

## Lessons learned on Embedded Training Technology Program for Soldier and Platform Centric Training

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### ABSTRACT

The Simulation and Training Technology Center (STTC) Human Dimension, Simulation and Training Directorate, Army Research Laboratory (ARL) completed a three year, Army Technology Objective Development program titled “Scalable Embedded Training and Mission Rehearsal (SET MR ATO)” which focused on embedded training (ET) for the current force, mounted and dismounted. The goal was to develop an advanced technology demonstration that would mature technology to train Soldiers using operational equipment. This would provide accessible and deployable training for the Army. Elements of Live, Virtual and Constructive were used to provide a training common component approach that could be applied to the Abrams, Bradley and Stryker vehicles and dismounted Soldiers. The key finding can be described as a soldier and platform-centric approach to training. In order to fully implement embedded training on operational equipment an understanding of what needs to be trained and where within the training spectrum (Individual, Crew/Team, Functional and Combined Arms and Battle Staff) needs to be conducted before implementation. Technology is no longer an obstacle or barrier to fully embed training into mounted vehicles. Challenges remain for Embedded Training in dismounted which focus on size, power and weight constraints. This paper will identify key technologies developed and lessons learned that can be applied to future embedded training procurements (i.e. Ground Combat Vehicle) and future technology development.

### ABOUT THE AUTHORS

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### INTRODUCTION

In 1987 the Army National Guard came out with the first Training Device Requirement (TDR) for Army embedded training (ET) called the Guard Unit Armory Device Full-Crew Interactive Simulation Trainer (GUARD FIST) for the M60A3 and M1 Tanks. The TDR stated

“An immediate need exists within Reserve Component (RC) units to capitalize on training opportunities at local armories during drills so that M60A3 and M1 Armored Crewmen (19E's 10 thru 30) can acquire and sustain tank skills proficiency. In the RC, tank crew job performance is not up to mission requirements, primarily as a result of insufficient time, facilities and training devices. Training must present a realistic, stress filled series of battlefield scenarios with full crew interaction.” (Army National Guard, 1987).

Even back then, the Army started to recognize the value and importance of ET. Thus began the Army's long history in research and acquisition in ET in order to achieve the ultimate goal of 'training as you fight' by using the operational equipment in order to maximize training proficiency and achieve cost savings.

On the acquisition side of ET, development of the GUARD FIST program evolved into the A-FIST XXI program in 1999 which upgraded the original Army-Full Interactive Simulation Trainer (Army-FIST) trainers to improve their performance and added PC based visual components (Riley, 2000). The A-FIST XXI program used an appended training device approach to achieve ET. The active Army has fielded and developed embedded training for the Stryker family of vehicles providing virtual gunnery simulation for the Stryker Remote Weapon System (Mosely, J., 2009) and for Abrams, Bradley Gunnery Training, the Common Embedded Training Systems (Biolchini, G., Crawley K., Kinney, K., 2010). Unfortunately, these current approaches do not fully achieve the Army's full vision and goal for ET. The Army's vision of

implementing ET was embodied under the Future Combat System (FCS) acquisition program and documented in the Army Training Doctrine Command's (TRADOC), Pamphlet 350-37 which lays out the operational requirements for embedded training for the Objective Force (Department of the Army TRADOC Pam 350-37, 2003). For the first time, under the FCS program, the Army identified ET as a key performance parameter, meaning it had to have that capability as a threshold requirement. The FCS program goal was to use a fully embedded approach for ET supporting Live, Virtual and Constructive (LVC) Net-Ready 24/7 capability and utilize the same vehicle software for the Training Aid Device Simulation System which synchronized operational and training platform concurrency. Even though DOD cancelled the FCS's Manned Ground Vehicle portion and has restructured under the Brigade Combat Team Modernization (BCTM) program, the Army's goal for ET still stands as documented and ET is being implemented on the remaining unmanned vehicles and controlling platforms.

Around the same time that the AFIST XXI program started development, the Army began a series of science and technology programs spanning over 12 years in an attempt to mature technologies to achieve the Army goal and vision for ET. From 1998 to 2001, The Inter-Vehicle Embedded Simulation Technology Science and Technology Objective (INVEST STO) was conducted with the goal to “demonstrate the technology that will lay the foundation for incorporating ET into future as well as legacy vehicles” (Bahr, A., H., Abate, W., C., 1998). The Embedded Training for Dismounted Soldier and Mission Rehearsal Army Technology Objective (ECATT MR ATO) program ran from 2002 to the end of 2004 with the focus on ET for dismounted infantry. The Embedded Combined Arms Team Training and Mission Rehearsal ATO program, which ran from 2003 to the end of 2006, brought together technology for mounted and dismounted ET for Combine Arms Training. Finally, the Scalable Embedded Training and Mission Rehearsal (SET MR) ATO advance

technology demonstration effort, which ran from 2007 to the end of 2009, was the final Army ATO to focus technologies to bring the Army ET vision closer to reality. Surprisingly, many of the technologies that started back under the INVEST STO have come to fruition on the SET MR ATO program.

**Goal of the SET MR ATO program**

The SET MR ATO program had three major goals: 1) Research supporting technologies for Embedded Mission Rehearsal and Collective Training on Current Force Vehicles for combined arms mission rehearsal for small dismounted units and full vehicle crews. This included an approach analogous to the FCS/BCMT training common component (TCC) approach to provide own ship, Instructor/Operator Station, After Action Review and other common components to be implemented across current combat vehicles and dismount platforms. It concurrently developed conceptual hardware solutions for analog systems/crew stations that are difficult to simulate (i.e. driver station, steering systems and periscopes) 2) Embedded Dismounted Soldier ET - adding LVC capability for mission rehearsal on the next generation dismounted soldier platform 3) Live Embedded Training for Tactical Engagement Simulation Systems (TESS) which has the potential to replace or at least supplement the Multiple Integrated Laser Engagement System (MILES) capability by developing a small, low cost, accurate position sensor to realize geo-pairing technology to enable simulating a electronic bullet fly-out. The intent of the ATO is that it would provide lessons learned to PM Future Force office at the Program Executive Office for Simulation Training and Instrumentation (PEO STRI) which is working on implementing ET on the BCTM program.

**Stryker Experiment**

During the first year of the SET MR ATO program, we participated in an experiment sponsored by PM Stryker using mounted and dismounted elements in order to help understand the mission requirements for ET.

“The experiment used four actual Stryker vehicles with their embedded training modules linked via Ethernet to each other and to other appended computers (i.e. driver and dismounted Soldier interactions) to simulate a mission rehearsal and collective training exercise on a McKenna database. The database provided a common operating picture for all participants during the experiment. Each vehicle was connected to the network architecture for the experiment via Ethernet supporting HLA communication. Each vehicle had a live commander, gunner, and driver. There were two simulated nine

(9) man squads, each with a human Squad leader in-the-loop. FBCB2 (Force XXI Battle Command Brigade and Below) communications were stimulated via separate intra-net between the vehicles and squad leaders. User Subject Matter Experts from Ft. Benning and Ft. Knox participated as vehicle commanders and gunners.” (Mosely, J., 2009)

After the completion and analysis of the Stryker experiment, it became apparent that ET needed to better understand the training spectrum that the Soldier would require for his mission before tailoring the technologies. The current state of the art for fielded ET systems focuses only on Gunnery Training exercises and does not deal with the full spectrum of ground warfare that is being experienced in IRAQ and Afghanistan.

**Training Levels and Operational Environment**

As in other areas of training, ET relies on the Combined Arms Training Strategy (CATS). CATS is the Army’s over-arching strategy for current and future training of the force (Department of Army FM-7, 2008). Training begins by preparing the individual Soldier to practice military skills, then progresses through increasingly complex unit and collective training that prepares several echelons to perform major military operations. CATS defines four training levels, Categories A through D, as shown in Table 1. Each category builds upon the foundation provided by the previous categories The ET approach mirrors this continuous process.

<b>Category A</b>	Individual & Operator	Train and sustain individual operator and maintenance task skills.
<b>Category B</b>	Crew & Team	Train and sustain combat ready crew.
<b>Category C</b>	Functional	Train and Sustain commanders, staff, and crews/teams within each functional area to be utilized within their operational role.
<b>Category D</b>	Force Level & CATS	Train and sustain combat ready commanders and battle staffs utilizing the operational system in its operational role.

Table 1 - Combined Arms Training Strategy Categories

CATS is critical because the operational environment has changed and the focus of ET can no longer be just on Gunnery Tables and proficiency. As stated in FM-7.

“Operational environments will remain extremely fluid. Coalitions, alliances, partnerships, and actors will change continually. Interagency and joint operations will be required to deal with this wide and intricate range of players. International news organizations, using new information and communications technologies, will no longer depend on states to gain access to the area of operations. These organizations will greatly influence how operations are viewed. They will have satellites or their own unmanned aerial reconnaissance platforms from which to monitor the scene. Secrecy will be difficult to maintain, making operations security more vital than ever. Finally, complex cultural, demographic, and physical factors will be present, adding to the fog of war. Such factors include humanitarian crises and ethnic and religious differences. In addition, complex and urban terrain will often become major centers of gravity and havens for potential threats. Tomorrow’s operational environments will be interconnected, dynamic, and extremely volatile.” (Dept of Army FM-7, 2008)

### **Understanding and Defining ET**

The US Army defines ET as:

“A function hosted in hardware and/or software, integrated into the overall equipment configuration. Embedded training supports training, assessment, and control of exercises on the operational equipment, with auxiliary equipment and data sources, as necessary. Embedded training, when activated, starts a training session, or overlays the system's normal operational mode, to enter a training and assessment mode” (Dept of Army TRADOC Pam 350-37, 2003).

In early January 2009 a meeting was held with the TRADOC Capability Managers (TCM) for the Infantry Brigade Combat Team (BCT), Heavy BCT and Stryker BCT at the Maneuver Center of Excellence in Fort Benning. It became apparent that each proponent had a different understanding of ET. Follow-on meetings with PM Stryker and PM Heavy Brigade Combat Team also demonstrated the same variance in understanding. It was discovered when Combat Developers, such as TCMs, think of ET, they think built into, strapped onto, or plugged into. When Material Developers, like PMs, hear ET they think mission critical hardware and software built in, implying a material solution. TRADOC Pam 350-37 captured the challenge of ET within the Army. “Despite the best intentions on the

part of materiel, combat, and training developers, punctuated by a few remarkable successes, ET is a widely misunderstood concept that is not yet ubiquitous. At the core of the problem are requirements for ET applications that have been poorly defined, both by the Government, which contracts for it, and by industry as a whole, which developed them. Whether ET actually produces the desired training outcomes is also suspect, because many “successes” cannot be satisfactorily tested or shown to produce a training benefit. Part of the problem is that, to date, ET has been approached in a manner that emphasizes the administrative process, and disregards disciplined technical processes—an all-too-common practice that results in a high-risk manner of operation. In the majority of cases, upfront requirements identified in operational requirements documents (ORDs) merely state that ET will be provided, or words to that effect. ... Materiel developers are responsible for NET (new equipment training). But, NET is entry-level training on “knob-ology,” the type of skills traditionally documented in user manuals, not “battle-focused” training that achieves and sustains proficiency on all possible soldier, leader, and collective tasks” (Dept of the Army TRADOC Pam 350-37, 2003).

### **Platform Centric Training**

Another goal of the SET MR ATO program is to educate both the Combat Developer and the Material Developer on ET and work with TRADOC Headquarters and PEO STRI to develop a uniform understanding of ET. The SET MR ATO developed a working understanding of ET to bridge this misunderstanding. This is called Platform Centric Training.

Platform Centric Training (PCT) enables soldiers to augment their training on or with their operational systems. In implementation, PCT:

- a. Switches from an operational mode to a training mode. Ideally training would use the system’s normal controls and displays to practice using the system within a simulated operational context
- b. Support training assessment, and control of exercise on the operational equipment with auxiliary equipment and data sources as necessary
- c. Can range from computerized manual review to full mission rehearsal
- d. Reach back is a key enabler-enhances content updates, concurrency of Training Task Packages (TTPs) etc. (Note: This is an operational network issue not an ET issues)
- e. Must be integrated in a holistic training strategy that includes Institutional, Home Station and Deployed Training.

- f. Augments/Supplements existing TADSS - not replace them.

Historically, there are three levels of ET integration:

- Fully Embedded ET, under PCT, means integral platform hardware and software to provide the needed training capability (mission critical tasks). The hardware is organic and uses the operational equipment controls, computer processing, network and displays. This has the greatest platform impact and the Materiel Developer needs to define the boundaries. The Stryker Remote Weapon Systems is a good example of this type of ET.
- Appended ET, under PCT, means permanently designed-in components (i.e. sensors) which interface with the platform architecture and removable training hardware (non-mission critical hardware). This has less impact on the mission critical hardware but impacts in the logistics area. The CETS system which uses a replaceable Line Replaceable Unit (LRU) approach is a good example.
- Umbilical, under PCT, means temporary affixed hardware that interfaces with platform architecture via permanent connections. This has minimal platform impact but has the greatest impact on logistics. A good example of this is maintenance trainers.

ET offers the choice of Fully Embedded, Appended and Umbilical implementations to incorporate the material developer and combat developer's requirements. These definitions must work within the CATS Army strategy that begins with individual soldier training progressing up to complex unit and collective training that prepares several echelons to perform major military operations (Table 2).

Practice	Sustainment	Mission Prep	Mission Rehearsal
Individual, Knobology, Individual Safety	Gunnery (AGTS*) Onboard instruction, Computer Based, Interactive Multimedia.	Practice critical skills for mission Rock drill. Geo typical terrain	Onboard CCTT* Geospecific terrain. Vehicle networked together. Scenario development

Table 2 – Levels of Embedded Training

AGTS - Army Gunnery Training System  
CCTT – Close Combat Tactical Trainer

As ET progresses from Practice to Mission Rehearsal, the hardware and software complexity increases. A final experiment conducted for the SET MR ATO program, was performed at the Tank and Automotive Command (TACOM) in Warren Michigan, working with Subject Matter Experts (SMEs) from the Armor School.

An M1A2 SEP V1 was outfitted with appended display, computational, and sensor devices (indicated in yellow in Figure 1 below) to enable the full crew (less loader) to participate in a platoon size mission rehearsal type exercise. While a single vehicle was outfitted with ET equipment, the squad was filled out with OneSAF controlled entities. Modified Advanced Gunnery Training System (AGTS) software provided the vehicle simulation and ET interface.

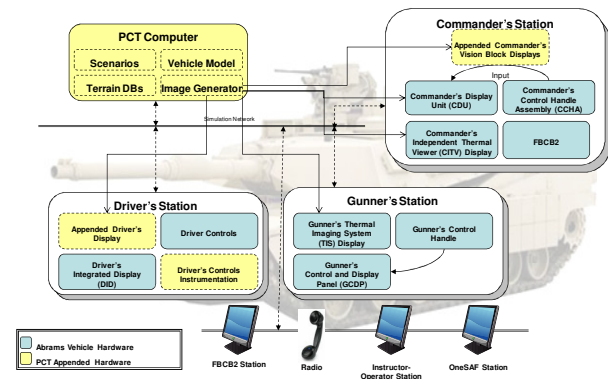


Figure 1 – ET Demonstrator Configuration

The feedback from the SMEs showed that as ET was increased from Practice to Mission Rehearsal, the complexity of the training exercise, involving mission planning, exercise execution and after action review increased the crew work load and time substantially. Given the short time that Soldiers have during deployment, the type of training and the complexity of the hardware and software will impact both combat developers and material developers plan for ET. This needs to be factored in the equation.

### Soldier Centric Training

Secretary of the Army John McHugh spoke June 11, 2010 at the Association of the United States Army Institute of Land Warfare and stated "that it is well trained Soldiers who win America's battles, more so than the equipment Soldiers use, One of the reasons this Army has been so successful is because ... we always will do everything we can ... make every investment that's required to field the best equipment, the best weapons, the best platforms for our men and women in uniform," McHugh said. "But ... Army's

success on any future battlefield will be answered at least as much, if not more, by the creativity, the agility, the level of intelligence of our future leaders, as it will (be by) whatever that new weapons system may look like.” Lopez, C.T (2010). The Secretary of the Army recently signed an order shifting the emphases from equipping the soldier to ‘generating’ the Soldier. Generating the Soldier means producing the type of Soldier that the Army needs for current and future operations. Training plays a big role in this process.

One of the conclusions drawn from the SET MR ATO is that ET must focus on the range of Dismounted and Mounted CATS and not just focus on the equipment knob-logy and Gunnery training. It must provide training consistent with the current operating environment which includes coalition, humanitarian operations under complex, cultural demographic and physical factors. The training focus may require training in non combat decision making, cultural language and negotiation and medical skills. STTC has already begun to develop game based training involving bi-lateral negotiations, decision making in non combat skills to deal with insurgency (Urban Sim game) and medical skills (TC3 game).

STTC has a Technology Transition Agreement (TTA) with Natick Soldier Research Development Engineering Center (NSRDEC) to partner and develop dismounted ET on the next generation dismounted equipment (Ground Soldier System) to PM Soldier Warrior (PM SWA) to investigate and include the full spectrum of training. STTC is part of the RDECOM team which is part of the Soldier Planning Integration Network (SPINE) ATO that is delivering technologies to PM SWA for the Ground Soldier System Increment 2 advance technology demonstrator. STTC also has a TTA with PM Stryker to develop ET for the next modernization phase of the family of Stryker Vehicles which must include the dismounted soldier. STTC is working with TRADOC and G6 for ET training on low cost mobile hardware (iPhone, iPad, Android based) platforms to support the dismounted soldier.

### Technology Accomplishments

The SET MR ATO program made major technology accomplishment in ET in several areas. Three technologies will be highlighted: one involves embedding display capabilities into combat vehicle periscopes, the second is the development of advanced orientation tracking sensors to enable electronic bullet fly-out simulation for live training, and finally the implementations of compact 3D terrain representations that fit in current and future vehicle and dismount soldier equipment e.g. command and control systems.

The Enhanced Vision Block (EVB) is a ground combat vehicle periscope with integrated collimated display capabilities. The EVB provides a visual imaging solution for low cost, virtual, fully embedded vehicle driver training with night vision display capability. As shown in Figure 2 below, the device has multiple operating modes.

The EVB prototype is modeled after the Stryker M17 periscope. It preserves the optical performance of the basic periscope. It includes a collimated display with a minimum number of optical elements; static electro-optical view-mode switching that provides parallax-free performance for all modes; and relief from eye fatigue during prolonged periods of embedded training. The prototype uses a unique diffractive combiner for optimum reflectivity of display source, maximum outside-world transmission and reduced weight/size of optical train.

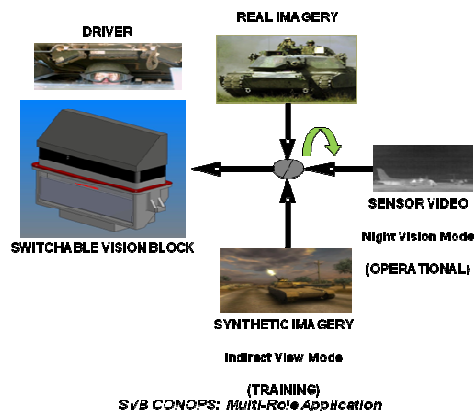


Figure 2 - Enhanced Vision Block Operating Modes

A prototype of the vision block containing two electronically switchable mirrors with both reflective and transparent capabilities enabling multiple view modes exists in both collimated and un-collimated variants. As shown in Figure 3, this device offers three operating modes: 1) the normal optical view of the battlefields 2) a combined view similar to an aircraft Head-Up Display (HUD) and 3) a synthetic image displaying sensor imagery or a simulated battlefield view.



Figure 3 – Prototype Enhanced Vision Block

The SET MR ATO is supporting PM TRADE's next generation tactical engagement simulation system to develop next generation live training technology. This research is developing Tactical Engagement Simulation (TES) sensors that will provide an embedded live training capability for mounted and dismounted Soldier equipment. This technology is intended to augment and/or eventually replace the current live training shooter-target pairing systems that are laser based and require line of sight for operations (MILES).

Accurately tracking individual weapon location and orientation is the most technically challenging problem facing the next TES. In coordination with PM TRADE the ATO is attempting to mitigate risk by developing two sets of sensors that satisfy the size, power and accuracy requirement and are suitable for embedding on Soldier and weapon systems.

The Weapon Orientation Measurement (WOM) sensor system measures linear and angular motion associated with weapon attitude (bearing and azimuth) with accuracy sufficient for geometric pairing engagements. It will be small enough to mount on the underside of an M4 rifle butt stock and have power consumption low enough to conduct 72-96 hour training exercises without replacing batteries. When paired with the WOM, the Position/Navigation (Pos/Nav) sensor system measures position of both shooter and target with sufficient accuracy to pair shooters with targets and adjudicate hits and misses. The sensor systems will be capable of operating in urban training environments including building interiors and other environments where GPS satellite signals are degraded.

Prototypes of both sensors have been developed and delivered to PM TRADE for field evaluation. The Figure 4 below shows the WOM mounted on a 60mm mortar and a mechanical graphics drawing of the sensor.



Figure 4 – Prototype WOM Sensor

The High Fidelity Runtime Database Engine (HFRDE) is an STTC research effort that is developing a terrain database format and terrain services that support extremely high resolution natural environments with a minimal processor and memory footprint. This Terrain format is being incorporated with the dismounted

research effort on the SPINE ATO in support of the GSS increment 2 prototypes with NSRDEC and PM SWA. This also supports research with PM TRADE involving next generation TESS.

Training applications must often correlate with the real world, requiring terrain skin and feature detail far beyond the capabilities of current Synthetic Natural Environment (SNE) representations for Virtual and Constructive domains. In addition, live and embedded applications often have limited processor and memory resources, whereas most modern SNE implementations requirement high-end desktop machines to process. HFRDE has address this gap by developing prototypes for next generation terrain formats (Layered Terrain Format - LTF) and services that will correlate with the real world with excellent performance on less capable processors. HFRDE terrain research addresses several key technical issues:

- **High Resolution:** Support sub-one meter 3D terrain (e.g. for geo-pairing) and arbitrarily complex feature data that can scale efficiently. This allows extreme detail where needed, e.g. modeling of speed bumps on roads or branches of trees.
- **Lightweight:** compact; services will run on hand-held devices.
- **Adaptable:** allow each application to store & use only what is needed, e.g. an LOS engine should not have to store route data.
- **Easily modified:** support rapid run-time updates from raw data. For example, this would support requirements to respond to environment changes on the fly.
- **Just-In-Time Availability:** Dynamic data integrated incrementally as CPU cycles permit
- **Efficient:** fast service responses on low-end processors.

The following Figure 5 is the HRRDE's LTF embedded in GSS prototype and on an Apple iPhone/iTouch device.



Figure 5 – LTF iPhone App

## LESSONS LEARNED FROM SET-MR ATO

During the three year SET-MR ATO effort, much has been learned through discussions with others involved in the ET community, and through research conducted on supporting technologies and during the M1A2 ET exercise. Some of these lessons learned include:

- The ET community needs common definitions for ET. The ATO has attempted to provide a framework through the platform-centric training concept.
- While researching requirements for mission rehearsal, we found a variety of definitions for this concept as well. Again, a common definition is needed.
- The skills/tasks that ET should target need to be defined – this will aid in defining the requirements for ET.
- As a follow-on to the above, ET should be considered scalable (e.g., see CATS) – many consider ET to be “all or nothing” – full mission collective versus individual or crew. This could allow levels of ET integration in a crawl-walk-run approach, or to the level supported by platform architecture and technology.
- To the latter point above, ET integration into the current force is limited by system architectures and hardware.
- Many of the software components envisioned for ‘true’ embedded implementations are too computationally expensive for onboard hosting.
- From the M1A2 ET exercise:
  - Coordinating SAF with manned simulators for a cooperative exercise remains problematic – specifically filling out the M1A2 platoon with SAF entities.
  - Inability to use vision blocks was a limitation for formation-keeping and target acquisition
  - Sound cues were very important to the crew and were lacking in the implementation
  - A less expensive solution to integrating dismounts into the visual scene is needed (versus purchasing commercial application)
  - Despite limitations of the specific implementation the Soldiers involved could see the potential benefits a true ET solution could provide.

## CONCLUSION

When the INVEST ATO was performing its research, one of the key capabilities mentioned was Live vehicle firing rounds vs. virtual target on virtual terrain capabilities (Bahr, A., H., Abate, W., C., 1998). The INVEST ATO published a cost effective analysis for ET on Army Ground Vehicles, assuming this capability was fully matured. It stated that the operating cost of

and M1A2 was \$432 per mile versus a Virtual ET exercise which would cost \$129 mile. (McDonald, L., B., A., H., Abate, W., C., 2000). A savings calculated of almost two thirds the operating cost. Back then, the Army knew that if the full vision of ET was realized, it could reduce Live Training cost down to almost one third of the amount. The technology developed under the SET MR ATO brings closer the capability to realizing those cost savings.

Most of the technology challenges for ET no longer require ground breaking technology and research. There still remain challenges in incorporating mount and dismount ET and continuing to reduce size, weight, cost and increased computational processing under a limited footprint. But by and large ET for sustainment training is very doable using today’s technology. As future mounted and dismounted systems are procured, fully embedded mission rehearsal capability that provides soldier centric training is very achievable given the technology advances on the SET MR ATO. STTC will continue to work with PM Stryker and NSRDEC on the SPINE ATO to achieve that level of ET training.

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