# Research on the Cost Effectiveness of Embedded Simulation and Embedded Training An Update

*Bruce McDonald*
McDonald Research Associates, Inc.
Winter Park, FL 32792
407-644-1900
bruce@mrassociates.com

*Hubert A. Bahr*
HQ STRICOM AMSTI-ES
Orlando, FL 32826
407-384-3874
bahrh@stricom.army.mil

Keywords:
Embedded Training, Embedded Simulation, Embedded Operations, Cost Effectiveness.

**ABSTRACT**: *This paper describes the current findings on the cost and operational effectiveness analyses being conducted on the Embedded Simulation (ES) to support Embedded Training (ET) and Embedded Operations (EO) under development in the STRICOM Inter-Vehicle Embedded Simulation Technology (INVEST) program. The basic approach is to determine the goal capabilities of ES, compare these goals to the estimated performance improvements of simulation hardware/software in the future and estimate when each of the ES goals can be achieved in a cost effective manner. The authors presented a paper at the last workshop and were invited to present progress on the project at the Fall SIW. This paper will present initial findings in terms of the required ES cues and responses and alternatives for presenting these cues.*

## 1. Background and Objectives

As indicated in our pervious paper [1], the goal of the INVEST program is to develop and demonstrate the technology that will lay the foundation for incorporating embedded simulation into future as well as legacy combat vehicles. This simulation capability will support tank combat operations as well as training that spans from individual training, through crew training, to force-on-force training exercises. Along this continuum, however, there are many technological challenges. These challenges range from the injection of artificial terrain into the driver's viewport for individualized training, to the intermixing of live and virtual images in the commander's and gunner's display on the battlefield.

The basic approach for the cost effectiveness analysis is to determine the goal capabilities of ES, compare these goals to the estimated performance improvements of simulation hardware/software in the future and estimate when each of the ES goals can be achieved in a cost effective manner. At this early point in the analysis, we are concentrating on how ES can be used to provide ET and EO support for the M1A2 Abrams Main Battle Tank Sensor Enhancement Package (M1A2 SEP). The sections below will discuss the ES requirements to support ET as well as EO.

## 2. ES to Support ET

Training requirements for tank platoons have been analyzed to determine what ET functionality would be required to create more cost effective training capabilities than the current system. The first source of information was FM 17-12-1 Tank Gunnery (Abrams) [2]. This manual describes how the Abrams tank crew and tank platoon train for combat weapon system proficiency.

First, FM 17-12-1 indicates on page 14-3 that the Tank Commander begins with Preparatory Tank Combat Training followed by Basic, Intermediate and Advanced Tank Combat Tables. Preparatory Training begins with Crew Skills Training. Initial tracking skills are developed using Tracking Boards (Snake Boards) which are set up in the motor pool. With the tank stationary, the gunner and Tank Commander track lines on the board including commands to change magnification and munition selection. These Tracking Boards could be injected in the gun sights with little advancement in image generator and display technology. The ET system could also track and score trainee tracking performance such as percent time on target or RMS error. Since these Tracking Boards are meant to simulate evasive target actions, matching scripted (low intelligence) targets could be developed for ET with little advance in technology.

Another drill is Gun Laying (p. 14-8) in which the tank commander lays the gun on targets for the gunner. The next step of Crew Skills training in FM17-12-1 is Target Hand-Off (p. 14-15). This requires 1/30 scale models on pop-up targets and a circuit tester in the breach to produce a flash when the gun is triggered. This equipment could also be easily replaced with little advance in ES/ET technology as discussed above. The targets displayed by ES/ET should be both visual and thermal.

Crews must have passed the Tank Crew Gunnery Skills Test (TCGST) within the last six months in order to fire the main gun. This TCGST has 17 stations. The following stations require fixed and moving thermal targets and a laser safe training area or eye-safe laser filter:

- Station 11. Acquire targets through the thermal imaging system
- Station 12. Engage targets with the main gun from the gunner's station
- Station 14. Issue initial and subsequent fire commands
- Station 15. Prepare for three-man crew and fire from tank commander position
- Station 16. Lay the main gun on a target from tank commander position

Again, this equipment could also be easily replaced with little advance in ES/ET technology as discussed above.

The tank gunnery tables are divided into Crew and Platoon segments. By definition, training of the crew concentrates on activities inside the tank and the need for communication of simulated targets and weapons effects between moving tanks should be minimal. Consequently, developing ES/ET for the crew segment of the tank gunnery tables will require less technology development in the area of communications, and could be implemented in a cost effective manner earlier than ES/ET for the platoon segment of gunnery tables. The requirements for ES to provide ET on the tank gunnery skills training above are covered in the following section on ARTEP.

## 2.1 ARTEP 17-237-10-MTP

The primary tool for conducting training in the Army is the Army Training and Evaluation Plan - Mission Training Plan (ARTEP-MTP). The ARTEP for tank platoons is ARTEP 17-237-10 MTP (Mission Training Plan for the Tank Platoon) [3]. This MTP provides the tasks, conditions and standards to develop a tank platoon training program. Consequently, the primary target of ET for tank platoons must be ARTEP 17-237-10-MTP. Table 1 contains a list of all Battlefield Operating Systems (BOSs) and Task Titles from the ARTEP along with the ES capabilities required to provide ET on these tasks. Note that ET can be used to train almost all of the ARTEP tasks except for Combat Service Support and placement of obstacles. ES cannot support these tasks because most of the activity occurs outside the vehicles. Three tasks involving Nuclear, Biological and Chemical (NBC) attacks can be trained in the actual vehicles without the aid of ES.

All ES requires a terrain data base, the injection of simulated vehicles and terrain in the viewport, and detection of operator responses. These three requirements were left out of the table for the sake of brevity. The first requirement for effective ET is a high resolution terrain data base. High resolution is required in order to allow trainees to occupy battle positions with realistic cover and concealment. The Topographic Engineering Center, in its Rapid Terrain Visualization Advanced Concept Technology Demonstration, is developing high resolution data bases that will be used by INVEST in the mid term time frame. Commercial industry is moving toward small, low cost, powerful and ruggedized image generators and displays that will fulfill INVEST ES requirements in the mid term time frame. As the M1A2 tank moves to greater use of digital data, it becomes easier to detect operator actions. Table 1 lists the remaining ET functionality required to support ARTEP training requirements.

Table 1

ET Functionality and Required ES Capabilities

| BOS and Task Title | Req. Embedded Simulation Capabilities | | | | | | | | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No ES Req. | Unable to Train | Enemy/Neut. Vehs | Friendly Vehicles | Enemy Dismtd Inf. | Frndly Dismtd Inf. | Tr. Real Veh. P/S | Trans. Interactions | Combat Support | Enemy Indirect Fire | Mines/Obstacles | Stealth Display | |
| Command and Control | | | | | | | | | | | | | |
| Conduct Troop-Leading Procedures | | | | | | | | | | | | | |
| Planning | | | X | X | X | X | | | | | X | X | Use stealth for COAA and support issuing operations order. |
| Mission Rehearsal | | | X | X | X | X | X | X | X | | X | X | Use ES in vehicles to conduct mission rehearsals. |
| Conduct Assembly Area Activities | | | | X | | X | X | | | | | X | Use Stealth for reconnaissance and marking area. |
| Conduct Linkup | | | | X | | X | X | X | | | | X | Use stealth to evaluate linkup point. |
| Intelligence | | | | | | | | | | | | | |
| Establish Observation Posts | | | X | X | X | X | | | | | | X | Separate stealth display to simulate observation posts. |
| Mobility and Survivability | | | | | | | | | | | | | |
| Conduct Breach Force Operations | | | X | X | X | X | X | X | X | | X | X | Must simulate mine plow and roller. |
| Conduct Operational Decontam. | X | | | | | | | | | | | | |
| Cross An NBC Contaminated Area | | | | | | | X | | | | | | Must simulate NBC sensors and contaminated terrain. |
| Emplace and Retrieve Hasty Obstacle | | X | | | | | | | | | | | Most activity outside vehicles. |
| Air Defense | | | | | | | | | | | | | |
| Conduct Passive Air Defense Meas. | | | X | X | | | X | | | | | | Requires greater use of head mounted displays. |
| Combat Service Support | | | | | | | | | | | | | |
| Conduct Consol. and Reorg. Activ. | | X | | | | | | | | | | | Most activity occurs outside of vehicles. |
| Conduct Resupply Operations | | X | | | | | | | | | | | Most activity occurs outside of vehicles. |
| Platoon Battle Drills | | | | | | | | | | | | | |
| Change of Formation Drill | | | | X | | | X | | | | | | |
| Contact Drill | | | X | X | X | | X | X | | | | | Transmit target locations via IVIS. |
| Action Drill | | | X | X | X | X | X | X | | | | | Transmit target locations via IVIS. |
| React To Indirect Fire Drill | | | X | X | | | X | | | X | | | |
| React To Air Attack Drill | | | X | X | | | X | X | | | | | Requires greater use of head mounted displays. |
| React To Nuclear Attack Drill | X | | | | | | | | | | | | |
| React To Chem/Bio Attack Drill | X | | | | | | | | | | | | |

Table 1
ET Functionality and Required ES Capabilities (Continued)

| BOS and Task Title | Req. Embedded Simulation Capabilities | | | | | | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | No ES Req. | Unable to Train | Enemy/Neut. Vehs | Friendly Vehicles | Enemy Dismtd Inf. | Frndly Dismtd Inf. | Tr. Real Veh. P/S | Trans. Interactions | Combat Support | Enemy Indirect Fire | Mines/Obstacles | Stealth Display | |
| Maneuver | | | | | | | | | | | | | |
| Conduct Bypass Operations | | | X | X | X | | X | X | | | | X | Use stealth to explore potential bypass routes. |
| Conduct Convoy Escort | | | X | X | X | | X | X | X | X | X | X | Use stealth to plan route and recon. obstacles. |
| Coord/Conduct Passage of Lines | | | | X | | X | X | | | | | X | Use stealth to plan passage. |
| Conduct Tactical Movement | | | | X | | | | | | | | X | Use stealth for reconnaissance and movement plan. |
| Conduct a Tactical Road March | | | | X | | X | X | | | | | | |
| Execute Actions on Contact | | | X | X | X | X | X | X | X | X | | | |
| Destroy An Inferior Force | | | X | X | X | X | X | X | X | X | | X | Use stealth to determine routes with cover. |
| Assault an Enemy Position | | | X | X | X | X | X | X | X | X | | X | Use stealth to determine routes with cover. |
| Conduct an Attack By Fire | | | X | X | X | X | X | X | X | X | | X | Use stealth to determine routes with cover. |
| Conduct Overwatch/Support by Fire | | | X | X | X | X | X | X | X | X | | X | Use stealth to select routes with cover, select overwatch sites. |
| Conduct Reconnaissance by Fire | | | X | X | X | X | X | X | X | X | | X | Use stealth to select routes with cover, select terrain ref points. |
| Follow and Support | | | X | X | X | X | X | X | X | X | | X | Use stealth to determine routes with cover. |
| Coord/Assist Passage of Lines | | | | X | | X | X | | | | | X | Use stealth to plan passage. |
| Disengage From the Enemy | | | X | X | X | X | X | X | X | X | | X | Use stealth to determine routes with cover. |
| Conduct Deliberate Occ. Of Battle Pos. | | | | | | | | | | | | | |
| Planning | | | | | | | | | | | | X | Use stealth to select battle positions, terrain ref. Points. |
| Rehearsal | | | X | X | X | X | X | X | X | X | | X | Use stealth to simulate Observation Posts. |
| Execution | | | X | X | X | X | X | X | X | X | | X | Use stealth to simulate Observation Posts. |
| Conduct Hasty Occ. Of Battle Pos. | | | X | X | X | X | X | X | X | X | | X | Use stealth to simulate Observation Posts. |
| Conduct A Perimeter Defense | | | X | X | X | X | X | X | X | X | | X | Use stealth to select positions and simulate Observation Posts. |
| Conduct A Platoon Defense | | | X | X | X | X | X | X | X | X | | X | Use stealth to simulate Observation Posts. |
| Conduct A Relief In Place | | | | X | | X | X | | | | | | |
| Displace to A Successive Battle Pos. | | | | X | | | X | | | | | | |

## Legend:

| | |
|---|---|
| No ES Req. | Tasks can be trained with operational vehicle and no embedded simulation. |
| Unable to Train | Task requires simulation beyond stimulation of sensors and monitoring of controls. |
| En/Neut. Vehs | Requires simulation of intelligent enemy and neutral vehicles. |
| Friendly Vehs | Requires simulation of intelligent friendly vehicles. |
| Enemy Dismtd. | Requires simulation of intelligent enemy dismounted infantry. |
| Friendly Dismtd. | Requires simulation of intelligent friendly dismounted infantry. |
| Tr. Real Veh. | Requires transmission of real vehicle position and state to other vehicles. |
| Trans. Interact. | Requires transmission of interactions (e.g. fire) to other vehicles. |
| Combat Support | Requires simulation of combat support (e.g. artillery). |
| Enemy Indirect | Requires simulation of enemy indirect fire. |
| Mines/Obstacles | Requires simulation of mines and obstacles placed in environment before scenario start. |
| Stealth Display | Requires stealth display for planning. |
| COAA | Course of Action Analysis |
| NBC | Nuclear, Biological and Chemical |
| IVIS | The Intra/inter-vehicular Information Sharing System |

Enemy and neutral vehicles must be simulated and the enemy vehicles must be intelligent enough to tax the capabilities of experienced crews. These capabilities exist now and computers powerful enough to support their computation requirements and small enough to fit into the M1A2 card racks will be available in the mid term time frame. The location and state of friendly vehicles operated by other members of the platoon must be depicted in the ET system. Enemy dismounted infantry must be depicted in a realistic manner because anti-tank units are a major threat. Friendly dismounted infantry must be depicted to train tank operators to respond to signals from dismounted guides. Since the position and state of friendly vehicles (as well as interactions such as firing weapons) must be depicted accurately, the location, state and interactions of vehicles operated by other members of the platoon must be transmitted between vehicles. This communications load is beyond the capabilities of current tactical communications and future advances are required to support ET. These advances are anticipated in the long term future and INVEST is working on less bandwidth intensive means of conducting this communication. INVEST ET must support simulation of combat support, enemy indirect fire and mines and obstacles in order meet the training needs of the ARTEP. Combat support, enemy indirect fire and mines and obstacles are simulated in fixed simulators now and the only technology required for ET is the continued miniaturization of computers. The need for a stealth display is addressed in the next section.

### *3. ES to Support EO*

The same ES that supports ET can be used during combat to support embedded operations (EO). Since EO has a more direct impact on M1A2 SEP operational effectiveness, considerable resources on the INVEST program will be devoted to EO. Table 2 contains an initial list of embedded operations capabilities for inclusion in the M1A2 SEP tank using the INVEST technology. Each of these capabilities is discussed separately below.

Table 2
Potential Embedded Operations For M1A2 SEP

| Embedded Operations | Embedded Simulation Requirements |
|---|---|
| Mission Planning Using Terrain Data Base and Stealth | High resolution terrain data base of operations area<br>Display and user controls in Platoon Leader tank |
| Mission Briefing Using Terrain Data Base and Stealth | Same<br>Larger display usable outside of tank |
| Mission Rehearsal | High resolution terrain data base of operations area<br>ES with access to control actuations and display stimulation |
| Display of Threat/Friendly Locations | Threat/friendly locations from IVIS<br>High resolution terrain data base<br>Tank/turret position/orientation |
| Overlay Map Symbols on Real Terrain | Map symbol locations from IVIS<br>High resolution terrain data base<br>Tank/turret position/orientation |

## 2.1 Mission Planning

Once the proposed EO capabilities of INVEST are implemented, the platoon commander will be able to use the stealth and detailed terrain data base of the operations area for mission planning. This three-dimensional data base will allow the platoon leader to better locate routes with cover and concealment from the threat as well as identifying likely ambush sites. As indicated above, the Topographic Engineering Center is developing high resolution data bases that could be used by INVEST. While ET capabilities can be exercised by using the normal tank controls and

displays, Mission Planning will require the addition of controls for controlling the stealth eye point during movement through the terrain data base.

## 2.2 Mission Briefing Using Terrain Data Base

Mission briefing is currently done using maps and objects placed on the ground. With the stealth and three-dimensional data base, platoon leaders can give a more understandable briefing. This capability will require the same ES capabilities as above plus a large display that is usable outside the tank. This tool may be a separate notebook computer or a large display on an umbilical from the tank. This display would also be used for after action reviews during training.

## 2.3 Mission Rehearsal

Mission Rehearsal in the M1A2 SEP tank using the INVEST technology will require the same technology as required for ET. A detailed analysis of what operator tasks must be sensed by EO and what imagery must be injected into the operator view ports is currently underway.

## 2.4 Display of Threat/Friendly Locations

In order to display threats and friendlies in the operator display, the ES must know threat and friendly locations. The Intra/inter-vehicular Information Sharing System (IVIS) has the capability to receive the location of threats and friendlies and display their locations on the IVIS display. Once the EO system receives these coordinates, the system can compare the location to the high resolution data base and determine threat and friendly locations in three dimensions using standard simulation algorithms and terrain clamping. Then as the field of view of each operator viewport looks in the direction of the target/friendly, the ES will inject a model of the vehicle in the appropriate location. If the vehicle is occluded by terrain, the vehicle can be displayed as a dashed outline to warn the crewmen as to the location of the threat. This increased situational awareness will lead to a tremendous tactical advantage.

## 2.5 Overlay Map Symbols on Real Terrain

The EO system will not be limited to displaying threats and friendlies. Since IVIS can also transmit and receive map symbols, the coordinates of these symbols will be available to the EO system. Map symbols useful to EO would be:

- Terrain Reference Points
- Dead Spaces
- Phase Lines
- Trigger Lines
- Battle Positions
- Check Points

FKSM 17-15-1 [4] indicates that even with IVIS, the "Tank commanders must still use a map with overlay to identify major terrain features, contour changes, etc." The manual also repeatedly states "Do not get glued to the IVIS screen." This warning is because the tank commander will lose situational awareness in a head-down state.

By using the EO system to overlay IVIS map symbols on the terrain, EO will give the tank crew the same improved situational awareness currently enjoyed by pilots using head-up-displays. Instead of having to look at the IVIS display and use a map to relate it to a terrain reference point on the paper map, the tank commander will be able to see the terrain reference point symbol overlayed on the real terrain. This EO capability should encourage the tank commander to maintain a heads up state leading to greatly improved situational awareness and increased tactical proficiency.

## *4. Conclusions*

The analysis described in this paper indicates that the ES capabilities being developed in the INVEST program will be able to meet almost all training requirements for tank platoons in the mid term future. Many of the training requirements can be met in the short term with very little technology development. The ES being developed for INVEST will support operations by providing the crew with greatly increased situational awareness along with the ability to operate in a head-up fashion similar to aircraft pilots. ES will provide the tank commander with a stealth display for mission planning, crew briefing and after-action review.

## References


[1] McDonald, L. B. and Bahr, H. A., "Research on the Cost Effectiveness of Embedded Simulation and Embedded Training", Proceedings of the Spring 1998 Simulation Interoperability Workshop, Orlando, Florida, March 1998.

[2] FM 17-12-1. Tank Gunnery (Abrams), Headquarters, Department of the Army, Washington, D.C., 1992.

[3] ARTEP 17-237-10-MTP Mission Training Plan for the Tank Platoon, Headquarters, Department of the Army. Washington, D.C. 1996.

[4] FKSM 17-15-1(Draft) Tactics, Techniques and Procedures for the M1A2 Tank Platoon, U.S. Army Armor School, Fort Knox, Kentucky, 1992.


## Author Biographies

**BRUCE MCDONALD** has been working in the area of Embedded Training since 1988 and has over 25 years of experience in modeling, simulation and training systems. He received his Ph.D. in Industrial Engineering from Texas A&M University in 1973. He has been active in the SIW since its beginning and served as the chair of the DIS Steering Committee. He is the former chair of the SIW Special task group on High Level Architecture. He is currently the secretary of the LIVE Forum.

**HUBERT BAHR** is a Decorated Vietnam Veteran with 28 years of Federal Service. He received his BS degree in engineering from the University of Oklahoma in 1972 and his Masters Degree in computer engineering from the University of Central Florida in 1994. For the past 18 years he has been involved with instrumented Force on Force Ranges. He is currently the lead engineer for the INVEST STO in the Research and Engineering Directorate of STRICOM. His research interests are in the areas of parallel processing, artificial intelligence, and computer architecture. He is also pursuing his Ph.D. at the University of Central Florida.