EMBEDDED SIMULATION FOR ARMY GROUND COMBAT VEHICLES

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ABSTRACT

In the past, embedded training has been dismissed as too hard and too expensive. Simulation, Training and Instrumentation Command (STRICOM) simulation technology division (AMSTI-ET) has an ongoing program to leverage current simulation technology into a form suitable for embedding into ground vehicles for training and other uses. This paper presents the concept and challenges driving this investigation. This concept embraces the warfighter using simulation for training from a stationary single crew, to fully interactive vehicle on the move, and beyond to enhancement of situational awareness.

The concept is based on low cost image generation, with pre-recorded databases providing a background to computer generated forces. Providing a DIS/HLA type linkage for team interaction expands this. Technology issues include image generation, live and virtual image registration, communications support for the simulations, and signal injection into appropriate platform subsystems. Efforts are underway to identify a common embedded simulation interface for future upgrades to Army combat vehicles.

ABOUT THE AUTHORS

Hubert A. 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.

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John R Collins received his BS degree in engineering from the University of Central Fla. in 1977. He is currently working towards a Master's Degree in Simulation and Engineering Management at UCF. For the past 18 years he has been working as a government employee in the simulation arena. He has extensive experience in Distributed Interactive Simulations both as a program manager and engineer. He currently is the Chief Engineer at PM TRADE. His research interests include expert systems, artificial intelligence, image generation and computer architecture.

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INTRODUCTION

The power projection Army of the 21st Century will require a flexible go-to war on-board training capability. Individual, crew and unit training currently conducted in stand-alone simulators will not meet the needs of rapidly deploying forces and geographically dispersed Reserve Component units. Emerging technologies and miniaturization are advancing at such a rapid rate that embedded autonomous trainers can soon replace stand-alone exogenous trainers. The symbiosis of embedded simulation technologies can also be exploited to support the operational capabilities of our ground combat vehicles. The Inter-Vehicle Embedded Simulation Technology (INVEST) is a technology exploration program with the goal of identifying those key technologies that have the highest pay-off. This paper outlines a program that will set the course for a totally embedded training (ET) and embedded simulation (ES) system for ground combat vehicles.

INVEST requirements definition is incomplete, yet some key research areas have been identified and prototypes started based on contractor experience in building training simulators and instrumenting force-on-force exercises at the Combat Training Centers. As we build a prototype and continue sharing our experiences with the requirements community we expect consensus to form and the emergence of a firm set of requirements prior to the transition to vehicle program managers (PM s). To meet the aggressive schedule identified in the INVEST program plan calls for the constant coordination between the user Training and Doctrine Command, (TRADOC), the concept developers Simulation, Training, and Instrumentation Command (STRICOM) and the implementers Tank and Automotive Command Project Managers (TACOM PM s). Emerging results from the TF XXI AWE 97-06 exercise confirmed the advantage of providing the force with a situational awareness capability and other digitized force multiplication enhancements that could be embedded on the vehicle.

This effort, while aimed specifically at Embedded Simulation (ES) in Army ground combat vehicles, will address many of the embedded training issues raised in the TRADOC ET Action Plan, reference 1. There are many benefits of embedded simulation, which includes an on-board go to war training and operational capability. This will allow for task sustainment training on site, help fight the skills decay problem, provide the capability to plan and train for newly developed operations on relatively short notice, and emulate electronically the battlefields of tomorrow to meet a diverse enemy in a wide variety of terrain environments.

Today s training simulators present tactical information in a form intuitive to the trainee. It is presented in the form of map displays similar to the paper maps using standard military symbology and scene displays that emulate the actual view seen by the combat crew. Advanced ground combat systems are taking advantage of electronic visual technology to provide better battlefield visualization from the buttoned-up vehicle. These same vehicles have moved to the VETRONICS system architecture approach where all controls are converted to digital signals, which are then used to activate the appropriate subsystems. With these trends in vehicle architecture, digital displays and electronic controls; the challenge to integrate embedded training/simulation has been simplified. Training scenarios can be used to govern the injection of virtual targets into the live video signal for live (vehicle on the move) training. Electronic images can be mixed with the sensor inputs for range finders, video and audio systems. Control signals can be monitored to keep the virtual signals registered with the live scene. For stationary training the visual displays can be generated by the simulation system and the control signals intercepted and used to key actions and cues of the simulation instead of operation of the vehicle.

Issues beyond embedded training that will be addressed by INVEST are the use of parameterized models that allow the rapid reconfiguration of force and equipment capabilities to allow concept development/exploration.

INVEST will provide repeatable results from scenarios executed for identical sets of inputs, so they can also be used during operational testing. The program will explore the use of simulations to predict opponent strategy, thus enhancing the vehicle commanders situational awareness.

The goal of the INVEST STO is to develop/ 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 training that includes from individual training, through crew training, to force-on-force training exercises. Along this continuum, however, there are many technological challenges. These 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 commanders and gunners display, on the battlefield. This includes all possible types of interaction, e.g., live on live, live on virtual, etc. Finally, there is the need to integrate command and control in order to provide complete and productive training.

A CONCEPT FOR EMBEDDED SIMULATION

The figure in the next column (figure 1) shows the relationships between the Training, Operations and Combat Development/Testing arenas. Simulation plays a central role in all three of these arenas. ES is the subset of the simulation arena that will be fully integrated into the combat vehicle. ES will play a role in Army XXI and play a key role in the Army After Next (AAN). ET is all embedded training technology, including those not requiring simulation, and will be an integral part of the training arena. Embedded Operations (EO) which include the operational enhancement functions of situational awareness (SA), battlefield visualization (BV), mission rehearsal (MR), command coordination (CC), critical decision making (CDM) and course of action analysis (COAA) will be an integral part of combat operations. That portion of ES where ET and EO overlap is when training moves from the motor park into the field. The INVEST program ES will permit commanders to seamlessly migrate from ET into EO and vice versa.

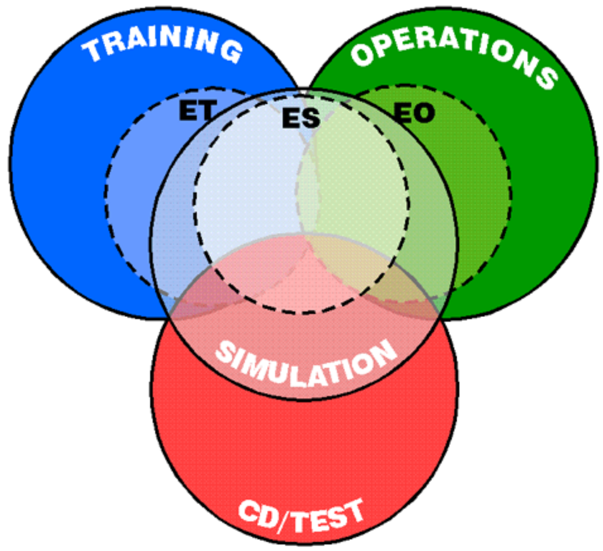

Figure 1 ES Relationship

This document identifies technologies needed to support embedded simulation (ES) and the development timelines for achieving these technologies. The INVEST STO focuses on a set of vehicles that are closely related in a technological sense. This target set is identified later in the document and will be refined as the investigation progresses. Using the target set as the baseline, plans can be developed to transition embedded simulation to the other combat vehicles. One primary characteristic of the target set, for the initial development, is that the commander and gunner s primary displays are electronic rather than optical.

To date the most prevalent target for embedded simulation (ES) has been to support embedded training (ET) to enhance or maintain the soldier s skill proficiency. It allows the soldier to train, either individually or collectively, using the operational system. ES has other potential uses over the total system life cycle. ES can support vehicle development from concept development through acceptance and operational testing. In the future it will be used to enhance the decision-making process and reduce information overload.

The training goal is to emphasize the correct doctrine or polish specific skills. Training and Doctrine Command (TRADOC), will develop instructional scenarios/databases that could be mass-produced and distributed to units as a training library. Each vehicle will be equipped with a scenario reader and the appropriate computer technology to inject the sensor and visual information into the vehicle's sights, displays, and targeting systems. The crew would be required to use the actual vehicle controls to engage the opponent. Interconnecting the vehicles with local area networks using DIS/HLA communications would accommodate team and force level training. This would also allow the interaction with other units and systems. Mission specific preparation would be accommodated by providing, at the appropriate headquarters, the tools to rapidly generate a scenario based on expected battle plans that would support mission rehearsal preparation. The ultimate level of training would be accommodated by replacing the simulated terrain with actual training sites and the integration of live and virtual forces into the scenarios.

USES OF EMBEDDED SIMULATION

Domain Applicability

ES\ET technologies have historically been thought to have their greatest use in the Training, Exercise and Mission Operations (TEMO) domain. ES\ET technologies can also provide payoffs in Research, Development and Acquisition (RDA) domain and the Advanced Concepts and Requirements (RDA) domain. The Army needs a coherent integrated plan that will allow successful exploitation of the capabilities of ES technologies in all three domains. The evolution of a weapon's system or platform from ACR to RDA to TEMO presents some unique challenges and requirements for embedded systems. In the ACR realm the embedded systems on today's vehicles can explore and help the warfighter imagine the possibilities of tomorrow. The RDA arena can have a current M1A2 help the Army design an M1A3 or Future Combat System (FCS). The TEMO domain will allow the exploitation of the ES\ET system via mission planning, rehearsal and after action review.

Training Enhancement

The ability to train and fight anytime and anywhere in the combat system affords a capability never before enjoyed by any modern fighting force. Training Aids Devices Simulators and Simulations (TADSS) previously strapped on, tethered to and/or look alike combat vehicle crew stations may no longer be needed if those same technologies can be reduced and embedded into the vehicle VETRONICS and injected into the fire control systems. A simple flip of a switch can transition the crew from a combat to training mode and vice-versa.

Those individual, crew, and collective training tasks currently conducted on part task trainers and stand-alone simulators may in the near future be conducted on the combat vehicle. This on board capability will place the training responsibility under the control of the chain-of-command, support training in unit motor parks, in the field, and on the range as concurrent or hip pocket training. The training can also be accomplished without the need for a centralized scheduling activity or on a time sharing rotation schedule.

The primary tasks currently needed to attain and sustain combat proficiency include gunnery and ARTEP tactical training and a secondary task of driver training. These tasks are currently trained on stand-alone trainers like COFT, SIMNET and CCTT. These simulators were paid for by a reduction in OPTEMPO miles driven or maingun ammunition expended. Embedded autonomous trainers could possibly stop or reduce any further tradeoff of OPTEMPO dollars.

Gunnery training currently conducted on stand-alone trainers will have similar capabilities built into the combat system. Multiple vehicle exercises may be accomplished by using digital communications over the tactical internet or a supplemental wireless LAN. With an autonomous trainer gunnery exercises can be developed using an on-board SAF capability, or be developed at battalion level and ported down or sent by CD ROM to the using unit.

Tactical training similar to the tasks scheduled for the CCTT will be conducted using the combat vehicle. The tactical radio or wireless LAN and synchronized player model technologies (live-on-virtual interaction) will provide the inter-vehicle communications link and parings required for force-on-force training.

Driver training will have a similar on-board capability less a motion platform when training in a stationary mode. In the stationary mode, the driver will have terrain graphics injected into his vision blocks or sensors to give the appearance of moving over the terrain database. Driver participation would be an advantage over the UCOFT where the Instructor Operator plays that role.

The training transfer associated from the use of ES/ET can be directly related to operational proficiency because the crew will: (1) train on their fighting vehicle, (2) operate under real conditions and under the watchful eye of unit cadre, (3) increased availability of the system for training and (4) the synergistic benefit gained from the dual use of the on board training and operational systems.

Operational Enhancement

Battlefield Visualization (BV):

The process whereby the commander develops clear understanding of the current state with relation to the enemy and environment.

ES\ET when integrated into the battlefield TOC's, will aid the company and battalion commanders ability to plan, research and analyze different courses of actions and their resultant outcomes. Expert systems could eventually be built into the operational gear to assist in route selection, deployment of forces, and use of assets. These systems could help determine the most effective uses of troops and their equipment, or the best sectors of fire given the terrain and force level.

Situational Awareness (SA):

Timely recognition of both enemy and friendly situation such that the warfighter can gain and sustain the initiative.

ES\ET can be used to perform filtering of incoming data. The commander can request display of only certain high priority targets. The resultant filtered output to the human decision maker will permit faster, better decisions by the battlefield commanders.

Command Coordination (CC):

The ability to coordinate the 3 functions of command and control, plan, conduct and sustain operations. The correlation, fusion and display of information needed by commanders at all levels.

The advent of Interface Design Specifications (IDS) for ES of various combatant vehicles will standardize informational interchange on tomorrow's battlefield. The command coordination between the various elements of the 21st Century force will be heightened and improved. The evolution of embedded simulation will push the force structure into a seamless simulation environment where simulation is not just for training anymore. Simulation can be used to set up and diagnose communication nets, plan missions, and analyze log support requirements and constraints.

Mission Rehearsal (MR):

Mission rehearsal is the use of modeling and simulation applications to facilitate mission execution.

Mission Rehearsal is an inherent strength of ES. Missions can be planned and rehearsed against an intelligent adversary (ModSAF or CGF). Weaknesses in the plan or human performance levels required by the plan can be determined. The plan can be adjusted to achieve best results. The mission rehearsal will increase unit awareness of mission requirements and difficulties and will allow the unit to maintain proficiency and practice against intended targets immediately preceding the actual mission.

Critical Decision Making (CDM):

Critical Decision Making - The ability to identify the critical decisions that emerge within the combat decision making process and reduce information overload and the stresses associated with the decision making process.

An inherent advantage of the US Army has always been the initiative and intellect of the on site commander. ES capabilities will allow the unit leader to make tactical decisions based upon a better understanding of the evolving situation. The pace of modern warfare dictates that the battlefield commanders need immediate access to that information relevant to his decision making process. Extraneous data needs to be filtered out to prevent human overload and clutter on displays.

Course of Action Analysis (CAA):

The ability to support the tactical/operational decision making process by selection of the best course of action based upon a rapid COA wargame modeling & simulation comparison.

The ES technologies can be mated with expert systems to help analyze different courses of action. Quick simulations can be run to determine possible results of the planned engagement or mission. The commander can make a decision based on a better understanding of the attendant risks and possible outcomes. In the battlefield TOC's the presentation of the mission to unit leaders could be linked to operational units in the field. Then details on the individual unit actions and tasks can be quickly determined and planned. This planning would be via the on board ES technologies. This would maximize the use of assets and minimize exposure to the enemy and reduce mission risks.

Procedural and Diagnostic Aids

The ET capabilities can be used on board for maintenance and repair. The crews could diagnose vehicle problems and facilitate repairs. The crew, depending on complexity and parts availability, could perform some repairs.

After Action Review (AAR)

The ES\ET system can be programmed to collect data during the battle for playback and analysis later. The AAR can be used to determine deficiencies in unit performance and possibly pinpoint enemy weaknesses.

EMBEDDED SIMULATION TECHNOLOGY

Key technologies that need to be developed for cost effective embedded simulation include low cost image generators, virtual target injection into sensor displays, scenario generation, scenarios, and scenario players. Areas that require enhancement include burst on/off target effects, live to virtual image registration, and determination of aim point. The embedded training starts as an autonomous capability, where one vehicle and its crew is all that is needed for effective training. The embedded simulation concept will require synchronization techniques to keep all of the vehicles on the same scenario during collective training. These topics are covered in further detail in references 2 and 3.

GUIDING PHILOSOPHY

As a Science and Technology Objective it is not INVEST s goal to provide the full scale engineering of any product. As an R&D effort it will identify the state of the art in embedded simulation for Army tactical vehicles. This will include investigations into certain classes of key technologies such as low cost image generators to determine current capabilities and require future development. It will also build a rapid prototype embedded trainer to allow enhanced discussions with potential end users, and continued investigation of interface issues. The spiral development approach repeatedly reestablishes the goals (requirements) for the next level of performance. When the state of the art is advanced to the point that the user community agrees a concept is ready for Full Scale Engineering Development, the concept will be transitioned for inclusion in the next round of vehicle enhancements.

Products

The products to be developed by INVEST are proven/demonstrated concepts with detailed technical reports on those capabilities. In addition, specific byproducts of the investigations will be delivered such as interface and architecture standards. Some of the benefits of using multiple organizations are that interfaces will have to be documented, and the good ideas are not limited to those of just one R&D organization. Requirements documents will be developed and coordinated with TRADOC.

TARGET VEHICLES FOR INVEST

M1A2 System Enhancement Package (SEP)

The M1 Abrams Main Battle Tank is the US Army's primary combat weapon for closing with and destroying the enemy. The M1A2 SEP has increased capability and capacity over the M1A2, that includes electronic color digital terrain maps; Army Standard C4I architecture; under armor auxiliary power unit (APU); improved thermal imaging; improved vehicle intercom; improved position/navigation, and improved VETRONICS architecture.

Future Scout and Cavalry System (FSCS)

The FSCS is a system for scout and cavalry units that is optimized to conduct reconnaissance, surveillance and target acquisition on the Force XXI battlefield. This system will have improved survivability, mobility, lethality, and deployability. over the existing scout platforms. In the area of tactical information dominance the FSCS will have a sensor package for rapid target acquisition, identification and destruction and a fully integrated and shared C4I system.

INVEST-STO LABORATORY

INVEST will use various System Integration Laboratory (SIL) facilities already in place at TARDEC and the various contractors sites. Instead of demonstrating the proof of concept system on an actual vehicle prototype an alternative demonstrator/emulator will be developed that has similar design components and sensors as the actual vehicle crew station(s). The alternative demonstrator/emulator approach has some distinct advantages over using a vehicle prototype. It should be a cost effective way of proving concepts by providing a demonstrator that is smaller, cheaper to build, easier to modify and move (to the SIL s, test and demonstration sites and conference locations), and will remain under the control of the R & D community. It provides a needed steppingstone to the actual vehicles. The demonstrator is called the Mobile Crew Station Simulation Laboratory (MCSSL). The MCSSL will consist of crew stations packaged in a form suitable for mounting on the back of a HMMWV. The current plan is to use commercial equivalent components of the actual vehicle sub-systems. The MCSSL will use an Abrams M1A2 SEP commander s station and possibly the gunner s station.

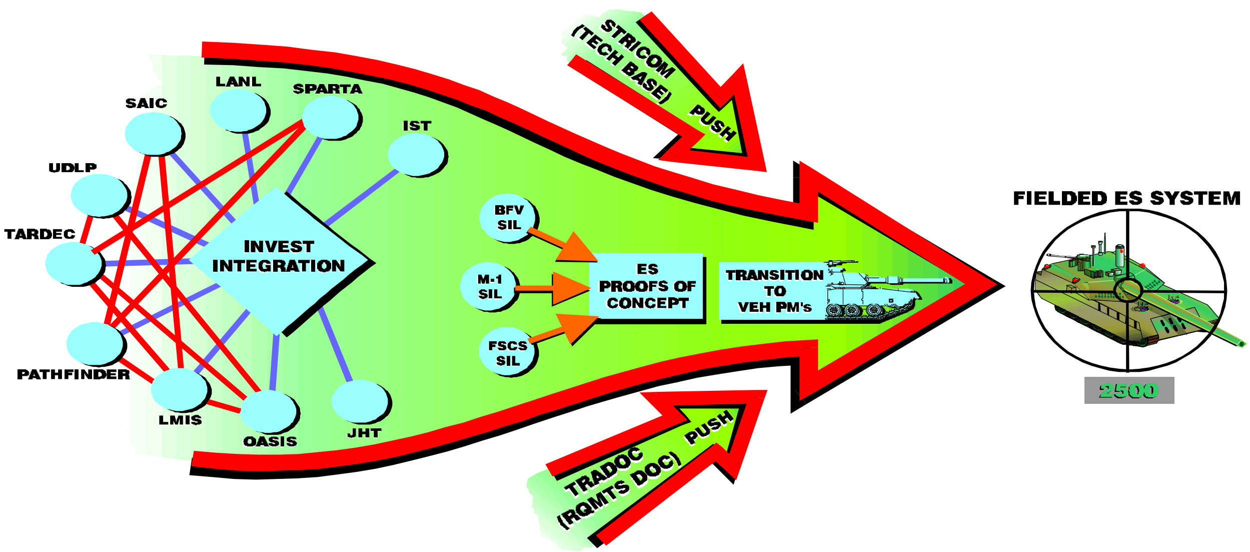

Figure 2

INVEST STO MILESTONES

The INVEST-STO evolution can be explained in terms of several distinct phases from inception to fielding an ES system on a future ground combat system.

The INVEST-STO program began in late 1996. Multiple proposals applicable to each research area of interest were approved. Contracts were awarded based upon contractor expertise and experience with the various technologies needed to meet the domains of Advanced Concept Requirements (ACR), Research Development and Acquisition (RDA) and Training Exercise and Mission Operations (TEMO) domain associated with embedded simulation. Once under contract an Integrated Product Team (IPT) was established to collaborate/coordinate efforts to meet program milestones.

Phases of Evolution

Technology Development Phase FY 97-99
During this period all participating contractor R & D efforts are developed and fed into the INVEST Integration Cell. Coordination will take place between contractors to meet the selected technology requirements.

Demonstration Phase FY 99-00
This phase starts with a vehicle hot bench or brass board and virtual prototyping conducted at the Systems Integration Labs (SIL) for the selected target vehicles e.g. Abrams M1A2 SEP and Future Scout and Cavalry System.

Proof of Concept Phase FY 01-02
This phase will occur in steps: (1) ES on a stationary vehicle, (2) ES on a moving vehicle, and (3) ES as operational enhancements to the vehicle combat systems.

Transition Phase FY 99-02

The transition to the vehicle PM s phase will complete after the vehicle on the move proof of concept and the identification and publication of a TRADOC Requirements Document. This transition will involve ES integration on future systems and legacy systems under a P3I program.

Fielding Phase CY 07

The fielding phase has as its goal a fully embedded training and simulation system in a ground combat vehicle that is capable of supporting both training and operational requirements and have the ability to switch between the two modes with the flip of a switch.

Development Milestones

By Mid FY98

Demonstrate Crew Proficiency application with Abram s commander s station

Develop and deliver a feasibility analysis study for Embedded Simulation. Assess which soldier tasks and skills are appropriate and affordable candidates for embedding (ref 4). Convert training objectives into embedded simulation goals.

By End FY98

Demonstrate Unit Proficiency Application with MCSSL. Uses prototype ES modular hardware and software components.

Prototype a virtual-live interactive system.

By Mid FY99

Demonstrate Mission Rehearsal with vehicle simulator. The key element is that this is the demonstration of a rapid scenario generation facility and the capability to generate mission specific training and then use it for a training demo within a prescribed time period.

By End FY99

Demonstrate vehicle-on-the-move (VOM) application with MCSSL on a vehicle.

Determination of aim point demonstrates that a live player can engage both virtual and live targets during the same scenario.

Demonstrate that the crew can interact with remote entities while on the move.

During FY00 FY02

Deliver technology as accepted to vehicle PM s.

Complete definition and demonstration of inter-vehicle embedded training capability. Develop a standard ES simulation architecture using common components. Permit development of a consistent synthetic battlefield representation for use in all ES systems and improve interoperability and affordability among future systems.

Continue investigation of emerging technologies, unresolved issues, and operational enhancement techniques.

Organizations Involved in Development and Their Roles

U.S. Army Tank Automotive & Research Development and Engineering Center (TARDEC) is responsible for development of the vehicle to trainer interface standard, and architecture. TARDEC will assists coordination between the INVEST office and vehicle PM s, and will participate in development and testing of the MCSSL.

Institute for Simulation and Training (IST), University of Central Florida is responsible for evaluating what training should be performed using ES/ET, develop an ES/ET Technology Development Plan, assess commercial image generation technology, assess direct live and virtual target pairing technology, and investigate burst on target display realism.

Sparta, Inc. Assess the benefits of Ultra Wide Bandwidth (UWB) wireless LAN technology to support connection of multiple vehicles in a collective training exercise. Track development of tactical internet and provide communication interface document.

Los Alamos National Labs (LANL) Study the application of adaptive simulation systems technologies for designing and implementing intelligent observer objects (actors) in warfighting simulations. Evaluate intelligent observer objects to facilitate and automate human-in-the-loop player/ controller tasks of real-time and faster than real-time distributed simulation activities.

Science Applications International Corporation (SAIC) Develop an approach for synchronized vehicle models required for extending ES to support a collective training exercise involving both live and virtual vehicles.

United Defense Limited Partnership (UDLP) Prime for Bradley family of vehicles and Crusader.

Pathfinder Systems, Inc Demonstrate the feasibility of integrating realistic appearing and behaving virtual targets into the live scene on live vehicles using Virtual Image Combination Technology with Object Recognition (VICTOR), a method for live and virtual target registration.

Lockheed Martin Information Systems (LMIS) Develop the initial ES Prototype. To integrate, test and evaluate the stimulation of sensor images to crew sensors on a designated INVEST target vehicle for individual, crew and collective tactical training.

Orion Advanced Simulation & Intel Systems (OASIS), Inc Develop functional and performance specifications for ES systems for ground combat vehicles. Provide an Abrams M1A2 SEP commander s crew station.

Jardon & Howard Technologies (JHT), Inc Investigate and conduct a proof of concept demonstration of the use of an embedded intelligent tutoring systems for crew and team level training.

SUMMARY

Today s technology allows us to demonstrate the initial capabilities of tomorrow s implementation. Over the past decade, we have seen in the commercial world the impact of the evolution of computer technology. In the business arena we have seen the acceptance of this ongoing evolution with planned replacement of the desktop computer every three years to incorporate new capabilities. The current practice of developing militarized equipment to last the service life of the vehicle, needs to be re-addressed to properly take advantage of the evolution of computer hardware and software. Ever increasing sizes of databases, driven by higher fidelity representation of terrain and targets, can be used by higher fidelity models, executed on faster processors and presented on higher resolution displays to give our warfighter a better picture of the battlefield. The commercial world is placing similar demands on computer technology, and takes advantage of the products the industry is delivering. We must structure our fielding plans to do the same.

This is an ongoing program so all data in this paper was as of the date of submittal which was 4 September 1997. Most of the identified roles are based on contracts awarded in 1997 and postulated extensions for 1998.

CONCLUSION

The ES / ET application provides a new look at an age-old dilemma of what TADSS is needed. For the combat ready deployable force, stand-alone TADSS have been over taken by electrons. Just imagine MILES, TWGSS, TSV, SAWE, and CCTT totally embedded into the ground system and the added benefit of information superiority to include: situational awareness, terrain familiarization, mission rehearsal for rapidly changing scenarios, and course of action analysis. As the former CSA Sullivan said in his book (ref 5), Success is a journey not a destination . The road to a fully embedded training and simulation system will be a journey to success on the battlefields of tomorrow.

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