Shared Reality: Integrating Virtual Worlds, Constructive Simulations, and Collaborative Tools in a Web Browser

Dr. Michael W. Freeman
Adayana Government Group
Fayetteville, NC
mfreeman@adayana.com

Andrew Tietz, Mark Heimburger
Adayana Government Group
Urbana, IL
atietz@adayana.com, mheimburger@adayana.com

ABSTRACT

Virtual worlds are promising environments for providing concrete contexts for military training. They have limited training value, however, without the necessary planning and tactical control systems used by leaders at all levels.

This paper describes the design, architecture, standards, and innovations for a system of virtual worlds integrated with constructive simulations and a suite of collaborative tools to enable multi-echelon training. Leaders collaboratively create plans on a 2D map using doctrinally correct task organizations, drawing tools, and graphics. A 3D view is provided to enhance visualization of the 2D plan, and "hot spots" enable teams to enter virtual worlds as avatars to manipulate the environment directly and witness the results. A military constructive simulation provides adjudication of the results of the plan using calculations of movement and combat power. A master database maintains individual entity-state data and integrates the virtual world and constructive simulation to provide a synchronized view of the battle space and plan. All of these capabilities are based in the server cloud with customized interfaces provided in a web browser to reduce the load on the client and dramatically increase access to the system.

This integrated system enables leaders to plan an operation using familiar battle command tools, icons, graphics, and collaborative tools including video, eight-channel VOIP radio, whiteboards, and application sharing. The plan is then implemented by teams of soldiers in a first-person virtual world which is part of a larger environment created and controlled by the military constructive simulation. Leaders monitor the mission using 2D tools and influence the outcome by allocating assets such as indirect fire and reserve forces. Entities appear as avatars in the virtual world and are tracked as icons on the 2D map. Manipulation in either environment affects the other, resulting in a shared view of the battle space and world.

This paper will also outline details of the validation conducted by the Army as part of the program.

ABOUT THE AUTHORS

Michael Freeman is currently the Adayana Government Group's program manager for the Multiuser Online Virtual Exercise system. A career Army officer, Mike is a certified Defense Acquisition Professional in Program Management, a certified Project Management Professional (PMP), and a graduate of the U.S. Army Command and General Staff College, the Army Management Staff College, and Army Engineer Officer Career Courses. Mike holds a doctorate in Vocational and Technical Education from Clemson University.

Andrew Tietz is currently the Adayana Government Group's Immersive Learning Architect and chief architect for the Multiuser Online Virtual Exercise system. His career focus has been in developing approaches to combing existing web-based immersive technologies in new and innovative ways and enhancing those technologies where necessary. Current responsibilities include defining architecture and managing development of multiple immersive learning solutions across various technologies. Andrew holds a BS in Computer Graphics from Purdue University.

Mark Heimburger is currently the Adayana Government Group's Lead Instructional Designer for the Multiuser Online Virtual Exercise system, preparing Training Support Packages that include scenario-based exercises and system user training and support. He is also an Immersive Learning Designer focusing on serious games and game-based learning solutions. With more than 12 years' experience in computer and web-based training, he is also an accomplished script writer and multi-media developer. Mark is presently pursuing a Master's of Science in Technology from Eastern Illinois University.

Shared Reality: Integrating Virtual Worlds, Constructive Simulations, and Collaborative Tools in a Web Browser

Dr. Michael W. Freeman
Adayana Government Group
Fayetteville, NC
mfreeman@adayana.com

Andrew Tietz, Mark Heimburger
Adayana Government Group
Urbana, IL
atietz@adayana.com, mheimburger@adayana.com

INTRODUCTION

Virtual worlds are promising environments for providing concrete contexts for military training. They have limited training value, however, without the necessary planning and tactical control systems used by leaders at all levels (Hill, Belanich, 2006).

This paper describes 1) the Army's need for distributed, persistent learning solutions; 2) the components required to meet this training need; and 3) how these components have been successfully integrated into a system of virtual worlds, constructive simulations, and collaborative tools to enable multi-echelon training.

Training Requirements

We are living in an era of uncertainty and persistent conflict. In order to prevail, warfighters and units confronted with persistent conflict require persistent learning. Persistent learning requires persistent access to the full spectrum of technical systems, anytime, anyplace (Remily, 2011).

The emerging Army Persistent Learning Capability (PLC) Strategy envisions enabling the conditions for persistent access to training and education enablers, the blending of physical and virtual collaborative environments, and measurable learning outcomes across training domains that allow soldiers and leaders to prevail in the competitive security environment. It also bridges the institutional and operational Army through an integrated training environment.

Objective PLC attributes will enable and support formal/informal collaboration that, in turn, supports instruction/facilitation, mentoring, and peer-to-peer exchanges. PLC also includes facilitation of integrated multiplayer online virtual exercises. Furthermore, through the Army Training Information System, it will provide linked/embedded Live, Constructive, Virtual Gaming (Remily, 2011).

Increasingly, government and military organizations are demanding growing levels of complex interactions in learning products and services (Committee on Modeling and Simulation for Defense Transformation, 2006). This complexity of learning design requires interfaces and tools that span the gamut of virtual, constructive, and live collaborative problem solving to execute (Federation of American Scientists, 2006).

Military training organizations are also striving to dramatically reduce or eliminate instructor-led slide presentation lectures and begin using a blended learning approach that incorporates virtual and constructive simulations, gaming technology, or other technology-delivered instruction (U.S. Army Training and Doctrine Command (hereinafter TRADOC), 2011).

The Army Learning Concept 2015 states, "Soldiers and leaders require more relevant, tailored, and engaging learning experiences through a career-long continuum of learning that is not location dependent, but accessed at the point of need. Additionally, the Army must challenge and inspire learners who have grown up in a digital world, are adept at using technology, demand relevance, and require feedback and support from peers and mentors" (TRADOC, 2011).

THE SHARED REALITY CONCEPT

Shared reality refers to continuous synchronization of state data and annotations between multiple components of a training system. This synchronization enables the graphics and simulation objects created, displayed, and manipulated in one of the components of the system to be visualized and edited in the other components. The plan data is fused into a common operational picture displayed through single or separate screen interfaces.

The Shared Reality system integrates virtual worlds with constructive simulations and a suite of collaborative tools to enable multi-echelon training. This design approach enables users to plan an operation using familiar battle command tools, icons, graphics, and collaborative tools including video, eight-channel VOIP radio, whiteboards, and application sharing. The plan is then implemented by teams of soldiers in a first-person virtual world which is part of a larger environment created and controlled by the military constructive simulation. Leaders monitor the mission using 2D tools and influence the outcome by allocating assets such as indirect fire and reserve forces. Entities appear as avatars in the virtual world and are tracked as icons on the 2D map.

The Shared Reality System is composed of:

- Virtual World
- Constructive Simulation
- 2D Planning Map
- 3D Visualization Map/Digital Sand Table
- Collaborative Tools
- Integration Subsystem

SYSTEM COMPONENTS

Virtual Worlds

Definition

Virtual worlds are synthetic environments that include the replication of warfighting equipment and operational environmental conditions; allow for the sharing of a common environment which multiple users can access; and support interactions with simulated entities (including objects, avatars, and equipment) that mirror, in response fidelity, those that would occur in the real world (Office of the Undersecretary of Defense for Personnel and Readiness (hereinafter OUSD P&R), 2009).

Characteristics of a Generic Virtual World

1. Information is arranged in 3-D and accessed via geospatial referencing.
2. User is immersed in information with unique representation in common virtual space.
3. Experience is social where users interact with each other (visual, chat, voice).
4. Content is user generated and maintained.

Virtual worlds are especially well suited for small unit tactical training and leader development (see Figure 1). Leaders and Soldiers in small units can use virtual worlds to practice individual and team skills and battle drills (Digiovanni, 2009).

Figure 1. Virtual Worlds Are Well Suited for Small Unit Tactical Training

The shift from an outside orthographic perspective to a first-person agent embedded in the virtual world shifts the player from outside of the virtual world into becoming part of the environment. The result of this shift creates more-engaging experiences for the player (Riddle, 2002).

Current virtual worlds do not train operational planning, military decision making processes, or visualization of the battlespace in 2 dimensions/simplified 3 dimensions. They also require large numbers of real-time players to represent elements above platoon size. They are generally not useful for training leader skills above the platoon level or the formal military decision making process **(**OUSD P&R), 2009).
.

CONSTRUCTIVE SIMULATIONS

Definition

Constructive Simulations are simulated forces that respond to trainee actions. Typically, real human inputs are needed to fully operate these simulated forces which then carry out the resultant actions in a synthetic environment (see Figure 2). Semi-automated Forces (SAF) are one example of constructive simulations; wargaming models are another example (OUSD P&R, 2009).

Figure 2. Constructive Simulations Train Commanders and Staffs through Highly Complex Models That Provide Symbolic Representation of Their Plans (DoD Image)

A military constructive simulation provides adjudication of the results of a plan using calculations of movement and combat power. Constructive simulations can also partially create an environment where leaders get a real-world battle command feel and gain awareness of terrain.

Constructive simulations include SAFs for "unmanned entities." Official military simulations contain authoritative entities and behaviors that are validated, verified, and approved by proponents to make sure they perform correctly. This includes the full range of detailed weapons and vehicle attributes (e.g., cross sectional area, range, armor protection) and performance (e.g., probability of hit/kill, speed).

High fiscal requirements (contractor/simulation support staff for LVC exercises) and time investments (scenario and database development) for each exercise, however, limit use and access to full-scale constructive simulations. Direct access to full-scale military constructive simulations by trainees is seen as requiring detailed, time-consuming efforts to develop plans and compare options. This renders them unusable for lower echelon units and leaders in their current implementation (James, Dyer, and Wampler, 2008).

The emerging primary constructive simulation for U.S. ground forces is OneSAF. . OneSAF is a constructive simulation that provides entity-level computer generated forces (PEO STRI, 2007). It models and simulates combat entities and systems. The entities have some level of autonomy that allows them to react based on their situational awareness. These entities are semi-automated in that they generally require human operators to do holistic planning, provide goals for goal-directed behaviors, etc. (Coolahan, Sanders, Morse, Kay, and Erdman, 2010). These semi-automated forces provide intelligent, doctrinally correct behaviors representing the modular force in the contemporary operating environment (James, et al., 2008).

IMPORTANCE OF 2D PLANNING AND EXECUTION MAP

Currently, military leaders collaboratively create plans on a 2D map using doctrinally correct task organizations, drawing tools, and graphics. Digital 2D maps are easily recognizable representations of the current planning environment and are very efficient at displaying large amounts of information at a high level on highly simplified terrain information. They represent the basic input and deliverable for the military decision making process at the command and staff level (see Figure 3).

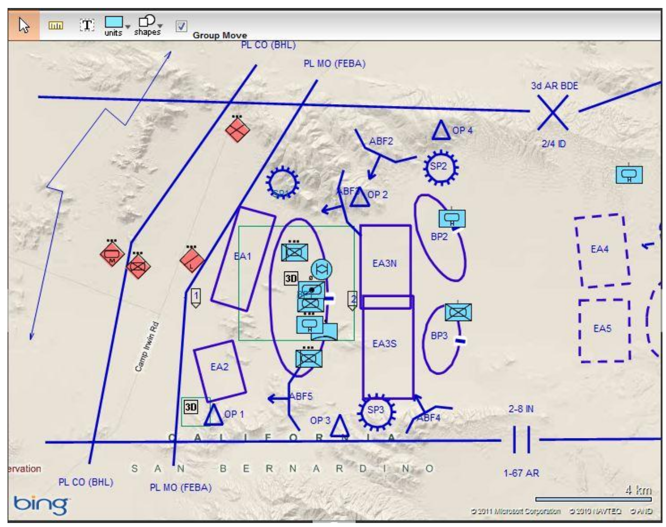

Figure 3. 2D Planning and Execution Maps Provide Recognizable, Simplified Views of the Plan and Terrain

IMPORTANCE OF 3D MAP REPRESENTATIONS

A 3D view is provided to enhance visualization of the 2D plan over a simplified representation of the terrain by providing an orthographic projection of the normally 2D information (Wisher, Macpherson, Abramson, Thornton, and Dees, 2001). This capability meets the same intent as a traditional sand table to see information in geographic perspective (Perla, 1990), except that the 3D view is continuously synchronized with data from the 2D maps and both constructive and virtual worlds (Belanich, Moses, and Orvis, 2005). A traditional sand table is depicted in Figure 4, while the 3D Map View is depicted in Figure 5.

Figure 4. Leaders Use a Traditional Scale Model Sand Table for Planning (DoD Image)

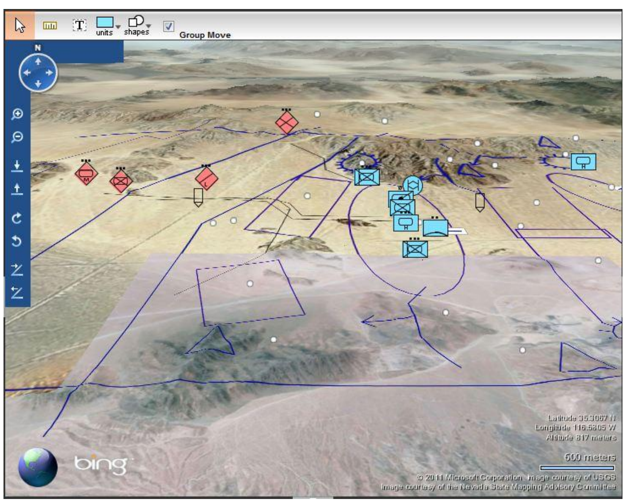

Figure 5. The 3D Map View (Digital Sand Table) Provides Visualization of the Plan in Relation to Simplified 3D Terrain

This dynamic synchronization greatly enhances high-level visualization of the plan's relationship to terrain without the cognitive load and clutter associated with a full immersive virtual world view. Both the 2D map and 3D terrain views are good examples of enabling the planner to see the abstraction of the "forest" without the confusing detail of the "trees."

3D views have significant limitations owing to their necessarily simplified presentation. Because of the orthographic or angled view for creating the 3D views, it is very difficult to place symbols and graphics precisely to represent the plan on the terrain.

IMPORTANCE OF COLLABORATIVE TOOLS

Mission command implies decentralization of capability and authority. Further, it implies that collaboration and trust are as important as command and control (TRADOC, 2008). Collaboration informs situational understanding. Effective collaboration enables assessment, fosters critical analysis, end anticipates adaptation. It assumes that the strategic end state is not fixed. Collaboration allows operational commanders to recognize and react to changes in the situation. Operational commanders can then adjust operations so tactical actions remain linked to conditions in the operational environment. Finally, collaboration informs problem framing (TRADOC, 2008).

Military and other educational experience has shown that training with a coach or mentor is one of the most effective ways to learn (Fletcher and Chatham, 2009) (see Figure 6). Additionally, the level of interactivity between learners and both coaches and peers is a key measure of training, in terms of both cost and effectiveness (Frank, Helms, and Voor, 2000).

Figure 6. Collaborative Tools Enable Higher Levels of Learning through Coaching and Peer Interaction

When a blended learning approach is coupled with collaborative, context-based, problem-centered instruction, it creates a powerful learning experience. Employing self-paced, technology-delivered instruction reduces the amount of face-to-face instruction, but increases the quality with a richer, socially supported learning experience. This instructional strategy can be used in the schoolhouse with live facilitators and peer learners, or distributed through networked links from a facilitator hub to a distributed student cohort group (TRADOC, 2011).

Collaborative tools have the potential to form the basis for small group collaborative problem-solving exercises and for capstone course events, with individuals collaborating across networks linked to branch schools and regional learning centers (Dempsey, 2009).

IMPORTANCE OF CLOUD COMPUTING AND WEB DELIVERY

Wireless internet devices and cloud computing provide expanded opportunities for anytime, anywhere access to information (TRADOC, 2011). Soldiers use computers, mobile devices, and the Internet in units and off-duty experiences that too often are radically different from what they experience in institutional learning (TRADOC, 2011). Additionally, the advent of Web 2.0 technologies opened a world of digital social interactions that have become a natural part of life for digital-age learners (TRADOC, 2011).

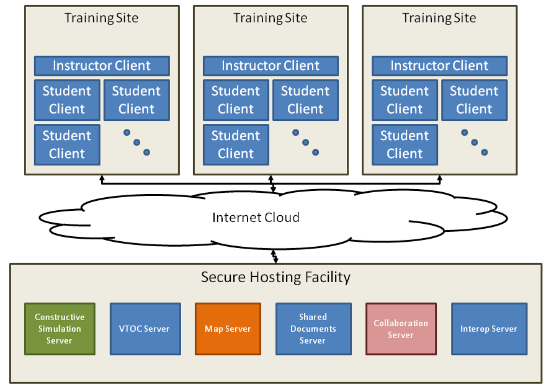

Figure 7. Cloud Computing and Web Delivery

The Army has specified the requirement to deliver digitized learning content to Soldiers worldwide using cloud computing or other advanced networking means to eliminate user frustration and download issues (TRADOC, 2011).

As the graphics capabilities of commercial off-the-shelf (COTS) personal computers have increased, it has become possible to host high-quality virtual environments on these machines without requiring special-purpose graphics hardware. This advancement results in training devices that can be upgraded easily to new COTS computers through the cloud server and client interface, rather than dealing with the expensive lifecycle costs of obsolete training-specific hardware.

Furthermore, the acquisition costs of personal computers are often 1,000 times cheaper than the cost of military hardware mockups. Each student, therefore, can train on his or her own desktop trainer at a fraction of the cost of providing each student with dedicated hardware only available in a fixed location (Frank, et al., 2000).

The shared reality concept leverages Web and Internet technologies to enable training and communications that are interoperable, scalable, cross platform, cross operating system, and mobile device ready. By following accepted Internet specifications and standards, security issues are also minimized and well understood.

Integration for Shared Reality

The objective of an integrated virtual and constructive simulation is to immerse and engage the learner in a realistic setting that presents authentic situations and relevant tasks. Effective learning in integrated virtual and constructive simulations links task performance to the larger mission, the context in which learning will take place, cues to indicate the need and timing for activities, and ultimately the results achieved. The strategy allows learners to use higher-order critical thinking skills as they make choices and experience the consequences of those choices (see Figure 8) (Federation of American Scientists, 2006).

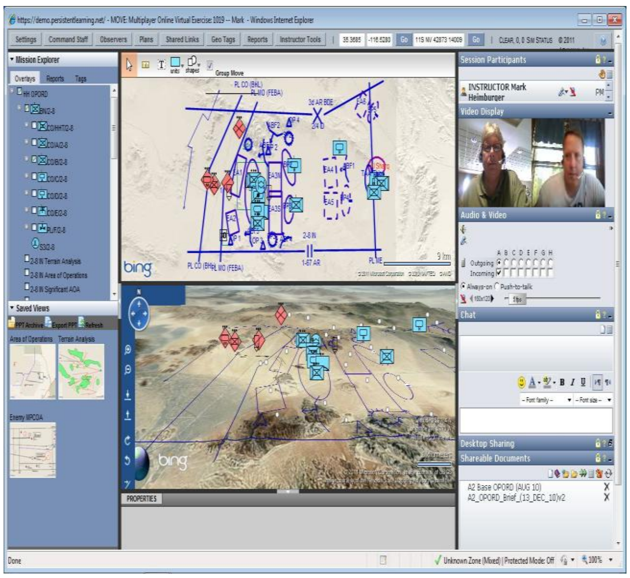

Figure 8. Shared Reality between Virtual Worlds, Constructive Simulations, and Collaborative Tools Provides Higher Levels of Learning

The shared reality approach described here enables users to effectively drag and drop units and entities onto the 2D map, and the icons and symbols are automatically geosynchronized onto the 3D sand table and even in the virtual world (see Figure 9). The virtual world allows the user to assume the role of any entity and interact with the other entities in the virtual world, whether they are controlled by the constructive semi-automated force or another live player in the virtual world.

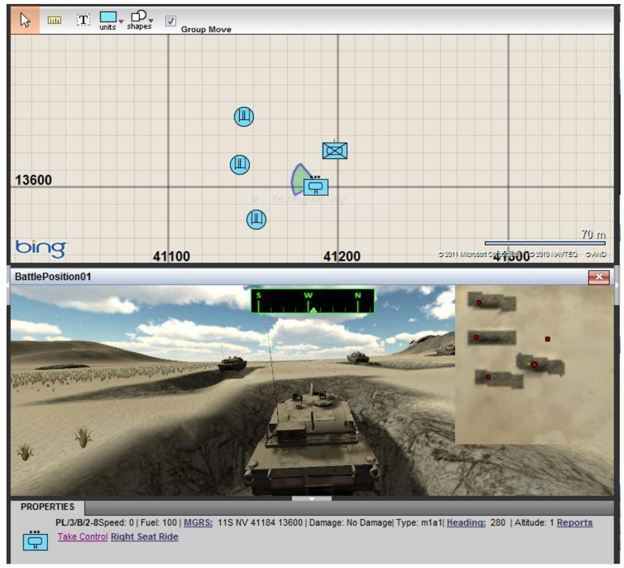

Figure 9. Example Virtual World Combined with a Constructive Representation on a 2D Map

DESIGN, ARCHITECTURE, AND STANDARDS

The Approach

The approach was to federate a military constructive simulation, a web-based COTS virtual world, and a web mapping suite to create a fused visualization of plans, operations, and relationships to geo-specific terrain. This approach resulted in a system of virtual worlds integrated with constructive simulations, geospatial representations and a suite of collaborative tools to enable multi-echelon training (see Figure 10).

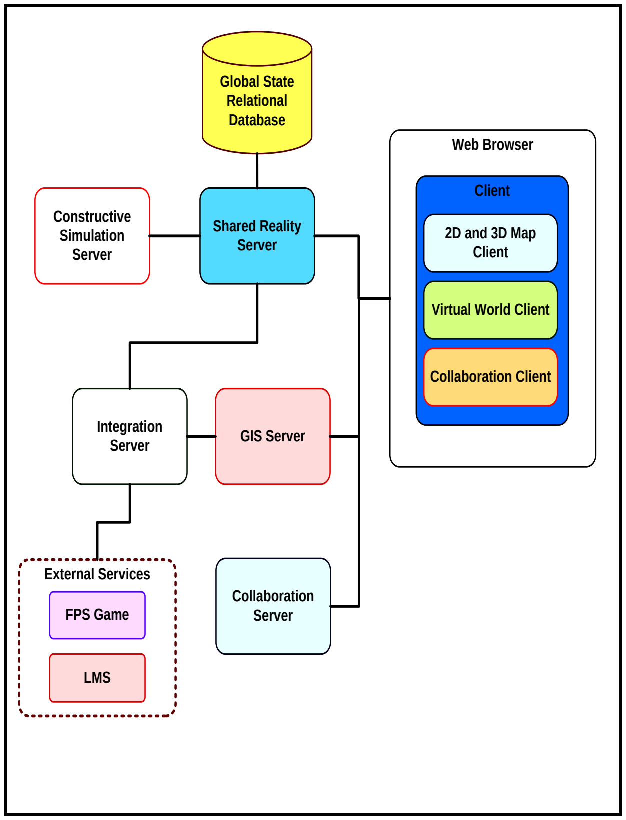

Figure 10. Simplified Shared Reality System Architecture

Standards

The foundations of the Shared Reality system are open source software, w3c Web standards, and DoD/International standards. This combination improves interoperability and security while reducing both licensing and maintenance costs. It also enables faster development and deployment on DoD information systems (U.S. Army CIO/G6, 2010).

The basis of interoperability and shared state data among the virtual world, constructive simulation, and 2D and 3D maps is the innovative Global State Relational Database (GSRD). This database complies with ISO/IEC 13249-1:2007 Information Technology – Database Languages SQL multimedia and application packages Part 1: Framework, Third Edition, 12 February 2007. This ensures predictability in the data structure and storage.

The GSRD is essentially federated with the constructive simulation using the Federation Object Model specification in IEEE 1516-2000, Standard for Modeling and Simulation High Level Architecture (HLA) – Framework and Rules. The HLA provides the glue to combine simulations and other systems (Kuhl, Weatherly, and Dahmann, 1999). Following the HLA standards enables the state data, entity definitions, and annotations to be synchronized with the constructive simulation while providing a model for synchronizing all other components with the relational database. The HLA Federation Object Model (FOM) is a common object model that describes the data that federates share within a federation (Reid, 2000).

Essentially, the state data of record is stored in the GSRD. Then, the virtual world and geospatial visualization components (2D and 3D maps) are synchronized with the database, and through it the constructive simulation. The synchronization information is also communicated back from the virtual world and geospatial visualization components, through the GSRD, to the constructive simulation. During execution of the constructive simulation, all state data, status, and annotations are captured in the relational database at one-second intervals. This capture frequency enables on-demand playback, pause, and viewing of the simulation results from any point in the battlespace at any point in time.

The geospatial visualization components comply with WMS 1.3 OpenGIS Web Map Service to display geographic information in the web client. They also are capable of importing military CADRG (Raster Product Format/Compressed ADRG) in accordance with MILPRF-89038. Current mapping data are from either commercial services (i.e., Bing or Google) or open source (i.e., LandSat or USGS). Detailed terrain data for the virtual world and simulation follow U.S. Military Specification Digital Terrain Elevation Data (DTED) MIL-PRF-89020B.

All user client representations follow IETF RFC 4346 The Transport Layer Security (TLS) Protocol, Version 1.1, April 2006 (U.S. Army CIO/G6, 2010), which enables https security and encryption. To ease administration and facilitate network security, the entire web client uses only one port, 443, for all services.

In the Shared Reality implementation, WMS access also works to generate virtual environments on the fly. For instance, a user can request through the Shared Reality Server that a virtual scene be added in a specific location. The Shared Reality Server then utilizes the WMS interface to the map server to provide data for construction of the virtual world terrain assets. The virtual world player then will load these dynamically generated assets (see Figure 11).

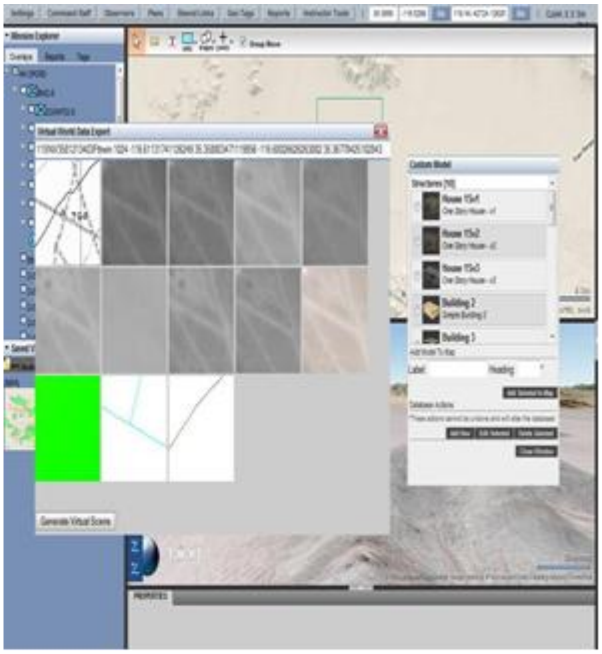

Figure 11. Capturing Map Data for Virtual World Integration

The user can then interact directly with the terrain to add building features or direct changes to the terrain for digging trenches or other earth-moving activities. The results of these terrain alternations in the virtual world are then communicated to the constructive simulation, so that it will use these virtual world constructed details in its modeling of the unit's behavior and ability to see and be seen in the larger context of the battle.

The client interface utilizes w3c Web standards in its development. Utilizing browser detection methodologies allows users to access the shared reality views from mobile browsers on tablets and smartphones to full browsers on Windows, MacOS, and Linux from a single client codebase (see Figure 12). This is done by altering the stylesheets based on the target device detected and enabling or disabling various panel components based on those devices' current support.

Figure 12. Shared Reality Client Running on iPad

Furthermore, w3c standards allow extension and skinning of the client interface to mimic various battle command systems without alternating the underlying codebase that handles server communication and overall client state management. In this way, the interface can be set to allow only certain views for learners based on their log ins, so that one user might be presented with the virtual world and another just with the constructive map interface, should that be specified by the training requirements.

TRAINING EFFECTIVENESS ANALYSIS

A training effectiveness analysis (TEA) was conducted on a Shared reality system as an example of a persistent learning capability. The example system was the Multiuser Online Virtual Exercise (MOVE). The TEA was sponsored by the Army Training Support Center and designed for leader training in the military decision making process. The TEA was conducted by TRADOC Analysis Center, White Sands Missile Range, in collaboration with the Maneuver Center of Excellence and the Future Force Integration Directorate.

The test case for the TEA was doctrine and tactics training for unit leadership on effectively integrating Brigade Combat Team Modernization increment 1 sensors into unit combat operations. The test bed consisted of the leadership of an Infantry company with the Army Evaluation Task Force at Ft. Bliss, TX. This intact company leadership group consisted of five officers (commander, executive officer, three platoon leaders) and 14 non-commissioned officers (First Sergeant, three platoon sergeants, ten squad leaders) (see Figure 13).

Figure 13. Audience for Training Effectiveness Analysis Use Case Consisted of Officers and NCOs of an Infantry Company

Training consisted of interactive multimedia instruction using the shared reality system for collaborative planning exercises with coaches and unit leadership. The exercises consisted of 60 facilitated collaborative sessions over 11 days of training, progressing from platoon-to company-level tactical operations planning and execution.

While final findings have not been published, initial findings are encouraging. The company leadership judged the training conducted via MOVE as being "to standard" and recommended using it for training the first unit equipped with the sensors (see Figure 14). The soldiers initially were skeptical of training using a shared reality system, but ultimately reacted positively after learning the system interface and becoming actively engaged in solving tactical problems during the sessions. Additionally, the soldiers gained more confidence as they began to explore the system capabilities and to actively innovate in leveraging those capabilities to support learning and collaboration (Gettman, 2011).

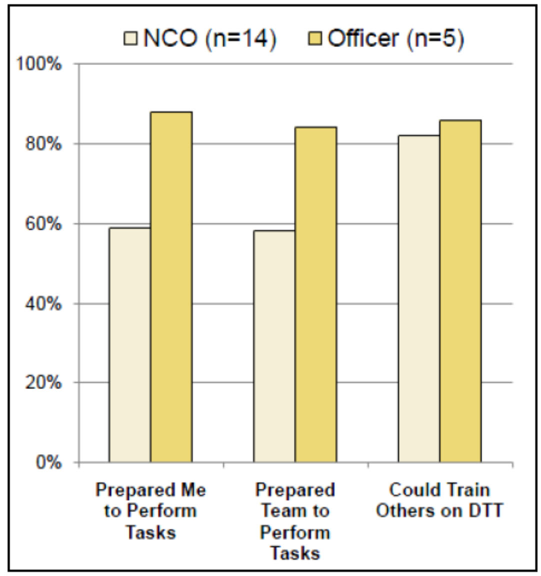

Figure 14. Example Responses to Effectiveness Survey Questions by Officers and NCOs

RECOMMENDATIONS FOR CONTINUED RESEARCH AND IMPLEMENTATION

The shared reality approach and design described in this paper accounts for virtual worlds, constructive simulations, and collaborative tools based in the cloud and delivered through ubiquitous Web browsers. It does not address, however, the live component of the training environment or direct stimulation of battle command systems.. Therefore, efforts should be made to review the literature related to live simulations and battle command system stimulation and to incorporate those elements into future shared reality systems.

CONCLUSION

The example system demonstrates the benefits of using shared reality for multi-echelon training. The integration of virtual worlds, constructive simulations, 2D planning maps, unlimited map overlays, and 3D planning maps into a fused visualization of the relationship of complex plans and operations to geo-specific terrain enhances training effectiveness. The inclusion of collaborative tools enables higher levels of learning through interaction with coaches, peers, and subordinates. Perhaps more importantly, the example system provides all these capabilities persistently, anytime, anywhere Internet connectivity and a Web browser are available. This persistence is provided by a database that constructs, saves, and reconstructs sessions dynamically, from data elements, rather than the static images on a typical Web page. This decreases session overhead and improves persistence.

ACKNOWLEDGEMENT

We thank Mr. Luciano Iorizzo for his contributions to the concept and development of MOVE which helped to shape it into the powerful persistent learning system it is today. Without his vision and focus on the future learning environment for soldiers, this paper would not have been possible.

REFERENCES

Belanich, J., Moses, F., & Orvis, K., (2005). Distance learning: A way for life-long learning. (ARI Research Report 63). Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Committee on Modeling and Simulation for Defense Transformation. (2006). *Defense modeling, simulation, and analysis: Meeting the challenge.* Washington, DC: National Academies Press.

Coolahan, J. E., Sanders, R., Morse, K. L., Kay, S. W., & Erdman, C. L. (2010). *Final report, study on management concepts for broadly needed simulation tools*. (NSAD-R-2010-055). Laurel, MD: Johns Hopkins University Applied Physics Laboratory.

Dempsey, M. (2009). Mission enabler: Providing trained, mission-ready soldiers for current and future operations. *Military Training Technology 15*(4), 2022. Rockville, MD: KMI Media Group

Digiovanni, F. (2010). Virtual worlds—A discussion. Presentation to 2010 Defense Technical Information Center Conference: Alexandria, VA.

Federation of American Scientists. (2006a). *R&D challenges in games for learning*. Washington, DC: The Learning Federation.

Fletcher, J. & Chatham, R. (2009). Measuring return on investment in training and human performance. In P. E. O'Connor & J.V. Cohn (Eds.), *Human performance enhancements in high risk environments: Insights, developments, and future directions from military research* (106-128). Santa Barbara, CA: Praeger.

Frank, G., Helms, R.F., & Voor, D. (2000). Determining the right mix of live, virtual, and constructive training. *Proceedings of the 2000 Interservice/Industry Training Systems and Education Conference*.

Gettman, D. (2011). Persistent learning capability training effectiveness analysis, phase I: Instructional validation. Invited presentation to the 79th Military Operations Research Symposium. Monterey, CA.

Hill, R., Belanich, J. (2006). Pedagogically structured game-based training: Development of the ELECT BILAT simulation. *Proceedings of the 25th Army Science Conference*. Washington, DC: Office of the Assistant Secretary of the Army (Acquisition, Logistics and Technology).

James, D., Dyer, J., & Wampler, R. (2008). *Exploring the potential value of OneSAF at the small-unit level*. (ARI Research Report 1884). Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Kuhl, F., Weatherly, R., & Dahmann, J. (1999). *Creating computer simulation systems: An introduction to the high level architecture*. Upper Saddle River, NJ: Prentice Hall.

Office of the Undersecretary of Defense for Personnel and Readiness (2009). *Military training*. (Department of Defense Directive 1322.18). Washington, DC: Department of Defense.

Perla, P. (1990). *The art of wargaming*. Annapolis, MD: Naval Institute Press.

Reid, M. (2000). An evaluation of the high level architecture (HLA) as a framework for NASA modeling and simulation. *Proceedings of the 25th NASA Software Engineering Workshop*. Goddard Space Flight Center, Greenbelt, MD.

Remily, H. (2011). Army persistent learning strategy. Presentation to the U.S. Army Distance Learning Conference. Newport News, VA.

U.S. Army Program Executive Office for Simulations, Training, and Instrumentation. (2011). OneSAF Objective System (OOS). Retrieved June 29, 2011, from http://www.peostri.army.mil/PRODUCTS/ONESAF/

U.S. Army Training and Doctrine Command (2008). *Operations, Field Manual 3-0.* Washington, DC: Headquarters, Dept. of the Army.

U.S. Army Training and Doctrine Command (2011). *The United States Army Learning Concept for 2015.* (TRADOC Pamphlet 525-8-2). Fort Monroe, VA: U.S. Army Training and Doctrine Command.

U.S. Army Training and Doctrine Command (2010). *The Army capstone concept, operational adaptability: Operating under conditions of uncertainty and complexity in an era of persistent conflict: 2016-2028*. (TRADOC Pamphlet 525-3-0). Fort Monroe, VA: U.S. Army Training and Doctrine Command.

U.S. Army CIO/G6 (2010). *Common operating environment architecture: Appendix C to Guidance for 'end state' Army Enterprise Network Architecture*. Washington, DC: Headquarters, Dept. of the Army.

Wisher, R. A., Macpherson, D. H., Abramson, L. J., Thornton, D. M., & Dees, J. J. (2001). *The virtual sand table: Intelligent tutoring for field artillery training.* (Research Report 1768). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences.