THE SQUAD SYNTHETIC ENVIRONMENT - A NEW VIRTUAL SIMULATION FACILITY FOR DISMOUNTED INFANTRY

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ABSTRACT

The U.S. Army is in the process of fielding a Squad Synthetic Environment (SSE) at the Land Warrior Testbed located at Fort Benning, Georgia. This state-of-the-art virtual simulation facility consists of nine Dismounted Infantry Simulators, ModSAF 5.0 including newly developed individual combatant simulation capabilities, and two Reconfigurable Ground Vehicle Simulators. The SSE represents the culmination of many years of investment by the government, industry and academia working together to achieve a unique virtual simulation environment aimed squarely at meeting the needs of the infantryman. The Dismounted Battle Space Battle Lab (DBBL) and the US Army Infantry Center (USAIC) at Fort Benning are the proponents for the SSE. It is envisioned that the SSE will be used to support DBBL and USAIC simulation needs across the entire simulation regime, from TEMO to ACR and R&D. In this paper we describe the SSE in some detail, postulate the role of virtual simulation within the modeling and simulation (M&S) domain, and then look to the future and provide our vision of how the SSE can be used to support the Army's M&S needs well into the 21st century.

Robert Ferguson is employed in Lockheed Martin's ADST II office in Orlando, Florida where he has served as Project Director for the Dismounted Warrior Network (DWN) project since its inception. Mr. Ferguson has over 20 years experience in the simulation industry, in the areas of distributed systems, visuals, and database generation. **Brian Plamondon** is also with Lockheed Martin's ADST II office where he has served as the Lead System Engineer for DWN. Mr. Plamondon has 14 years of experience in training simulator development, simulation R&D, and avionic system design, both at LMC and previously at Sikorsky Aircraft.

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Matthew Kraus is the Project Director for DISAF at SAIC in Orlando. His research interests are in the areas of distributed computing, artificial intelligence, and computer graphics. **Douglas Reece** is a Senior Scientist at SAIC in Orlando and the software architect for DISAF. He has been developing physical and behavioral models for Individual Combatant CGFs for five years.

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BACKGROUND

Several years ago DBBL and the USAIC identified the need for immersive virtual simulation. In February of 1994 DBBL hosted an Individual Combatant (IC) and Simulation Symposium to focus attention on the "... critical requirement to improve the representation of Individual Combatants across all modeling and simulation domains, for the purpose of improved Warfighting, Training, and Combat Development" (DBBL, 1994). These requirements prompted STRICOM, the US Army Research Lab (ARL), and other organizations to initiate a number of technology initiatives aimed at developing IC simulation capabilities, such as locomotion devices (e.g., Sarcos' IPORT and TREADPORT) and untethered immersive visual systems (e.g. Veda's DSS). It also resulted in STRICOM's initiation of an ADST II delivery order to bring some of these technologies together into an integrated synthetic environment called the Dismounted Warrior Network (DWN).

The DWN project was initiated in June of 1996. The initial objective was the integration of a number of existing virtual simulation systems into an interoperable network of individual soldier simulators and simulations. Virtual Individual Combatant Simulators (VICS) developed by STRICOM, TRAC-WSMR (TRADOC Analysis Center, White Sands Missile Range), NPS (Naval Postgraduate School) and NAWCTSD (Naval Air Warfare Center Training Systems Division) were integrated with DISAF (Dismounted Infantry Semi-Automated Forces), a modified version of the Marine Corps Individual Combatant SAF, and installed at the Land Warrior Testbed (LWTB) at Fort Benning in May of 1997. This first instantiation of the DWN was utilized to support an initial set of experiments in late May and early June 1997.

In September 1998 a follow-on project called DWN ERT (Enhancements for Restricted Terrain) was initiated, with a focus on Military Operations in Urban Terrain (MOUT). New low cost IC simulators acquired by DBBL from Reality By Design (RBD) were modified based on lessons learned during DWN. In addition, DISAF was modified to support operations inside buildings. Experiments were conducted in July 1998 with these modified systems, assessing locomotion methods, visual systems, aiming techniques, and DISAF-VICS interoperability. Further background information on these projects is provided in Jones (1998), Reece (1998), and Lockheed Martin (1999).

We are now entering the third phase of development. Although the DWN effort per se has come to an end, STRICOM's Advanced Concepts and Research Tools (ACRT) program is in the process of fielding next generation Dismounted Infantry Simulators at the LWTB. The objective of ACRT, another delivery order under ADST II, is to provide Commercial-Off-The-Shelf (COTS) solutions for meeting some of the requirements established by TRADOC under the Battle Lab Reconfigurable Simulator Initiative (BLRSI). Specifically, ACRT is installing reconfigurable simulators at several Army testbeds to upgrade and extend the existing synthetic environment infrastructure.

In addition, STRICOM is continuing to develop DISAF capabilities through SAIC, the DISAF developer for DWN. ModSAF 5.0 incorporates the last release of DISAF, and as DISAF continues to evolve STRICOM intends to update ModSAF/OneSAF with the latest DISAF developments. The ACRT Simulators and associated infrastructure is scheduled to be installed and integrated into the Army's first Squad Synthetic Environment at Fort Benning, Georgia prior to the commencement of year 2000.

WHY VIRTUAL SIMULATION?

Discussions of virtual simulation, outside from the accepted applications of air and ground vehicle simulator trainers and part-task trainers for specific system operation or maintenance, are often confronted with the question of "Why?" or "So What?" This section presents our response.

We believe that virtual simulation capabilities can provide unique insights to Army (and other) equipment and weapon system evaluators not offered by other evaluation techniques, such as live exercises, constructive simulation, and engineering simulation or modeling. To support this notion we first define terms (see Figure 1):

- Virtual simulation is defined as real-time, Man-In-The-Loop (MITL) simulation, where interactions are driven by human perception of time and space. Semi-Automated Forces simulations such as ModSAF are included in the virtual simulation domain because they are designed to work cooperatively with real-time MITL simulators. Typically virtual simulations focus on individual and collective tasks up to platoon levels, although they can extend higher; e.g., CCTT extends to company and battalion levels. In all cases the virtual simulation entity is the individual platform, which can be a soldier, a vehicle, or even a munition.

- Constructive simulation is defined as aggregate level, force-on-force simulation, and is often (but not necessarily) based on a "roll of the dice" to determine event outcomes. Typically constructive simulations run faster than real-time so that the large scale scenarios being played out do not take excessive clock time. Examples are CBS, BBS, Eagle, and Janus. Typically the terrain databases used by constructive simulations are gross approximations to the terrain, e.g., constant valued hexagon or grid shaped surfaces. Normally the constructive simulation entity is a unit - a battalion, brigade, etc. - and interactions between these entities occur at an aggregate level via statistical techniques.

- Engineering simulation/modeling is defined as a component level simulation, where the physics of the component are modeled, often with very high fidelity. Typically engineering models run slower than real-time due to the complexity of the models. Examples of engineering simulations are explosion models, sensor models, electromagnetic propagation models, engine models, and so forth. The engineering model entity is typically a single component, however systems may also be modeled by aggregating the component models.

- Live exercises are considered to be simulations in the sense that the exercises are not being conducted against a real enemy, or as the STRICOM logo states, "all but war is simulation". Live exercises are similar to virtual simulations in that the focus is on real-time, MITL operations, typically aimed at individuals and small units. The key difference between live and virtual is that in live exercises real soldiers perform activities in real-world settings and with the real weapon systems or modified weapon systems (e.g., MILES).

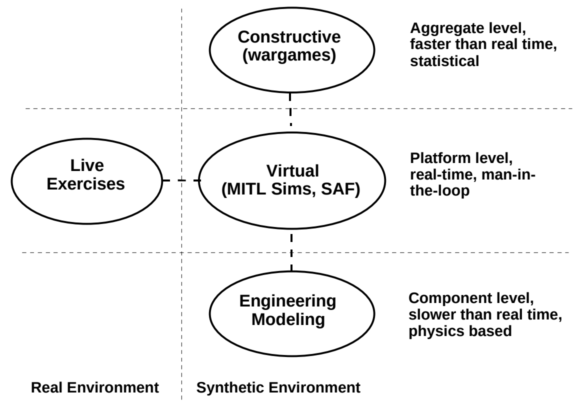

Figure 1. Simulation Domains

The simulation community has been attempting to link all of these simulation domains into one unified architecture, called the High Level Architecture (HLA). Many technical challenges remain to be solved before this will be possible, at least with legacy simulations. Some of the key problems are summarized in Figure 2.

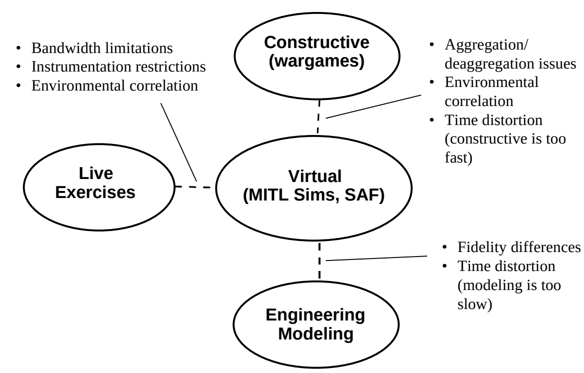

Figure 2. Simulation Linkage Problems

Next generation simulations combined with HLA will help to overcome these linkage problems. For example, WARSIM, which will ultimately replace the BBS, CBS, and Janus constructive simulations, will be implemented as a virtual wargame, with as many as 100,000 individual entities. Virtual prototyping is a class of simulation that will continue to develop in complementary fashion to engineering modeling, and support real-time MITL component/system level evaluations. Embedded systems constitute another class of simulations that will continue to emerge, and to complement live exercises with real-time, MITL simulations (e.g., MILES). The overall trend seems to be one of migration towards the virtual simulation domain via these new "hybrid" simulation classes. This notion is illustrated in Figure 3.

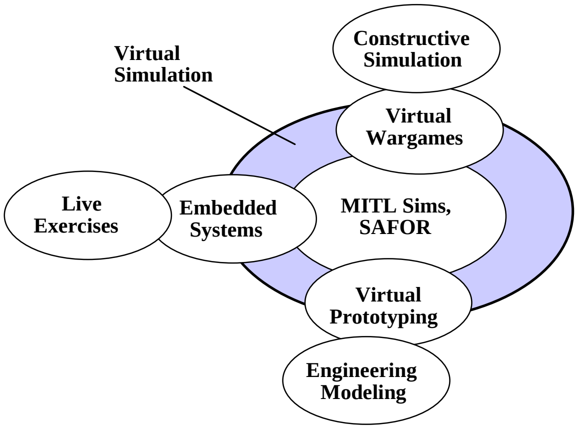

Figure 3. The Trend Towards Virtual Simulation

There are several reasons that virtual, real-time, MITL simulations have been growing in popularity with simulation developers and users:

- The focus is on the warfighter and the interaction of humans with other real and surrogate humans as opposed to a roll of the dice.
- Events occur in real-time (i.e., clock-time), without time distortion; they are neither too fast (constructive simulation) nor too slow (engineering models).
- Potentially dangerous scenarios may be played out that could not be done in live exercises because of associated personnel risks (e.g., live munitions used by friendlies and enemies).
- Environmental conditions (wind, rain, fog, time of day) may be changed to suit the exercise, whereas with live exercises sometimes the reverse is true.
- The environment can be changed during the exercise via simulated explosives (e.g., mouseholes, breaching) whereas in live exercises the time and cost to repair the training facilities would prohibit their use.
- A number of simulation runs can be conducted under various conditions in a short time, which increases the statistical validity of the exercise results as compared to live exercises.

THE SQUAD SYNTHETIC ENVIRONMENT

As mentioned earlier, the ACRT program is in the process of fielding the SSE at the LWTB. It will consist of a total of nine immersive Dismounted Infantry Simulators, one desktop Dismounted Infantry Simulator, two Ground Reconfigurable Simulators, OPFOR and BLUFOR SAF Simulators, and support equipment (see Figure 4).

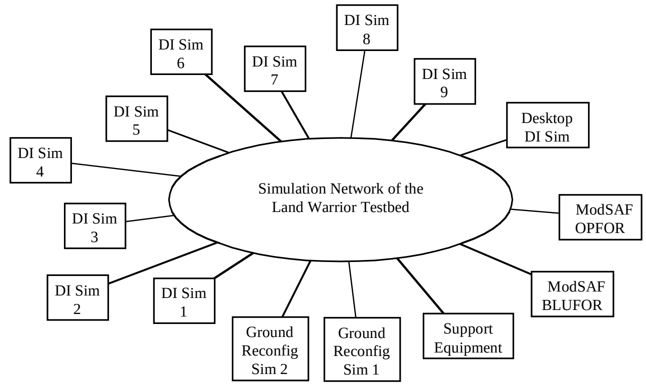

Figure 4. Squad Synthetic Environment Block Diagram

This system of systems will provide a unique capability to future users of the SSE - the ability to operate with a full squad of soldiers in a realistic virtual MOUT environment, with the ability to move, shoot and communicate collectively against a common enemy simulated by ModSAF/OneSAF and supported by simulated ground vehicles. From an experimental perspective, the types of measures of effectiveness/performance that will be measurable with the SSE are tabulated in Figure 5.

Measure of Effectiveness	**Measure of Performance**
Time to complete Mission	Mission start time Mission end time
Loss Exchange Ratio	Enemy killed Friendly killed
Rescue Success	Number of hostages released
Enemy Engagement Success	Number of enemy troops Number of enemy troops fired upon Number of enemy troops killed Average range of enemy killed Weapon used to destroy enemy Rounds per enemy casualty
BLUFOR Survivability	Number of BLUFOR Number of BLUFOR fired upon Number of BLUFOR killed
Communication Effectiveness	Time of event to be reported Time to construct message Time message sent Time message responded Number of voice communications
Maneuver Effectiveness	Time to reach defined waypoints
GRAYFOR Identification Effectiveness	Number of GRAYFOR killed Number of civilians killed Number of Hostages killed by BLUFOR Number of BLUFOR killed by GRAYFOR
Ingress Tactical Performance	Loss Exchange Ratio outside building
Building-Clearing Tactical Performance	Loss Exchange Ratio inside building

Figure 5. Potential SSE Experimental MOE's and MOP's

The major components of the SSE are briefly discussed in the following paragraphs.

ACRT Dismounted Infantry Simulator (DI Sim)

The ACRT DI Simulator consists of a Soldier Visualization System or SVS™, a monocular Head Mounted Display (HMD), a DI C4I system, and a virtual radio (see Figure 6). The SVS™ is a low cost, PC based, DIS compatible DI simulator developed by Reality By Design (RBD). It uses a surrogate weapon with an integrated thumb transducer for unencumbered movement through the virtual environment. Posture changes (standing, kneeling, or prone) and weapon aiming are captured via a position tracking system.

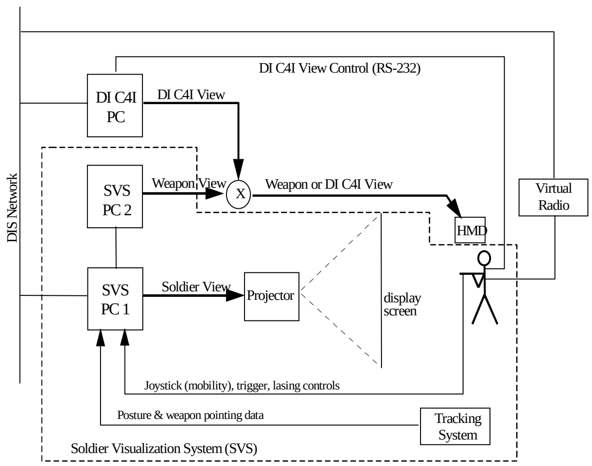

Figure 6. Dismounted Infantry Simulator (DI Sim) Block Diagram

Two views are presented to the soldier: an eyeball or soldier view of the environment on a rear projection screen, and a separate, independent line-of-sight video camera view presented on the HMD. This video camera view is normally slaved to the direction the surrogate weapon is pointed, thus it is referred to as the weapon view.

The HMD can also display C4I information to the soldier. The DI C4I simulation is controlled by a dedicated PC that is networked to other DI C4I simulations via DIS to act as a virtual VMF (Variable Message Format) network. The DI C4I simulation was developed under DWN ERT and includes three types of screens: Send Report (which has several sub-types), Receive Report, and a Map View. Send Reports can include enemy locations that may be input automatically based on a laser range finder function performed by the host SVS™. The soldier controls the display mode and enters data via a hand controller attached to his uniform (see Figure 7).

Figure 7. ACRT DI Simulator

The SVS™ has been significantly improved since it was initially fielded to the LWTB. These improvements include higher resolution displays (1024 x 768), higher update rate (typically >15 Hz), improved aiming, and use of an enclosure to reduce ambient light and sound. In addition, the HMD has been customized by Kaiser Electro-Optics Inc. to support a full color, high resolution monocular display, the ability to position the eyepiece over either eye, and with an integrated audio headset. Aiming improvements are primarily due to use of next generation acoustic sensor technology from Intersense Corporation combined with the acoustic isolation properties of the enclosure. The enclosure also improves the soldier's sense of immersion in the virtual world.

ACRT Ground Reconfigurable Simulator

ACRT is also fielding ground reconfigurable simulators to several Army testbeds. Two such devices are being installed at the LWTB and will become part of the SSE. These COTS products are manufactured by Raytheon and are known as the Tiger Simulation System. The simulator is capable of being reconfigured to support the following vehicles: M1A1, M1A2, FSCS (Future Scout), HMMWV, M2A1, M2A2, M113, M577, and HEMTT (Heavy Expanded Mobility Tactical Truck). Up to four crewstation positions are supported. Graphical user interface screens displayed on CRT's configured with touchscreens are used as the primary reconfigurable control interface for the various positions. In addition, grips are provided for commanders and gunners, and a steering/pedal assembly provided for drivers. All positions are equipped with headsets, which are tied into the vehicle intercom as well as the SSE virtual radio network. Performer-based visual software is hosted on an SGI Onyx 2 with Infinite Reality graphics hardware.

The Bradley Fighting Vehicle configurations are expected to be of primary interest to users of the SSE. The M2 modes of operation provide realistic vehicle and turret motion, support for the 25 mm main gun, TOW missile and 7.62 mm coax machine gun, sound effects, and damage/kill effects. The Commander's position includes a popped-hatch view with 120 degree horizontal field of view, grip assembly to control the gun and turret, gun sight repeater, and headset. The Gunner's position includes a grip assembly to control the gun and turret, a gun sight, a weapon control panel, and a headset. The Driver's position includes three periscope displays, assemblies for steering, moving, and shifting, and a headset (see Figure 8).

Figure 8. ACRT Ground Reconfigurable Simulator

<u>SAF Simulator</u>

The SSE OPFOR and BLUEFOR SAF Simulators provide Computer Generated Forces (CGFs) to the synthetic environment. This CGF representation is done via a ModSAF-based architecture known as the OneSAF Testbed Baseline (OTB). Among other things, the OTB provides the capability to represent the IC in the synthetic environment and interact with the rest of the SSE Simulators via distributed simulation protocols. The IC functionality included in the OTB is provided by the Dismounted Infantry Semi-Automated Forces (DISAF) Research and Development (R&D) project sponsored by the U.S. Army's STRICOM Synthetic Environment & Technology Management Division (SETMD).

The initial DISAF capabilities were developed by SAIC under the DWN program. These capabilities were designed to support IC general operations in urban terrain, and specific exercises with Infantry Simulators. Requirements for supporting exercises with DI Simulators included communication using the life form states first enumerated in DIS 2.0.4, support for animated state transitions on visual systems, standardization of entity physical parameters, close correlation of a terrain database with multi-elevation buildings with detailed interiors, and a dynamic terrain capability that can put a hole in a building wall.

The DISAF development included enhancements to the ModSAF entity type representation, entity appearance representation, plan view display, entity component representation, entity control over body posture and weapon position, visual detection and acquisition, small arms gun model, entity physical parameter representation, life form movement control, collision detection, and multi-elevation structure (MES) processing (see Figure 9). In addition, a new database with detailed MES features was created to match the visual database, and a dynamic hole-blowing mechanism was implemented. New entities were defined—soldiers carrying an M16A2, a SAW, an AT-8 (with an M16A2 as a secondary weapon), and an AK-47. Two fireteams (one with and one without the AT-8) and a squad were also defined.

Behaviors created for these entities included a high-precision individual movement behavior which can also control posture and weapon position; an individual location fire behavior for firing munitions at specific locations; a unit suppressive fire behavior; and a fireteam clear-room behavior. An overall description of the DWN-DISAF background, objectives, and accomplishments can be found in Dumanoir (1998). A detailed description of the initial DWN-DISAF functionality can be found in Reece (1998). This initial DWN-DISAF functionality was integrated into the ModSAF V5.0 baseline on Feb 99.

Figure 9. DISAF Supports Operations Inside Buildings

STRICOM's SETMD continues to sponsor enhancements to the DISAF application. Follow-on work to DISAF has included improvements to all of the IC-based behaviors, especially the location and suppressive fire tasks. An M203 grenade launcher has been added to complete the standard fire team.

Hand grenades have also been added to make MOUT tasks more realistic. Movement behavior has been expanded to provide more autonomy in individual and unit movement. These enhancements are described in Dumanoir (1999), and will be integrated into the OTB on a yearly cycle, beginning November 1999.

Support Equipment

In addition to the operational components, the SSE contains equipment and software that supports data logging, analysis, and after-action review (AAR) capabilities. All data distributed on the network can be logged and made available for subsequent statistical analysis or AAR by this support equipment. The primary data elements of interest are the standard DIS PDUs: entity state, collision, fire, and impact. This is in addition to the subjective data that is normally collected during these experiments by the Army Research Institute (ARI).

A new SSE capability provided by the CDF (Core DIS Facility) Upgrade program is ModIOS, an exercise controller developed by Motorola. ModIOS uses SIMAN PDUs, to start, stop, freeze, and resume exercises in a synchronized manner. ModIOS also provides a plan view and a 3D stealth view of the synthetic environment.

The Land Warrior Testbed (LWTB)

The Land Warrior Testbed located at the Simulation Center at Fort Benning, Georgia is run by Lockheed Martin Technology Services Group for STRICOM under the ADST II contract. When the SSE is fully installed later this year, it will span two buildings of the LWTB. Fiber optic linkages between the buildings have already been installed. Figure 10 is a photograph of the first two DI Simulators installed with their enclosures at the LWTB.

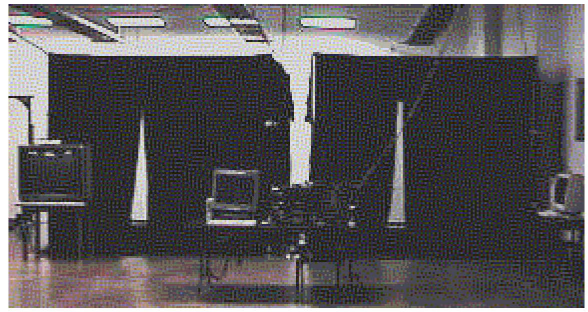

Figure 10. First two DI Sims Installed at the LWTB

POTENTIAL APPLICATIONS

The range of possible Modeling and Simulation (M&S) applications for the SSE is as broad as the number of ways a soldier can interact with the environment using a weapon or other piece of equipment. Within the US Army, modeling and simulation applications are divided into three domains: Advanced Concepts and Requirements (ACR), Research, Development, and Acquisition (RDA), and Training, Exercises, and Military Operations (TEMO). The Army Model and Simulation Master Plan (October 1997) defines the activities of these domains and the types of models and simulations associated with each according to Figure 11.

Domain	Domain Activities	Models and Simulations
Advanced Concepts and Requirements (ACR)	Force Planning Developing Concepts Developing Requirements Warfighting Experiments	Reconfigurable Simulators Constructive Models Live Exercises
Research, Development, and Acquisition (RDA)	Basic/Applied Research System Acquisition and Logistics Weapon System Development Test and Evaluation	System Prototypes (Hardware or Virtual) Engineering and Physics Models Live Exercises
Training, Exercises, and Military Operations (TEMO)	Individual and Collective Training Joint and Combined Exercises Mission Rehearsal Operations Planning	System/Device Simulators Training Simulations (Constructive) Live Exercises

Figure 11. Army Modeling and Simulation Domains

While to date the SSE developments have been aimed primarily at the ACR domain, they can readily be extended to support activities in all three domains. Some illustrations are provided below.

- Tactics, Techniques, and Procedure (TTP) development. TTPs for new or conceptual systems can be developed, implemented, and evaluated in the SSE. For example, C4I (command, control, communication, computers and intelligence) systems envisioned for future soldiers can be fielded at the squad, fireteam, or individual levels. The allocation of C4I resources and how they would be employed at these levels could be investigated using the SSE. Issues concerning routing of information, resolution of conflicting data, management of time-sensitive data, and soldier-machine interface could all be evaluated, thus serving the ACR/RDA domains at multiple levels. Tests could be conducted with new weapons or sensors in a similar manner.

- System acquisition/weapon system development. System development could be assisted through the integration of mockups or prototypes of various levels of fidelity. Functional, virtual prototypes could be introduced into the SSE initially to assess performance and operational utility. This could be accomplished with simple physical prototypes. As the weapon system concept matures, more representative mockups could be introduced along with higher fidelity functional characteristics to continue the operational effectiveness assessments. From an acquisition perspective, the functional characteristics of systems being evaluated in an ACTD (Advanced Concepts and Technology Demonstration) effort could be inserted into the SSE to augment live exercises. This could serve to increase the effective sample size or to assess the systems in ways that live tests cannot support due to environmental, safety, or other considerations.

- New equipment training. The SSE could be used as an initial or supplemental training resource for newly fielded equipment. It could serve as a training multiplier when actual equipment assets are scarce, or could be used for initial user familiarization to limit the consumption of associated expendables.

- Mission rehearsal. Given the ability to rapidly generate virtual databases of any location in the world, the SSE could support site-specific and mission-specific training for any region of interest, open or urban. The SSE can support terrain (and even building) familiarization as well as rehearsal of small unit operations.

- Training. Eventually, once issues associated with the SSE concerning operational effectiveness and validity are resolved, it could be used to train selected collective tasks. It can be envisioned that the SSE could prove useful in:

  – Preservation of perishable skills

  – Training in tactically varied and realistic scenarios

  – Maintenance of small unit proficiency

  – Enhancement of mission planning effectiveness

  – Integration of individual soldiers and small units into the combined arms training arena.

The potential utility of the SSE to support the various M&S domains is clear; integration and test efforts planned for the 3rd and 4th quarters of FY 1999 are aimed at assessing the ability of the SSE to realize this potential.

SUMMARY

In this paper we have presented a brief description of the Squad Synthetic Environment, a new simulation facility at Fort Benning designed to support the virtual M&S needs of the infantry. We have highlighted some of the advantages of virtual simulation in contrast to other simulation modalities, and then delineated several potential application areas for potential users. For additional information please contact any of the following:

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