Embedded Simulation: INVEST-STO and Beyond

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ABSTRACT

The army has placed a renewed emphasis on an embedded training capability as a result of lessons learned from the Advanced Warfighting Experiment (AWE) 97-06 on the potentials of digitization. Through the Inter-Vehicle Embedded Simulation Technology (INVEST) Science and Technology Objective (STO), the Simulation Training and Instrumentation Command (STRICOM) developed the technology that has layed the foundation for incorporating embedded simulation into future and legacy combat vehicles. In October 1997, STRICOM started the INVEST – STO. This was a 5 year project that looked at the technologies required to integrate Simulation into combat vehicles, first to enable Embedded Training but with the eye to enhance situational awareness. This paper introduces the concepts of INVEST, describes the results and identifies work that still needs to be accomplished.

Introduction

Apart from the myriad of philosophical arguments, to fight and win on the modern battlefield two measurable components can provide a distinct advantage; weapons systems that out perform the opponents weapon system, and crews that are better trained to use the weapon system effectively. A cost effective means of improving weapon system performance is Embedded Simulation (ES), which includes Embedded Training (ET) or the capability to train and maintain crew proficiency on the same equipment they will go to war on, and the Embedded Operations (EO) functions of situational awareness (SA), mission rehearsal (MR), command coordination (CC), critical decision making (CDM) and course of action analysis (COAA).

It could easily be argued that in many cases the two aspects of weapon systems advances and better training are likely to be in direct competition with each other. The classic example is the advance in the rocket powered aircraft by the Germans at toward the end World War II. While the new rocket powered aircraft could clearly outperform the propeller driven aircraft of the time, adequately training pilots on the more complex system came at a cost of time which could not be afforded. To date, the most common training system are large stand alone trainers have been employed at the school house and in the units. The power projection army of the future will have to spend more time maintaining task proficiency while stand-alone trainers cannot meet the deploying force requirements and are too costly to operate and maintain. One option that will overcome this deficiency is a training system that is integrated into the vehicle. However, any sub-system that is integrated into the vehicle becomes a luxury unless it provides improved combat effectiveness. For this reason, the proposed approach of embedded simulation (ES) technology addresses a system that provides both training support and go-to-war capabilities. An expanded discussion of ES training uses can be found in reference 1.

In this paper we are going to walk through the various levels of training applications (gunnery) from a single vehicle to multiple vehicles to multiple vehicles participating in live fire and force-on-force exercise similar to training conducted at the Combat Training Centers (CTCs) and finally go-to-war examples.

Background

While stand alone trainers such as COFT/AGTS, SIMNET/CCTT and M-1 Driver Trainers have served the Army of Excellence well, technological advances and miniaturization now provide a foreseeable ability and affordability for embedding crew and collective training systems into the vehicle. We will refer to these ground combat systems with an embedded training capability as autonomous trainers.

The goal of the Inter-Vehicle Embedded Simulation Technology- Science and Technology Objective (INVEST-STO) program was to develop and demonstrate the technology that will lay the foundation for incorporating ES and ET into future as well as legacy vehicles.

The enabling technologies and components used to run an Embedded Simulation System (ESS) are basically the same for the standalone trainer with the exception that they must be smaller, faster, more powerful and less expensive. Common components include image generators, simulation computer, Semi-automated Forces (SAF), data logger, terrain database, communications and instructor operator. Stand alone image generators of today are located in large racks and wired to monitors located at the various crew stations. In the future they will be no larger than a card and the images projected directly into vehicle sights or sensors. The large rack mounted computers will be replaced by a very small and powerful lap top size computer that is accessible to the crew and loaded with software (SW) containing reconfigurable SAFs and terrain database models for the area of interest. An application hardware (HW) data logger will be linked into the simulation computer to record crew actions and support AARs. The only common component that is non-applicable to an ESS is a dedicated instructor operator because that task belongs to the vehicle commander or senior cadre personnel.

When units deploy to a combat zone in response to a rapid deployment mission in the next century, the benefits of autonomous trainers become readily apparent. In addition, the dual-use design of the ESS can be used to enhance operational effectiveness.

ESS Training Applications

Let us assume that in any future combat system the crew will have to be trained to maneuver and engage targets using a highly sophisticated suite of fire control sensors and devices. The design of the ESS will be such that the crew can hone its maneuver and gunnery skills by projecting selected training exercises into vehicle optics or sensor systems. Due to advances in technology and miniaturization, the graphics card and open scene visual processing will be capable of displaying a terrain database (world models support SW), and the SAF (CGF support SW) will display the target array on the database. These SAF entities will be fully functional (move, shoot and maneuver) and replicate enemy capabilities. The on-board data logger will record all engagements for follow-on After Action Review (AAR) by the unit cadre or vehicle commander. This training can be conducted in the motor pool, assembly area or enroute to a combat theater. Training can be tailored to meet individual or crew (collective training) needs in terms of tactical conditions (offense/defense), force ratios, degree of difficulty in terms of probably of hit & kill, and environmental, terrain and light conditions. This provides a virtual 360-degree battlefield with ground and air targets.

Training Example

Training will follow the normal crawl, walk, run strategy starting with a stationary single crew exercise and progress to multiple moving vehicles in a combined arms live fire exercises. However, autonomous trainers require a further segregation of exercises in terms of simulation mode, i.e. (1) live vehicles firing virtual rounds vs. virtual target on virtual terrain; (2) live vehicle firing virtual rounds vs. virtual target on live terrain and (3) live vehicle firing live rounds vs. virtual target on live terrain. The technology / engineering challenges associated with each mode are listed below.

1. Live vehicle firing virtual rounds vs. virtual target on virtual terrain requires:

a. Geometric pairing vice laser pairing: Geometric pairing will be required because a laser pairing system will not work between live and virtual targets (no vehicle present to provide a laser return). In virtual on virtual simulation shooter target pairing is practically inherent because the locations and orientations of the vehicles and weapons are known almost perfectly in the simulation world. Engagements are simulated by computing the ballistic flyout of simulated rounds and determining where they impact on target or the terrain. The geometric pairing solution takes place at the time of ranging to the target (in the shooter s sight picture). The on board simulation computer calculates the distance to target and stimulates the vehicle to enter the appropriate range return in the gunners sight.

b. Aim point determination: Aim point determination will be calculated by capturing, at the instant of firing, the crosshair location with respect to the target. In a virtual on virtual engagement, the locations and orientations of vehicle are known essentially perfectly (they are synthesized by the simulation) and their orientation relative to each other are easily derived from their world coordinates. The simulation computer knows the relative position of crosshair to the target and stimulates the appropriate burst on target effect. Location of impact is also needed to determine target and casualty effects.

c. Realistic fire on target effects: Realistic fire on target effects models are stored as part of the terrain database and will be generated by the IG at the time of round impact on the target. Obscuration, gun recoil and visual tracers will also be stimulated in the sights of the firing vehicle at the time of firing

d. Scenario generation: Scenario generation would be accomplished at the battalion level and in accordance with published gunnery tactics, techniques and procedures. The scenarios developed in this example, would be a series of crew gunnery exercises or firing tables designed to train or sustain crew proficiency. All targets would be virtual and arrayed to match current enemy fire and maneuver doctrine. Firing scenarios can either reside on the vehicle simulation computer HW, on a CD-ROM or ported down to the using unit or plugged into the removable storage application HW.

2. Live vehicle firing virtual rounds vs. virtual target on live terrain requires:

a. Terrain fidelity and terrain correlation: Terrain fidelity and terrain correlation supports a clear image of the virtual target that is spatially correlated to the live terrain. For example, the virtual target must realistically move over the live terrain and not give the appearance of floating above or sinking into the terrain.

b. Injection of virtual target into a live scene: Injection of virtual target into the live scene or augmented reality involves the process of generating virtual images that appear to fit seamlessly into the real world environment. A critical requirement is image clipping or removal of those virtual images that should be partly or fully obscured by intervening real-world objects.

3. Live vehicle firing live rounds vs. virtual targets on live terrain requires:

a. GPS location of firer: All vehicles will be equipped with a global positioning system (GPS). This system accurately identifies the location of the firer in terms of its X & Y coordinates and every other friendly or enemy vehicle in the exercise can be tracked and geopaired for gunnery purposes.

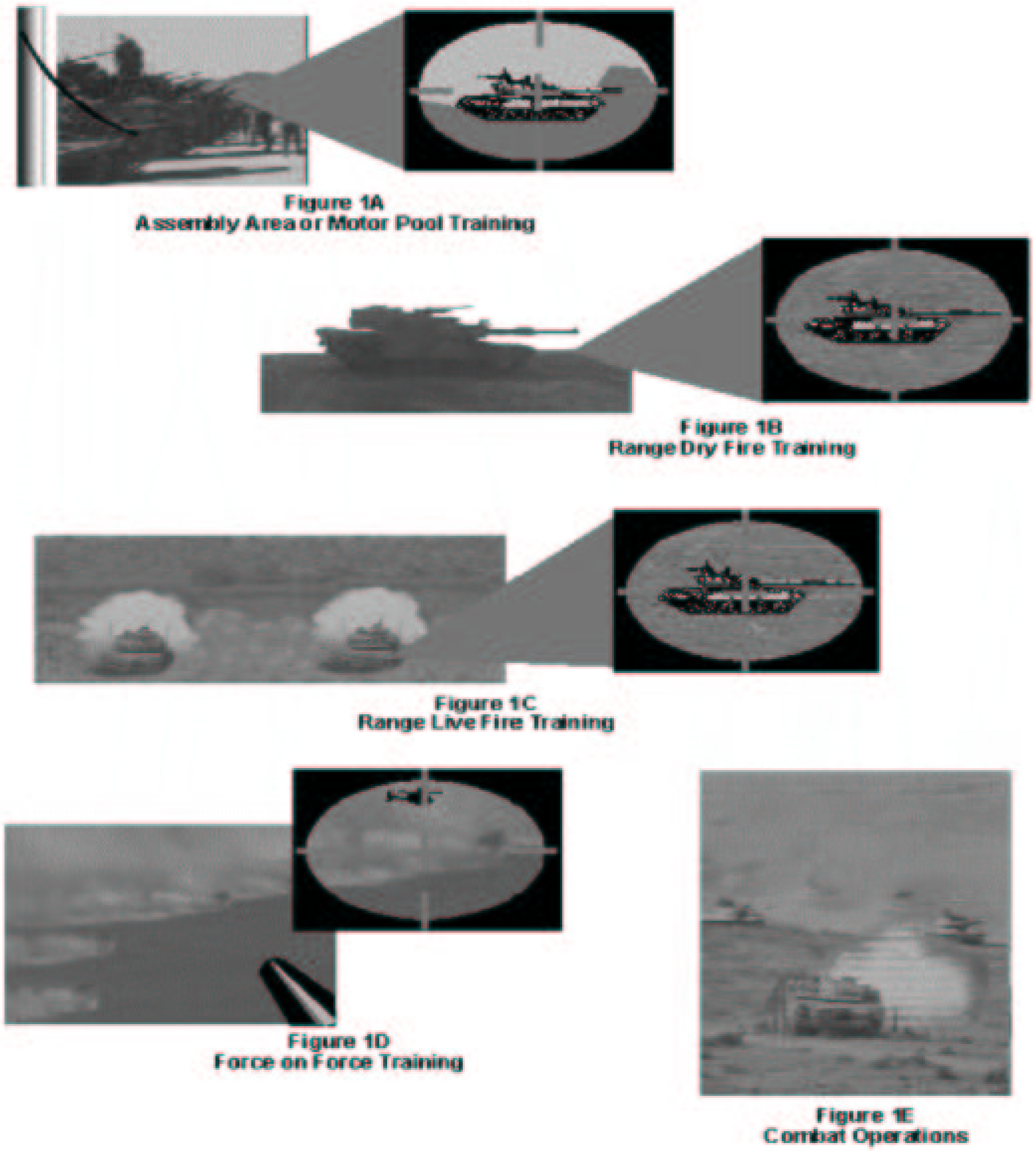

Figure 1A
Assembly Area or Motor Pool Training

Figure 1B
Range Dry Fire Training

Figure 1C
Range Live Fire Training

Figure 1D
Force on Force Training

Figure 1E
Combat Operations

Figure 1

b. Vehicle/hull attitude: The hull attitude of the virtual target is important to determine the strike of round and to calculate vehicle damage. Orientation of a virtual vehicle influences its vulnerability and ability to identify and engage the live vehicle. The simulation computer on the live platform is generating this information.

c. Gun/turret orientation (AZ & Elev.): Gun orientation further defines the virtual vehicle s ability to identify and engage the live vehicle. The simulation computer on the live platform generates this information.

d. Safety overwatch (observer console): If this technology is used to replace wooded targetry on live fire ranges at home station or at the CTCs, then it is essential to have tower or safety officer overwatch in order to see the live engagement of a virtual target. Safety over watch can only be accomplished by providing a safety-overwatch console with the virtual target array similar to those on the firing vehicle. A simulation computer and image generator (IG) capability must be available to safety personnel or sent by telemetry from the firing vehicle to overwatch element sensors.

e. Aim point determination (GPS Interferometry): When crossing the boundary between live and virtual (or engaging real targets that cannot be seen) the orientation of the real shooter vehicle with respect to the world becomes important. This situation requires solving the problem of measuring accurately not only the position of the shooter and target vehicles, but also the pointing angle in world coordinates of the shooter's gun

f. Geo-pairing: In the real world of live-instrumented vehicles on training ranges, it is not possible to determine locations and orientations very well. Geometric pairing from shooter to target is determined using geometry, namely the locations of the vehicles, the pointing angle of the shooter s gun and the line from shooter outward toward the target.

4. ESS in support of multi-echelon combined arms (collective) training conducted at our Combat Training Centers requires:

Additional set of enabling technologies. (The fact that multiple players are participating means communication links become pacing items for successful execution). These technologies include:

a. Digitized terrain database: High resolution digitized terrain databases are essential for any live virtual exercise. Resolution must be to Digital Terrain Elevation Data (DTED) level 4 with horizontal resolution at 5 meters and vertical resolution at 1.5 meters or less. All databases should be standardized & interoperable or compliant with Synthetic Environment Data Representation & Interchange Specification (SEDRIS) conversion mechanisms.

b. Optimal live/virtual registration: (Geometric pairing combined with GPS, vehicle attitude and gun orientation). Implementation of geo-pairing for direct fire and non line-of-sight engagement simulation is base upon accurate GPS position location measurements and accurate GPS-based turret angle measurements (shooter-target pairing and accurate visual representation of live vehicles in the virtual world)

c. Synchronized SAF: Synchronized SAF or the Collective Observation of a Common Entity (SAF) is designed to synchronize the SAFs generated on each player platform. For example, in a platoon exercise all tanks will see exactly the same view of the Opposing Force (OPFOR) as they move or as they are attrited by platoon direct fire. The advantage of synchronizing is the reduction of update communications traffic between friendly players as actions take place affecting the status of the SAF entities. The technology involves the modeling of the SAF entity at a high level (in terms of behaviors) so that only infrequent updates to the model are required.

d. Increased communications bandwidth / reduced commo / distributed processing: ESS has more stringent communication requirements than any stand-alone system. These requirements include weight, volume, range, power, and bandwidth management. With multiple players in the simulation exercise they must be constantly reporting current state (a few updates per second at a minimum) and interaction information to ensure proper representation.

e. Automated vehicle / smart models: By accurately modeling the behavior of a human player, each live or virtual entity can use this behavior model to predict the state of other live entities on the battlefield; and thus reduce the communication bandwidth required to update operational and status information exchange between all entities. The optimization of model information can be using on-board computational resources (simulation computer and vehicle modeling SW).

f. Automated battlefield information filtering tool: A SW application connected to the simulation computer system will be designed to process tactical information and/or use intelligent agents to filter out extraneous information not readily needed by the commander. This system will automate the collection & dissemination of critical information automatically allowing rapid decision-making. This system will prevent information overload by eliminating nonessential information, reducing communications bandwidth, and uncluttering the commander s display.

g. Scenario builder / modification tool: The TRADOC community will provide a standard library of ARTEP scenarios and the units will have the capability to develop their own scenarios or modify existing ones to meet METL requirements. This technology will be located at battalion staff level and interfaced to the automated Battle Planning System (BPS).

Go-To- War Operational Enhancements:

ESS in support of operational enhancements makes the technology more affordable than a single training enhancement system. An expanded discussion of ES uses for the AAN can be found in reference 2.

a. Situational awareness: Situational Awareness (SA) can be enhanced by an ESS. The rapid processing and sharing of enemy and friendly location information in a structured format can assist the commander with making timely decisions. ESS can be used to automate the Tactical Decision Making Process (TDMP) because the computer can collect and compile essential enemy information and filter out non-essential information and display as either a 2D or 3D view. The simulation computer can compare old and new enemy situational templates to predict possible enemy actions or intentions. As the enemy closes the computer can display on screen weapon range arcs to alert the crews of their vulnerability to enemy direct or indirect fire.

b. Battlefield visualization: Tactical information from the various ground and airborne sensor systems can be ported into the battalion Tactical Operations Center (TOC) for use by the commander and staff to make timely decisions. If necessary this information can be displayed on every vehicle tactical display instantaneously to give every crew a clear picture of enemy action. The rapid graphic display of enemy info like a Family of Scatterable Mines (FASCAM) minefield becomes a powerful tool that can save time and lives. Operations orders and graphics can be transmitted electronically and thereby reducing report preparation and distribution times

c. Mission planning/rehearsal: Mission planning and rehearsal can be realistically accomplished by conducting a virtual reconnaissance of the battle area or a virtual look back at the defensive position, and a virtual rehearsing against a GGF on the same terrain database and using similar light & environmental conditions. Electronic planning and stealth reconnaissance will maximize the use of planning time and minimize exposure to enemy observation and fire. The concept of Perfect practice makes for perfect execution would enhance crew confidence.

d. Course of action analysis: Developing the best course of action can be made easier by running the various Blue courses of action virtually against the Red courses of action. Quick simulations can be run to determine possible results of the various courses of action. The commander can make his final decision based upon the result of the computer comparative analysis and risks involved.

e. Critical decision making: An ESS can automate the collection & dissemination of key information (SA) automatically, thereby allowing rapid decision making based upon the most recent information available and models of enemy tactics, techniques, procedures and order of battle information. Using the ESS to reduce the commander s information processing duties can abate the stresses of combat decision making. ESS contributes to digitization as a force multiplier.

f. Command & Control (staff uses): Command, control and communication will be expedited and improved by using the on-board processing capacity, smart models, intelligent agents, covert digitized communications, and the real time display of enemy and friendly activity / status. Graphical displays vice verbal transmission of critical information will save time and standardize information exchange. Commanders and staffs can overwatch unit personnel & logistical status and anticipate support requirements.

g. Information overload reduction (Info Filtering Tool): ES can be used to perform as an intelligent agent to filter out extraneous information and provide non-redundant transmission of information that is crucial to decision making. The resultant filtered output to the human decision-maker will permit faster and more accurate decisions and prevent information overload and display clutter. The system can be embedded into the Advanced Tactical Command & Control System (ATCCS) and the display tailored to show information the commander considers critical to his decision making process.

Progress to Date and Remaining Challenges

All of the functions of training case 1 have been demonstrated on multiple combat vehicles that include the Marine LAV, the Army's Abrams Tank and Bradley Fighting Vehicle. In addition to the standalone capabilities they have also been networked together with components of the CCTT training environment and used for collective training. The technologies required for the merge of live and virtual simulations have been studied but still need considerable development. In most cases concepts have been demonstrated but not at a level sufficient for engineering development. Individual areas are discussed below:

a. Geometric pairing: A training/operational testing instrumentation system based on GPS Interferometry has been developed and in use by the National Guard. This geometric paring system was developed by SRI.

b. Aim point determination: As Shiavone reports in reference 7 the concept has been demonstrated but further analysis of the targeting output of sensor systems is required. This will require collection of targeting information from actual combat systems.

c. High definition terrain database: The JFTB has demonstrated the collection of 1 Meter databases with processing completed within 24 hours of the flights for data collection. The integration of this information into Simulation databases still needs to be investigated. With the inclusion of onboard sensors in modern combat vehicles we need to develop technologies to integrate in near realtime updated information with the prepared databases.

d. Live Virtual Terrain Registration: Gelenbe etal have demonstrated a method of registering a virtual scene with a a live view to the level necessary to allow virtual targets to inserted in the live view with sufficient resolution for training. Better databases could improve this technique, but this technique does not require the sophisticated instrumentation of previously demonstrated techniques.

e. Communication reduction techniques: Progress has been demonstrated on the Concurrent Player Model approach reference 6 as reported by McHale and Braudaway in reference 4. Current work has demonstrated two independent platforms maintaining duplicate scenarios with very low synchronization costs. This is expected to be demonstrated by provinding for remote SAF operation within the next year. Heninger etal have reported techniques for improving models to be used for this purtpose.

Conclusion

The enabling technologies associated with INVEST-STO are a significant first step to meet the training and operational challenges needed to support the Army After Next (AAN). The force projection army of the next century will have the benefit of an autonomous training system and dual use ESS capable of providing improved SA and other operational enhancements. This capability will give new meaning to the train as you fight imperative. Intelligent tutoring systems and a robust on-bpard training support package will ensure that the crews attain and sustain proficiency advantages over any adversary. The mental agility and information dominance gained through Force XXI will spawn the technology enablers that will make an ESS a key component of combat and training readiness in all future crew and command & control systems. INVEST-STO is at the leading edge of these future operational and training capabilities .

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