the real range. Also, the Army's objective force is having us integrate prototypes of their new weapons systems into *Operations* to evaluate their potential utility. We are building special levels of the game for the Special Forces, both for recruiting and SF training.

We have strong interest from Commander Naval Surface Forces Pacific in our building a game for material-assessment training. They have approved both proposal and schedule and are raising funding for the project. One extraordinary possibility, raised by the undersecretary of defense's office, is massively multiplayer (MMP) gaming. The *AA* project is being looked at both as a model of how such an effort could be carried out within government and as possible starting point for a MMP project. The work involved might include the procurement (or development) of a government-owned game engine capable of full-spectrum combat modeling and large-scale inter-operability integration, as well as a programming interface for modeling individual and organizational behaviors and stories.

An additional goal would be a rapid prototyping interface to the MMP that would allow any mission to be put together nearly overnight.

## 8. Conclusion

This has been a spectacular year, in which we have spent considerable time building our reputation outside

NPS in the DoD and Navy. We are known outside of NPS as *the lead technical and educational organization* in defense modeling, virtual environments, and simulation. Our largest issue is space to accommodate new projects.

## 9. Theses and Dissertations

- Arisut, LTJG Omer, Turkish Navy. "Effects of Navigation Aids on Human Error in a Complex Navigation Task." MS in MOVES, 2002.
- Aronson, MAJ Warren., USA "A Cognitive Task Analysis for Close Quarters Battle." MS in computer science in cooperation with MOVES, 2002.
- Back, LT David, USN. "Agent-Based Soldier Behavior in Dynamic 3D Virtual Environments," MS in MOVES, 2002.
- Brannon, LTCOL David, USMC and Villandre, MAJ Michael, USMC. "The Forward Observer Personal Computer Simulator (FOPCSIM)." MS in computer science in cooperation with MOVES, 2002.
- Calfee, LT Sharif, USN. "Autonomous Agent-Based Simulation of an AEGIS Cruiser Combat Information Center Performing Battle Group Air Defense Commander Operations," MS in MOVES, 2003.
- Campbell, LT James, USN. "The Effect Of Sound Spatialization on Responses to Overlapping Messages," MS in operations research in cooperation with MOVES, 2002.
- Desypris, LT Georgios, Hellenic Navy. "Enhancement Of Learning Process In Web-based Courses Using Combined Media Components," MS in computer science in cooperation with MOVES, 2002.
- Dickie, CAPT Alistair, Australian Army. "Modeling Robot Swarms Using Agent-based Simulation," MS in operations research in cooperation with MOVES, 2002.
- Greenwald, MAJ Thomas W., USA. "An Analysis Of Auditory Cues For Inclusion in a Virtual Close- Quarters Combat-Room Clearing Operation," MS in MOVES, 2002.
- Harney, LT James W., USN. "Analyzing Tactical Effectiveness for Anti-Terrorist Force Protection (AT/FP) Using X3D Graphics and Agent-Based Simulation," MS in MOVES, 2003.
- Krebs, CDR Eric M., USNR. "An Audio Architecture Integrating Sound And Live Voice for Virtual Environments," MS in MOVES, 2002.
- Lennerton, MAJ Mark, USMC. "Exploring A Chromakeyed Augmented Virtual Environment As An Embedded Training System For Military Helicopters," MS in computer science in cooperation with MOVES, 2002.
- List, MAJ Robert, USMC. "A Rendering System Independent High-Level Architecture Implementation for Networked Virtual Environments," MS in computer science in cooperation with MOVES, 2002.
- Michael, LT Robert, USN and Staples, LT Zachary, USN. "Targeting Networks: Stimulating Complex Adaptive Systems for Accelerated Learning and Organizational Impotence," MS in MOVES, 2003.
- Mowery, MAJ Samuel, USMC. "Enhancing the Situational Awareness of Airfield Local Controllers," MS operations research in cooperation with MOVES, 2002.
- Orichel, CAPT Thomas, German Army. "Adaptive Rules In

- Emergent Logistics (ARIEL)," MS in MOVES, 2003.
- Osborn, CDR Brian, USN. Dissertation, "An Agent-based Architecture For Generating Interactive Stories," Ph.D. in computer science in cooperation with MOVES, 2002.
- Peitso, LCDR Loren, USN. "Visual Field Requirements for Precision Nap-of-the-Earth Helicopter Flight," MS in MOVES, , 2002.
- Perkins, MAJ Keith M., USA. "Implementing Realistic Helicopter Physics in 3D Game Environments," MS in MOVES, 2002.
- Reece, CAPT Jordan, USMC. "Virtual Close Quarters Battle (CQB) Graphical Decision Trainer," MS in computer science in cooperation with MOVES, , 2002.
- Sanders, MAJ Richard, USA, and Scorgie, LT Mark, USN. "The Effect of Sound Delivery Methods On A User's Sense of Presence in a Virtual Environment," MS in MOVES, 2002.
- Spears, LT Victor, USN. "Terrain Level of Detail in First-person, Ground-perspective Simulation," MS in MOVES, 2002.
- Thien, CAPT Robert, USMC. "Realistic Airspace Simulation through the Use of Visual and Aural Cues," MS in computer science in cooperation with MOVES, 2002.
- Ulate, LT Stephen O., USN. "The Impact of Emotional Arousal on Learning in Virtual Environments," MS in MOVES, 2002.
- VanPutte, MAJ Michael, USA. "A Computational Model and Multi-agent Simulation for Information Assurance," Ph.D. in computer science in cooperation with MOVES, 2002.
- Wu, LT Hsin-Fu, USN. "Spectral Analysis and Sonification of Simulation Data Generated in a Frequency Domain Experiment," MS in operations research in cooperation with MOVES, 2002.

## 10. Publications

### 10.1. Conferences: accepted /published papers

- Andrade, S., Rowe, N., Gaver, D., and Jacobs, P. "Analysis of Shipboard Firefighting-team Efficiency Using Intelligent-agent Simulation," *Proceedings of the 2002 Command and Control Research and Technology Symposium*, Naval Postgraduate School, Monterey, CA, June 11-13, 2002.
- Barkdoll, T. C., Gaver, D. P., Glazebrook, K. D., Jacobs, P. A., and Posadas, S. "Suppression of Enemy Air Defenses (SEAD) as an Information Duel," *Naval Research Logistics* 49: 723-742, 2002.
- Blais, C.L., Brutzman, D., Harney, J.W., & Weekley, J. "Emerging Web-Based 3D Graphics for Education and Experimentation," *Proceedings, Interservice/Industry Training, Simulation, and Education Conference*, Orlando, December 2002. Nominated, best paper, ITSEC.
- Blais, C., Brutzman, D., Harney, Weekley, J. "Web-based 3D reconstruction of scenarios for limited objective experiments," *Proceedings, Summer Computer Simulation Conference*, San Diego, July 2002.
- Brutzman, D., Zyda, M., Pullen, M., Morse, K. "Extensible Modeling and Simulation Framework (XMSF) Challenges for

Web-Based Modeling and Simulation,” findings and recommendations report, Technical Challenges Workshop, Strategic Opportunities Symposium, Monterey, October 2002.

Gaver, D. P., and Jacobs, P. A. “Battlespace/Information War (BAT/IW): a System-of-Systems Model of a Strike Operation,” Naval Postgraduate School Technical Report, NPS-OR-02-005, August 2002.

Shilling, R., Zyda, M., Wardynski, C. “Introducing Emotion into Military Simulation and Videogame Design: *America’s Army: Operations* and VIRTE,” in *Proceedings of the GameOn Conference*, London, 30 November 2002.

Shilling, R.D. “Contribution of Professional Sound Design Techniques to Performance and Presence in Virtual Environments: Objective Measures.” *Proceedings of 47th Department of Defense Human Factors Engineering Technical Advisory Group Meeting*, September 2002, San Diego, CA.

Shilling, R.D. “Enhancing Performance in Tactical Environments Using Immersive Auditory Displays and Data Sonification Techniques.” ONR Cognitive Sciences Workshop, George Mason University, 2002.

Shilling, R.D. “Entertainment Industry Sound Design Techniques to Improve Presence and Training Performance in VE,” European Simulation Interoperability Workshop, London, England, 2002.

Shilling, R.D., Zyda, M. & Wardynski, E. “Introducing Emotion into Military Simulation and Videogame Design: *America’s Army: Operations* and VIRTE,” European Simulation Office, Game-On 2002, London, England, 2002.

Trefftz, H., Marsic, I., and Zyda, M. “Handling Heterogeneity in Networked Virtual Environments,” *Proceedings of IEEE VR*, Orlando, Florida, 25 - 27 March 2002

Trefftz, H., Marsic, I., and Zyda, M. “Handling Heterogeneity in Networked Virtual Environments,” *Presence*, Vol. 12, No. 1, February 2003: 38-52, (revised from IEEE VR 2002 paper).

VanPutte, M., Osborn, B., Hiles, J. “A Composite Agent Architecture for Multi-Agent Simulations,” 11th Computer Generated Forces and Behavioral Representation Conference, Orlando, FL, May 2002.

## 10.2 Invited papers

Stanney, K. M. and Zyda, M. “Virtual Environments in the 21st Century,” in *Handbook of Virtual Environments—Design, Implementation, and Applications*, Lawrence Erlbaum Associates, Publishers, Mahwah, NJ, 2002.

Zyda, M., Mayberry, A., Wardynski, C., Shilling, R., Davis, M. “The MOVES Institute’s *America’s Army: Operations Game*,” *Proceedings of ACM SIGGRAPH 2003 Symposium on Interactive 3D Graphics*, 28-30 April 2003: 217-218, color plate p. 252.

Zyda, M., and Bennett, D. “The Last Teacher,” in *2020 Visions*,

from the Summit and Press Conference on the Use of Advanced Technologies in Education and Training, US Department of Commerce, 17 and 27 September 2002.

Zyda, M., Hiles, J., Mayberry, A., Wardynski, C., Capps, M., Osborn, B., Shilling, R., Robaszewski, M., Davis, M. “Entertainment R&D for Defense,” *IEEE Computer Graphics and Applications*, January/February 2003.

## 10.3. Books, chapters

Cockayne, W. & Darken, R.P. (in press). “The Application of Human Ability Requirements to Virtual Environment Interface Design and Evaluation.” *Handbook of Task Analysis for Human-Computer Interaction*. Diaper, D. & Stanton, N. Eds.

Shilling, R.D., Shinn-Cunningham, B. “Virtual Auditory Displays.” *Virtual Environments Handbook*, Kaye Stanney, New York, Erlbaum, 2003.

## 10.4. Videotape, Live Demos, and Press

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**Figure 2. Classroom for medic training in *America's Army***