Study Report 2007-01

Immersive Simulation Training for the Dismounted Soldier

Bruce W. Knerr
U.S. Army Research institute

20070319414

United States Army Research Institute for the Behavioral and Social Sciences

February 2007

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Authorized and approved for distribution:

Scott E Graham

Michelle Sams

SCOTT E GRAHAM
Acting Technical Director

MICHELLE SAMS
Acting Director

Technical review by

Timothy Sayers, Army's Combat Developer Project Lead for Dismounted Soldier Simulations

Diana Tierney, Chief, S&T Research, Studies and Experimentation Division, TPCRD, DCSOPS&T, TRADOC

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REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy)	2. REPORT TYPE	3. DATES COVERED (from. . . to)
February 2007	Final	October 2005 – October 2006

4. TITLE AND SUBTITLE Immersive Simulation Training for the Dismounted Soldier	5a. CONTRACT OR GRANT NUMBER
	5b. PROGRAM ELEMENT NUMBER 665803
6. AUTHOR(S) Bruce W. Knerr	5c. PROJECT NUMBER D730
	5d. TASK NUMBER 338
	5e. WORK UNIT NUMBER H01
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U. S. Army Research Institute for the Behavioral & Social Sciences ATTN: DAPE-ARI-IF 12350 Research Parkway Orlando, FL 32826-3276	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U. S. Army Research Institute for the Behavioral & Social Sciences 2511 Jefferson Davis Highway Arlington, VA 22202-3926	10. MONITOR ACRONYM
	11. MONITOR REPORT NUMBER Study Report 2007-01

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

Subject Matter POC: Bruce W. Knerr

14. ABSTRACT *(Maximum 200 words)*:

A study was conducted to document the need for immersive dismounted virtual Soldier and leader training and the available research evidence regarding the effectiveness of virtual training for training Soldiers and leaders in complex skills. A literature search of research reports, journal articles, and conference proceedings to identify evaluations and experiments related to the study topic of the training effectiveness of immersive virtual simulations was conducted. Particular attention was paid to an expended series of evaluations conducted by the Army R&D organizations during the period 1997 – 2005. The major findings are organized around the topics of training effectiveness, Soldier task performance, and advantages and disadvantages of immersive virtual simulations. Soldiers and small unit leaders report that their skills improve as a result of training in virtual simulations, and these self-reports by have generally, if informally, been confirmed by observers. While the simulators impose constraints on the performance of some Soldier activities, this should limit training effectiveness only if those activities that cannot be performed in the simulator are not trained by other means. Advantages and disadvantages of immersive simulations are also described.

15. SUBJECT TERMS

Immersive simulation. virtual simulation, virtual environment, mission rehearsal, collective training, Infantry training

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON
16. REPORT	17. ABSTRACT	18. THIS PAGE			
Unclassified	Unclassified	Unclassified	Unlimited	63	Ellen Kinzer Technical Publications Specialist 703-602-8047

Standard Form 298

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Immersive Simulation Training for the Dismounted Soldier

Bruce W. Knerr
U.S. Army Research Institute

Simulator Systems Research Unit
Stephen L. Goldberg, Chief

U.S. Army Research Institute for the Behavioral and Social Sciences
2511 Jefferson Davis Highway, Arlington, Virginia 22202-3926

February 2007

Army Project Number
665803D730

Personnel and Training
Analysis Activities

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IMMERSIVE SIMULATION TRAINING FOR THE DISMOUNTED SOLDIER

EXECUTIVE SUMMARY

Research Requirement:

ARI was tasked to conduct a study to develop a training/benefit analysis documenting the need for and expected benefits of immersive dismounted virtual Soldier and leader training, and to prepare a report documenting the available research evidence regarding the effectiveness of virtual training for training Soldiers and leaders in complex skills, the cognitive and decision making skills that will foster adaptability and the capability to respond to rapidly changing situations.

Procedure:

ARI conducted a literature search of research reports in the Defense Technical Information Center (DTIC), and journal articles and conference proceedings in the open literature to identify evaluations and experiments related to the study topic of the training effectiveness of immersive virtual simulations. Particular attention was paid to an expended series of evaluations conducted by the U.S. Army Research Institute (ARI), Program Executive Office, Simulation, Training and Instrumentation (PEO STRI), the Army Research Laboratory (ARL), and the Research, Development, and Engineering Command Simulation and Training Technology Center (RDECOM STTC) during the period 1997 – 2005. This series of related development and evaluation activities constitutes the most extensive examination of questions of dismounted Soldier performance and training effectiveness in immersive simulations.

Findings:

It is difficult to draw definitive conclusions about the effectiveness of immersive virtual simulation for training dismounted Soldiers and leaders because the technology is relatively new, and organizations have not had the resources to conduct evaluations of sufficient scope to provide definitive results about training effectiveness. The evidence that is available comes from assessments involving small numbers of Soldiers and units who received limited amounts of training. In these assessments, Soldiers and small unit leaders have consistently reported that their skills improved as a result of training in virtual simulations, with the most improvement in controlling, coordinating, communicating, and planning (conducted prior to use of the simulators), and less improvement in the mechanics of tasks and battle drills. These self-reports have generally been confirmed by observers. They are also consistent with evaluations of collective marksmanship trainers, which use different technology, but are functionally similar to immersive virtual simulators. There is objective performance data indicating that the marksmanship training provide effective training in tactical skills as well as marksmanship.

Virtual immersive simulators necessarily do limit how some tasks can be performed, particularly those involving locomotion and touch. This limits training effectiveness only if those actions that cannot be performed in the simulator are not trained by other means. Even

though the simulator may not allow Soldiers to perform physical actions as they do in the real world, it does allow them to practice and learn the cognitive skills they need. These include the planning that needs to be done prior to missions, the skills required to maintain situational awareness, and learning to think on their feet and make appropriate decisions in complex situations.

Virtual simulations possess a number of advantages relative to the use of live simulation for dismounted Soldier training. They can represent any terrain or environment that has been modeled, weather, and other environmental conditions. Use of immersive virtual simulation is likely to reduce the amount of time required by a unit to conduct a training exercise relative to live training. Fewer human role players should be required to fill the positions of enemy units, other friendly units, and civilians in virtual simulations than in live simulations. The reduced risk of accident or injury makes it possible to more realistically depict the effects of demolitions or indirect fire than is possible in live simulations. Virtual simulations require less physical space than a live simulation facility, and reduce the need for use of actual equipment.

Virtual After Action Reviews (AARs) provide unique capabilities that are not currently possible with live simulations. They can provide an overall view of the action that is not possible with video cameras, which provide multiple separate views of portions of the action. They can provide a view of the action from any perspective, not limited by camera locations. They capture and provide an accurate representation of ground truth. Finally, they can provide a variety of aids to analyze and depict events.

Virtual simulations possess a number of disadvantages relative to the use of live simulation for dismounted Soldier training. Some physical activities cannot be practiced. Weapons effects may not be modeled correctly, or position and location tracking may not be accurate enough to depict realistic weapons effects. Soldiers may, therefore, develop inappropriate expectations. Virtual simulations require improved facilities (enclosed space, air conditioning, and power) and technical support to implement training scenarios and operate and maintain computers and other equipment. Trainees may not take virtual simulations seriously because they are similar to video games, and might, therefore, practice actions that are inappropriate in the real world, or attempt to "game" the system. Some trainees may experience "simulator sickness."

Virtual immersive simulations can provide the opportunity for small unit leaders and unit members to practice, in the context of realistic simulated operations, the cognitive and decision making skills that will foster adaptability and the capability to respond to rapidly changing situations. Focused, repetitive, deliberate practice, with feedback based on performance, is an effective method for training the recognition of situations and developing expertise. Cognitive and decision making skills can be trained even if some physical tasks cannot be performed in the situation.

Utilization and Dissemination of Findings

It is recommended that the following actions be taken as the next steps toward acquisition and fielding of an immersive virtual training system for dismounted Soldiers.

Conduct a large-scale evaluation using current technology. This evaluation should consider objective measurement of both skill improvement on the simulator and transfer of those skills to a live simulation environment. A sufficient number of units should participate so that any meaningful real differences in the training effectiveness of different can be detected. The evaluation should be embedded in the unit's normal training progression, and unit personnel should be involved in its development and delivery.

Consider cost-effectiveness of fully immersive and desktop or laptop systems. There is a large cost differential between fully-immersive simulators and simulators using desktop or laptop computers to provide the same functionality. In contrast, the research evidence indicates that any difference in training effectiveness between immersive and desktop systems is likely to be small, although immersive systems have a small advantage when training spatially-oriented tasks. Whether they are better when training squads to conduct urban or counter-insurgency operations, and if so, whether the difference is large enough to justify the increased cost, are unknown, but should be investigated.

Conduct a survey of potential officer and enlisted trainees to determine game-playing skill. An assumption underlying the growing popularity of the use of video and PC-based games for training is that the potential trainees are interested in and experienced with such games. They, therefore, need little training in their use, and are motivated to play. However, data from small samples of Soldiers who participated in evaluations suggests that this may not be the case. Since game playing experience has implications for the types of games that could be used for training and the amount and type of prerequisite game playing training required, we would like to have a much better picture of the both current and projected Soldier and leader familiarity and experience with different types of interactive games.

Continue to improve virtual simulation capabilities and assess their training effectiveness. Some aspects of immersive virtual simulation technology, such as large-screen displays, will continue to improve, or become less expensive, as a result of commercial market forces. However, it will require a continuing science and technology investment by the Army to produce a tailored system that provides cost-effective training.

IMMERSIVE SIMULATION TRAINING FOR THE DISMOUNTED SOLDIER

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Introduction

TRADOC DCSOPS&T and TPIO Virtual requested that ARI conduct a study to develop a training/benefit analysis documenting the need for and expected benefits of immersive dismounted virtual Soldier and leader training. This report documents the available research evidence regarding the effectiveness of virtual training for training Soldiers and leaders in complex skills. It is based on an extensive review of research findings from all Services and industry that impact upon the use of immersive simulation for the dismounted Soldier.

Study Objectives

The objectives of this study are: (a) to review and synthesize the accumulated evidence, from the research literature and reports of field experiments, that is related to the effectiveness of virtual simulation for dismounted Soldier training; (b) to use this information as a basis for conclusions about the expected effectiveness of virtual training approaches; and (c) to present this information in a straightforward, non-technical format.

To accomplish those objectives, this report is organized around fiver major questions.

- What is the Army's training need which is to be met through the application of virtual simulation and gaming technology?
- What virtual simulation and gaming technology exists today to meet this need?
- What evidence is there that virtual simulation and gaming technology can meet those training needs?
- What recommendations for future actions can be made based on this evidence?
- What are the unresolved issues and further research/study needs?

Immersive Simulations for Dismounted Soldiers: The Army Training Need

This report will not provide a detailed or exhaustive task-level analysis of the specific skills that immersive virtual simulation is expected to train. However, the Army Strategic Planning Guidance 2005 (Department of the Army, 2005) and the Soldier CATT Operational Requirements Document (ORD; Department of the Army, 2004) provide a broad picture of requirements. Three major needs emerge. First, Soldiers and small unit leaders need to be adaptable and capable of responding to and taking advantage of rapidly changing situations. Second, they must be attuned to cultural conditions and knowledgeable in the culture, history, and language of the area of operations. Third, they must be able to rapidly and accurately assess the evolving situation using all of the tools at their disposal. Officer and junior non-commissioned officers must also be able to communicate effectively with a variety of different governmental and non-governmental organizations, to include media representatives. Table 1 provides more detail about these needs.

Capabilities to be provided by Immersive Simulation

The Soldier CATT ORD also describes the capabilities to be provided by immersive simulation. The following excerpts provide a high level summary of the capabilities.

> [The] centerpiece is the "Virtual Warrior," a high fidelity dismounted leader trainer providing a natural virtual environment in which dismounted leaders see the battlefield in three dimensions, control subordinate virtual Soldiers through voice recognition/voice synthesis, and communicate via FM voice communications. (p. 6)
>
> Soldier CATT is a Soldier and leader collective combined arms virtual training simulation focused on dismounted infantry centric training. It will provide a sufficient quantity of Virtual Warrior simulators to support from individual Soldier training at the squad level up to platoon and infantry company leader training. Soldier CATT is designed to train ... the full-spectrum of operations in a combined arms and joint environment. Leaders will train such tasks as the command and control of units, fire coordination, employment of joint enablers, engineer support (obstacle integration) and logistical support. Soldier CATT will support full spectrum training (e.g., infantry tasks of raid, dismounted assault and area presence; Reconnaissance, Surveillance, and Target Acquisition (RSTA) tasks of multidimensional area reconnaissance, multidimensional route reconnaissance and screen). Additionally, Soldier CATT will support training for urban operations (UO) and operations on complex terrain. (p. 7)
>
> Soldier CATT will provide ... a home station and deployed unit training capability ideally suited for walk-level and sustainment training as well as mission rehearsal training. (p. 7)

Table 1
Training Need Statements

Recent experience in Iraq and Afghanistan has shown the need for Soldiers who are not only well trained and equipped, but who are also adaptable and capable of responding to rapidly changing situations and are attuned to cultural conditions. In addition to rigorous, repetitive training in weapons and fieldcraft, Soldiers also require training in how to adapt to quickly evolving situations, not just how to react to changes, but also how to shape the environment to create the best possible outcomes. (Army Strategic Planning Guidance 2005, p. 4)
Iraq in particular has proven to be a non-linear battlefield. Given the security environment, we can expect this to become the norm. This requires all Soldiers understand they are warriors first and that they must be ready to fight. The distinctions between combatant and noncombatant have blurred, as have the distinctions between combat operations and stability operations. Simultaneous operations across the range of military operations, rather than sequential operations will likely be the rule. To succeed in such an environment, Soldiers and leaders must be capable of rapidly and accurately assessing the evolving situation. In order to make accurate assessments, they must also be capable of using all the tools at their disposal. This requires Soldiers and leaders who understand and are capable of leveraging the latest technology and Joint Capabilities. It also requires Soldiers and leaders who are knowledgeable of culture, history and the language of the area of operations. (Army Strategic Planning Guidance 2005, p. 5)
Today's environment requires lieutenants and junior noncommissioned officers to communicate regularly with a variety of actors; from interagency partners, to members of non-governmental organizations, to local leaders, to members of the U.S. and foreign media. To succeed, leaders at all levels must have situational understanding that extends beyond the tactical level. This requires a robust leader development system that grows leaders who are prepared, versatile and adaptive and who have a broad understanding of the political and military objectives of the campaign, as well as the potential implications of their actions upon those objectives. (Army Strategic Planning Guidance 2005, pp. 5-6)
Recent operations, such as operations in Afghanistan and Iraq, identified an immediate and critical need for a virtual training simulation to build and sustain the training readiness of dismounted infantry-centric units ... required to conduct close combat operations in complex/restrictive terrain against asymmetric forces, integrating multiple enablers and platforms and the associated fires and effects of fires in the joint and/or multinational operational battlespace. (Soldier CATT ORD (revised 8 June 2004), p. 1).
Virtual training is required to prepare and build confident and adaptive dismounted infantry leaders and Soldiers, that can rapidly dominate battlefield situations, and dilemmas in varying conditions (combined arms, joint interagency multi-national, contemporary operational environment, urban and complex terrain), through small unit actions, while dispersed, deployed, or distributed, and remain self aware while digitally connected or networked between shooters and sensors, and dismounted and mounted forces. Since every Soldier must be prepared to be a leader, virtual training will improve the dismounted Soldier's ability to remotely control weapon and sensor systems to include robotic systems and unmanned platforms to enhance his ability to see, understand, and act first. (Soldier CATT ORD (revised 8 June 2004), p. 1)
The dismounted Soldier and leader require training in a multiplicity of environments and terrain (e.g. urban, desert, mountainous, jungle) that generally cannot be replicated at homestation training areas or the Combat Training Centers. (Soldier CATT ORD (revised 8 June 2004), p. 2)
It is a critical requirement to prepare junior leaders to successfully lead multifunctional units, effectively use digitized systems, integrate into combined arms and joint organization and conduct decentralized and dispersed operations across the full-spectrum of possible missions. To develop and sustain the tactical and technical proficiency required of current and future Soldiers and leaders, units need home station and deployable training tools that enable frequent and repetitious complex task training. (Soldier CATT ORD (revised 8 June 2004), p. 2)

The Soldier CATT ORD provides a more detailed description of the training requirements that a virtual simulation system should satisfy:

- General Requirements:
  - Support training for dismounted infantry from squad to company level.
  - Allow the expansion of the training audience from individual Soldier up to battalion level leader.
  - Support the mounted training requirements of the Stryker Brigade Combat Team.
  - Support initial leader training at institutions (USAIS, USJFKSWCS, and the USAARMC).
  - Support unit sustainment training.
  - Provide structured, multi-echelon, collective task training to active and reserve component dismounted infantry units.
  - Support Soldier and leader training during peacetime, mobilization and deployment.
  - Support conduct of command and control and tactical training.
  - Support external evaluations, mission training and combined arms exercises.
  - Complement live training.
  - Allow dismounted leaders, mounted leaders and crews, and units to operate in combined L-V-C exercises.

- Institutional Training Requirements:
  - Enhance leader skill training in subjects including decision making, planning for operations, command and control of small units, direct fire coordination, fire support coordination, integration of obstacles and logistical support.
  - Incorporated into programs of instruction for infantry, SOF and scout officer and enlisted leader courses.

- Unit Training Requirements:
  - Support TOE unit training requirements for active and reserve component training at home station and in deployed locations worldwide.
  - Teach and sustain proficiency in individual and collective leader tasks.
  - Live force-on-force exercises required to validate proficiency.

What is Virtual Simulation?

Virtual simulation is defined in TRADOC Pamphlet 350-37 as "a simulation involving real people operating simulated systems. Virtual simulations inject humans-in-the-loop in a central role, by exercising motor skills, decision skills, or communication skills." (TRADOC Pamphlet 350-37, 9 June 2003)

The Columbia Electronic Encyclopedia provides a more detailed and more descriptive definition of largely equivalent and interchangeable terms virtual reality (VR) or virtual environment (VE). "Computer-generated environment with and within which people can interact. The advantage of VR is that it can immerse people in an environment that would normally be unavailable due to cost, safety, or perception restrictions. A successful VR environment offers users immersion, navigation, and manipulation. VR encompasses a range of interactive computer environments, from text-oriented on-line forums and multiplayer games to complex simulations that combine audio; video, animation, or three-dimensional graphics; and scent. Some of the more realistic effects are achieved using a helmet like apparatus with tiny computer screens, one in front of each eye and each giving a slightly different view so as to mimic stereoscopic vision. Sensors attached to the participant (e.g., gloves, bodysuit, footwear) pass on his or her movements to the computer, which changes the graphics accordingly to give the participant the feeling of movement through the scene. Computer-generated physical feedback adds a "feel" to the visual illusion, and computer-controlled sounds and odors reinforce the virtual environment. Other VR systems, such as flight simulators, use larger displays and enclosed environments to create an illusion. Less-complicated systems for personal computers manipulate an image of three-dimensional space on a computer screen. In a virtual network many users can be immersed in the same simulation, each perceiving it from a personal point of view. VR is used in some electronic games, in amusement-park attractions, in military exercises, and to simulate construction designs. Experimental and envisioned uses include education, industrial design, surgical training, and art." (virtual reality, 2003)

For purposes of this report, immersive simulations are defined to include a broad range of virtual simulations. At one extreme, it will include the use of videogame platforms (e.g., Full Spectrum Warrior). At the other extreme, it will include networked fully immersive simulators with full-screen or head-mounted displays (e.g., the Virtual Integrated MOUT Training System (V-IMTS). Between these two extremes, a variety of PC-based simulations are possible and will be considered.

Campbell, Knerr, and Lampton (2004) have provided a list of necessary functions that must be performed in order to use virtual simulations for dismounted Soldier training.

- Realistic representation of terrain in different conditions (e.g., night, fog) – *How will the Soldier see his environment?*
- Locomotion devices that provide realistic perception of movement and some degree of accurate energy expenditure – *How can he move or change position? How can he cross a field or climb stairs?*
- Ability to select weapons and other systems and use them with realistic effects – *How will the Soldier be able to use his M4 rifle, throw smoke grenades or concussion grenades, and use binoculars or night vision devices?*
- "Intelligent" computer-controlled forces to represent enemy, friendly, and neutral forces – *How can the simulated people react to the Soldier's actions? Will they fall when shot, and walk around rather than walk into Soldiers and other obstacles?*
- Dynamic terrain showing damage to structures, rubble and other micro-terrain obstacles – *How can scenery features (such as trees, cars, and street lights) also "behave" like their real world counterparts? Will buildings and other structures show effects of the Soldier's actions?*

- Accurate portrayal of Soldier actions and movements in the virtual environment *–How do the Soldiers see each other or interact?*

- Voice and gesture recognition by simulated "Soldiers" – *How can leader trainees control computer-generated Soldiers with voice and hand-arm signals?*

- Performance recording, analysis, and tailorable feedback at an AAR station – How can a trainer know what's going on in the simulation, so there can be appropriate feedback and performance improvement?

While there are multiple ways the essential components and capabilities required for dismounted Soldier simulation could be configured or described, the following categorization covers the key elements.

- Computer environment generator/processor. This component displays the simulated environment and processes calculations to determine environments and weapons effects. It is usually a PC, although it may also be a game console.

- Network. This transmits information among the participating simulators and between the simulators and the management system. Network characteristics depend on the simulation. High-end military systems typically use a Distributed Interactive Simulation (DIS) or High Level Architecture (HLA) network. Systems based on commercial game engines use protocols developed for use over the internet.

- Trainee Control Suite. This consists of the components of the individual simulator by which the trainee affects the simulation. The major components are:
    - Weapon Controller – A device for controlling the trainee's weapon (aim point, ammunition selection, firing rate, etc.). It could be as sophisticated as an instrumented, demilitarized weapon, or as simple as a game controller.
    - Locomotion Controller – A device for controlling the trainee's posture, orientation, and movement. The range of sophistication is quite varied. It could be combined with the Weapon Controller.
    - Voice Input device – A microphone is used to capture the voice signal, but there are many ways to process and transmit it.
    - Other Devices – To select or control additional equipment such as digital systems, night vision goggles, etc.

- Trainee Display Suite. This consists of the components of the individual simulator which present information to the trainee. The major components are:
    - Visual Display – There are three approaches:
        - Large-screen displays. These have typically been rear-screen projection displays, although some systems have used front-projection displays. They may be either single-screen or multi-screen. Large Light Emitting Diode (LED) and plasma displays may become a reasonable alternative.
        - Head-mounted displays (HMD).
        - Standard-size PC monitor.

- Auditory Display – Speakers or headphones. They deliver environmental sounds and voice communications.
- Haptic Display – Uses pressure or vibration to provide cues such as physical contact with environmental objects or people.
- Other Devices – To receive input from additional equipment such as digital systems, night vision goggles, etc.

- Management System. This includes a variety of capabilities used to set up training scenarios, track unit and individual progress, control computer-generated entities (people and objects), and provide feedback (AAR) to the trainees.

Background on Simulators

It is beyond the scope of this report to provide a detailed review of the use and effectiveness of simulators for military training. However, the long history of use of simulators has established both "conventional wisdom" and empirical data about the effectiveness of simulators. Orlansky, Dahlman, Hammon, Metzko, Taylor, & Youngblut (1994) provided a list of advantages and disadvantages of the use of simulators. These are cited as "conventional wisdom," which may not always be correct when applied to a particular situation.

Advantages

- Trains many tasks as well as the use of the actual equipment.
- Costs less than actual equipment to procure and use.
- Provides training that otherwise requires use of actual equipment.
- Permits training for dangerous and potentially catastrophic conditions not otherwise possible in actual equipment.
- Reduces risks, safety hazards, and wear and tear from use and maintenance of actual equipment, and extends useful life of equipment needed for combat.
- Reduces impact that actual equipment has on environment, and the noise and use of ranges have on communities.
- Protects operational security of tactics and mission rehearsal, of electronic warfare, and sensitive performance characteristics of new weapons.
- Provides features needed for instruction and feedback, including performance measures.
- Saves on use of fuel, munitions, and support facilities.
- Provides initial familiarization, trains procedures (less so for advanced students), and avoids risk to actual equipment by novices.
- Permits training not readily affordable with actual equipment.
- Permits use of actual or anticipated threat conditions to examine doctrine, effect of the combat environment, and potential responses.
- Permits testing of effectiveness of plans and tactics prior to actual operations.
- Permits joint training of DoD forces and of coalition forces.
- Can recreate significant battles to identify key events and to train leaders.

Disadvantages

- Could adversely affect training readiness if use of simulators reduces Operational Tempo (OPTEMPO), as well as confidence in use of actual equipment.
- If uninformed by data from actual performances of weapons and service crews, virtual and constructive simulations can be dubiously valid.
- Require funds to procure and use.
- May instill habits that are incorrect for use in actual equipment.
- Limited fidelity of visual resolution, sensors, aerodynamics, and motion platforms can lead to inadequate or misleading training.
- Differing response characteristics of visual displays and of motion platforms often leads to motion sickness.
- There is a potential compromise of security if information about sensitive tactics and equipment can be gained by access to networks that support interactive simulators.
- Accurate performance of weapons and platforms in simulations requires accurate engineering models and data that may not be available or are expensive to develop.

Results of research on the use of simulators for military training

Orlansky et al (1994), in a review of research on the use of simulators for individual flight and maintenance training in the military, report that a combination of real equipment and simulators were always as effective as use of the actual equipment alone, and cost less. For example, an hour of aircraft simulator training was equivalent to .48 hours of actual aircraft time, while operating costs of the simulator averaged about 10% of those of the actual aircraft, and total costs about 20% of actual aircraft.

A review by Hayes et al (1992) (based on 26 of 247 documents) concluded that the use of both a simulator and the actual aircraft for jet aircraft training consistently resulted in better performance in the aircraft than did the use of the aircraft for training alone. Caretta and Dunlap (1998) reviewed 67 articles, papers and reports regarding the use of simulators for flying training written after the Hayes et al review. Of these, 13 actually reported measures of transfer from the simulator to the aircraft. All showed that at least some of the training received in the simulator transferred to the actual aircraft.

This research summarized above is largely concerned with the use of simulators for individual training in institutions. However, as Orlansky et al point out, this differs from one of the situations of interest to us, collective training in units. First, the objective of individual training in institutions is to achieve standards of proficiency at the lowest possible cost, while the objective of collective training in units should be to get the best possible training at little or no increase in cost. Second, there is very little data to indicate how effective simulators and simulations are for unit and collective training. Several reviewers (Boldovici, Bessemer, and Bolton, 2002; Simpson, 1999) discuss the fact that it is difficult and highly resource intensive to do such evaluations.

Results of Research on the Use of Immersive Simulation for Training Dismounted Leaders, Soldiers, and Units

Introduction

This section will provide a review of research on the use of immersive simulations to train Army personnel for tactical training. It will include individual Soldier, leader, and collective tasks. The criterion for including studies and experiments has been fairly liberal with regard to the definition of "immersive" simulation. Two marksmanship trainers, one of which used videodisc-based technology, are included. On the other hand, technology descriptions or demonstrations which obtained no structured feedback from trainees or subject matter experts (SMEs) were not included.

The Army began to be interested in the use of immersive simulation for dismounted Soldier training in the early 1990's. This was largely a result of the influence of Gorman (1990), who was an early proponent of the use of VE for dismounted infantry (DI) training. Partly as a result of his efforts, a conference was held in Snowbird, Utah in 1990 to discuss individual Soldier systems and the role that an individual immersive simulator, which he termed an individual portal (or I-Port), would play in their development (Goldberg and Knerr, 1997). The conference did create an awareness of the difference in simulation capabilities between those available to support training of Soldiers fighting from vehicles, and those fighting dismounted. Although consensus was achieved on the need for an I-Port, Operation Desert Storm preempted the initiation of a large-scale cooperative research and development program to develop such a simulation capability. The meeting did, however, provide the impetus for organizations to initiate Research and Development (R&D) programs in the area.

Methodological Considerations

The evaluation activities which followed can roughly be divided into three categories: analyses, laboratory experiments, and field experiments.

In analyses, SMEs use information about the capabilities and characteristics of the simulation or simulator and the tasks to be trained to assign ratings to each task or task component (activity) which indicate how well they believe it can be performed or trained in the simulation. Rules can be used to aggregate these ratings from task components to higher level tasks. The quality of the results from an analytic approach is highly dependent on the familiarity of the rater with both the simulation and the tasks to be trained. It also may require making some sophisticated distinctions between being able to perform a task in a simulation and learning in a simulation to perform a task in the real world. For example, in one currently available simulator, a Soldier can throw a simulated grenade by selecting the appropriate type of grenade from a menu, choosing direction and launch angle by pointing his mock weapon, choosing the amount of force desired by adjusting a slider with a pair of buttons on the weapon, and pulling the trigger. While this bears little resemblance to the physical act of throwing a real grenade, it does provide practice in deciding which type of grenade to use, and where and when to employ it.

In laboratory experiments, trainees (who may or may not be Soldiers) perform or learn to perform tasks under highly controlled conditions. The tasks may be actual Soldier tasks or synthetic Soldier tasks (designed to have the key elements of Soldier tasks but modified so that they can be performed or learned by non-Soldiers). Laboratory experiments compare performance or learning under different conditions. Trainee performance is measured objectively.

In field experiments, Soldiers perform or learn to perform Soldier tasks under controlled conditions (although the conditions may be less tightly controlled than under laboratory experiments because of operational constraints). There may or may not be multiple groups for comparison. Trainee performance may or may not be measured objectively.

Some experiments provide more convincing evidence of effectiveness than others. There are two important aspects to the design of an experiment: the training methods being compared, and the measures of training effectiveness or performance that are used. In terms of the comparison of training methods being made, the best evidence of training effectiveness is provided by those experiments which compare simulation-based training with an alternative training approach and/or a control group which receives no training. Experiments that compare only pre-training and post-training performance of Soldiers trained in a simulation provide less convincing evidence. In addition, some criteria used to evaluate training effectiveness are better than others. The best criterion is performance on similar tasks in a live simulation as measured by objective performance data or SME ratings. The next best would be objective measures of performance or SME ratings on the tasks as performed in the simulation, again as measured by objective performance data or SME ratings. Self-reports by the trainees of what and how much they learned are less informative than objective measures. Trainees may not be able to assess how much they learned accurately, and their ratings may also be affected by other factors, such as the novelty of the training situation or how much they enjoyed the training. These self reports can vary from very general and global to highly detailed and specific. The more specific they are the better.

Analyses

The first attempts to evaluate the training potential of immersive simulations for Army training had to be analytical, since they preceded the development of prototypes designed for Army training. They were instead based on knowledge of limited off-the-shelf commercial systems, systems under development in university laboratories, and projections of the capabilities of future technology. Levison and Pew (1993) were the first to conduct an analysis of simulation requirements for dismounted Soldier training. Their report is of interest now only largely for historical reasons, since it was conducted at a fairly gross level of detail, and VE technology was primitive at the time, however, it is interesting to note that they saw benefit in the use of then current simulation technology:

> (Current) technology is considered adequate for most CPT (Combat Proficiency Training) and MPR (Mission Planning and Rehearsal) training requirements. More sophisticated visual display technology will be required to train in situations that provide rapidly-unfolding activities in close proximity to the Soldier

(operations in urban and other close-in environments), where the resulting large and rapid head movements place a higher demand on the VE technology needed to supply the visual information adequate for training. An advanced haptic display interface is required for tasks that rely on the sense of touch (such as assessing the surface condition for supporting heavy equipment), or for situations where it is deemed important to have realistic tactile feedback from control and manipulation of weapons, equipment, and other physical objects. (p.79)

Levison and Pew (1993) also made a key distinction between "performance fidelity" and "training fidelity" that is still relevant. Full performance fidelity is achieved when a Soldier performs a task with the same result in the simulator as in the real world, according to any objective measure of performance. Full training fidelity is achieved when training in the simulator allows a Soldier to perform a task in the real world as well or better than if the training had been conducted in the real world. Performance fidelity, they said, would be required for mission planning and rehearsal, and training fidelity would be required for training.

Jacobs et al (1994) followed up on this work by conducting an analysis of four Infantry and Special Forces Army Training and Evaluation Plan Mission Training Plans (ARTEP MTPs) and drills (MTP for the Infantry Rifle Platoon and Squad, Battle Drills for the Infantry Rifle Platoon and Squad, MTP for the Special Forces Company: Special Reconnaissance, and MTP for the Special Forces Company: Direct Action). From these, they selected 67 unique tasks which they further broke down into 252 individual Soldier activities. They then determined the simulation capabilities required in order for each of those activities to be performed in a VE, and compared this with the then current and projected state of VE technology. They concluded that none of the missions or tasks analyzed could be fully supported by VE technology at that time, but that the great majority could be partially supported. The list of 252 individual Soldier activities has provided a basis for subsequent evaluations of what Soldiers could do in virtual simulations.

In retrospect, it is clear that VE technology has not progressed as rapidly as projected in these early analytical efforts. Capabilities in the areas of speech recognition, position and orientation tracking, computer recognition of human gestures, and low-cost high-resolution wide field-of-view HMDs has not become available as rapidly as forecast. However, the emergence of PCs with the capacity to drive the simulations and generate the graphics required was not projected.

Perhaps surprisingly, the Navy was the first service to produce a prototype of a virtual individual combatant simulator. The Team Tactical Engagement Simulator (TTES), a graphic of which is shown in Figure 1, consisted of a 8' X 10' rear projection display, demilitarized rifle and tracker, head tracker, computer graphics generator, and system software. Trainees moved through the virtual world through the use of a foot pedal; pressure on the front of the pedal moved the trainee forward (in the direction of gaze), while pressure on the back of the pedal moved the trainee in the opposite direction. TTES was expected to serve multiple applications: individual marksmanship trainer, individual and unit tactical trainer, and decision making trainer. TTES was first evaluated in 1994 (Lind and Adams, 1994) by 21 military and civilian SMEs who rated the importance, current capability, and potential capability of TTES for each of those three applications. Each application was defined by multiple events or activities which were

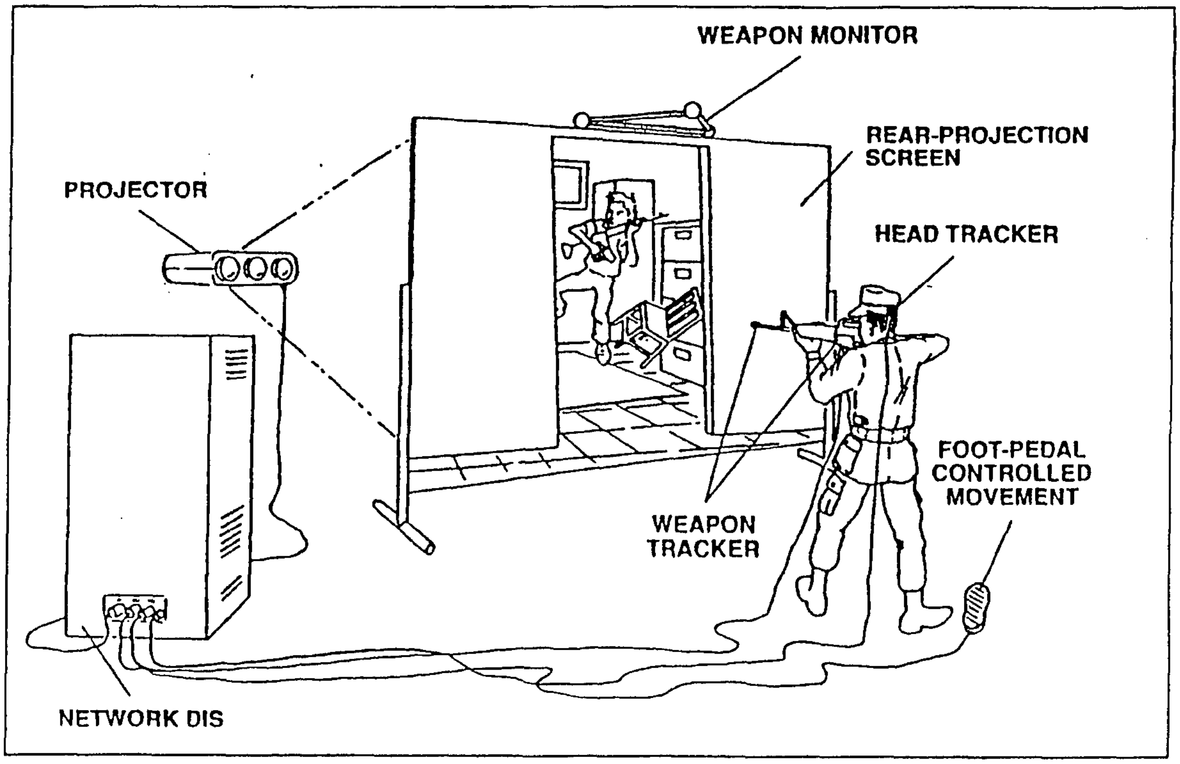

Figure 1. A graphic depiction of the TTES (From Lind and Adams, 1994).

rated separately. Prior to providing their ratings, SMEs received a briefing describing TTES and projected future enhancements, used the simulator for approximately 25 minutes, and had the opportunity to observe others using it. Major results are summarized in Table 2. Ratings were aggregated and converted so that the numbers shown in the table are expressed as a percentage of the highest possible rating. Lind and Adams recommended as a result that emphasis be placed on developing the functions that had the perceived highest importance and potential capability ratings, Marksmanship and Discretionary Decisions. However, it is also clear that the SMEs considered the current version of TTES to be well short of its potential.

Table 2.
1994 SME Ratings of TTES Functions

Function	Importance	Potential Capability	Current Capability
(Tactical) Training Situations	76.4	76.4	45.0
Marksmanship	85.0	80.0	46.3
Discretionary Decisions	83.5	85.5	41.3

Note: The numbers in the cells represent the percentage of the maximum possible rating assigned to the events in that category.

Lind (1995) conducted a similar evaluation one year later in which 28 SMEs participated. Procedures were generally the same, although not all of the SMEs participated in the TTES exercises (some merely observed the participation of others), and those who participated did so as two-man teams using two networked TTES, rather than as individuals. The questionnaire was changed slightly. The list of functions was expanded to include Mission Preview and Mission Rehearsal, and "Importance" and "Potential Capability" were replaced by "Potential Usefulness." The results are shown in Table 3. Based on the high Potential Usefulness ratings (93.9% and higher), Lind concluded that simulators such as TTES could produce "phenomenal savings in time, ammunition, and other costs related to training, while providing the capability to train to higher standards and to challenge trainees in ways not currently possible" (p.3). It is perhaps more significant to note that the Current Capability ratings for the (Tactical) Training Situations, Marksmanship, and Discretionary Decisions functions increased substantially from 1994 to 1995, presumably a result of improvements in the TTES.

Table 3.
1995 SME Ratings of TTES Functions

Function	Potential Usefulness	Current Capability
(Tactical) Training Situations	96.4	69.5
Marksmanship	95.0	71.1
Discretionary Decisions	95.2	70.0
Mission Preview (walkthrough)	94.8	72.6
Mission Rehearsal	93.9	73.0

Note: The numbers in the cells represent the percentage of the maximum possible rating assigned to the events in that category.

These two TTES evaluations probably best serve to document the fact that SMEs perceived TTES to have the potential to provide effective training in a variety of areas. The TTES implementation, however, was perceived to be short of that potential. Most importantly, no actual training was conducted or evaluated.

Experimental Efforts

Marksmanship trainers

Eisley, Hagman, Ashworth, and Viner (1990) conducted an evaluation of the Squad Engagement Training System (SETS) as both an individual marksmanship trainer and a squad tactical trainer. While SETS does not use computer-generated graphics, it could be considered to be immersive. It uses computer-controlled, videodisc-based visual imagery projected on a wide screen, and laser-instrumented individual weapons to train both individual marksmanship and to a limited extent, squad tactics. Conceptually, it seems very similar to the current Engagement Skills Trainer (EST 2000). This evaluation provides sound evidence that simulators can provide effective tactical training for small dismounted units.

Thirty-six squads of National Guard Soldiers (18 Infantry and 18 support) were randomly assigned to either the experimental or the control group. Experimental group squads received two hours of SETS training that included both simulated firing for record and two tactical defensive scenarios. They then zeroed their weapons on a live-fire range, conducted two tactical live-fire exercises, and then fired for record on a live-fire range. Control group squads had no SETS training. They only zeroed their weapons on a live-fire range, conducted two tactical live-fire exercises, and then fired for record on a live-fire range. Squad Leader performance, as rated on 27 tasks extracted from ARTEP standards, improved from the first to the second SETS exercise, and was higher on the live-fire exercises for the experimental group than the control group. This difference was particularly apparent for the leaders of the support squads. The fire distribution of experimental group squads on the live fire test was also superior to that of the control group squads. While the qualification scores of the Soldiers in the experimental group were slightly (but significantly) higher than those of Soldiers in the control group, the relationship between live fire and SETS qualification scores was not sufficiently strong that SETS could be recommended as a substitute for live fire qualification. The authors concluded that SETS had the potential to support home-station training of basic defensive tactical skills.

This experiment showed conclusively that SETS provided a training benefit for leaders, Soldiers, and units that transferred to the real world. However, this benefit was achieved through two hours of additional training. There is no indication of how this would compare with two hours of live training. The authors also stressed the instructor dependence of SETS-based training. It is up to the instructors to establish the training context, determine how to evaluate leader performance, and evaluate it.

In a related evaluation with more current technology, Miller and Zeisset (2002) conducted a Post-Fielding Training Effectiveness Evaluation of the EST 2000. The EST 2000 is a small arms simulator design to augment and substitute for individual marksmanship training and squad collective training. It provides simulated weaponry that simulates the physical and operational characteristics of several weapons. Unlike the Eisley et al (1990) experiment, which used the simulator as a means of providing additional training, Miller and Zeisset compared a control group which trained using live fire procedures with an experimental group that substituted EST 2000 training for a portion of the live fire. The extent of the training, either in terms of the number of rounds fired or time required, was not described. The largest number of Soldiers trained on the M16A2 384 using live fire and 76 using the EST. There were no significant differences in the qualification scores between the EST and the live fire groups, either in terms of mean scores or in the proportion qualifying as Expert, Sharpshooter, or Marksman. The results for the M240B machine gun were similar, in that no significant differences were found, although the sample sizes were so small (22 Soldiers in each group) that little confidence can be placed in this conclusion.

The Dismounted Warrior Network Experiments

Involvement of Army Soldiers in what we would today think of as immersive virtual simulation began with the Dismounted Warrior Network (DWN) program in 1997. DWN was a U.S. Army Simulation, Training and Instrumentation Command (STRICOM)[1] program to develop a reliable, low-cost, easy-to-use capability to insert dismounted Soldiers into VE. The

[1] What was then the R&D component of STRICOM is now the U.S. Army Research, Development, and Engineering Command Simulation and Training Technology Center.

DWN program (and its successor, DWN Enhancements for Restricted Terrain (ERT)) did not evaluate training effectiveness, but did obtain data, through automated data capture, Soldier questionnaires, and observation, about task performance in the virtual simulators used in the program.

A series of experiments was conducted during 1997 to investigate different interfaces for inserting dismounted Soldiers into virtual simulations. Four Virtual Individual Combatant Simulators (VICS) were selected for evaluation based on three criteria: a desire to have a diverse mixture of characteristics to examine; a cost/benefit assessment of system characteristics; and system availability. The VICS were designated Alpha, Bravo, Charlie, and Foxtrot.

Figure 2. A Soldier in VIC Alpha.

VIC Alpha used full body tracking with multiple fixed-position video cameras and reflective markers on the head, body, and weapon to track posture, orientation and weapon aiming. Locomotion used a "human joystick" approach, with movement direction determined by body orientation, and speed of movement determined by distance from a marked center point on the floor; the further the user was from the center point, the faster the movement. Return toward the center point was required to slow down or stop. A low resolution (420 x 230 pixels) wireless

HMD was used to provide a view of the virtual world. A photograph of a Soldier using VIC Alpha is shown in Figure 2. The white spheres are the reflective markers for the tracking system.

VIC Bravo projected visual images on four rear-projection screens that surrounded the user. Locomotion was provided by the Omni-Directional Treadmill (ODT), which used interlocked belts oriented at right angles in conjunction with a centering harness to permit the user to walk in any direction while remaining in the same position. A Soldier in VIC Bravo is shown in Figure 3.

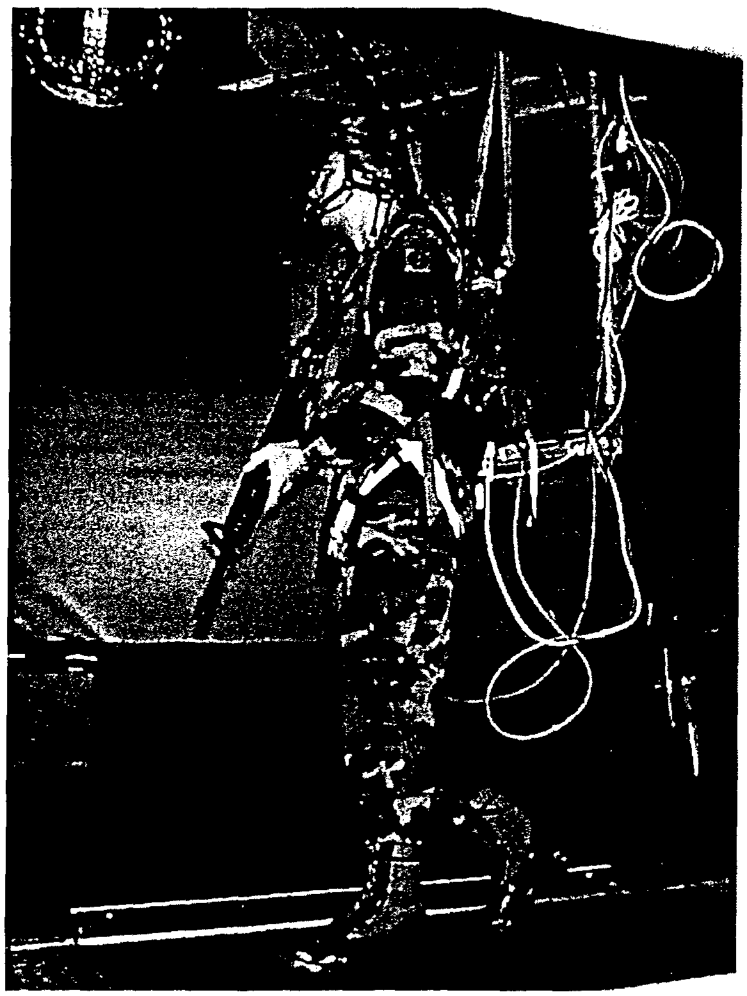

Figure 3. A Soldier in VIC Bravo.

There were two versions of VIC Charlie, one used during the Engineering Experiments and the other used during the User Experiments. While they had different simulation software, the interface for both was a computer monitor and joystick.

VIC Foxtrot was the then-current version of the Navy TTES, described earlier and shown in Figure 1. It used a foot pedal for control of movement, a single rear projection screen, and a tracking system to determine head and weapon position and orientation.

The DWN evaluations were conducted in two phases. Eight Soldiers participated in each. The first was a set of Engineering Experiments, which focused on how well individual Soldier tasks (detect targets, engage targets, move through a building, etc) could be performed in the simulators. The Engineering Experiments made extensive use of objective measures of Soldier performance. After the Engineering Experiments were completed, the VICS, a DI Semi-Automated Forces (DISAF) station, an Exercise Support Station, and an AAR station were tied into a DIS network and installed at the Soldier Battle Lab (SBL)[2], Fort Benning. A set of User Experiments was then conducted which focused on the performance of team and squad tactical tasks. The User Experiments relied heavily on the use of questionnaires to obtain feedback from Soldiers regarding how well they could perform tasks in the simulators. Soldiers rated each VIC on the extent to which they could perform selected tasks, and the difficulty of performing those tasks. Tasks covered movement, orientation, visual recognition, and weapon engagement. The detailed results are presented in Lockheed Martin (1997) and Pleban, Dyer, Salter, & Brown (1998).

The DWN experiments were successful in showing that Soldiers could perform basic Infantry tasks in the simulators. All VICS were somewhat effective for engaging targets, simulating locomotion, and identifying people and objects. However, the experiments also revealed many limitations of the VICS. Soldier performance on visual tasks was closely related to the resolution of the visual display: the higher the resolution, the better the performance. Weapon use was difficult to implement with an HMD. It required presenting a graphic image of the weapon in the HMD in a position that corresponded with the actual position of the weapon with little margin for error. In addition, the bulk of the HMD prevented the Soldier from bringing the weapon into its proper aiming position. Some of the interfaces were difficult to master. DISAF did not work in buildings. System reliability was a major factor in determining Soldier preferences. Soldiers preferred VIC Bravo over VIC Alpha, but otherwise there were no differences.

A follow-on project to DWN, entitled DWN ERT focused on Military Operations in Urban Terrain (MOUT). Some VICS were modified and new ones developed based on lessons learned in the DWN experiments. New locomotion methods were introduced, improved visual systems were incorporated, and new aiming techniques were implemented. In addition, DISAF was modified to support operations inside buildings. Engineering experiments, live tests at the Fort Benning McKenna MOUT site, and user experiments were conducted in July 1998 with these modified systems. The goal of this round of experiments was to investigate how well a fire team of VICS and DISAF could support MOUT tasks at the individual Soldier, fire team, and squad, levels.

The four VICS included an improved version of VIC Alpha from the 1997 experiments, and three VICs based on the Soldier Visualization Station (SVS™). Improvements to VIC Alpha included changing locomotion control from the "human joystick" to a weapon-mounted joystick, and upgrading the HMD. All SVS™-based VICs used two PCs for calculations and image generation, a demilitarized weapon, and a tracking system to determine head position and weapon position and orientation. VIC Delta was the basic SVS™ used with a 10' x 8' rear projection screen and a rifle-mounted joystick for movement. VIC Echo was the basic SVS™

[2] This is the current name for the facility. There have been several name changes since its founding.

used with a front projection dome display which provided a field of view approximately 150 degrees wide by 40 degrees high. As in VIC Delta, movement was controlled by a rifle-mounted joystick. VIC Golf used the SVS™ software with an HMD and the ODT from the 1997 experiments.

Eight Soldiers participated in tests of the systems over a two week period. The detailed results are documented in the DWN ERT Final Report (Lockheed Martin Corporation, 1998) and Salter, Eakin, & Knerr (1999). The results are to some extent tied to the specific (and now outdated) equipment employed, but they also serve to illustrate some trends that continue to the present. First, locomotion in the virtual world was difficult. It took the Soldiers approximately four times as long to complete a route through a virtual building than it did to complete the same route in the actual building at the McKenna MOUT site. Inability to track weapon positions accurately led to the weapon aiming portion of the test being curtailed. Even at the shortest range (25 meters), the best VICs hit only 67% of the targets. In addition, the accuracy of the trackers decreased with the distance of the weapon from the tracker (which was mounted overhead). This resulted in the prone position being the least accurate firing position.

In both the engineering and user experiments, the Soldiers rated the VICS on the dimensions of similarity to the real world, and speed, quality, and difficulty of performance. In the engineering experiments, the activities rated were Detect Targets, Engage Targets, Move Inside Buildings and Move Outside Buildings. In the user experiments the activities rated were Tactical Movement, Room Clearing, React to Contact/Engage, and Communicate. When there were significant differences among the VICs, it generally indicated that VIC Golf, with the combination of an HMD and the ODT, performed less well than the others. VIC Golf also produced more symptoms of simulator sickness. (See separate section on simulator sickness).

Salter, Eakin, and Knerr (1999) identified four major areas for improvement. The first was position and orientation tracking. Improved tracking was necessary to improve weapons accuracy. The second was the means of simulating locomotion. While walking in the real world is natural and is usually accomplished without much conscious effort, "walking" in the virtual world was not. Within the amount of time available, Soldiers did not acquire full proficiency in the simulators and consequently moved more slowly in the virtual world than in the real world. They also frequently collided with walls. Locomotion required conscious effort that may have impaired the performance of other tasks or interfered with training. The third was providing a means of non-verbal communication, such as gestures and facial expressions. The fourth was wide-angle visual displays.

The Virtual Environment Science and Technology Objective (STO)

During the period 1999 – 2005 there were a series of related technology development and transition activities which shared a common assessment methodology and used nearly identical measures of task performance and training effectiveness in VE. In the following sections, the assessment activities will be described, and then the collective results twill be described and discussed.

Following the completion of the DWN experiments, a four-year (FY 1999-2002) STO effort was initiated to develop a demonstration virtual dismounted leader trainer at the fire team, squad, and platoon level. Five Army organizations[3] collaborated on the research and development. Each had a particular area of interest, but all worked together to explore concepts and systems and to recommend directions for further work on training, concept development, and mission rehearsal.

One of the emphases during the first year of the STO (FY 1999) was on identifying high-payoff small unit and leader training applications. Pleban, Eakin, and Salter (2000) took the task lists from analytic efforts (including Jacobs et al, 1994), and eliminated those tasks that could not be supported by the technology as represented in the then currently available SVS™; (VIC Delta in the DWN ERT experiments). Tasks were: move through built-up areas, reconnoiter area, react to contact, assault, and clear a building. They then refined their findings by having six Soldiers carry out 15 tactical scenarios in the simulators as three-man teams, and then additional scenarios as a six-man team. After completing a set of three similar scenarios, they rated their ability to perform each of the component activities of that task on a four-point scale (Very Poor, Poor, Good, or Very Good). Ratings were then aggregated to produce an overall rating for each task. The activities and the rating scheme developed by Pleban Eakin, and Salter (2000) formed the basis for Soldier ratings of their ability to perform tasks in virtual simulations in a number of subsequent investigations performed during the conduct of the STO and even subsequent efforts.

Each year of the STO a culminating event (CE) was conducted. The CEs were comprehensive demonstrations and assessments conducted with Soldiers, using as much of the developed technology as was feasible in a realistic training exercise. Three of the four CEs (1999, 2001, and 2002) were conducted at the SBL and will be discussed here.

The 1999 CE consisted of squad-level exercises which were conducted on three consecutive days, with different squads involved on each of those days. All Soldiers participated using what was then called the Squad Synthetic Environment (SSE), a network of individual simulators, each of which consisted of a SVS™ and a virtual radio. The SVS™ is a PC based, DIS compatible DI simulator developed by Reality By Design (RBD), and was essentially VIC Delta.

Squads generally consisted of a Squad Leader and two fire teams. Each fire team was composed of three Soldiers and a fire team leader. The focus of the evaluation was as the squad leader as the primary trainee. Five exercises were conducted for each squad, although not all squad members were involved in each. The first and fifth exercises were assessment exercises and the entire squad participated in both. The second, third, and fourth exercises were conducted with different mixes of virtual Soldiers and DISAF. Each squad leader conducted exercises with an all-virtual squad, an all-DISAF squad, and a Half-SAF squad (one virtual fire team and one DISAF fire team). AARs and, to a limited extent, coaching were used improve learning.

[3] The organizations were the U.S. Army Research Institute Simulator Systems and Infantry Forces Research Units, the U.S. Army Simulation Training and Instrumentation Command, and the U.S. Army Research Laboratory Human Research and Engineering and Computational and Information Sciences Directorates.

At the completion of their exercises, all Soldiers who were not squad or fire team leaders rated their ability to perform 48 tasks (from Pleban Eakin, and Salter, 2000) in the simulators as very poor, poor, good, or very good. Squad and fire team leaders instead completed a questionnaire which asked them to rate their improvement in 11 areas as a result of their training. The areas were: Plan a Tactical Operation, Coordinate Activities with your Chain of Command, Assess the Tactical Situation, Control Squad or Fire Team Movement during the Assault, Communicate with Members of your Team or Squad, Clear a Building, Clear a Room, Control Squad or Fire Team while not in Contact with the Enemy, Control your Squad or Fire Team, React to Contact Battle Drill, and Locate Known or Suspected Enemy Positions. These same questionnaires, with minor variations in the Soldiers tasks, would be used repeatedly in subsequent assessments, and provide a basis for year-to-year comparisons.

By the third year of the STO (2000-2001), the focus was broadened to include a heavy emphasis on the human interface aspects of the VE systems for training, including the use of automatic speech recognition to control DISAF, development of an AAR system, and incorporation of a broad range of DISAF behaviors. At the same time, the technologies were becoming more mature and stable, and interoperability issues were being addressed with increasing success. Training continued to be a principal area of investigation.

The FY 01 CE was held in September 2001 at the SBL (Knerr et al 2002). The key technologies included: a Dismounted Infantry Virtual AAR System; new behaviors and improved operator control for DISAF; fire team leader control of DISAF through Voice Recognition and Synthesis; enhancements to the SVS™; an improved ODT; and a dynamic terrain server.

Infantry Soldiers participated in scenarios in the simulators, with one group of six Soldiers participating for one day, and two groups of six soldiers participating for two days each. The network configuration for the CE is shown in Figure 4. The following items were connected to the network:

- Five SVS™ individual Soldier simulators. These were used by the squad leader, the two fire team leaders, and two of the three Fire Team A members. The simulators were identical, except for additional equipment in the Fire Team B leader's area for the voice recognition system. All SVSs were equipped with ASTi™ radio headsets, which permitted verbal communication on up to two channels, depending on the duty position. The squad leader could talk to the platoon leader (a role player) and his fire team leaders. Each fire team leader could talk to the squad leader and his subordinates. Fire team members could talk among themselves and with their fire team leader.
- One ODT station. The third A fire team member used this simulator. Like the SVSs, this station was equipped with an ASTi™ radio headset.
- One Voice Recognition PC.
- One AAR System PC.
- One Dynamic Terrain Server.
- One BattleMaster/DISAF Operator Station. The DISAF Operator and the Exercise Controller used this station.
- One Desktop SVS™ used by a role player.

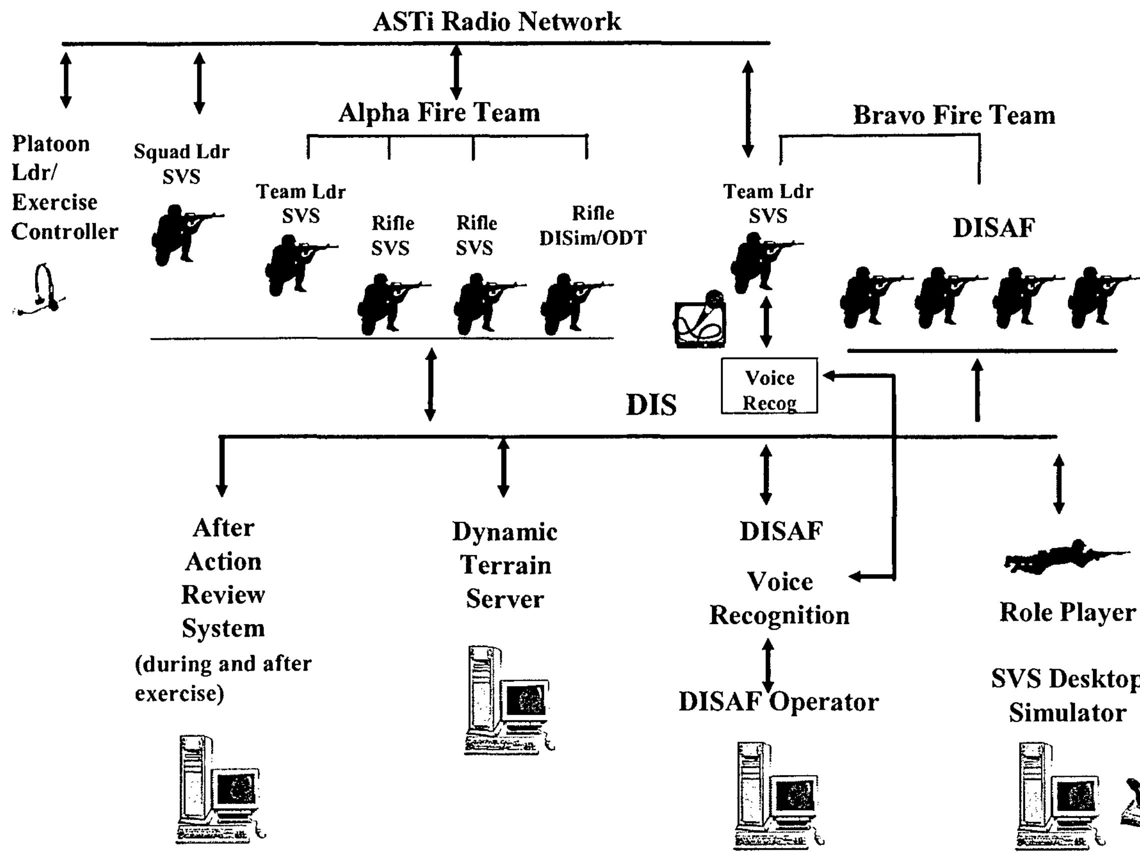

Figure 4. 2001 CE System Configuration, Soldier Battle Lab, Fort Benning. The 2002 System Configuration was similar, except the DISim with ODT was replaced with an additional SVS™.

A general situation and eight different scenarios were developed. Each of the scenarios was designed to be about 20 minutes in duration. They focused specifically on forcing the Soldiers to use the various new devices and capabilities in the VE. Each scenario provided a different mission so the capabilities would be used under differing circumstances. Scenarios were also designed to actively involve as many squad members as possible. Seven of the eight scenarios took place in a virtual representation of the Shugart-Gordon MOUT facility at Ft. Polk, LA. The eighth scenario took place in a high-rise office building described as being in an adjacent town. The scenarios covered a variety of wartime and SASO. The descriptive scenario titles were: Support Operations Checkpoint, Hostage Rescue, Support by Fire, Assault and Clear a Building, Roving Patrol, Air Assault and Clear a Building, Crowd Control, and Downed Helicopter.

In the final year of the STO (FY 2002), there was a concerted effort to document the training potential of the systems, and to prepare recommendations for the road ahead. The FY 02 CE was held in August 2002 at the SBL (Knerr et al, 2003). Both the hardware and software configuration and the scenarios were similar to those of 2001. Also, three squads participated for two days each. Two different versions of the Hostage Rescue and Deliberate Attack scenarios were designed to be comparable in terms of mission type and difficulty, although the starting points and objectives were different. By using these parallel versions, researchers were able to identify improvements in performance or effects of simulation fatigue across time. In addition to the Leader ratings of changes in their performance that had been obtained previously, SMEs rated squad leader performance on 14 different factors during each scenario.

The Virtual –Integrated MOUT Training System (V-IMTS) Assessment

V-IMTS was a short-term project to speed the transition of the virtual simulation technology developed under the STO that specifically considered the integration of live and virtual training. The objective of the assessment was to obtain information about the performance of Soldier tasks and training effectiveness in the V-IMTS configuration.

The Cassidy Combined Arms Collective Training Center at Ft. Campbell, KY was the initial transition site for V-IMTS and the site for the assessment (Knerr and Lampton, 2005). It consists of a 28-building complex of one- to four-story buildings representing a small town. As part of the V-IMTS program, a deployable shelter approximately 40 feet square was placed next to the Cassidy control center. Three Immersive SVS™ simulators (SVSI) and six Desktop SVS™ simulators (SVSD) were installed inside. The squad leader and two fire team leaders used the SVSI. The remaining Soldiers used the SVSDs located immediately behind their fire team leader. DIVAARS, DISAF, and SVSD stations for human opposing forces were located in the control room.

The assessment took place in September 2004. Twenty-seven Soldiers from three squads participated. The squads were actual units, not groups formed specifically for this event. While 68% of the squad members had served a tour in Iraq or Afghanistan, all three squad leaders, and three of the six team leaders, had served in their current duty position for one month or less. Their unit personnel, assisted by technical personnel, controlled the exercises and conducted the AARs. The scenarios consisted of multiple variants of two missions: Search and Cordon a Building and Attack/Assault a Building. The variants differed in the buildings involved and the positions and actions of the enemy. Each exercise consisted of the delivery of the operations order to the squad leader, a planning period, mission execution, and an AAR (usually conducted by the Platoon Leader).

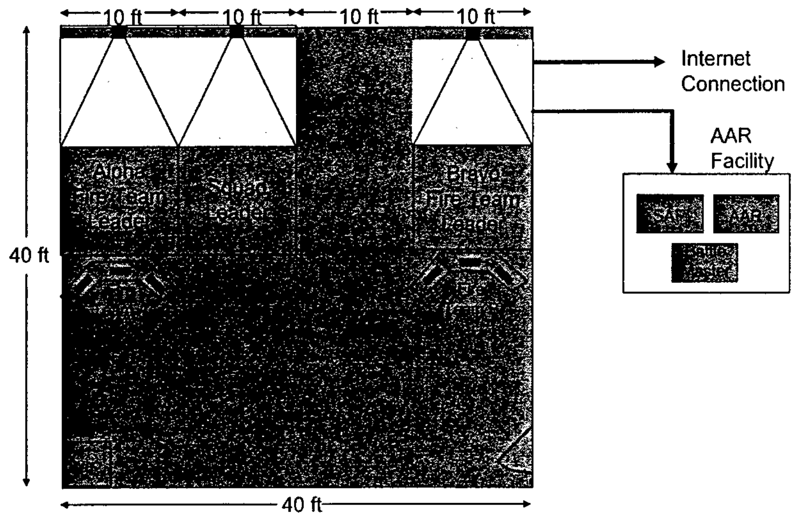

Figure 5. V-IMTS physical configuration.

Each squad completed two live exercises separated by two, three, or six virtual exercises. Squad 1 participated in six virtual exercises lasting a total of 96 minutes (mean = 16.0 minutes), squad 2 participated in four virtual exercises lasting a total of 77 minutes (mean = 19.2 minutes), and squad 3 participated in three virtual exercises lasting a total of 44 minutes (mean = 14.7 minutes). Overall mean duration of the virtual exercises was 16.7 minutes.

Situational Awareness in Virtual Environments (SAVE)

The SAVE assessment was conducted at the SBL in 2005. The purpose of the assessment was to try out tools for collection data on Squad Leader Situation Awareness. However, since it involved full squads conducting tactical exercises in immersive simulators (the SVSI), Soldier rating of simulator capabilities and Soldier and leader ratings of training effectiveness were obtained. Each of three squads participated in three building clearing exercises and six urban operations exercises (three security patrol and three search for arms cache) over a two-day period. Average scenario duration was about 30 minutes.

Results

Table 4 summarizes the results of the immersive simulator capability ratings for the assessments/exercises described above conducted during the period 2002 – 2005. The complete breakout of the ratings for each assessment is shown in Appendix X. Fifty-three Soldiers and leaders participated in those exercises using immersive simulators. While simulation technology in general and the SVS™ in particular were evolving, the capabilities were fairly static during the 2002-2005 period, and for this reason those ratings have been combined to produce a summary rating. Activities are ordered from best (Very Good, 3.0) to worst (Very Poor, 0.0). Thirty of the fifty-four activities were rated Good or better (2.00 and above); eighteen were rated between the Good/Poor midpoint (1.50) and Good (2.00); and six were rated Poor (1.00-1.49). Activities which were rated highly included outdoor movement, identification of types of people (civilians, non-combatants within a room, enemy soldiers), identification of tactically significant areas (sectors of observation and responsibility), and individual weapons use (but not grenades).

Table 4.
Combined Ratings of Simulator Capability (2002 – 2005)

Task	Mean Rating
Move through open areas as a widely separated group.	2.49
Identify civilians.	2.47
Execute planned route.	2.42
Move in single file.	2.38
Fire weapon in short bursts.	2.35
Understand verbal commands.	2.31
Locate assigned areas of observation, e.g. across the street.	2.30
Identify assigned sectors of observation.	2.29
Move according to directions.	2.29
Identify non-combatants within a room.	2.27
Identify sector of responsibility.	2.25
Execute the assault as planned.	2.25
Communicate enemy location to team member.	2.22
Move quickly to the point of attack.	2.21
Aim weapon.	2.21
Communicate spot reports to squad leader.	2.21
Fire weapon accurately.	2.19
Coordinate with other squad members.	2.17
Identify covered and concealed routes.	2.16
Identify safe and danger areas.	2.13
Assume defensive positions.	2.11
Locate support team positions.	2.11
Use hand-held illumination (flares).	2.10
Identify enemy soldiers.	2.08
Locate buddy team firing positions.	2.06
Employ tactical hand-held smoke grenades.	2.03
Maintain position relative to other team members.	2.00
Identify areas that mask supporting fires.	2.00
Maneuver below windows.	2.00
Use flash-bang grenades to help clear rooms.	2.00
Take hasty defensive positions.	1.98
Engage targets within a room.	1.98
Scan from side to side.	1.90
Look around corners.	1.89
Determine other team/squad members' positions.	1.84
Take position to one side of a doorway.	1.81
Locate enemy soldiers inside buildings firing at your unit.	1.80
Move close to walls.	1.77
Scan the room quickly for hostile combatants.	1.75
Maneuver/move around obstacles.	1.75
Use fragmentation grenades.	1.70
Estimate distances from self to a distant object/point.	1.67
Maneuver close to others.	1.66
Take a tactical position within a room.	1.66
Move past furniture in a room.	1.63
Climb up or down stairs.	1.59
Maneuver around corners.	1.53
Visually locate the source of enemy fire.	1.52
Move quickly through doorways.	1.40
Distinguish between friendly and enemy fire.	1.39
Maneuver past other personnel within a room.	1.36
Determine the direction enemy rounds are coming from.	1.33
Scan vertically.	1.19
Determine the source of enemy fire by sound.	1.15

Poorly rated items included maneuver indoors (close to others, past furniture, close to walls, around objects, past other personnel, around corners, through doorways, up and down stairs), and identifying the source and type of fire (enemy or friendly), either by auditory or visual cues.

Table 5.
Summary of Simulator Capability Ratings by Assessment

Assessment	Pleban 1999	VE STO 1999	VE STO 2001	VE STO 2002	V-IMTS 2004	SAVE 2005
N	6	18	18	18	9	26
Mean Rating	2.27	1.90	1.72	2.13	1.67	1.90

What is most striking about the ratings, however, as shown in Table 5, is that there has been no systematic improvement in the ratings over a six-year period. In fact, the highest ratings were obtained in 1999 (mean = 2.27) and the lowest in 2004 (mean = 1.67). Possible reasons for this will be discussed below.

Table 6 summarizes the results of the administration of the Training Effectiveness Questionnaire. This was administered to Squad and Fire Team Leaders in every assessment beginning with the VE STO CE in 1999, and to Soldiers (fire team members) in the V-IMTS and SAVE assessments. The pattern here is much more consistent, with the mean ratings increasing consistently every year, from 0.82 (less than slight improvement) in 1999 to 2.06 (moderate improvement) in 2005. Leaders and Soldiers report learning different things. Leaders report the most improvement in controlling their units, assessing the tactical situation, and communication. Soldiers report the most improvement in communication and planning a tactical operation.

Table 6.
Training Effectiveness Questionnaire Results

	VE STO 1999	VE STO 2001	VE STO 2002	V-IMTS 2004			SAVE 2005			2002-2005		
Question	*Leaders*	*Leaders*	*Leaders*	*Leaders*	*Soldiers*	*Combined*	*Leaders*	*Soldiers*	*Combined*	*Leaders*	*Soldiers*	*Combined*
N	*9*	*9*	*9(18)*[a]	*9*	*18*	*27*	*9*	*17*	*26*	*27*	*35*	*62*
Assess the tactical situation.	*0.99*	*1.44*	*1.72*	2.33	*1.76*	*1.96*	2.22	*1.59*	*1.80*	2.09	1.68	1.86
Control of squad/fire team movement during the assault.	*1.10*	*1.22*	*1.50*	2.44	*1.71*	*1.96*	2.56	*1.50*	*1.87*	2.17	1.61	1.85
Communicate with members of your team or squad.	*1.10*	*1.56*	*1.39*	*1.89*	2.00	*1.96*	*2.11*	*1.65*	*1.80*	1.80	1.83	1.82
Coordinate activities with your chain of command.	*0.77*	*1.78*	*1.39*	2.00	2.00	2.00	2.00	*1.41*	*1.61*	1.80	1.71	1.75
Plan a tactical operation.	*0.55*	*1.22*	*1.50*	*2.11*	*2.18*	*2.15*	*1.56*	*1.31*	*1.40*	1.72	1.76	1.74
Control squad or fire team movement while not in contact with the enemy.	*1.10*	*1.22*	*1.44*	*1.67*	*1.69*	*1.68*	2.22	*1.06*	*1.45*	1.78	1.38	1.56
React to Contact Battle Drill.	*0.55*	*1.22*	*1.44*	*1.11*	*1.65*	*1.46*	*2.11*	*1.41*	*1.64*	1.55	1.53	1.54
Control your squad or fire team.	*1.10*	*1.22*	*1.50*	*1.67*	*1.59*	*1.62*	2.33	*1.00*	*1.44*	1.83	1.30	1.53
Clear a building.	*0.66*	*0.78*	*1.29*	*1.33*	*1.94*	*1.73*	*1.89*	*1.12*	*1.37*	1.50	1.54	1.53
Locate known or suspected enemy positions.	*0.55*	*1.11*	*1.39*	*1.22*	*1.59*	*1.46*	2.00	*1.35*	*1.57*	1.54	1.47	1.50
Clear a room.	*0.55*	*0.88*	*1.44*	*1.33*	*1.88*	*1.69*	*1.67*	*0.94*	*1.18*	1.48	1.42	1.45
Mean	*0.82*	*1.24*	*1.45*	*1.74*	*1.82*	*1.79*	*2.06*	*1.30*	*1.55*	1.75	1.57	1.65

[a] Each of the nine leaders completed the questionnaire at the end of each day of training, resulting in a total of 18 questionnaires.

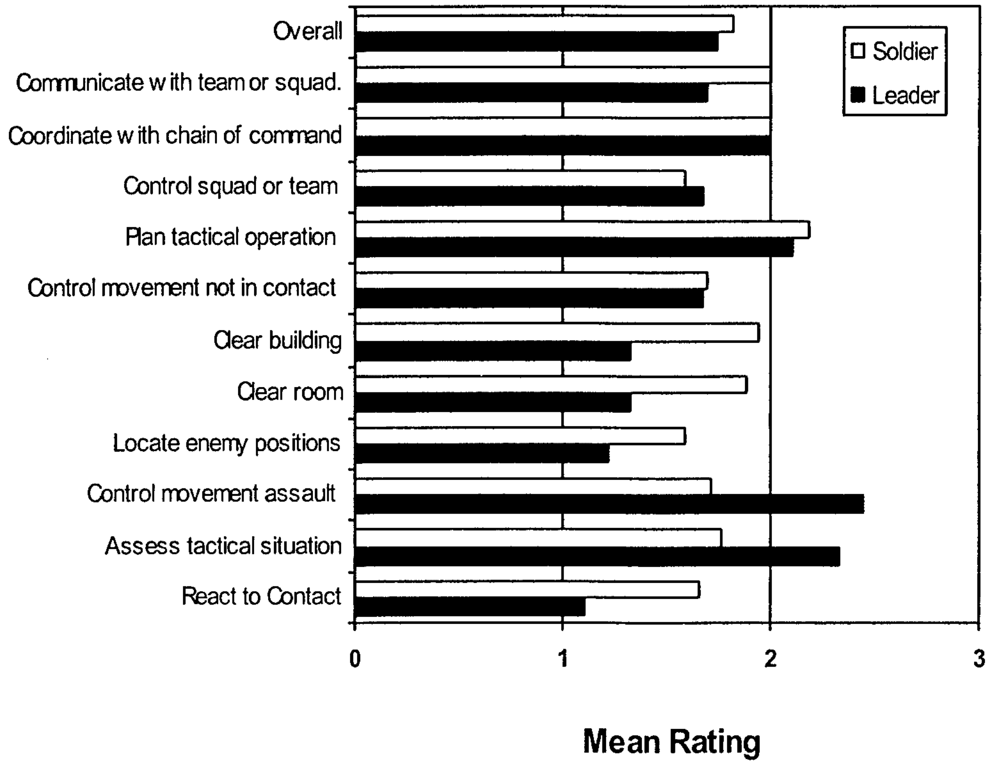

Figure 6. V-IMTS training effectiveness ratings for leaders and Soldiers.

In the V-IMTS assessment, the Squad and Fire Team Leaders used immersive simulators (SVSI) while the Soldiers used desktop simulators (SVSD). The training effectiveness ratings from the V-IMTS assessment are presented in Figure 6. The mean rating for training effectiveness was 1.8 on a scale where 1.0 equaled slight improvement and 2.0 equaled moderate improvement. Interestingly, both the leaders and the Soldiers reported about the same amount of overall improvement (mean rating of 1.76 vs. 1.66), although the skills on which they reported improving the most differed. The SVSI and SVSD ratings were positively correlated ($r = .62$), indicating that in general the same activities tended to be rated similarly on both simulators. Leaders reported the greatest improvement on Control *of squad/fire team movement during the assault*, *Assess the tactical situation*, *Plan a tactical operation*, and *Coordinate activities with your chain of command.* Soldiers reported the most improvement on *Plan a tactical operation*, *Coordinate activities with your chain of command*, and *Communicate with members of your team or squad.* Perhaps because of the small numbers involved, the differences between leader and Soldier ratings approached statistical significance for only one task, *Control of squad/fire team movement during the assault.*

The 2002 VE STO CE included an objective measure of unit performance, a fourteen-item checklist of unit behaviors that was scored independently by three raters for each scenario. Possible scores ranged from a low of 1.0 to a high of 5.0. Squads received a mean score of 3.47 on the first occurrence of a scenario, and a mean score of 3.72 on the subsequent occurrence of a similar scenario. This provides rare evidence, beyond trainee opinion, that the training was effective.

Other Experiments and Evaluations

Lampton, McDonald, Rodriguez, Cotton, Morris, Parsons, and Martin (2001) found that practice of a building search task in VE by two-person teams results in improved performance under a variety of training conditions (practice only, demonstration, and AAR).Experimental participants were college students.

Pleban, Eakin, Salter, and Matthews (2001) conducted an evaluation of the use of the SVS™ for training and assessment of decision making skills. The trainees were Army Lieutenants and Captains playing the role of Infantry platoon leaders. Role players and DISAF were used to fill the other positions required to conduct the training scenarios. Thus this was an individual training situation. Four different scenarios were conducted in a simulated virtual village: Stability and Security Operations, Company Assault, Defend, and Secure Village. Role players filled the Company Commander, Platoon Sergeant, and Squad Leader positions, and DISAF was used to fill out the remainder of the platoon. Objective measures of the accuracy of the decisions the officers made improved significantly over the four training sessions (scenarios). The officers also reported that they believed that their decision making skills had improved as a result of the training.

Pleban and Salvetti (2003) evaluated the transfer of training received in immersive simulators (again, the SVSs in the SBL) to live simulation. Four Infantry squads participated. In the Real-World condition, two squads conducted rehearsals of an assault in a real building similar to the one on which they would subsequently be tested. In the VE condition, two squads conducted rehearsals in a VE representation of the actual building on which they would be tested. All squads were then tested on two missions in the actual building (the transfer task). Two observer/controllers scored performance on each mission. Performance differences between the two groups on the final two missions were considered to be "small to negligible." However, Soldier opinions about the effectiveness of the VE training differed depending on when they received it. One-half of the Soldiers in the VE condition felt that it was just as effective as the real world for conducting mission rehearsals. However, all of the Soldiers in the Real-World condition, who received training in the VE after completing the transfer task, felt that VE was inferior to real world training.

Pleban and Salvetti (2003) note that performance in the VE was hampered by simulator constraints that made precision movement in confined areas and use of grenades difficult. They concluded however, that while immersive simulators lacked realistic qualities in certain areas, they could be used effectively for certain types of training, specifically during the walk phase of training, for improving decision making, situation awareness, and communication and coordination skills.

Loftin, Scerbo, McKenzie, Catanzaro, Bailey, Phillips, and Perry (2004) investigated the use of an immersive CAVE (CAVE Automatic Virtual Environment) simulator to train checkpoint operations. The CAVE visual display consisted of two 10 X10 foot screens each with 1280 X 1040 resolution. Other capabilities included a speech recognition system, position tracking, and sophisticated avatars for the computer-controlled entities in the scenarios. Two groups of 16 college students participated. The experimental group participated in two 45-

minute shifts, receiving feedback on their performance between the shifts. The control group participated in only a single shift. The experimental group performed better on their second shift than on their first, and in addition, performed better on shift 2 than the control group did on shift 1. Both comparisons indicate that the training was effective. In a second experiment, Loftin et al replicated the conditions of the first experiment using a monitor and touch screen in place of the CAVE. Although the number of participants was smaller, they were basically able to replicate the findings of the first experiment: the simulation (in this case delivered by a monitor) significantly reduced the number of errors committed in the scenarios. They also reported that the trainees in the fully immersive system (CAVE) consistently performed better than those in the monitor and touch screen condition. However, they concluded that:

> Although this difference was found across groups and conditions, the magnitude of the difference was not dramatic. Thus, the ability to port a similar training experience to a less expensive PC platform without major performance differences underscores the potential for providing greater access to this type of VE training in a much more cost effective medium(p. 12).

Singer, Kring, and Hamilton (2006) investigated the use of immersive simulation to train positioning and maneuver skills in an urban environment. They found significant improvements in both performance and the time required to perform the tasks. The basic patterns for the time to perform the tasks is relatively clear, with steadily decreasing amounts of time required for steadily improving (overall) performance.

Discussion of Immersive Simulation Results

Limits of Experimentation

Despite a decade of interest and research and development activity in the use of immersive simulation, evaluations of the technology using Soldiers performing Soldier tasks have been limited. There are a number of reasons for this. First, experimentation is limited by the available simulators, and the only facility available with sufficient simulators to outfit a full squad has been the SBL. The lack of availability of Soldiers to participate in evaluations has been a second constraint. Operational and training demands, have greatly limited the number of squads and the amount of time that they can participate in an evaluation. Finally, the costs of an evaluation, in terms of facilities rental, technical and support personnel, and travel costs, limit exercise duration.

SVSs have been the predominant simulators for experimentation, not necessarily because they are the best (they might or might not be), but because they exist in sufficient quantities at an Army site. This means that to some extent the results obtained are limited to that simulator.

It is somewhat surprising that Soldier ratings of SVS™ capabilities have not systematically improved between 1999 and 2005. There are several possible explanations for this. One is that as capabilities have been added to the SVS™, system performance has deteriorated. While this might explain one dip in the ratings, the SVSs have been upgraded regularly so long-term effects are unlikely. A second possibility is that the training scenarios have become more challenging and complicated in an attempt to keep pace with current operational conditions. They have pushed the Soldiers to perform more complicated tasks in the simulators, and therefore they were more likely to encounter the limits of the simulators. Moving more of the action inside buildings, for example, placed an emphasis on precise movement, which in turn emphasized simulator weaknesses in that area. The unavailability of hand grenades made it extremely difficult to clear buildings, but adding hand grenades increased the complexity of using the simulator. It is also likely that Soldier ratings of simulator capability are strongly influenced by the amount of time they spend in the simulator acquiring proficiency. This has not been controlled over the years. Finally, the impact of the increasing sophistication of computer and video games may have caused a gradual escalation of Soldier standards for simulator performance. The simulator capabilities are being compared with increasingly realistic and sophisticated commercial products. This may have, in effect, raised the standards by which automated entities and environments are judged.

What factors are responsible for the increase in training effectiveness ratings? First, the complexity and realism of the scenarios has improved. Second, the AAR capabilities have improved. Recall that the VE STO program did not develop an AAR capability until 2001, and that it has been incrementally improved since. Third, capabilities such as grenades, smoke, and improved DISAF behaviors have been added. However, remember that the trainer, whether called an observer/controller or an AAR leader, is key in setting the effectiveness of the training.

The results of the V-IMTS assessment, combined with the results of the Loftin et al (2004) experiment, raise the question of how realistic simulators need to be in order to be effective. An interesting and unexpected aspect of the V-IMTS results is the lack of a significant difference in rated training effectiveness between the Soldiers trained in the desktop simulators and the leaders trained in the immersive simulators. Admittedly, they were performing and learning different tasks, but nevertheless it seems to suggest that the features of a fully immersive simulator might not produce a training benefit that justifies the cost premium over a simple desktop computer. Loftin et al (2004) found small differences in effectiveness between immersive and desktop simulators, and questioned the effectiveness of the immersive simulator.

Research on Simulator Fidelity

Other research addressing the question of interface fidelity on training effectiveness is limited. The basic concept is that immersive VE systems, as compared to desktop VE systems, provide the trainee with more information about their orientation in and movement through physical space. Systems with head-tracked HMDs provide vestibular and kinesthetic cues about changes in direction of movement and viewing direction. Systems with a walking mechanism, such as a treadmill, or which use sensors to implement walking in place, provide kinesthetic cues about distance traveled. Systems with wide FOV displays provide visual cues in the periphery of the visual field about distance and speed of movement. If these factors make a difference in effectiveness, they would most likely affect learning routes through and the configuration of physical spaces, an area of research known as wayfinding. Researchers in this area make a distinction between route knowledge (which allows one to successfully move from one known point to another known point along a specific route, using landmarks and waypoints, but does not allow for deviations from the route), and configuration or survey knowledge (which enables uses to create a map of an area or create new routes).

As background, it should be noted that the question of whether VR systems can be used to train configuration and route knowledge is not in dispute. A large number of experiments have shown that they can (e.g., Witmer, Bailey and Knerr, 1995; Bliss, Tidwell, and Guest, 1997; Tate, Siebert, and King, 1997). The question is whether more realistic and sophisticated interfaces enhance that learning.

Grant and Magee (1997) compared a walking in place interface with a joystick in an experiment investigating the acquisition and transfer of spatial knowledge. All participants viewed the VE through a head-tracked HMD. The participants' task was to learn the location of a number of landmark objects in a science museum. During a transfer test in the actual building, the walking simulator group walked significantly less distance to find all of the landmarks than did the joystick trained group, but they did not find them significantly faster. Grant and Magee claim this as evidence that there is something learned from the walking interface *in addition to* the visual information that can be used for spatial navigation.

Singer, Allen, McDonald, and Gildea (1997) found that training a Hi-VE interface (head-linked stereoscopic HMD and treadmill) produced better configuration knowledge and more rapid response time than a Low-VE interface (non-head-linked stereoscopic HMD and joystick) in a terrain learning task. Students trained using the Hi-VE interface also did better than those trained using topological maps.

Waller, Hunt, and Knapp (1998) compared blindfolded maze-walking performance of groups trained with immersive VE (HMD with no head-tracking plus joystick), desktop VE (monitor plus joystick) and map, among other conditions. While the performance of all groups improved, the map condition was superior to the immersive VE and desktop VE conditions, which did not differ. However, their immersive VE condition provided no additional kinesthetic or vestibular cues relative to the desktop VE condition.

Jacquet (2002) found no significant differences between groups trained to perform tank turret troubleshooting tasks using immersive (HMD and 3D mouse) and desktop (two monitors and a mouse) versions of an M1 tank turret simulator.

Lathrop and Kaiser (2005) compared immersive and desktop interfaces in terms of search performance and maintenance of orientation. Immersive users wore a head-tracked HMD, changed direction of movement by rotating while seated in a chair, and clicked a button on a hand-held mouse to move forward or backward. Desktop users viewed a Monitor and used the hand-held mouse to both turn and move forward or backward. Immersive users were able to locate target objects in a complex environment more quickly than desktop users, but did not develop better configuration knowledge of the space they searched.

Singer, Ehrlich, Cinq-Mars, and Pappin (1995), investigating the effects of head-coupling and stereoscopic displays on the performance of simple tasks in VE, found that those two variables had a significant effect only on distance estimation at short distances (10 feet or less).

In summary, it appears that head-tracked visual displays, body controlled movement, or a combination of the two can improve the performance of spatially-oriented tasks and acquisition of spatial knowledge, but this difference, based on a limited number of experiments, does not appear to be large.

The Use of Computer Games for Training

Over the past ten years, there has been increasing interest in the use of computer games, played on either a PC or a game console, such as the X-Box, Playstation, or Gameboy, for Army training. Once these games were believed to be visually attractive, but too limited in terms of the actions they permitted the players and those of the simulated entities, and too unrealistic in terms of how players made those actions (e.g., using a game controller, joystick, or mouse), to be considered as a means of training. Today, games are being seriously considered for a variety of reasons.

First, it is assumed that most Soldiers play computer games. Two additional assumptions follow from this one. The first is that Soldiers are motivated to play games designed to train, even to the extent that they will do so in their off-duty hours. The second is that Soldiers are skilled in playing games, and therefore they need little introductory train-up or preparation, such as game concepts or learning how to use game controllers, prior to using these games for training.

Second, game consoles and PCs, particularly laptop PCs, are readily transportable and deployable. They are also low cost relative to special purpose simulators.

Third, many games can be networked to provided collective training. Some games (massively multiplayer games) can include hundreds of simultaneous participants.

Finally, the use of computer games provides a way to capitalize on the investments already made by game developers. This can translate into low per copy acquisition costs, particularly if the game can be used as is.

The issue of training effectiveness, however, is the most important consideration. If games do not provide effective training, then the reasons given for their use do not matter. What evidence is there that computer games can provide effective training?

Hayes (2005) conducted an extensive review of the use of games for education and training. Of 270 documents he identified in a literature search, only 48 reported evaluations in which empirical data on effectiveness was obtained. Of those, six used military personnel as trainees. Skills trained in those six experiments included periscope skills; chemical, biological, and radiological defense principles; and technical, electrical, or electronics skills and terminology. Three experiments showed better learning or retention with the game, one worse, one no difference, and one showed transfer of the skills learned in the game but had no control group for comparison. Hayes' review showed that games *can* provide effective training for a variety of training audiences and a variety of skills. However, he concluded that there is no evidence that instructional games are more effective than other well-designed instructional activities.

While a few of the evaluations reviewed by Hayes represent military tasks, fewer address the issue we are most concerned with, Soldier training of combat tasks.

DeBrine and Morrow (2000) demonstrated that a computer off-the-shelf (COTS) computer game (Quake III Arena™) could be modified to support conduct of a walkthrough of a real building. It took about 300 hours of labor for unskilled programmers to modify the game code and implement the building model. No try-outs or evaluations of the resulting game were conducted.

Beal and Christ (2004) conducted an evaluation of Full Spectrum Command (FSC), a PC game designed specifically for use in the Infantry Captains Career Course (ICCC). Fifty-four ICCC students participated. One-half of the students participated in their normal course work. The rest did that and in addition played FSC for an average of 4.8 hours (in addition to 4.8 hours of demonstration and train-up). The decision making of officers in both groups was then assessed as they conducted individual exercises using the JANUS Simulation. No differences in decision making performance during the JANUS exercises were found. Overall, the trainees reported highly positive opinions about the overall training value of FSC. They reported that the scenarios were challenging, the realism of the battlefield events and actions was quite good, and playing FSC provided practice in many of the tasks that were relevant to course objectives. On the other hand, the majority indicated that they had to focus their attention on the game's display and control devices, rather than on the experiences created by the game.

Beal and Christ (2004) believe that they failed to find a difference between the two groups in performance on the JANUS exercise because of limited time available to play FSC, the lack of controlled procedures for use of FSC (e.g., trainee selection of scenarios), and the lack of any feedback or evaluation of decision making performance during or after the FSC scenarios. While an AAR capability was built into FSC, it was not used due to operational constraints.

Belanich, Sibley, and Orvis (2004) conducted an experiment using the "America's Army" game, a first person shooter designed as a recruiting tool. Twenty delayed entry recruits and one Reserve Officer Training Corps cadet played the basic training section of the game, consisting of Army background information, marksmanship training, obstacle course, weapons familiarization, and a MOUT mission. After playing the game, the participants answered a series of multiple choice questions about information presented in the game. The participants remembered procedures better than facts, and information presented in graphics and spoken text better than information presented in written text (perhaps because the written text could be skipped over without reading). They also recalled information relevant to progressing through the game better than irrelevant information.

Diller, Roberts, Blankenship, and Nielsen, (2004) evaluated the DARWARS AMBUSH! at Fort Lewis, WA, in May 2004. AMBUSH! is a computer-based collective training game that lets units experience and respond to ambush situations. A total of 18 participants (16 enlisted personnel and two officers) used the system in three groups. Each group participated for about three hours, to include a training session and the conduct of three missions. At the conclusion of the training, participants rated their overall satisfaction with the system as a convoy operations training tool as 5.88, on a scale of 1 (low) to 7 (high). All participants gave ratings at or above the midpoint of the scale (4). Participants were even more positive about using the system as a tactics, techniques, and procedures training tool (mean = 6.36). Trainee performance was not assessed.

Beal and Christ (2005) conducted an assessment of the Rapid Decision Trainer (RDT). The RDT is a PC-based simulation built on game engine software. It was designed to prepare Infantry lieutenants to serve as platoon leaders during the Infantry Officer Basic Course (IOBC) platoon Live Fire Exercise (LFX). It requires the trainee to conduct mission analysis and planning and to make decisions in response to conditions that emerge during the execution of the simulated mission. This assessment used a single RDT scenario, which closely resembled the terrain and battle conditions that occur during the IOBC LFX. Twenty lieutenants participated in the RDT scenario as two person teams, a platoon leader and an observer, who rotated positions. Nineteen lieutenants participated as a large group, some of whom rotated through the platoon leader position while the others observed the exercise. Questionnaires were used to obtain feedback from the trainees after the RDT training but both before and after the LFX. No performance data was collected. Trainees indicated that the RDT:

- Permitted training and rehearsal of the types of decisions a platoon leader must make during a LFX (85% of ratings in highest three [of seven] categories)
- Provided meaningful practice for exercising command and control of platoon operations (82%)
- Accurately simulated tasks and conditions specified in current platoon-level battle drills (80%)
- Had a valuable impact on preparing them for leading a platoon in a unit (77%)
- Provided meaningful practice for planning a platoon mission (72%)

Despite concluding that the RDT had training value, the authors also provided a number of cautions: the sample size was small, no performance measures were available, training time on the RDT was limited, only one scenario was available, and the simulation was still under development.

Nolan and Jones (2005) assessed the use of *Delta Force: Black Hawk Down – Team Sabre*™ to train IOBC students to perform the React to Contact Battle Drill. In this case, full squads at individual computers were networked together to conduct the training scenarios. Two squads each completed two eight-hour training sessions (completing six or seven missions) using the game in addition to their regular training. Two control squads received only their regular training. All squads then conducted a live exercise, and completed questionnaires. All participants in the game condition rated the training effectiveness of the game as "good" or better. All game participants also reported that the game had a "positive" or "very positive" effect on their performance on the subsequent live exercise. No performance data on the live exercise were obtained.

Issues in Game-Based Training

ARI hosted a symposium on the use of PC-based simulations and gaming for military training in November 2003 (Belanich, Mullin, and Dressel, 2004). Approximately 50 researchers and trainers participated. Beal (2005) documented lessons learned and issues based on his conduct of evaluations of the RDT, Full Spectrum Command, and FSW. There is considerable similarity between the symposium conclusions and Beal's lessons learned.

First and most important, the consensus is that games can be effective for training, but the empirical evidence to support this is lacking. In particular, there is a belief that games can be effective in training cognitive skills prior to their application in field exercises. In other words, games could bridge the gap between classroom training and field exercises.

Instructors are believed to be highly important to the successful use of games for training. Beal (2005) gives two general areas of instructor support. The first is in explaining the purpose of the game, demonstrating game functions, and explaining game limitations and shortfalls. The second is in providing coaching and feedback, to include the conduct of AARs. Feedback to the trainee by the instructor was the most frequently mentioned instructional techniques for use with games. This feedback can range from immediate feedback during the game or scenario to an AAR at its conclusion. Feedback should both highlight positive lessons learned and diminish the possibility that the trainees will learn suspect behaviors that may enhance success in the game, but not in the real world.

Also important is the need for game design to be based on training objectives. Clear training objectives and follow-through by instructors are important for successful implementation.

Data on game playing

Both the ARI symposium and Beal (2005) called into question the assumption that all Army trainees are skilled game players. The attractiveness of these games, in addition to presumed training effectiveness, is that Soldiers are assumed to already be familiar with them, and motivated to train with them, even in off-duty hours. Are these assumptions justified? Symposium participants considered the time required to learn to play a game is a barrier to successful implementation.

Roberts, Foehr, and Rideout (2005) conducted an extensive survey of American youth and media in 2004. They found that 8-18 year olds spent an average of 19 minutes per day playing PC games and 49 minutes playing console and handheld games. Fifty-nine percent (68% of males and 51% of females) play some type of interactive games on any given day. These results seem to be fairly consistent across race and parent's education and income. However, it cannot be determined from the report what percentage of youth rarely or never play interactive games.

No recent large-scale surveys of Soldier game playing have been conducted. However, Soldiers participating in evaluations of simulations and PC games have been asked about their game-playing experience. Soldiers in the V-IMTS evaluation described earlier reported a mean of 9.5 hours (median 6.5 hours) per week playing computer or video games. A sample of 27 Infantry Soldiers from a separate assessment conducted in FY 2004 (Knerr, Garrity, and Lampton, 2004) reported a mean of 8.5 hours (median 5.0 hours) per week playing computer or video games. However, 7% and 22% of the Soldiers in these samples, respectively, did not play video games. Beal and Christ (2005) found that 30% of their sample of 39 Infantry lieutenants involved in the evaluation of the RDT did not play video games, and 51% described themselves as Novice PC game players. Only 13% reported playing more than two hours per week. In their evaluation of the FSC game, Beal and Christ (2004) found that 57% of their sample of 54 Infantry lieutenants and captains did not play computer games. Diller, Roberts, Blankenship, and Nielsen (2004), when evaluating the game DARWARS Ambush!, found that 14 of their 18 participants reported playing computer games for at least one hour per week (mean = 12.9 hours per week). Their sample included 2 officers and 16 enlisted personnel, three of whom were women. Nolan and Jones (2005) reported that 10 of the 41 IOBC students in their experiment had played no computer games in the previous two years, and only 15 had played weekly or more frequently.

The results involving enlisted personnel seem fairly consistent with those of the Roberts, Foehr, and Rideout (2005) survey data reported above. The results involving junior officers seem very different. Whether this is a result of differences in age, education, social factors, or the particular questions asked is not clear. It is safe to assume that a large portion of our potential trainees are familiar with computer or video games. However, we cannot assume that all of them are skilled or enthusiastic game players. This does not mean that games could not provide effective training for them, but it does indicate a need to provide adequate training in playing the game before training begins in earnest. Beal (2005) found that leaders differed in their proficiency with games and personal computers. More than 70% of the participants in the FSC evaluation reported that they had to focus on computer control devices and functions rather than the experiences created by the simulation. He reported finding similar results in other evaluations. Experimenters tended to overestimate trainee proficiency and underestimate training time.

A related question is whether Soldiers have access to computers to use for training in their off-duty hours. The ARI Army Personnel Survey Office conducted a survey in the fall of 2002 and found that 99.1% of all Army officers and 87.4% of all enlisted personnel reported having access to the internet, while 98.7% and 84.1%, respectively, reported having access to a PC. The group with the lowest access was junior enlisted personnel, with only 80.4% having access to the internet and 74.8% having access to a PC. These data may have changed, but no recent survey data are available. Moreover, having a computer and internet access in the barracks or residence does not guarantee that those resources can be used by the Soldier for training in off-duty hours.

Simulator Sickness

Simulator sickness refers to unwanted side effects and aftereffects that may result from using simulators, but does not result from similar use of the actual equipment. Major symptoms include nausea, dizziness, and headache or eyestrain. Simulator sickness is closely related to, but nevertheless different from, forms of motion sickness such as sea sickness, car sickness, and air sickness. Simulator sickness is a concern because it can affect the well being of the trainee and reduce training effectiveness, even if it does not produce severe symptoms. Discomfort in the simulator may distract the trainee. It may also cause trainees to adopt behaviors that reduce discomfort in the simulator, but will be detrimental if transferred to the actual task (such as reducing side-to-side scanning). Aftereffects involving the sense of balance or visual flashbacks could impair the trainees' ability to drive safely or perform skilled motor tasks after leaving the simulator. The training value of a simulator is also reduced if simulator sickness causes a reduction in the frequency or duration of its use.

Experts do not agree about the causes of simulator sickness (Johnson, 2005; Kolasinski, 1995). However, according to the most popular theory, simulator sickness is thought to result, at least in part, because simulated movement results in a conflict between the body's mechanical systems and visual systems for sensing movement. Normally, our sense of balance is maintained by a complex interaction of several senses including: the eyes, which monitor where the body is in space and direction of motion; the inner ears, which monitor the directions of motion; the skin pressure receptors such as in the feet and seat, which indicate what part of the body is down and touching the ground; and the muscle and joint sensory receptors, which indicate what parts of the body are moving. When the relationships among these senses differ from our normal experience (as when our eyes perceive us moving down a corridor while our other senses indicate that we are standing still), discomfort results.

Kolasinski (1995) has documented a variety of factors that affect the incidence and severity of simulator sickness. These are shown in Table 7. It is not necessary to review these in detail. However, it is important to recognize that the extent to which a trainee will experience simulator sickness symptoms will depend on their individual characteristics, the characteristics of the simulator, and the characteristics of the task they are trying to perform.

Simulator sickness is usually measured by using questionnaires. A commonly used questionnaire is the Simulator Sickness Questionnaire (SSQ), (Kennedy, Lane, Berbaum, & Lilienthal, 1993). The SSQ consists of 16 symptoms, each of which is rated by the simulator user on a 4-point scale (0=none, 1=slight, 2=moderate, 3=severe). These ratings form the basis for three subscale scores (Nausea, Oculomotor Discomfort, and Disorientation) as well as a Total Severity score. The symptoms making up the three factor scores are as follows: Nausea - general discomfort, increased salivation, sweating, nausea, difficulty concentrating, stomach awareness, and burping; Oculomotor - general discomfort, fatigue, headache, eyestrain, difficulty focusing, difficulty concentrating, and blurred vision; and Disorientation - difficulty focusing, nausea, fullness of head, blurred vision, dizzy (eyes open), dizzy (eyes closed), and vertigo. One complication is that these symptoms as not unique to simulator sickness. They can be caused by a variety of factors, such as insufficient sleep, cold, flu, or alcohol consumption.

Table 7
Potential Factors Associated with Simulator Sickness in Virtual Environments

Individual	Simulator	Task
• age	• binocular viewing	• altitude above terrain
• concentration level	• calibration	• degree of control
• ethnicity	• color	• duration
• experience with real-world task	• contrast	• global visual flow
• experience with simulator (adaptation)	• field of view	• head movements
• flicker fusion frequency threshold	• flicker	• luminance level
• gender	• inter-pupillary distance	• method of movement
• illness and personal characteristics	• motion platform	• rate of linear or rotational acceleration
• mental rotation ability	• phosphor lag	• self-movement speed
• perceptual style	• position-tracking error	• sitting versus standing
• postural stability	• refresh rate	• type of application
	• resolution	• unusual maneuvers
	• scene content	• vection
	• time lag (transport delay)	
	• update rate (frame rate)	
	• viewing region	

Is simulator sickness really a problem for users of immersive simulators? Knerr et al (1998) reported that simulator sickness symptoms among college students who participated in a series of VE laboratory experiments were sufficiently severe that 5.6% (29/517) withdrew from the experiments. Fourteen (4.1% percent) of the 338 participants who were specifically asked indicated vomiting.

Soldiers have typically reported fewer and less severe symptoms. Lockheed Martin (1997) reported low levels of symptoms among the Soldiers during the DWN engineering experiments (about one "slight" symptom for every four Soldiers). Scores for the DWN ERT experiments were higher. For three of the VICS, Soldiers reported symptoms equivalent to two slight symptoms at the end of each day. However, Soldiers who used VIC Golf reported the equivalent of five slight symptoms. Recall that VIC Golf used a combination of HMD and ODT.

In the 2001 VE STO CE, total symptom scores were slightly higher at the end of the day than at the start (0.67 vs. 0.31) but the difference was slight, equating to an increase of about one slight symptom for every three soldiers. The most frequently reported symptoms at the end of the day were fatigue and eyestrain, both with mean symptom scores of 0.17, a level of occurrence equal to about one slight symptom reported for every six soldiers.

In the 2002 VE STO CE, the occurrence of simulator sickness symptoms was very low, averaging the equivalent of 1.36 slight symptoms per soldier at the end of the day, compared with 1.16 at the beginning. The largest increases were in the symptoms headache and eyestrain (+.17 each).

In V-IMTS evaluation, there was an increase in the overall frequency and severity of symptoms following simulator use, but the increase was slight, averaging about the equivalent of one-half (0.55) a unit increase in one symptom. The increase was larger for Solders in the immersive simulators (1.00) than for Soldiers using the desktop simulators. (0.32).

The low level of occurrence of symptoms likely results from the use of short scenarios (approximately 20 minutes each) separated by non-immersive activities, and the use of rear-projection displays in the SVSs. Simulator sickness does not seem to be an obstacle to longer-duration training scenarios.

There was one additional assessment that obtained information about Soldier simulator sickness using immersive simulators. It has not been discussed previously because it was concerned strictly with simulator capability, not training effectiveness. It involved three squads conducting exercises with immersive and desktop SVSs, and three different versions of wearable simulators which used HMDs. All of the HMDs permitted peripheral views of the real world around the sides and bottom. The SVSs and two of the three wearable simulators produced symptom scores in the 1.19 – 1.56 range, but the third wearable simulator produced a means symptom score of 4.33. The highest scoring symptoms for that system were eyestrain (.58), general discomfort (.44), headache (.47), difficulty focusing (.35) and blurred vision (.26). This suggests that the visual display system was a causal factor. The same pattern remained when we looked at the scores for three different dimensions of simulator sickness, Nausea, Oculomotor Discomfort, and Disorientation: one simulator produced higher scores than the others, which did not differ among themselves. This was probably a result of the particular HMD it used. It had a very small exit pupil, which meant that it had to be precisely positioned on the head. Head movements could cause a temporary loss of the image. It also had an adjustment for inter-pupillary distance, which each Soldier had to make. If this was not done properly, the images seen by the two eyes would not fuse, and eyestrain would result. There was no way to check to see it the adjustment had been made properly.

What can we conclude? First, consider that in all situations involving Soldiers, exposures were short, usually under 30 minutes per exercise (although Soldiers participated in multiple exercises per day). Longer exercises, particularly with Soldiers who have little experience with the simulators, may cause more problems. Second, with a few exceptions, the Soldiers used the SVS™ immersive simulator, which provides view of the real world (the floor and walls of the simulator enclosure) while viewing the simulation on a rear-projection display. Other display systems, such as wide FOV projection systems or HMDs which completely obscure the view of the real world are more likely to cause problems.

Simulator sickness should be viewed as a real but manageable problem.

Discussion

Let us review some of the results presented earlier. A number of reviews have concluded that simulation is a cost-effective means of training. It is not necessarily more effective or efficient than the real world or use of the actual equipment, but it typically costs less. Simulators employing older technology, such as the Squad Engagement Training System and the Engagement Skills Trainer 2000, have proven to be effective for leader and weapons training. SME ratings of virtual simulators have tended to indicate potential, if not the actual effectiveness of the simulators.

With regard to individual training, there seems to be a consistent finding that training in virtual simulations can be effective. Whether the objective is wayfinding and navigation, checkpoint operations, tactical positioning and maneuver, or squad leader decision making, there is ample objective evidence that trainee skills improve with practice in the simulation.

The results with regard to collective training are more ambiguous. Trainee ratings indicate that they can perform a wide variety of individual tasks in the simulators at a level of "good" or better, which is a necessary but not sufficient condition for effective training. Trainee ratings have indicated that they believe that their performance improved as a result of training in the virtual simulators. Observer/Controller ratings, while limited, have indicated that leader/unit performance improved as a result of training in virtual simulators.

Whether or not one concludes that immersive simulations are effective for collective training of dismounted Soldiers depends largely on the standard of proof employed. The "gold standard" would be an improvement in objectively measured performance in actual combat or live exercises, in controlled experiments so that the improvement can be shown to result from the use of the immersive simulation to the exclusion of other factors, and a sufficient number of units trained to insure confidence that the results do not result from chance. Unfortunately, there is no evidence that meets this standard. Conversely, there is no evidence that immersive simulation could not meet this standard. Such an evaluation has not been conducted.

Without the evidence that a "gold standard" evaluation would provide, we must rely on research results that provide a lower standard of proof. Soldiers and small unit leaders who have participated in virtual simulation exercises have consistently reported that their skills have improved as a result of the training. There is ample evidence that Soldiers report that their skills have improved as a result of the use of immersive simulation, but there is little objective evidence (such as trainer ratings or mission success) to confirm this, or to show how the effectiveness of training in virtual simulations compares with other approaches. Those evaluations that have been conducted have also generally involved fewer Soldiers and units than would be required to establish statistical significance.

The problem is that there has not been an organizational commitment to conduct such an evaluation. Largely because of resource constraints, particularly on the availability of Soldier trainees to participate in evaluations, relatively few virtual simulation programs for dismounted Soldiers have evaluated collective training effectiveness using objective measures of Soldier performance. For the same reason, virtual simulation has not generally been compared to other forms of training. Ideally, we would like to have more rigorous data. Realistically, this data does not exist for other training methods, either.

In addition to the unresolved questions about the acquisition of skills in the simulators, there are some questions about the transfer of what is learned in the virtual simulators to the real world. Pleban and Salvetti (2003) found that practicing building clearing in a VE did not improve performance on the task in the real building. Statkus and Spring (2003) found differences in Soldier task performance between MOUT tasks performed in virtual simulation (SVS™) and performance of the same tasks in a live simulation with simunitions. Soldiers in the SVS™ engaged targets more rapidly and fired fewer rounds than did Soldiers conducting the same exercises at the McKenna MOUT site. They attributed the differences in performance to a combination of environmental effects (lighting and temperature), load carried (BDU only vs. full fighting load), increased fatigue in the live simulation (as a result of the previous two factors), and the adverse consequence of being shot with a simunition.

PC-based simulations, or PC games modified for training purposes, are receiving increasing attention. A number have been developed or modified for Army training. The general evaluation finding is that trainees respond positively to the game, but objective measures of training effectiveness are not obtained. An ARI workshop on the topic concluded that "while most researchers seem to agree that computer games can be effective training tools, there is very little empirical evidence to support that conclusion" (Belanich, Mullen, and Dressel, 2004).

In addition to the question of effectiveness, there is also the question of whether potential Solider trainees, both enlisted and junior officer, possess the computer and game-playing skills that would enable them to master PC games used for training readily. There are no wide-scale survey data on this question, but data from experiments with relatively small numbers of participants suggests that 20-57% of junior officers and 7-22% of enlisted personnel do not play interactive games. This indicates a need for introductory practice prior to use of interactive games for training, but the existing data are very limited.

Immersive simulations (or PC-based simulations) should not be used by themselves. They can provide a transition between initial or classroom training and live simulations. They appear to be best suited to training cognitive skills (not motor skills), decision making, communication, and teamwork. They require an instructor to provide a context and feedback.

Desktop or laptop simulators should be considered as an alternative to fully-immersive simulators which use large rear-projection or HMD. Fully-immersive head-tracked displays are more effective, particularly when performing spatially-oriented tasks and acquiring spatial knowledge, but based on a limited number of experiments, this difference does not appear to be large, and may not justify the increased cost.

Summary of Findings

The major findings are summarized in the following sections, organized around the topics of training effectiveness, Soldier task performance, and advantages and disadvantages of immersive virtual simulations.

What have we learned about training effectiveness?

The following are based on data and observation from five assessments of immersive simulation systems involving 45 squad and fire team leaders and 94 squad members during the period 1999 – 2005.

First, Soldiers and small unit leaders report that their skills improve as a result of training in virtual simulations. They report the most improvement in controlling, coordinating, communicating, and planning (conducted prior to use of the simulators), and less improvement in the mechanics of tasks and battle drills.

Second, these self-reports by Soldiers have generally, if informally, been confirmed by observers. In one of the assessments objective ratings of unit performance by two independent raters were obtained. These ratings showed improvement in performance over the course of the training.

These results are consistent with findings involving collective marksmanship trainers. Using different technology, but functionally similar to immersive virtual simulators, these trainers have produced objective data indicating that they provide effective training in tactical skills as well as marksmanship.

It should be noted that these results were obtained despite a number of limitations. The total amount of time that trainees spent conducting training scenarios was actually relatively short (no more than three hours). In most cases, the software was still under development, and not fully problem free. The scenarios were usually not tailored to the skill level of the leader or unit. The trainer/AAR leader was frequently unfamiliar with the technology and did not necessarily use it to best advantage.

What we have learned about what Soldier task performance?

Fifty-one Soldiers and leaders participated in tactical exercises using immersive simulators (all variants of the immersive Soldier Visualization Station, or SVS™) to conduct tactical exercises in assessments conducted during the period 2002 – 2005. While simulation technology in general and the SVS™ in particular were evolving, the capabilities were fairly static during that period. After Soldiers participated in the scenarios, they rated how well they could perform each of 54 Soldier activities in the simulators as Very Poor, Poor, Good, or Very Good. Overall, 30 of the 54 activities were rated Good or better; 18 were rated between the Good/Poor midpoint and Good; and 6 were rated Poor. Activities which were rated highly included outdoor movement, identification of types of people (civilians, non-combatants within a room, enemy soldiers), identification of tactically significant areas (sectors of observation and responsibility), and individual weapons use (but not grenades). Poorly rated items included maneuver indoors (close to others, past furniture, close to walls, around objects, past other personnel, around corners, through doorways, up and down stairs), and identifying the source and type of fire (enemy or friendly), either by auditory or visual cues.

The issue of fine or precision movement in confined areas, such as movement indoors, has consistently emerged as the most important improvements required. It appears to be a more complicated problem than can be solved by building a new movement control device. It involves a number of related issues: the size and complexity of the "bounding box" which detects collisions between Soldiers and other objects, and between Soldiers; the limited visual texture and shading cues on the walls inside buildings; the relatively narrow FOV of the SVS™ display; the problem representing objects which are located between the Soldier and the rear-projection screen; and the linkage between direction of gaze and direction of movement.

Precise movement in buildings is the primary example of the limitation on the physical actions that trainees could perform in the SVS™ simulator. Other simulators may differ in the specifics of the physical actions that can be performed. But no matter what the design, there are likely to be limitations, particularly with regard to locomotion and touch. For example, trainees in the SVS™ could drop to the ground, but they could not drop to the ground and roll. If they tried, they were likely to get tangled up in wires. They could not physically "throw" grenades. They selected a type of grenade from a menu, chose direction and launch angle by pointing their mock weapon, choose the amount of force desired by adjusting a slider with a pair of buttons on the weapon, and pulled the trigger to launch the grenade. While this bears little resemblance to the physical act of throwing a real grenade, it does provide practice in deciding which type of grenade to use, and where and when to employ it. They could not physically touch other people in the simulation, or objects other than their individual weapon and equipment. They consequently could not practice some aspects of room entry.

These simulator constraints limit training effectiveness only if those actions that cannot be performed in the simulator are not trained by other means. For example, the SVS™ approach to grenade throwing is a problem only if Soldiers are not taught to throw grenades by other means. It is important that immersive virtual simulation be conducted as part of a planned sequence of instruction that provides them with the prerequisite skills prior to the simulation, and provides subsequent live training to improve the physical skills that cannot be trained in the virtual simulation.

Even though the simulator may not allow Soldiers to perform many of the physical actions they need to perform in the way they need to perform them, it does allow them to practice and learn the cognitive skills they need. These include the planning that needs to be done prior to missions, the skills required to maintain situational awareness, and learning to think on their feet and make appropriate decisions in complex situations. These are all positive things that are one level of analysis above the physical actions Soldiers can or cannot do in the virtual environments with current technology.

What are the advantages of immersive virtual simulations?

Virtual simulations possess a number of advantages relative to the use of live simulation for dismounted Soldier training. These are described in the following paragraphs.

Virtual simulation can represent any terrain or environment that has been modeled, whether a real location or a generic one. It is not limited to the physical area where it is located.

Therefore, it can provide an urban training area with high rise buildings at a remote location, or a Middle Eastern village in a downtown armory. Environments can be selected based on training needs, rather than availability.

Weather and other environmental conditions (rain, fog) can be represented. Nighttime missions can be trained during the day and daytime missions can be trained during the night. There is no need to wait for the right conditions.

Use of immersive virtual simulation is likely to reduce the amount of time required by a unit to conduct a training exercise relative to live training. The following requirements should be reduced: transportation to and from the training site; drawing, cleaning, and returning weapons, ammunition, and gear such as MILES/OneTESS; positioning equipment and support personnel prior to the exercise; movement to the exercise start position; movement to the AAR area; and cleaning up the training site.

Both instrumented live and virtual simulation require support personnel, and both require support personnel with technical skills to maintain and operate the equipment. However, the requirements for human role players fill the positions of enemy units, other friendly units, and civilians should be much smaller for virtual simulations. OneSAF can fill many of these roles (enemy units, crowds, etc.). Human role players can fill multiple roles (although not simultaneously) without regard to physical appearance or location in the environment.

The risk of accident or injury is lower in virtual than in live simulation. Because of this, virtual simulations make it possible to more realistically depict the effects of demolitions (blow a hole in the building anywhere) or indirect fire than is possible in live simulations.

While virtual simulations require improved physical facilities, they require less physical space than a live simulation facility. They also reduce the need for use of actual equipment.

Virtual AARs provide unique capabilities for viewing events that are not currently possible with live simulations. First, they can provide an overall view of the action that is not possible with video cameras, which provide multiple separate views of portions of the action. Second, they can provide a view of the action from any perspective, not limited by camera locations. Third, they capture and provide an accurate representation of ground truth on which to base AARs so they can learn from their mistakes. Finally, they can provide a variety of aids to analyze and depict events (e.g., shot lines, movement paths, FOV, etc.).

These capabilities make it possible for virtual immersive simulations to be used to provide the opportunity for small unit leaders and unit members to practice, in the context of realistic simulated operations, the cognitive and decision making skills that will foster adaptability and the capability to respond to rapidly changing situations. Focused, repetitive, deliberate practice, with feedback based on performance, is an effective method for training the recognition of situations and developing expertise. Cognitive and decision making skills can be trained even if some physical tasks cannot be performed in the situation.

What are the disadvantages of immersive virtual simulations?

Virtual simulations possess a number of disadvantages relative to the use of live simulation for dismounted Soldier training. These are described in the following paragraphs.

Some physical activities cannot be performed in the simulators, or must be performed differently in the simulators than in the real world. These currently include actions such as throwing grenades, or touching or grasping other participants or objects. There is a risk that Soldiers may learn inappropriate behaviors. This risk can be reduced by having trainers emphasize the differences between the simulation and the real world, and by providing additional live training on the affected tasks.

Weapons effects may not be modeled correctly, or position and location tracking may not be accurate enough to depict realistic weapons effects. Soldiers may, therefore, develop inappropriate expectations. This disadvantage applies to live simulation as well. Any specially developed simulation system should model weapons effects, particularly individual Soldier weapons, accurately. Tracking accuracy may be a problem for fully immersive systems, and if so, would suggest that training scenarios not involve long range use of individual weapons by trainees. Inaccurate modeling may be a problem for use of commercial products.

Virtual simulations require improved facilities (enclosed space, air conditioning, and power). They also require technical support to implement training scenarios and operate and maintain computers and other equipment.

Trainees may not take virtual simulations seriously because they are similar to video games, and might, therefore, practice actions that are inappropriate in the real world, or attempt to "game" the system. This risk can be reduced by trainer emphasis.

Some trainees may experience "simulator sickness." This is unlikely to be a major problem. Risks can be reduced by making initial exposures to the simulators relatively short, and gradually increasing the duration.

Recommendations

Conduct a large-scale evaluation using current technology.

As discussed above, the evidence that immersive simulation can provide effective training is not sufficient to justify the immediate acquisition of such systems on a large scale. However, there is enough evidence that they can be effective to justify acquisition of a prototype system using current technology and use it to conduct a rigorous training effectiveness evaluation which would permit quantification of the effectiveness of the training and comparison with alternatives. While this would be costly, in terms of both dollars and Soldier time, it would lead to a more informed acquisition decision.

This evaluation should consider objective measurement of both skill improvement on the simulator and transfer of those skills to a live simulation environment. It should involve a sufficient number of units (probably squads) that any meaningful real differences in the training effectiveness of different can be detected. The evaluation should be embedded in the unit's normal training progression, and unit personnel should be involved in its development and delivery.

Consider cost-effectiveness of fully immersive and desktop or laptop systems.

The cost differential between fully-immersive simulators using large projection displays or HMDs and simulators using desktop or laptop computers to provide the same functionality can be enormous. Knerr (2006), analyzed cost data provided by Loftin, Dryer, Belfore, Petty, Phillips, Garcia, Seevi, Lusso, Mastaglio, and Park (2004), and estimated the difference at over $75,000 per simulator. While the cost difference is likely to decrease as the cost of large visual displays decreases, the fact remains that the major cost drivers for fully immersive simulators are the interface devices, particularly the position and orientation trackers and visual display systems. The computers are relatively cheap. The interface devices also increase space and support requirements.

In contrast, the research evidence indicates that any difference in training effectiveness between immersive and desktop systems is likely to be small. Immersive systems are more effective, particularly when training spatially-oriented tasks, such as learning a complex route or floor plan. Whether immersive simulators are also better when training squads to conduct urban or counter-insurgency operations, and if so, whether the difference is large enough to justify the increased cost, are unknown, but should be investigated, perhaps in conjunction with the large-scale evaluation recommended above.

Conduct a survey of potential officer and enlisted trainees to determine game-playing skill.

One of the assumptions underlying the growing popularity of the use of video and PC-based games for training is that the potential trainees, if not avid game players, are at least interested in and experienced with such games. They, therefore, need little training in their use, and are motivated to play. However, data from small samples of Soldiers who participated in evaluations suggests that this may not be the case. While a fairly large percentage of male enlisted personnel, possibly 75% or higher, play computer or video games weekly or more frequently, officers appear to play less frequently. In addition, based on civilian data, we would expect that female Soldiers would play less frequently than male Soldiers. We know little about the types of games that Soldiers play (e.g., first person shooter vs. role player). Since game playing experience has implications for the types of games that could be used for training and the amount and type of prerequisite game playing training required, we would like to have a much better picture of the both current and projected Soldier and leader familiarity and experience with different types of interactive games.

Continue to improve virtual simulation capabilities and assess their training effectiveness.

Some aspects of immersive virtual simulation technology, such as large-screen displays, will continue to improve, or become less expensive, as a result of commercial market forces. However, it will require a continuing science and technology investment by the Army to produce a tailored system that provides cost-effective training.

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Appendix A
List of Acronyms

AAR	After Action Review
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
ARL	U.S. Army Research Laboratory
ARTEP	Army Training and Evaluation Program
CATT	Combined Army Tactical Trainer
CAVE	CAVE Automatic Virtual Environment
CE	Culminating Event
CPT	Combat Proficiency Training
COTS	Commercial off-the-Shelf
DARPA	Defense Advanced Projects Agency
DARWARS	DARPA Training Superiority Program
DCSOPS&T	Deputy chief of Staff for Operations and Training
DI	Dismounted Infantry
DIS	Distributed Interactive Simulation
DISAF	Dismounted Infantry Semi-Automated Forces
DIVAARS	Dismounted Infantry Virtual After Action Review System
DoD	Department of Defense
DTIC	Defense Technical Information Center
DWN	Dismounted Warrior Network
DWN ERT	Dismounted Warrior Network Enhancements for Restricted Terrain
EST	Engagement Skills Trainer
FOV	Field of View
FSC	Full Spectrum Command
HLA	High Level Architecture
HMD	Head Mounted Display or Helmet Mounted Display
ICCC	Infantry Captains Career Course
IOBC	Infantry Officer Basic Course
I-Port	Individual Portal
LED	Light Emitting Diode
LFX	Live Fire Exercise
L-V-C	Live – Virtual - Constructive
MILES	Multiple Integrated Laser Engagement System
MOUT	Military Operations in Urban Terrain
MPR	Mission Planning and Rehearsal
MTP	Mission Training Plan
ODT	Omni-Directional Treadmill
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
One SAF	One Semi-Automated Forces
OneTESS	One Tactical Engagement Simulation System
OPTEMPO	Operational Tempo

ORD	Operational Requirements Document
PEO STRI	Program Executive Office for Simulation, Training, and Instrumentation
PC	Personal Computer
R&D	Research and Development
RDECOM STTC	Research, Development, and Engineering Command Simulation, and Training Technology Center
RBD	Reality by Design
RDT	Rapid Decision Trainer
RSTA	Reconnaissance, Surveillance, and Target Acquisition
SASO	Support and Sustainment Operations
SAVE	Situational Awareness in Virtual Environments
SBL	Soldier Battle Lab
SETS	Squad Engagement Training System
SME	Subject Matter Expert
SOF	Special Operations Forces
SSE	Squad Synthetic Environment
SSQ	Simulator Sickness Questionnaire
STO	Science and Technology Objective
STRICOM	US Army Simulation, Training and Instrumentation Command
SVS™	Soldier Visualization Station
SVSD	Desktop SVS™ simulator
SVSI	Immersive SVS™ simulator
TOE	Table of Organization and Equipment
TPIO	TRADOC Program Integration Office
TRADOC	U.S. Army Training and Doctrine Command
TTES	Team Tactical Engagement Simulator
UO	Urban Operations
USAARMC	U.S. Army Armor Center
USAIC	U.S. Army Infantry Center
USAIS	U.S. Army Infantry School
USJFKSWCS	U.S. John F. Kennedy Special Warfare Center and School
VE	Virtual Environment
V-IMTS	Virtual Integrated MOUT Training System
VICS	Virtual Individual Combatant Simulator
VR	Virtual Reality