

Low Cost, Effective Embedded Training Methods for Future Soldier Systems

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ABSTRACT

Soldier systems of the future will provide many new warfighting capabilities including computers built into the soldier-worn equipment. Embedded training—capabilities that are integrated into operational systems to provide or support training—will be one of the new capabilities that use these computers. Embedded training has been identified as a Key Performance Parameter for Ground Soldier Systems (GSS) that must be satisfied before the system can be fielded. GSS designers have many competing design issues, some of which will affect embedded training implementation. For example, long battery life is a critical requirement for GSS that may well come at the expense of computer processing power and graphics capability, both of which are considerations for embedded training. In addition, cost is a very important issue because embedded training systems for individual soldiers would be fielded in large numbers.

Several prototype systems have been developed to research embedded training issues for GSS. One of these systems, called Team Mission Assistant-Tactical/Exercise (TeamMATE), uses a Personal Digital Assistant (PDA) as the computing platform. This particular prototype was designed to address a range of embedded training use cases while operating within the power, cost and weight constraints of current soldier systems. The design considered mission planning and rehearsal techniques used by soldiers in the field today, the needs of live training and the need for interoperability with other virtual simulations.

This paper discusses the PDA as an embedded training platform and other dismantled soldier embedded prototypes and their strengths and weaknesses in meeting the GSS requirements. The paper also discusses user evaluations of this technology, implementation lessons learned and projects a way forward for this important technology challenge.

ABOUT THE AUTHORS

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INTRODUCTION

In recent years, the Army research and development community has emphasized development of fully-immersive, virtual approaches to providing mission rehearsal and training for dismounted soldiers (“DAGGERS”; “ETDS”; “TRADOC Pamphlet 350-37”). These systems, shown in Figure 1, allow the trainee to interact with a virtual environment seen through a helmet-mounted display. The soldier uses a weapon-mounted joystick to move in the virtual environment along with sensors mounted on the weapon, body, and head that monitor weapon and body orientation.



Figure 1. Fully-immersive virtual embedded training systems demonstrated at IITSEC 2005. These technologies will require reductions in cost, weight, and power to meet the embedded training Key Performance Parameter requirements of Ground Soldier Systems (GSS).

While these development efforts explore future virtual embedded training possibilities, they presently have weight, cost, and power consumption issues that cause a conflict between mission and program requirements for current and near-term Ground Soldier Systems

(GSS) and the state of current technology (InHand 2004).

Embedded training is defined as capabilities that are integrated into operational systems to provide or support training (“TRADOC Pamphlet 350-37”). Embedded training has been identified as a GSS Key Performance Parameter (KPP)—a capability requirement that must be satisfied in order for GSS to be fielded to soldiers (“GSS CDD”). With the possibility that the current technology base might not support the vision of fully-immersive training solutions, an approach starting from the existing technology limitations and then adding the training capability may be necessary to satisfy the embedded training KPP. In 2004, Army senior leadership proposed a challenge to the research and development community to investigate existing technologies and develop wearable ‘player units’ capable of providing embedded virtual dismounted mission rehearsal and collective training.

This challenge resulted in the addition of a new initiative within the Embedded Combined Arms Team Training and Mission Rehearsal (ECATT-MR) Army Technology Objective (ATO). The purpose of this initiative was to explore the potential of low-cost, high Technology Readiness Level (TRL) technologies constrained by the likely performance capabilities of first generation GSS equipment to support embedded collective training, mission rehearsal (MR), and after-action review (AAR) applications. This is an important endeavor, in that low-cost technologies offer several potential benefits relative to fully-immersive technologies, including:

- Earlier transition to acquisition programs and fielding
- No training-specific equipment or training-specific influence on system design, and therefore potentially lower cost, size, weight, and power

consumption (i.e. these could truly be 'embedded' systems within the GSS context).

- Provides training and rehearsal capabilities to dismounted soldiers that might not otherwise receive fully-immersive technologies due to cost or other considerations (“MIL-HDBK-29612 Part 1A”)
- Complements fully immersive technologies in certain situations, e.g. if high-fidelity, current 3D terrain data is not available for a mission location

Because the technologies are relatively inexpensive, they have a high potential for widespread use (“MIL-HDBK-29612 Part 1A”). Further, the technologies have capabilities and characteristics that are similar to existing and planned soldier system technologies. This allows for easier transition to acquisition programs and, more importantly, continuity with operational systems to allow soldiers to 'train as you fight' (“TRADOC Pamphlet 350-37”).

This paper describes an effort to develop a creative approach to providing effective embedded training and mission rehearsal for dismounted soldiers using technologies with performance capabilities and costs similar to planned GSS. We discuss the development of an embedded training and mission rehearsal concept given certain low-cost wearable computing technology design constraints. We then describe an initial prototype developed for use as a research platform to evaluate and refine the concept. Finally, we discuss user evaluations of this concept, implementation lessons learned, and project a way forward for this important technology challenge.

BACKGROUND

The ATO initiative implies a hypothesis that low-cost technologies can provide effective collective embedded training. To test this hypothesis, we undertook a development process that began with a consideration of the capabilities and constraints of available technologies, given the target TRL and desired delivery date. We then explored training approaches that are possible given the selected technologies. Finally, we conducted a subject matter expert user evaluation to provide a preliminary test of our hypothesis.

The wearable computing technology used for this task was to be inexpensive, at TRL 6 in FY06, and has been identified for use in existing or planned soldier system

programs in FY06. For our purposes, we assumed that these constraints are satisfied by existing commercial Personal Digital Assistant (PDA) platforms that cost between \$500 and \$1000 per unit in FY06, although any necessary ruggedization or other military-specific modifications would certainly result in a higher per-unit cost. Tablet-type PDAs are small, lightweight, and do not require extensive batteries to support long missions – all critical soldier system design criteria. These assumptions are based on our significant experience developing and fielding dismounted soldier system technologies, and are further validated by investigating existing soldier system programs and initiatives including Future Combat System Crewman's Remote Interface System, Land Warrior Commander's Digital Assistant, Objective/Future Force Warrior, Rapid Equipping Force Advanced Robotic Controller, and other programs.

Having determined the technology basis for the player units, we then asked—what embedded collective training approaches can the player units support? This question was principally answered by considering the human-system interface and processing capabilities of the wearable technologies. The player units will support the same type of visualization that is anticipated for current and planned dismounted soldier systems, including two-dimensional map displays and low-resolution video displays. These displays are provided by a small handheld screen and manipulated via an optimized graphic user interface (GUI), supplemented with audio output. The high-fidelity, large-screen image generation and processing capabilities required for immersive visualization are not anticipated to be feasible given the performance capabilities and costs of projected dismounted soldier systems without resorting to costly add-on high performance upgrades.

We also reviewed current embedded collective training approaches and determined that the primary goal of collective training is to train soldiers to make high-level decisions about individual tasks in support of collective tasks. Although individual tasks may be performed with varying amounts of fidelity among existing collective training approaches, the primary purpose of embedded collective training is not to provide individual task training; this is particularly true for dismounted soldiers. Dismounted soldier individual tasks are highly physical and are likely best supported by live training that may require specific facilities or equipment. The selection and synchronization of dismounted soldier individual tasks is the essence of collective task training for dismounted soldiers, particularly for combined arms teams where

close coordination between mounted platforms and dismounted soldiers is necessary to accomplish missions with maximum effect and minimized casualties while avoiding fratricide. As such, we can prioritize the development of our low-cost embedded collective training approach to focus less on individual task fidelity and more on the factors that influence individual task decisions.

These realizations, along with our prior technology analysis, allow us to develop a formal concept for how our proposed low-cost player units support embedded collective training. In general, dismounted soldier trainees participate in a collective exercise utilizing the same operational system functions of their player unit, such as manipulating the map displays, sending reports, and utilizing voice communications. Individual tasks that do not correspond directly to existing operational system functions, e.g. 'move to a location' or 'provide supporting fire,' are represented by either live physical actions or simulated actions that are integrated into the operational soldier applications. For live training events, some physical actions such as movement or weapons firing can be employed in a completely physical manner, perhaps via Multiple Integrated Laser Engagement System (MILES) integration. For other tasks or completely simulated exercises, the soldier trainees select the appropriate function(s) from the soldier applications when necessary to support the collective goal. Environmental or collective event cues, such as explosions or small arms fire, are indicated using the available low-fidelity visual and auditory capabilities of the player unit. Enemy type and location are indicated on the visual display according to simplified visibility algorithms.

This abstract representation of tasks is somewhat analogous to football games for entertainment consoles, where players control discrete, high-level actions (selection of offensive and defensive plays) and selected abstract actions that represent highly physical activities (passing the football to a particular receiver). While this type of game would not be useful for training football players how to pass or catch the football, it could be very helpful in teaching the players to work together as a team. By practicing different plays, the individual players would learn the sequence of the play, the role of the other players, and the various alternatives that exist in the play.

Applied to dismounted soldier rehearsal and training, this concept is similar to a rock drill. During a rock drill, each soldier walks through his actions at a high level, usually with the aid of a crude representation of

the mission area drawn on the ground. Soldiers are not training *how* to perform individual tasks in a rock drill, e.g. shooting or moving in a tactical formation, but rather *when* to perform individual tasks. Using this concept, soldiers using the player unit therefore concentrate on high-level collective tasks—*what should I do and when should I do it in relation to what others are doing*—and less on the actual performance of individual tasks—*how do I do it*. By concentrating on the high-level sequencing and selection of individual tasks without detailed performance of individual tasks, this concept allows more emphasis on decision-making.

In our view, collective training involves the sorts of things that a soldier should learn from a mission rehearsal or battle drill as opposed to weapons training or close-quarters combat training. Physically intensive individual tasks should be trained on an individual level with as much realism as possible ("ARTEP 7-8-DRILL"). The virtual representation capabilities of PDAs certainly do not challenge the five senses and are not intended to replace live training or other individual task training methods.

This abstract representation of individual dismounted soldier tasks also provides several other potential benefits:

- Individual task selection and activation by a participating soldier is distinct and easily analyzed for purposes of AAR, response time calculations, and other automated performance metrics
- Simplified interaction with the simulation decreases exercise participation training requirements
- Highly granular individual task structure is readily modeled for potential use of computer-controlled simulated entities to perform individual tasks, possibly to supplement a less than full strength unit wanting to participate in an exercise at full strength
- Simplified integration with role-specific or other applications or models available in operational systems, e.g. engineer munitions selection tutorials and job aids
- Simplified integration with constructive simulation tools for leader course of action (COA) analysis

It is important to realize that this virtual collective training concept is not a constructive simulator. A pure constructive simulation does not require or support soldier interaction during the simulation—once

the simulation inputs are provided, the soldier initiates the simulation and watches the results. The proposed approach supports virtual simulation, because the soldier is actively controlling his actions (or more precisely, the actions of his avatar) in the simulation. This is all the more apparent if the soldier is participating in a live-virtual exercise, where the soldier's position is provided by Global Positioning System (GPS) equipment. Compared to a fully immersive virtual simulation like the Enhanced Dismounted Infantry Manned Module (E-DIMM), the primary differences are in the display and the controls. E-DIMM has a three-dimensional display where the proposed PDA-based player unit utilizes a two-dimensional display. Both require the soldier to provide inputs to control the avatar's movement and actions. The E-DIMM has a realistic rifle with a trigger, while the PDA will have a user interface method of initiating fires. However, both allow the soldier to initiate fires or perform other mission-appropriate actions at the appropriate time to meet the simulation mission objectives.

Finally, although the ATO research primarily focused on simulation-based virtual training, we believe it is also important to explore the potential extension of the system to live training exercises: where soldiers conduct real actions on real terrain. This may allow for a great deal of flexibility in training options and may also help bridge the gap between individual and collective task training that potentially exists with virtual training approaches ("ARTEP 7-10-MTP").

PROTOTYPE RESEARCH PLATFORM

Following the design of the embedded training concept, we developed an initial prototype for use as a research platform to evaluate and refine the concept. The Team Mission Assistant—Tactical/Exercise (TeamMATE) system can be used to participate in three types of training exercises:

- Virtual exercise. Soldiers using TeamMATE control one or more virtual soldier entities in a virtual terrain. The soldier-controlled virtual entities can observe and engage other virtual opposition force (OPFOR) entities that are controlled by other systems (perhaps other TeamMATEs or standard Army simulation hosts).
- Live exercise. Soldiers conduct live force-on-force training, where soldiers move and engage OPFOR in a real environment with MILES or similar live training instrumentation. In this case,

the system tracks the decisions made in a passive observer mode for post-event analysis/replay.

- Combined live/virtual exercise. Soldiers conduct live force-on-force training, engaging OPFOR in a real environment but also participate in a virtual environment matched to the real environment. Soldiers can also observe or engage virtual entities in the virtual environment, perhaps to simulate combined arms blue force (BLUFOR – friendly) units or OPFOR units that are not available for the exercise.

TeamMATE can support ad-hoc peer-to-peer exercises, where soldiers using TeamMATEs conduct a live, virtual, or live/virtual exercise without a server computer and potentially in a field environment. TeamMATE can also participate in server-hosted exercises with a variety of standard Army simulation hosts and tools via the Distributed Interactive Simulation (DIS) standard protocol, e.g. One Semi-Automated Force (OneSAF) Testbed Baseline (OTB) v2.0.

The TeamMATE system consists of the following components:

- Personal Digital Assistant (PDA)



- optional external battery with power supply cable



- optional GPS receiver for live training



- optional MILES or surrogate weapon instrumentation system for live training

The primary TeamMATE functions can be accessed through the PDA hardware and large on-screen buttons, as shown in Figure 2.



Figure 2. The TeamMATE concept prototype supports a range of interaction techniques optimized for one-handed use.

The use of large buttons for primary functions allows soldiers with gloved fingers to use TeamMATE. The most frequently used functions are assigned to the rightmost buttons to facilitate right-handed use. For virtual exercises or advanced functions, the PDA stylus (stored on the side of the PDA) is used to allow precise on-screen control or sketching.

The PDA button functions are, from right to left:

- **Mode.** Pressing this button toggles through the main map screen modes – Move, Fire, Sketch, and Range. The map screen mode determines what happens when you click the map. The current mode is shown in the lower right corner of the display.
- **Action.** This button performs a function based on the current map mode, e.g. if you are in move mode, pressing the button stops your movement and clears your path.
- **Pan.** The center directional buttons pans the map, and the center button inside the directional button toggles the map details.
- **Soldier.** Pressing this button will show or hide the soldier menu, which provides several functions for

controlling the current virtual soldier, e.g. changing the stance or movement rate, reviving the soldier if he has been killed, or setting the map to center on the soldier as he moves.

- **Menu.** Pressing this button will show or hide the main menu, which allows you to add soldiers, navigate to the messaging screen, or quit the exercise.

The map display contains several features:

- A list of the current soldiers controlled by the PDA in the upper left corner of the display. Clicking the soldier in the list will select that soldier so that movement, fire, and other commands will apply to the selected soldier. Selecting the soldier in the list will also center the map on the soldier if the soldier is not currently displayed.
- On-screen buttons for zooming in and out in the lower left corner of the display.
- Distances are indicated by map ticks along the horizontal and vertical center lines of the map. The distance between map ticks is indicated above the zoom buttons in the lower left corner of the display.

To participate in a virtual exercise using TeamMATE, a soldier selects one or more virtual entities to control during the exercise. As the exercise progresses, the soldier can draw movement paths for the virtual entities or have them fire weapons at other entities. The movement rate and stance, weapon types, and other high-level parameters can be changed with a simple user interface. If any entities are hit by weapons fire, an audible indication is played and a simple health indicator is updated to reflect the status of the entity.

Live and combined live/virtual exercises are conducted in a similar manner. A soldier turns on a TeamMATE-compatible commercial GPS unit and selects a live entity to represent himself in the exercise. As the soldier moves in the real world, his entity's position is updated on his and other TeamMATE systems. As the soldier receives fire from a TeamMATE-compatible instrumentation system, the soldier entity's health is updated appropriately. This instrumentation integration capability was demonstrated with a surrogate MILES system. TeamMATE will be integrated with MILES systems in FY2006.

Following a live or virtual exercise, the entire exercise can be replayed using a preliminary AAR capability. This allows simple playback of the exercise and allows all TeamMATE systems to review the exercise, regardless of whether they participated in the exercise. During the playback, sketches and other annotations can be shared immediately among the AAR participants.

DESIGN STRENGTHS AND WEAKNESSES

The TeamMATE system represents an entirely new approach to providing dismounted embedded collective training. As such, there may be situations or applications where it is of limited use or where it is highly beneficial. While the full range of strengths, weaknesses, or tradeoffs can be assessed with long-term user evaluations in realistic, operational settings, there are several aspects of the design that can be directly discussed.

Limitations of two-dimensional representation of terrain using low-fidelity map data. It is anticipated that map data available for future operational dismounted soldier systems will be of fairly low resolution; perhaps 0.5-meter resolution at best and probably will not be available for all mission areas. This, along with the high probability that the data will only be two dimensional presents an issue for embedded collective training: a soldier might not be able to interact with certain built-up or urban environments in a manner that is supported by fully immersive virtual simulations. For example, a soldier might not be able to kick down a door or move within a building. This limitation is possibly fairly benign if you consider the potential for negative training and mission rehearsal with high-resolution terrain data that is not completely representative of the mission area. Further, this issue is primarily only of concern for squad-and-below training operations in highly urban environments primarily performing individual tasks and thus is generally not applicable for most situations found in combined arms collective training.

Mobile communication networks inherently exhibit a potential for data loss. Current DIS networks typically utilize wired networks for communicating data between participants ("IEEE Std 1278.1-1995"). Further, the DIS standard employs multicast and unicast protocols for much of this data, which are not reliable communication protocols. However, the historical performance of DIS participants communicating on wired networks has shown that the use of unreliable communication protocols on wired networks is generally acceptable. Mobile communication networks exhibit the same issues with

unreliable communication protocols as well as other potential issues including increased communication delays and greater potential for packet loss due to interference or other loss of connectivity. This is primarily a potential issue only for situations where real-time, distributed monitoring of an exercise is desired. In cases where the exercise is to be reviewed following the event, perhaps in support of an AAR, the exercise data can be stored on each soldier's TeamMATE and consolidated once the soldiers are in a common area.

Always-available tools support opportunity training. Whether incorporated into a soldier system or used as an appended PDA-based system, the concept of having a versatile embedded training and mission rehearsal tool available to soldiers at all times is compelling. Unexpected opportunities for training can be leveraged in a variety of ways. What was previously downtime could be used to conduct high-level rehearsals for an upcoming mission, battle drills, etc. Soldiers can conduct simulated force-on-force virtual exercises to develop and test mission plans as well as reinforce communication and learning of the collective mission parameters within the entire dismounted unit. The relative ease of obtaining two-dimensional map data and abstract simplified virtual representations support the capability to prepare for and conduct training and mission rehearsal quickly and easily.

USER EVALUATION

On October 11 and 12, 2005, twenty Observer Controllers (OCs) were given a briefing and hands-on demonstration of TeamMATE at the National Training Center (NTC) at Fort Irwin, CA. OCs serve as instructors, accompanying and providing feedback to soldiers being trained at NTC.

The twenty OC subjects had an average of more than 14 years in service, with a minimum of 7.5 and a maximum of 23. The subjects had a wide range of military experience, including infantry, cavalry scout, armor, field artillery, engineer, signals, and military intelligence. All were NCOs or officers with platoon, company, or higher command or HQ experience. As NTC OCs, all were recognized Army training experts and therefore intimately familiar with conducting training at brigade-and-below with a variety of Army and Joint forces in a multitude of high-intensity conflicts.

The subjects were informed that TeamMATE was an unfinished concept prototype and that their review was

being conducted early in the concept exploration process to ensure that the concept remained relevant to warfighter needs prior to any future development. Following the demonstration and a hands-on evaluation the subjects were asked to complete a

questionnaire and then participate in an open discussion. The evaluation environment and activities are shown in Figure 3.



Figure 3. The user evaluation consisted of a classroom briefing and demonstration followed by a hands-on outdoor evaluation, a questionnaire, and an open group discussion.

The questionnaire consisted of brief demographic data, three Likert-scaled statement responses, three open-ended questions, and a space for other comments. The Likert-scaled response statements were as follows:

- TeamMATE was easy to learn how to use.
- The TeamMATE concept could effectively support dismount collective live training.
- The TeamMATE concept could effectively support dismount collective virtual training.

The open-ended questions were as follows:

- What are the BEST characteristics of TeamMATE? Explain.
- What are the WORST characteristics of TeamMATE? Explain.
- How would you improve TeamMATE?

The subjects' Likert-scaled statement responses are shown and summarized in Figure 4 and Table 1.

It can be difficult for subjects to imagine the final form of an unfinished prototype, and many of the comments indicated that the subjects placed a significant amount of consideration on the physical aspects of the PDA, e.g. sunlight readability, potential for breakage, etc. Despite the differences between the current concept implementation and future soldier systems, the subject responses were positive (mean > 3.0) indicating at least partial agreement that the prototype implementation of the TeamMATE concept was easy to use and could effectively support both dismount live and virtual

training. Half of the subjects provided full agreement to one or more response statements and only three subjects providing any disagreement to one or more response statements.

The subjects provided a significant amount of written feedback and open discussion during the subject interviews. Much of the discussion centered on how TeamMATE could be refined or optimized to suit training of the OCs' assigned training unit types and missions.

Several notable comments are paraphrased below along with related discussion:

- Add data collection and AAR features. In order to be of most benefit to OCs and home station trainers, TeamMATE should incorporate a range of live trainer-support and AAR enhancements, e.g. fratricide analysis, geo-referencing of digital pictures taken during an exercise, etc.
- Needs to be evaluated under combat use to see if enablers can benefit troops. As with all soldier system technologies, the TeamMATE concept should be evaluated in realistic operational conditions. This evaluation should be performed on a suitably refined concept, however, to allow for proper assessment of the concept.
- Add basic support for buildings, terrain, and obstacles. TeamMATE should support some level of collision and line-of-sight capability for virtual terrain.
- Ability to send orders, interoperate with C2 system. If the TeamMATE system is intended to

serve as a low-cost surrogate soldier system, it should support appropriate message types and interfaces. If the training unit soldiers are not normally equipped with soldier systems,

TeamMATE should not be able to be used as soldier systems – rather, TeamMATE would be stowed during a live exercise and the display turned off (but still capturing AAR data).

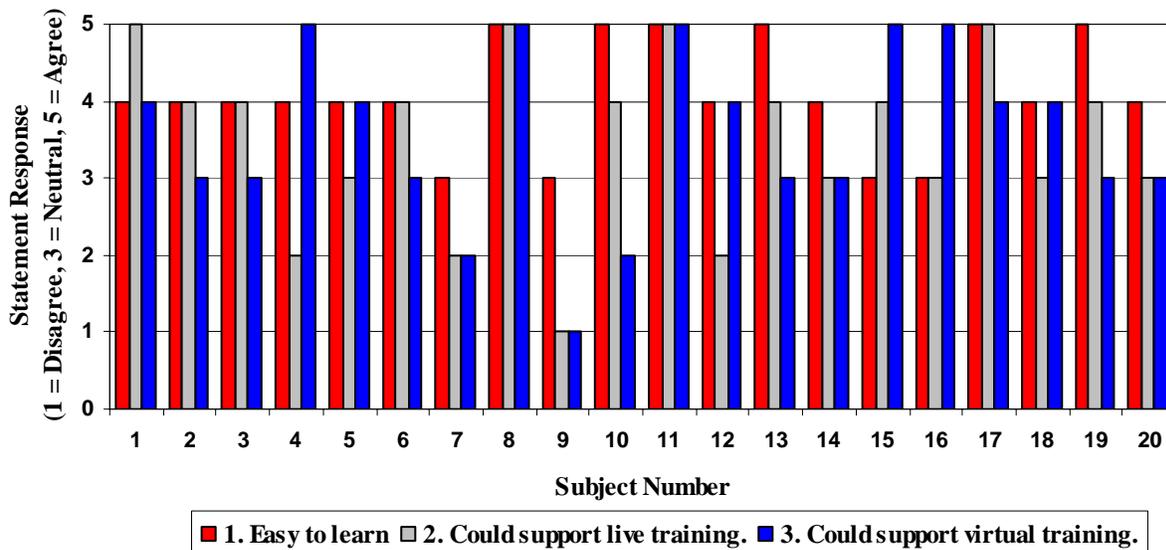


Figure 4. The Likert-scaled statement responses indicate that the subject responses were positive overall, indicating agreement that the prototype implementation of the TeamMATE concept was easy to use and could effectively support both dismount live and virtual training.

Table 1. Summarized Likert-scaled subject responses

Statement Number	Mean	95% Confidence Interval Minimum	95% Confidence Interval Maximum
1	4.1	3.8	4.4
2	3.5	3.0	4.0
3	3.6	3.0	4.1

- Allow group control of enemy and friendly entities as well as automated control. Although TeamMATE already supports any number of virtual OPFOR and BLUFOR entities controlled by any exercise participant, the ability to control groups and related group behavior capabilities should be refined. The extent to which TeamMATE mirrors existing constructive simulation system should be carefully considered, as the trade-offs between PDA processing capability, concept development cost, and ‘rock drill’ rehearsal fidelity are potentially significant.
- Range of transmitter. The range of a commercial PDA wireless network is approximately 30-100

meters line-of-sight. Although the TeamMATE AAR concept does not require long communication ranges (AAR data is synchronized among PDAs once in range as the soldiers converge after the exercise) if TeamMATE is employed as a soldier system surrogate a longer range radio may be necessary.

CONCLUSIONS

GSS programs require effective embedded training solutions to meet their embedded training KPP requirements. As current and future GSS programs proceed towards their development and fielding

milestones, there are potential cost, weight, and power implementation issues with the fully-immersive embedded training technologies planned for integration into these systems that prevent the solution from being truly 'embedded'.

We developed a concept to address this problem that utilizes low-cost wearable computing technologies to provide GSS embedded collective training. We then developed a PDA-based initial prototype to be used as a research platform to evaluate and refine the concept. Finally, we conducted a user evaluation of this concept prototype which provided several key insights and resulted in a positive review of the concept.

The prototype capabilities presented in this paper are being extended in 2006 with enhanced distributed AAR and MILES integration capabilities. In addition, several suggested areas of improvement identified in the user evaluation are being addressed. We also plan to conduct another user evaluation in an operationally relevant environment in late 2006 to help guide any further refinement. If successful, we hope that this research will be leveraged in current and future GSS programs. Soldiers deserve the very best training solutions we can provide them.

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