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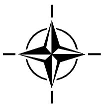
STO TECHNICAL REPORT **TR-HFM-165**

Improving Human Effectiveness Through Embedded Virtual Simulation

(Amélioration de l'efficacité humaine grâce à la simulation virtuelle intégrée)

Findings of Task Group HFM-165.

Published January 2014



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• IST	Information Systems Technology Panel
• NMSG	NATO Modelling and Simulation Group
• SAS	System Analysis and Studies Panel
• SCI	Systems Concepts and Integration Panel
• SET	Sensors and Electronics Technology Panel

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(NATO) RTO	(NATO) Research and Technology Organisation
AR	Augmented Reality
ATL	Attack Team Leader
BVR	Beyond Visual Range
CAS	Close Air Support
CAVE	Cave-Automatic Virtual Environment
CER	Cost Effectiveness Ratio
CGFs	Computer-Generated Forces
CTL	Confinement Team Leader
CW	Chief of the Watch
EMI	Electro-Magnetic Interference
ET	Embedded Training
EVS	Embedded Virtual Simulation
GSS	Ground Soldier System
HFM	Human Factors and Medicine
HMD	Helmet-Mounted Display
IBM	International Business Machines
IBSTPI	International Board of Standards for Training, Performance and Instruction
IFV	Infantry Fighting Vehicle
JTAC	Joint Terminal Attack Controller
MCRO	Machinery Control Room Operator

NASA-TLX	NASA Task load index
NATO	North Atlantic Treaty Organisation
NPC	Non-Player Character
OW	Officer of the Watch
R&D	Research and Development
RDECOM	(US Army) Research, Development and Engineering Command
RFT	Rod and Frame Test
RNLAF	Royal Netherlands Air Force
RTG	Research Task Group
SA	Situation Awareness
SAM	Surface-to-Air Missile
SUR	Simulator Utilization Ratio
TCR	Training Cost Ratio
TER	Transfer Effectiveness Ratio
VE	Virtual Environment
VID	Visual Target Identification
VR	Virtual Reality
WVR	Within Visual Range

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Improving Human Effectiveness through Embedded Virtual Simulation

(STO-TR-HFM-165)

Executive Summary

Present and anticipated NATO missions require highly trained and capable military personnel. It is important that policy, procedures, and technologies provide adequate means to prepare coalition forces for the full-spectrum of situations that they are likely to encounter. An important requirement is the need for units to deploy with little or no notice and for them to adapt effectively to evolving situations. This places military units in locations where they will not have the facilities and infrastructure they had at their home station limiting their ability to train for, and rehearse complex missions.

The use of Embedded Virtual Simulation (EVS), within a broader Embedded Training (ET) capability, is seen as a potential tool to provide more effective deployed training. EVS is a concept that tightly integrates training and mission functionality into operational equipment. Recent advances in training concepts, agent technologies, computers, communication and display technologies offer new opportunities for embedded training and mission preparation/rehearsal capabilities in a highly mobile military.

Deployed settings that provide little support to users, e.g., lack of instructional staff and/or infrastructure provide EVS its greatest challenges. To meet these challenges EVS applications will have to be designed into military systems with a range of training and training management capabilities. Individual and collective training will require systems to be equipped with display technology to present detailed virtual environments. With further maturation, Augmented Reality technology could be used to present virtual targets and maintenance problems. Intelligent agents would drive adversary, neutral and friendly forces to fill out scenarios and an intelligent tutor would provide feedback and training management functions. By utilizing network-enabled capabilities, team, collective, joint, and coalition training and mission preparation/rehearsal (for warfighting, peace keeping and maintenance skills) are possible.

This report summarizes the findings of a NATO Research Task Group (RTG) that was established to explore the potential of embedded training with particular emphasis on EVS. The RTG looked to users for their requirements and experiences with embedded training. The group met with experts in the component technologies: virtual environments, augmented reality, intelligent agents, intelligent tutors, training, and human interaction and performance. The contents and conclusions derived from these meetings and discussions are summarized in the papers that compose this volume. The RTG concluded that for successful application of ET/EVS to future military systems user requirements (including characteristics of the user, task, and environment) and training management will have to be considered early in the design process. Given the key potential role of intelligent tutor technology in the success of embedded training, the RTG felt that further study should be undertaken to determine the maturity and promise of tutor technology. EVS could become a disruptive technology by providing NATO forces a training readiness advantage on the battlefield, particularly if EVS systems can exploit the advances now being made in other fields, such as secure, wide broadband, wireless networking and intelligence gathering.

Amélioration de l'efficacité humaine grâce à la simulation virtuelle intégrée

(STO-TR-HFM-165)

Synthèse

Les missions actuelles et à venir de l'OTAN nécessitent un personnel militaire hautement entraîné et compétent. Il est important que les politiques, procédures et technologies offrent des moyens appropriés pour préparer les forces de coalition à l'ensemble des situations auxquelles elles peuvent être confrontées. La nécessité de déployer des unités dans un délai très court ou sans délai et de s'adapter à des situations changeantes est un facteur important. Ces unités se retrouvent dans des lieux où elles ne disposent plus des moyens ou infrastructures nécessaires pour s'entraîner, prévoir et répéter de façon optimale des missions complexes.

L'utilisation de la simulation virtuelle intégrée (EVS), dans le cadre d'une capacité d'entraînement intégré (ET) plus élargie est considérée comme un outil essentiel pour permettre un entraînement plus efficace en projection. L'EVS est un concept qui incorpore étroitement des fonctionnalités d'entraînement et de mission dans l'équipement opérationnel. Les progrès récents en matière de concepts d'entraînement, technologies d'agents, ordinateurs, communications et technologies d'affichage offrent de nouvelles occasions d'intégration des capacités d'entraînement et des capacités de préparation / répétition dans un contexte militaire à forte mobilité.

Les applications les plus délicates d'EVS sont les situations où le site de projection offre peu de soutien aux utilisateurs, par exemple, le manque de personnel d'instruction et/ou d'infrastructure. Pour faire face à ces défis, la simulation intégrée devra être conçue de façon à intégrer dans les systèmes militaires toute une panoplie de capacités d'entraînement et de gestion des l'entraînement. L'entraînement individuel et collectif requerra que les systèmes soient équipés des nouvelles technologies d'affichage afin de présenter des environnements virtuels détaillés. Maturation aidante, la technologie de Réalité Augmentée (AR) pourra permettre la présentation de cibles virtuelles et de problématiques d'etrentien. Des agents virtuels pourraient piloter des forces adverses, amis ou neutres afin de créer des scénarii et des tuteurs virtuels pourraient remplir les fonctions d'instructeur. Les capacités réseau-centriques rendent possibles l'entraînement en équipe, l'entraînement collectif, interarmées et de coalition, ainsi que la préparation / répétition de missions (pour les actions de combats, d'imposition et de maintien de la paix).

Le présent rapport résume les résultats du groupe de travail de l'OTAN qui a été créé en vue d'explorer les pistes potentielles relatives à l'entraînement intégré, en se concentrant sur la Simulation Virtuelle Intégrée. Le groupe de Travail s'est rapproché des utilisateurs afin de connaître leurs besoins et mesurer leur expérience. Le groupe a rencontré des experts des technologies associées : les environnements virtuels, la réalité augmentée, les agents virtuels, l'entraînement, l'ergonomie et la performance humaine. Les réflexions et conclusions issues de ces réunions et discussions sont résumées dans les pages qui suivent. Le groupe de travail a conclu que la prise en compte le plus en amont dans la phase de conception des besoins des utilisateurs en matière de EVS/ET (incluant les caractéristiques de l'utilisateur, la mission et l'environnement) et la gestion de l'entraînement est un facteur de succès. Compte tenu du rôle potentiel important de la technologie de tuteur intelligent pour le succès de l'entraînement intégré, le groupe de travail a estimé que des travaux doivent être poursuivis pour déterminer la maturité et le potentiel de cette technologie. L'EVS pourrait se révéler une technologie de rupture en dotant les forces de l'OTAN d'un avantage de mise en condition opérationnelle sur le terrain, en particulier si les systèmes EVS peuvent exploiter les avancées qui sont réalisées dans d'autres domaines comme les réseaux sans fil large bande sécurisés et le recueil d'information.

Chapter 1 – INTRODUCTION AND MOTIVATION

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1.0 BACKGROUND

Present and anticipated NATO missions require highly trained and capable military personnel. The military have to be well prepared to effectively and efficiently use state-of-the-art technology under highly complex and rapidly evolving conditions, e.g., ‘three-block-war’ scenarios (i.e., humanitarian aid, peace-supporting, full battle missions). It is important that training policy, procedures, and technologies provide adequate means to prepare coalition forces for the full spectrum of situations they are likely to encounter.

A number of factors are influencing training policies, procedures and technologies. An important factor is the need for units to deploy and to adapt to evolving situations. This places them in locations where they do not have the facilities and infrastructure needed to train for, plan, and rehearse complex missions. HFM-121 (NATO RTG-121 Final Report (2007)) investigated Augmented, Mixed, and Virtual Environments (AMVE) as a means of providing an advanced and intuitive human-system interaction for military applications. That study group identified military training and education as the main application area for AMVE technologies. HFM-121 concluded that recent advances in training concepts, agent technologies, computers, communication, and display technologies made embedding training and mission rehearsal capabilities in highly mobile military hardware both practical and effective. HFM-121 recommended that embedded virtual simulation technologies undergo a thorough review and analysis on conceptual and technical levels. This recommendation provided the impetus for the current research technical group and the contents of this report.

Embedded Training (ET) integrates training functionality into operational equipment, allowing military personnel to train and rehearse while deployed or away from fixed training resources. A recent vision for ET written by the office of the US Army's Project Manager for Training Devices (PM,TRADE, 2011) stated that ET minimizes the artificialities of combat training by maximizing the use of real combat equipment. The vision statement stated that ET will:

- Enable training while soldiers are deployed.
- Facilitate mission rehearsal without the need for special equipment.
- Increase utility of existing combat equipment and save money by giving equipment both a combat and a training function.
- Rapidly disseminate combat experience, cultural landscape awareness, tactical adaptations, and the latest intelligence through training in the war zone.
- Support home-station training by bringing training opportunities to locations that traditionally are not equipped for training or do not have the space for combat maneuver.

Embedding training capabilities in military equipment is not a new concept. Examples of embedded training capabilities have been incorporated in defense computer-based systems since the late 1950s (Morrison & Orlansky, 1997). ET successes were generally systems where space and power requirements were not issues. Examples of embedded training successes include Patriot missile and Aegis Command and Control systems. In their review of embedded training utility, Morrison and Orlansky (1997) found 56 systems that incorporated, or planned to incorporate, embedded training capabilities across the US Army, Navy, Air Force and joint service community.

2.0 DEFINITIONS

2.1 Embedded Training

The maturity of embedded training concepts was recognized 25 years ago when the US Army's Vice Chief of Staff and civilian acquisition executive wrote a joint letter to the Army's materiel acquisition community that established a policy requiring materiel developers to consider embedded training as the preferred alternative for system training. The policy also required material developers to justify why embedded training was not viable before choosing other training delivery options (Thurman and Ambrose, 1987). During the late 1980s, the US Army Research Institute produced a ten-volume guide on how to implement ET in Army systems (Finley, Alderman, Peckham & Strassel, 1988). Among the topics covered were development of ET concepts (Roth, 1988) and requirements (Roth, 1988), integrating ET into the prime system (Evans & Cherry, 1988), incorporating ET into unit training (Strasel, Strasel, Aldrich, & Roth, 1988) and logistics implications (Cherry, Peckham, Purifoy, & Roth, 1988). The overview volume contained the following definition of embedded training:

'ET is defined as that training which results from features incorporated into the end item of equipment to provide training and practice using that end item equipment. The features may be completely embedded within the system configuration by software application or a combination of both software and system configuration; or may be executed by some form of strap on (e.g., a video disc player) or plug in equipment: or a combination of embedded and appended components. The feature(s) MUST include stimuli necessary to support training: they should include: performance assessment capability, appropriate feedback, and record keeping.' (Finely et.al., 1988)

This definition includes three types of ET: fully embedded, strap-on and umbilical. Fully embedded requires the end item of equipment to have been designed with ET as part of its system architecture, while strap-on and appended ET can sometimes be added at a later point in design. Embedding training in aircraft and combat vehicles has been a difficult challenge due in part to limitations on space, weight and power in those vehicles. Recent miniaturization of electronics and computer components has reduced the need to offload training system components, making embedded training a more viable option for combat vehicles and aircraft. However, modern systems that were designed to incorporate ET can have a mixture of fully embedded, strap-on or appended components. An example is the German Puma infantry carrier. It was designed to have ET, and many of the components used for training are also used for fighting the vehicle. The image generator that produces the visual virtual environment for training is in effect an appended component. The image generator is loaded onto the rear of the carrier and occupies the seating area normally taken by an infantryman (Modern Armed Forces-Puma, 2007). The decision to include ET in a military system must be made early in the design process to allow the necessary weight and durability trade-offs to be made. Based on the ten-volume ARI guide, Witmer and Knerr (1995) produced a more usable guide to early embedded training decisions. This guide went through intricate decision trees to determine if ET was a viable option for a given system.

2.2 Embedded Virtual Simulation

Since then, new technologies and findings have become available to enable and inform the use of ET. They provide new capabilities for Embedded Virtual Simulation (EVS), which we define as an enabling technology that provides an interface to interactive simulations that reside within or stimulate operational equipment for ET. While the enabling technologies have grown in number and capability, they are also potentially more cost effective than ever. In many cases, the interface to the virtual simulation is the operational equipment’s own displays that can be placed into training mode. Helmet-mounted displays with see-through optics can provide augmented, mixed and fused reality that combine visual images of the real world, including prime equipment and other people, both real or synthetic. Computational models of human behavior can drive neutrals’ and enemy combatants’ avatars, as well as substitute for missing teammates. Automated tools are being developed to create training scenarios, to monitor, record and analyze individual and team/small-unit performance, and to deliver timely feedback through an After Action Review (AAR) process. EVS can: (1) link local and/or distant trainees and instructional resources; (2) provide a means for building individual or team knowledge and skills; and (3) be used for requirements analysis, test and evaluation, mission planning and mission rehearsal.

3.0 EMBEDDED TRAINING APPLICATIONS

3.1 US Army’s Future Combat Systems

The US Army‘s ill-fated Future Combat Systems (FCS) program would have been a landmark program for embedded training. For the first time in a major weapons system acquisition program, training was identified as a Key Performance Parameter at least partly because embedded training and simulation was to be the primary training system for FCS. Since Key Performance Parameters must meet their key milestones in order for the system as a whole to progress, embedded training would have been a key element in the US Army’s highest priority system of systems. FCS was to have a virtual training system that had much of the same functionality as the US Army's Close Combat Tactical Trainer. It would also have a training management system, and the capability to present interactive multimedia instruction, as well as to interact with engagement simulation systems (Shiflett, 2010). A training committee co-chaired by the Army's Program Executive Office, Simulation Training and Instrumentation and program contractor Science Applications International Corporation (SAIC) jointly made key decisions regarding the design and integration of the trainings system with the operational system. Since FCS had progressed for a number of years, SAIC had developed a final version of Brigade Combat Team Embedded Training Software (BETS). BETS consists of four training products: Computer-Based Training; Virtual Individual Operator Training; Leader-Battle Staff Training; and Live Training. While these products will not be used for FCS training, BETS capabilities can be adapted to other systems and applications by the addition of new courseware and simulation model data (SAIC, 2011). While the training materials were designed for delivery in an embedded training system, they are also capable of stand-alone operation. The developers of BETS used open standards, and the materials can be used on generic laptops and desktops.

The potential for embedded training as a means for training battle command were captured by Col. (retired) Jim Shiflett, the SAIC program manager for FCS, Training, in an unpublished paper. Shiflett (2011) pointed out the advantages to integrating operational and training battle command systems together. He argues that, given the size and complexity of battlefield information and sensor data, it will probably be difficult to practice in this type of environment without employing simulation, and an embedded training capability is likely the most efficient way of doing this. Shiflett identifies lessons learned taken from the FCS program that should be applied to future programs that will likely employ an embedded training strategy for Battle Command. The lessons learned identified were:

- Training simulations can be embedded in Battle Command Systems if the technical issues are addressed early in the design phase of the program. This does not necessarily require lockstep and complex integration between the simulation and Battle Command system, but could be achieved by key design principles and protocols that allow for some decoupling between the Battle Command system and the simulation.
- Several specific technical issues, such as time management and simulation distribution, need to be further addressed to find the right range of solutions.
- With the increasing complexity of our systems managing more varied and multi-faceted sensor data, training systems need to be designed as part of the Battle Command system to both manage complexity of operation and to support continuous, on-demand training and mission rehearsal.

3.2 Embedded Training in an Infantry Fighting Vehicle

The Puma, the new German infantry fighting vehicle developed and built by Kraus-Maffei Wegmann, includes several types of embedded training in its design. In designing the Puma, it was decided that a fully embedded virtual simulation system was not feasible due to operational requirements placed on the combat vehicle's infrastructure. Tactical driving training on the Puma is achieved with minimum effort and only requires simplified controls. Advanced driver training, which would require additional drive-by-wire technologies and a motion base, was not included since it would be cost and space intensive. As mentioned previously, for gunnery and tactical training the Puma uses an appended image generator which produces the visual virtual environment. The image generator is loaded onto the rear of the carrier and occupies the seating area normally taken by an infantryman (Modern Armed Forces-Puma, 2007). The virtual environment is visible through the vehicle's vision blocks and by helmet-mounted displays that provide out-of-the-hatch views. The Puma embedded training system can function either as a single vehicle or within a platoon-level or higher network that includes other vehicles and/or simulations and an instructor's station. Depending on the configuration of the vehicles) and the type of training, additional equipment is added to the system (Schmidt, 2010).

3.3 Embedded Training in Fighter Aircraft

Recently, the Royal Netherlands Air Force demonstrated the potential of EVS in fighter aircraft (Stokkel, 2010). They embedded training capability into F-16s that enabled pilots to practice against virtual hostile, friendly, and neutral players in realistic mission scenarios. The embedded training system injects virtual air and surface-to-air missiles into aircraft mission systems. The virtual entities have simulated flight and behavioral characteristics that mimic threats and defensive systems. The Netherlands program has demonstrated that fighter aircraft–based embedded training is both technically feasible and effective. Decisions to implement embedded training into more existing aircraft and support for embedded training in the Joint Strike Fighter program are dependent on Return on Investment analysis.

4.0 MOTIVATION FOR RTG-165

As the above examples demonstrate, embedded training is a concept that can meet NATO military training needs, especially when deployments are frequent and local requirements limit opportunities to train on each element's full range of military tasks units. The programme of work agreed to by RTG-165 was intended to fully explore, from a human-centered design perspective, the conceptual, functional, and technical promise of EVS for ET. The RTG's work called for a review of activities, knowledge and findings in the area of embedded virtual simulation; analysis of implications of various live, virtual and constructive simulation mixes with regard to training effectiveness, human performance, and potential side-effects; and the provision of recommendations for further research and best practices to achieve embedded training for individual, team, collective, joint and coalition applications. The emphasis was to be clearly placed on better understanding of the training and human performance issues that result from the introduction of simulation and other training capabilities to military equipment. The concern for the human interface, training approaches, and human performance and training effectiveness differentiated the work of this group from others that may have reviewed the possibilities for ET.

RTG-165 used several mechanisms for gathering data and opinions regarding the potential for EVS. In October 2009, the members of the technical group organized a NATO-sponsored workshop (RWS-169). The three-day workshop brought together experts who spoke about policy issues and requirements for EVS, human effectiveness in ET environments, human interaction in EVS, and learning in EVS.

A total of 14 papers were presented, in addition to keynote addresses by four of the technical group members: Dr. Lochlan Magee, who defined EVS, discussed the technologies involved, and provided context for the workshop through presentation of a possible scenario in which EVS was a key element; Lt. Col. Gerbe Verhaaf, who spoke about embedded training from a military user's perspective; Dr. Dirk Schmidt, who spoke about a researcher's perspective; and Col. (Ret.) James Shiflett, who spoke about embedded training development. The workshop combined these thought-provoking presentations with time for the audience to have facilitated discussion about the EVS issues related to session topics. The papers and presentations from RWS 169 can be found on the NATO Research and Technology Organization Website, www.rto.nato.int under 'Publications' and the title 'Human Dimensions in Embedded Virtual Simulation'.

The RTG developed a survey to assess service members' awareness and use of, and opinions about, the need for embedded training. A total of 129 respondents provided input. Results of the survey are presented later in this report. Finally, the RTG organized a session at the 2011 International Training and Education Conference (ITEC) during which they presented papers about the group's findings. Questions from the audience and a discussion followed.

The remainder of this report presents the findings of RTG-165, followed by recommendations addressed to NATO and allied Nations regarding requirements, human interfaces, technologies, training management and mission-support capabilities, training applications and other potential uses, and the maturity of intelligent agents and their role in EVS.

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Chapter 2 – OPERATIONAL USER REQUIREMENTS FOR EMBEDDED TRAINING

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1.0 INTRODUCTION

1.1 What are the User Benefits of Embedded Training?

Extended periods of force deployment to international theatres of war limits the access of warfighters to the resources required for training. This particularly affects continuation training, including proficiency training, refresher training, mission-qualification training, and mission rehearsal.

The possibility to perform ET exercises during deployment, just in time for the warfighters to gain or refresh expertise for the actual mission tasks, would increase the combat readiness of the force. The latter advantage is not to be underestimated in an era of shrinking defense budgets and an increasing Operations Tempo (Ops Tempo), with frequent out-of-area deployments and reduced opportunity for training in the homeland. In addition, when training in the homeland, ET would also increase the efficiency of training, likely with reduced environmental impact (noise and emissions), when compared with traditional 'live' training exercises with operational equipment.

At the unit or squadron level, ET enables training of the full mission cycle, on a day-to-day basis, with more realism than with conventional training equipment or operational equipment without EVS. ET reduces the need of mimicking adversary assets with 'role playing' live assets, and reduces the high costs for equipment, logistics, planning and personnel imposed by the use of instrumented ranges.

1.2 Who are the Operational Users?

The operational users addressed in the title of this paper are the individual warfighters, who are informally referred to as 'trainees' in this paper[1]. However, supervisors, instructors, and other personnel involved in training are also considered as users of ET and EVS.

At the level of these end-users, ET may provide a high-fidelity tactical training and rehearsal environment. This potentially includes challenging training scenarios, with an optimal number of learning events, and threat training anywhere and at any time, which would significantly increase the effectiveness of training hours for the trainees.

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[1] While these warfighters may not be trainees in the formal schoolhouse sense, when they are receiving embedded training in the field they are trainees for that short period.

However, when considering EVS as a training medium, it is legitimate to pose questions such as:

- Which tasks can be trained with ET and how does this training fit in with other training activities at the level of the individual operator, team and unit?
- What transfer-of-training can be expected from ET when the trainees are exposed to actual battlefield conditions?
- Are there elements in ET that carry the risk of negative training?
- What are the current limitations of ET?

1.3 How to Define User Requirements for ET?

Identification of the need for ET, the design and implementation of a training program with ET, and the selection and specification of the EVS may be supported by a form of training analysis methodology. Various general methodologies have been proposed in literature, and some of these have been devised specifically for simulator-based training. An example is the MASTER training design methodology (Farmer, van Rooij, Riemersma, Jorna, & Moraal, 1999). For the analysis of training requirements, such a methodology typically takes into account:

- Mission characteristics (mission systems, environment, mission demands and processes).
- Task analysis.
- Analysis of trainees/target groups.
- Training objectives.

However, since application of EVS is different from the use of traditional training media, training analysis methods such as MASTER may not be satisfactorily applicable to ET requirements. To take full advantage of ET, and related forms of training such as LVC, may require rethinking of our current approach to the training pipeline.

Also useful in this context is a publication by the U.S. Army (US Army Research Institute, 1996) that provides guidance for ‘early embedded training decisions’. These guidelines are for decision makers at both operational-system and training-system levels. One of the obstacles for effective implementation of ET is that multiple key decision makers are involved for ET. In the traditional defense organization, the acquisition and exploitation of weapon systems are separate from those of training systems. The different key decision-makers have different responsibilities and priorities. Contrary to decision making that deals with separate training systems and weapon system, ET and EVS require that the priorities of both the operational and the training decision makers and their communities to be reconciled.

Finally, since the acquisition of EVS integrated on operational equipment deals primarily with the operational equipment and only secondarily with the EVS, the training requirements may be partly derived through use of a requirements analysis that is utilized in systems-engineering management. (see, for example, System Engineering fundamentals, U.S. DoD, 2001, Chapter 4).

The importance of defining user requirements is fundamental to the success of ET. Although this may often appear to be stating the obvious to the practitioner, the user requirements are the basis for a production or delivery contract, and user requirements that have not been made explicit are unlikely to appear in the end product.

In this paper, requirements are discussed in terms of supposed need, not solution. These user requirements should nevertheless be achievable, consistent with other requirements at the user level. For the purposes of this paper, we make an attempt to classify military user requirements under three headings: (1) user interaction requirements; (2) training management requirements; and (3) affordability requirements.

2.0 USER INTERACTION REQUIREMENTS

Under ‘user interaction requirements’, five classes of lower-level user requirements for ET are subsumed. These are:

- The required level of realism of the training environment, e.g., in terms of visual cues, motion cues, aural cues, etc.
- The level of sophistication of other entities (i.e., other than the human operators) that are required to constitute an effective training scenario. In most training scenarios, synthetic entities, e.g., entities representing the enemy, must be included in the scenario to create meaningful learning events. The constituting models of, for example, weapons, behaviours and effects, need to have an adequate level of realism.
- When the ET is meant for the training of teams, the EVS should support communication and coordination between team members.
- The EVS should be user friendly.
- ET and interactions with the EVS should be safe to use.

The authors devised this simple classification for the current purposes only, based on experience and without attempting to provide a scientific justification. The fulfilment of these user interaction requirements are thought to contribute to the trust the user will have in the EVS. If the training environment lacks an adequate level of realism, despite the use of operational equipment, end-users will judge an ET to compromise live-training opportunities and hence their operational readiness. The trust in the EVS and the assessment that the ET positively contributes to operational readiness will strongly determine the acceptance of ET by the end-user community.

2.1 Realism of the Perceived Environment

When discussing the value of any training, a key issue is how well the training *transfers* to the tasks that the warfighter/trainee must perform during an actual mission. In this case, transfer of training is defined as the degree to which trainees are able to apply the competencies they gained in training to the real mission. Much has been written on the concept of transfer applied to simulator-based training (see, for example, de Fontenilles et al., 1996).

The main hypothesis underlying the need for realism in training is that the trainee’s performance and the processes involved in training and transfer are largely linked to the similarity between the tasks s/he has to perform during training (i.e., task A) and the tasks s/he has to perform in the real mission (i.e., task B).

This implies that A and B share a set of common characteristics and properties. ET exploits this fundamental point by using operational equipment, preferably in an environment that is similar to the operational environment, such that transfer from the training tasks (A) to the operational tasks (B) is facilitated. This, in turn, implies that requirements, with respect to realism, depend on specific operational tasks for which the training is intended. The behaviour to perform such tasks should be expressed in learning objectives, stating the competence and performance requirements that trainees should exhibit at significant points of the training, e.g., after each exercise. This further implies that an environment in which a full mission needs to be mastered generally needs more realism than an environment in which only the control of a piece of equipment needs to be mastered.

Requirements that relate to realism of the perceived environment may be subdivided according to the modalities in which the environment is perceived by the trainee:

- Perception of self-motion (via vestibular, visual, tactile, proprioceptive and/or kinaesthetic senses) may be the result of: (1) the trainee’s control of the operational equipment; or (2) external disturbances.

- Perception of the visual world around the trainee requires a specific image quality and content, and a certain legibility of visual cues, such as visual targets. Roessingh, Sijll and Johnson (2003) analyse these requirements for EVS onboard fighter aircraft.
- Perception of self-motion and perception of the visual world are interdependent, and when simulation is involved in the perception of both, specific design measures may be needed to prevent 'simulator sickness'.
- In reality, sound may be generated by the operational equipment itself or may originate in the environment. The recreation of (elements of) a realistic audible environment may be required in ET.

The reader is referred to Fontenilles et al. (1996), which provides an extensive review of perception in simulator-based training and related physical system parameters. However, the document by Fontenilles et al. does not cover the specific requirements that may be imposed on ET.

While legacy training simulators may be based on application of virtual reality techniques, EVS will more often rely on the application of *augmented* reality techniques to provide a live direct or an indirect view of the physical, real-world environment whose elements are augmented by computer-generated sensory input, such as sound or graphics. Magee, Sottilare, and Roessingh (2011) provide a short paper with a discussion of the relevance of the aforementioned factors for ET.

2.2 Realistic Behaviour of Synthetic Players

Intelligent CGFs or Non-Player Characters (NPCs) represent real people or weapon systems, including their behaviors and cognitive states (e.g., decision-making capabilities). CGFs are fully automated representations of friends, adversaries, or neutral 'characters'. Just like requirements for perceived realism, user requirements related to CGFs need to be primarily driven by training objectives.

Examples of user requirements may be:

- The inclusion of CGFs in EVS shall enable trainees to learn from opponent tactics to benefit their own tactical behaviour.
- The behaviour of CGFs in a training scenario shall be autonomous and goal-directed, using plans.
- Behaviour of CGFs shall be affected by their 'cognitive state', which takes into account, for example, decision-making ability, level of expertise, mental workload, situational awareness, and mental fatigue.

The first implementations of CGFs for fighter aircraft (for the F-16 aircraft, see Krijn & Wedzinga, 2004, and for the F-35 aircraft, see Bills et al., 2010) concerned two types of CGFs: adversary aircraft and adversary ground threats in the form of Surface-to-Air-Missiles (SAMs). The first generation of adversary aircraft CGFs is further characterized by their lack of visual features. These CGFs will never enter the visual range of the pilot during an EVS scenario. Hence, the training application of those adversary aircraft NPCs is limited to so-called Beyond Visual Range (BVR) scenarios. As a result, their behaviour will be observable only via cockpit instrument displays of onboard sensors (radar, radar warning receiver, possibly infra-red sensors). The behaviour that these NPCs must demonstrate needs to be realistic only insofar as being observable via those instrument displays in the EVS-equipped aircraft.

Most behaviour of CGFs in EVS will be far from trivial. For example, real enemies are, at least to some extent, unpredictable. They seek to maneuver themselves into a better position as the tactical situation changes. They react to friend and foe. They are adaptable. In other words, they are smart. The smart element in the behaviour of these virtual opponents involves a number of factors. For instance, they should be able to detect and identify targets to attack, but should also be capable of defending themselves against enemy action. To reach the level of proficient behaviour, intelligent CGFs could be ‘trained’, using machine learning algorithms, to instill the expertise that meets the requirements of the scenarios and the live participants. Harrison et al. (2010) propose genetic programming to train NPCs for EVS. However, the maturity level of machine learning applications for EVS has not been demonstrated as yet. Sottilare and Roessingh (2011) describe the application of intelligent agents in EVS.

2.3 Team Training

Many weapons platforms are operated by teams, and platforms operate with other platforms in many missions. Obviously, team training is an important area of application for EVS. Human interface requirements need to allow coordination among team members and platforms. This may require dedicated communication channels. The use of EVS for team training could promote unity in operational procedures and doctrines, and help train effective communication techniques. Training scenarios could be based, inter alia, on actual battlefield incidents involving factors related to teamwork.

2.4 Usability

Usability concerns the ease of use and learnability of the EVS. To determine user requirements for usability, it should be noted that there are tools for usability methods (design and testing). Shneiderman (1980) and Nielsen (1994) developed frameworks of system acceptability, in which usability was considered through the issues listed in Table 2-1:

Table 2-1: Usability Issues.

Usability Issue	Related test question
Learnability	How easy is it for users (trainees, supervisors, instructors) to operate the EVS when they use it for the first time?
Efficiency:	Once users have learned to work with the EVS, how quickly can they perform the tasks to operate it?
Memorability	When users return to the EVS after a period of not using it, how easily can they re-establish proficiency?
Errors	How many errors do users of the EVS make, how severe are these errors, and how easily can they recover from the errors?
Satisfaction	How pleasant is it to operate the EVS?

An ISO standard for usability is ISO/TR 16982:2002: *Ergonomics of human-system interaction—Usability methods supporting human-centered design*, which provides information on human-centred usability methods that can be used for design and testing. Examples of usability requirements for EVS are:

- In deployed conditions, (re-)configuration of the operational equipment from ‘training mode’ to ‘operational mode’ or ‘war mode’ shall be quick and easy.
- The logic behind operation of the EVS by the trainee (starting, stopping, switching between modes, switching between exercises) should be transparent for the trainees, with appropriate feedback on system status, minimizing the possibility for error.

- The EVS should support the use of training data by instructors for de/briefing and after-action review.
- If multiple EVS-equipped platforms are used for team training, establishing communication links and synchronization of the different simulations shall proceed automatically.

2.5 Safety

ET is based on the use of operational equipment. In the ‘training mode’, the trainee is supposed to act upon this operational equipment as if it were in a real mission or (combat) operation. In some ET applications for infantry fighting vehicles or tanks with on-board EVS, these vehicles would not be able to move when in training mode, because it would be unsafe to do so (e.g., ET for the PUMA infantry vehicle, see Schmidt, 2009).

The trainee, who is immersed in an embedded training scenario, will build Situation Awareness (SA) on the training situation, with augmented reality. This likely implies that the trainees’ SA on the actual state of the equipment and its environment is diminished.

Safety measures need to be installed such that the trainee can quickly recover its SA on the actual situation, when the situation requires. For example, in the case of EVS on-board fighter aircraft, a ‘safety guarding system’ should monitor that an aircraft remains in a temporary reserved airspace during the training. Such system may also provide a warning when loss of separation with other (real) aircraft or terrain is imminent. In an overview of the use of embedded training for the F-35, Bills, Flachsbart, Kern & Olsen (2010) emphasized safety of flight as a consideration within and following the ‘training’ mode.

Since the radar display in the cockpit of an EVS-equipped aircraft can contain both real and virtual information at the same time, trainees should always be aware which information is real and which is virtual. This helps them to make the appropriate trade-offs and decisions during the training scenario. It may not desirable to perform a potentially unsafe maneuvers or actions in response to a virtual entity in a training scenario, while such maneuver would be totally justified in an operational situation. A potential implementation for symbols on a display is to mark the virtual entities with a supplementary tag. In the fighter aircraft EVS that was used by the Royal Netherlands Air Force (RNLAF), this was accomplished by attaching a small ‘v’ to each virtual symbol on all displays where they could appear. Naturally such information should be designed carefully in order to guarantee positive transfer of training. Another effective strategy in the design of displays is to give symbols related to real entities a higher display priority. This way, symbols related to virtual entities do never obscure those related to real entities.

Other safety requirements may be associated with additional hardware that is attached to the operational equipment. For example, if a pilot helmet is modified to allow for projection of virtual targets on the see-through visor (augmented reality), this should not compromise pilot safety in terms of head movements, eye sight, crash survivability, high-g resistance, ejection safety, etc. For ET for the F-35, Bills et al. (2010) describe that software for ET would be partitioned from aircraft flight software to prevent interference with critical aircraft systems. Virtual weapon loads and responses would be partitioned from onboard weapon control. Accidental releases of real bombs would be inhibited by simulating all weapon employments onboard the aircraft while in training mode. Actual weapon releases would be prohibited in training mode and allowed only in the ‘live’ mode with ET off.

Each implementation of EVS is likely to bear its particular safety issues. In many cases, the development of a safety case or the execution of a risk analysis (e.g., STANAG 4404, US DOD. MIL-STD-882D) will be an obligatory item.

3.0 TRAINING MANAGEMENT REQUIREMENTS

Training management is the continuous process at an operational unit, to develop, implement, deliver, evaluate and improve training programs. The goal of training management is to optimize the available resources, materials, guidance, and time to meet specific training requirements. Relevant functions of training management for ET are identification of training needs, design of ET scenarios and planning of ET exercises, managing briefing, after-action review, data collection and training evaluation (Andrews and Roessingh, 2011).

3.1 Management of Training Scenarios

Cannon-Bowers (2010) argues that ET is, in fact, scenario-based, and the supposed training value is based on realistic scenarios as an effective means to accelerate the development expertise. Cannon-Bowers emphasizes that much of the instructional power of ET is actually attributable to the nature of the scenario that is expressed in the simulated environment. Hence it is imperative to understand how to design and implement effective scenarios as a means to optimize scenario-based training. Some user requirements related to the management of training scenarios are:

- The EVS should be able to run scenarios that address specific learning objectives, in accordance with the full set of learning objectives for ET.
- It should be possible to script events or ‘triggers’ in the scenario that allow the trainee to practice the targeted learning objectives (see, for example, Fowlkes, Dwyer, Oser & Salas, 1998).
- The EVS should support the execution of newly created scenarios. It should be possible to create these scenarios with a commonly accepted scenario management software package.
- The EVS should support maintenance, update and modification of existing scenarios.

3.2 Instruction and Feedback

Feedback is an essential element in ET, as it is in all forms of training. Feedback must be concise if it is to be useful in the field. Generally, the number of feedback items should be kept to a minimum if trainees and supervisors are to make use of them on a regular basis. The number of feedback items should be kept to no more than a dozen, less if possible (Andrews & Roessingh, 2011). Different requirements for providing training feedback to the users of ET are possible, depending on the specific application and implementation:

- The EVS may provide feedback to trainees and/or other personnel (instructors, supervisors) via the original displays of the operational equipment. In some applications, it may be required to provide the same information via multiple on-board displays so that supervisors and trainees can view the feedback at the same time for discussion purposes.
- Feedback information may be carried from the operational equipment to an off-board system (e.g., via a data link or manually), such that the supervisor can review performance for an entire team with the team that has trained on multiple weapon systems (a tank platoon, multiple aircraft involved in an air campaign). Alternatively, the team can review their performance without a supervisor present.
- Feedback may be provided to the trainee without involvement of an instructor or supervisor, i.e., fully automatic. In such case, the EVS may merely provide the instructor or supervisor a summation of performance. Alternatively, the EVS can be designed such that all feedback will be provided to the instructor or supervisor and he/she provides the feedback to the trainee. Generally, feedback via an instructor or supervisor may be more desirable in initial stages of training, while instructor involvement may not be required for mission rehearsal under deployed conditions.
- Feedback should be provided in a timely fashion, as this can greatly aid the training process.

- This doesn’t mean that all feedback information should be provided as quickly as possible. Provision of feedback for higher order cognitive skills like complex decision making is preferably delayed to facilitate learning retention.

3.3 Performance Evaluation

An important requirement for training management in EVS should be the precise detection and registration of the trainees’ level of expertise such that subsequent ET sessions and scenarios can be adapted to the appropriate level, yielding the highest training value. This also highlights the requirement that trainee performance during ET exercises should be carefully recorded for the purpose of selecting subsequent training activities.

3.4 Management of Training Sessions

ET may diminish the role of the human instructor because the operation equipment that hosts the EVS most often doesn’t provide physical space for a human instructor. An obvious way forward here, is the replacement of the instructor by an intelligent tutoring system (see e.g., Sottilare, 2010, Jensen, Mosley, Sanders & Sims, 2010).

At a meta-instruction level, the training sessions could be managed by a Learning Management System (LMS) which (1) keeps record of exposure to specific training events (counting), (2) schedules trainee events in order to optimize the learning process, (3) performs scenario configuration management (which scenarios are updated and ready for use), and (4) performs continuing trainee profiling on the basis of performance measures. A possible user requirement is to provide a coupling between the EVS and these (off-board) LMS functions.

4.0 AFFORDABILITY

The decision to introduce ET in the military organization will be largely based on projected cost savings while combat effectiveness need to be maintained or increased, in other words, making training more affordable. It will routinely be required during an acquisition process to provide:

- an estimate of the value of the added capability of ET (in terms of an increased OPS-level).
- an estimate of the costs of ET.
- an estimate of the cost savings of ET relative to current training practice.
- a cost comparison between alternative training methods.

The aforementioned guide for early embedded training decisions by the US Army Research Institute (1996) provides a helpful worksheet to compare ET with: (1) training using just the operational equipment without EVS, and (2) training using stand-alone training devices. Four different cost categories are distinguished:

- Design and development costs.
- Procurement costs.
- Maintenance costs.
- Operations costs.

A thorough source for quantitative modeling of training costs is provided by Orlansky (1989), which provides useful indicators for training and cost effectiveness, including the Transfer Effectiveness Ratio (TER), the Training Cost Ratio (TCR), the Cost Effectiveness Ratio (CER) and the Simulator Utilization Ratio (SUR). If there are data on, or estimates of, cost and effectiveness for two methods of training, the decision diagram (Table 2-2) can be used to choose between them (Orlansky, 1989).

Table 2-2: Decision Diagram between Two Methods of Training.

	LESS EFFECTIVE	SAME	MORE EFFECTIVE
LESS COST	Uncertain	Adopt	Adopt
SAME COST	Reject	Uncertain	Adopt
MORE COST	Reject	Reject	Uncertain

More recently, cost-utility analysis (CUA), a form of economic analysis used to guide procurement decisions, has been introduced to evaluate the utility of training (e.g., Arthur et al, 2011).

A practical example of projected training savings with implementation of ET for the F-35 Joint Strike Fighter is shown in Table 2-3. ET is planned to be introduced in a specific training syllabus (see Bills et al., 2010):

'In terms of student costs, the projection reduction is 14 Red Air sorties [i.e., sorties with fighter aircraft that mimic the enemy's tactics], equivalent to 23.8 flight hours for $100k, and Surface to Air Missiles/Electronic Warfare range reductions of 7.2 hours for $25.5k. Looking at start up, calendar years 2015 through 2017, the projected cost avoidance is $411.5M. When the F-35 reaches steady state at calendar year 2030, the projected cost avoidance is $1,046M. Over the expected life cycle of calendar years 2013 through 2057, the program savings could reach $2,976M.'

Table 2-3: F-35 Embedded Training Cost Avoidance Implementing Activity Model (taken from Bills et al., 2010).

	($M)	Air to Air	Air to Ground	Total
Start Up	CY15	$67.6	$21.6	$89.2
	CY16	$103.3	$30.8	$134.1
	CY17	$146.5	$41.7	$188.2
Steady State	CY30	$775.5	$270.5	$1,046.0
Life Cycle	CY13-57	$2,370.0	$606.0	$2,976.0

It is important to balance all advantages and disadvantages of ET in a cost analysis. By properly defining requirements, advantages of ET can be exploited to the maximum while disadvantages can be minimized or avoided. Several examples of advantages are listed below. (Finly, Alderman, Peckham & Strasel, 1988; Bills et al, 2010; Roessingh & Verhaaf, 2010):

- The capability to provide training (e.g., refresher, sustainment, proficiency, continuation and mission qualification training) that is resident in the operational unit, also during extended periods of weapon platform deployment to international theaters of war.
- ET is fielded and maintained concurrent with the operational equipment.

- There is a reduced need for other training equipment (simulators, trainers) with potential cost savings in procurement, maintenance, infrastructure and operation of this equipment.
- ET reduces wear and tear on operational equipment, thereby decreasing maintenance costs and manpower requirements, e.g., in the case of the F-35, ET eliminates the need to carry actual weapons during a training mission.
- ET reduces the number of ‘live assets’ required for role-playing (e.g., mock enemies) by using constructive entities.
- There is reduced need to use large instrumented training ranges. For example, highly realistic day-to-day fighter pilot training for RNLAF pilots could take place in reserved airspace above the North Sea. Through the use of virtual enemy aircraft the required airspace for air-air engagements is further reduced. Apart from logistic advantages, this results in abatement of noise and emission.
- There are various options to reduce the training management burden at the operational unit (for example, the EVS provides training capability when an instructor is not present or readily available, see Section 3.0).
- Training is standardized across operational units.
- As a by-product, high quality job-aids for the system could be developed easily from the ET materials.

Also, potential disadvantages must be taken into account, for example:

- Costs associated with the operational equipment will increase with EVS.
- The operational equipment is required in order to conduct training[2]. Additional systems may be required solely for the purposes of providing training.
- Components of the EVS may need to be hardened or ruggedized, and therefore may be more expensive than they would need to be when used in conventional training.
- ET may cause additional wear and tear on components of the operational equipment.
- ET may not be available in the initial phase of deployment/mobilization, particularly if personnel and equipment are transported separately.
- EVS components may take up space and add weight to the operational equipment.

Bills et al. (2010) further argue that current experience with and research into ET is still too sparse for a conclusive analysis for training effectiveness and efficiency.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This paper provided an overview of possible user requirements for ET. A thorough analysis of the operational user requirements is needed to realize the numerous advantages of ET. This includes training needs analysis providing a set of training objectives for the ET, requirements analysis and cost analysis. Operational user requirements have been classified in three categories: user interaction, training management, and affordability.

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[2] However, ET may also be integrated in training equipment, e.g., training aircraft. In the EUCLID (European Collaboration for Long term in Defence) RTP 11.12 program, ET was integrated in the Aermacchi MB 339 training aircraft in 2003.

User Interaction

User interaction requirements include realism of the perceived environment, realism of (intelligent) CGFs, team training requirements, usability requirements and safety requirements.

The required realism in terms of perceived self-motion, the visual and audible environment, etc. will strongly depend on the training objectives. Some training objectives may require solutions that are not yet available in current EVS designs. Augmented reality is a key technology. Conflicts between visual cues and/or vehicle movement must be avoided to prevent simulator sickness.

The realistic behaviour of synthetic players or CGFs will often be a strong user requirement. Required flexibility in scenarios will require, for example, the behaviour of enemies to be ‘smart’, i.e., intelligent and autonomous. For team training, coordination and communication among team members and platforms will be required, possibly using dedicated data links. Usability aspects of the EVS concern operation by trainees and instructors and re-configuration of the platform. Main safety concern is the recovery of situation awareness from the training situation to ‘real life’, for example in case of emergencies or unusual situations.

Training Management

The position of ET in the training program, like any other type of training, should optimize the learning curve towards the required mission competencies. This requires an analysis of training objectives to which it could contribute, given the full range of operational tasks. The notion that ET is ‘scenario-based training’ requires that an instructor or scenario manager can create, update and modify meaningful scenarios. Further training management requirements relate to feedback, performance evaluation and the diminished role of the instructor.

Affordability

ET should result in cost savings while combat effectiveness need to be maintained or increased. It is important to balance all advantages and disadvantages of ET in a cost analysis. The lessons learned from the last two decades are that those responsible for Defence budget cuts have a tendency to choose for combat capabilities at the expense of training. Although the consideration of training as a closing entry at the bottom of the list is comprehensible, it doesn’t seem logical. A very substantial part of combat-effectiveness is attributable to the quality of the training and the combat readiness of the warfighter.

Recommendations for Research & Development

There is generally a lack of research results on the training effectiveness and efficiency of ET. The critical components of the EVS and the training design that is most suitable for ET are largely unknown. A training design methodology that is used for the development of training should explicitly consider ET and EVS as options. In current ET applications, training management methods and techniques often seem to be neglected.

Important techniques that are likely to be required in many ET applications are: (1) visualization of virtual entities in augmented reality; (2) intelligent CGFs; (3) intelligent tutoring; and (4) data links for ET (e.g., for team communication and team coordination in case of team training, scenario manipulation, feedback, interventions by instructors, etc.).

Other areas for R&D are: cost models for ET, safety and regulatory aspects of ET, and certification of EVS equipment.

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Chapter 3 – RESULTS OF THE EMBEDDED VIRTUAL SIMULATION USER SURVEY

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1.0 INTRODUCTION

The members of the NATO Human Factors and Medicine Panel – Research Task Group (NATO HFM-RTG-165) developed a survey to learn more about the military population that have used and might be using Embedded Virtual Simulation (EVS) technologies in the future. Comprised of twenty questions, the survey also served to ascertain the level of awareness of EVS in the military population and their opinions of current embedded training capabilities in theatres of war. The questions included in the survey are attached as an annex to this chapter. This chapter summarizes the survey data to provide insight into the potential of EVS. Recommendations are also provided for the practical implementation and deployment of future EVS based on the survey data.

EVS is anticipated to be deployed as a tool to support future embedded training in theatres of war. EVS is considered the enabling technology and embedded training is the capability available to military users. Since our focus is on user opinions and their view is less on the technology (EVS) and more on the capability (embedded training), we have opted to use the term ‘embedded training’ when referring to user opinions and EVS when discussing the enabling technology.

Embedded training concepts have been around for over 30 years, but have not grown to meet those early expectations to support ‘training on the move’ or ‘training in deployed locations’. The motivation for the survey described in this chapter was to learn what users think about embedded training, their level of exposure to EVS technologies, and current use in theaters of war today.

To gather information about the users’ exposure to and opinions on embedded training, the Panel developed a survey for anonymous input by the military members through ‘Survey Monkey’ where data was collected and analyzed. The questions detailed in the survey are attached as an appendix. This chapter serves to describe the survey participants (potential embedded training users), their knowledge and use of training in theater, and their opinions about embedded training in general.

2.0 USER PROFILE SURVEY RESULTS

The intended population for this survey was a NATO military population with a normalized distribution across various ranks (enlisted and officer), services (e.g., Army, Navy and Air Force) and operational occupational series. The actual sample distribution (N = 129 participants) was much different from expectations, with a high concentration of Army participation (93 percent), low participation from Air Force personnel (6 percent) and no participation from Naval (0 percent) personnel, including Marines. It is expected that additional participation from naval personnel would positively influence the statistics described in this chapter.

There was some international sensitivity about collecting data about the participants' countries and their ranks, but the survey did classify participants as Enlisted (77 percent), Officer (19 percent) and unknown (4 percent). Their occupational series varied from combat to combat services to combat series support. Participants classified their competency levels in their occupational specialties as novice (13 percent), journeyman (33 percent) or expert (54 percent), demonstrating a high level of training/experience across the survey sample. Training was reported by 74 percent of the participants as an important part of their pre-deployment preparation. As noted in Figure 3-1, over 73 percent of the participants noted that they had been deployed to a theater of war within the last two years. This lends credibility to their opinions regarding the frequency and effectiveness of training in theater and the potential need for embedded training options.

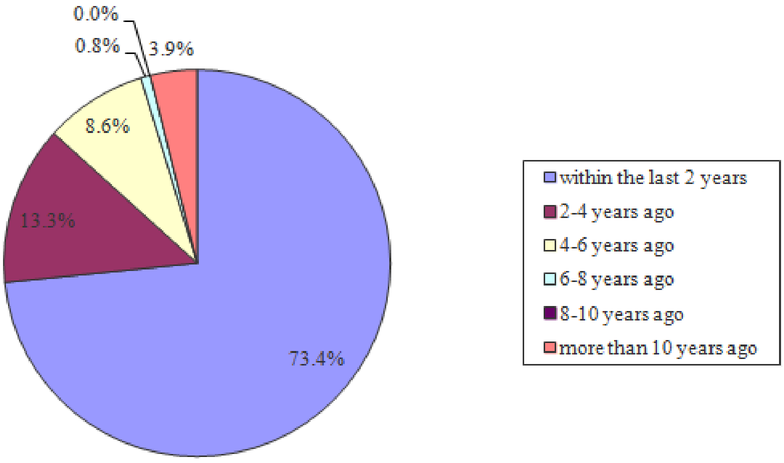

Figure 3-1: Last Deployment to a Theater of War.

When asked about how effectively they were prepared to carry out their specialty duties when they arrived in theater, participants reported they were well prepared (mean = 6.36 on a 7 point Likert scale where 7 was defined as fully prepared). The distribution of preparation effectiveness scores is shown in Figure 3-2. This distribution shows 89.8 percent of the participants felt they were at least moderately prepared and over 31 percent felt they were fully prepared to execute their duties.

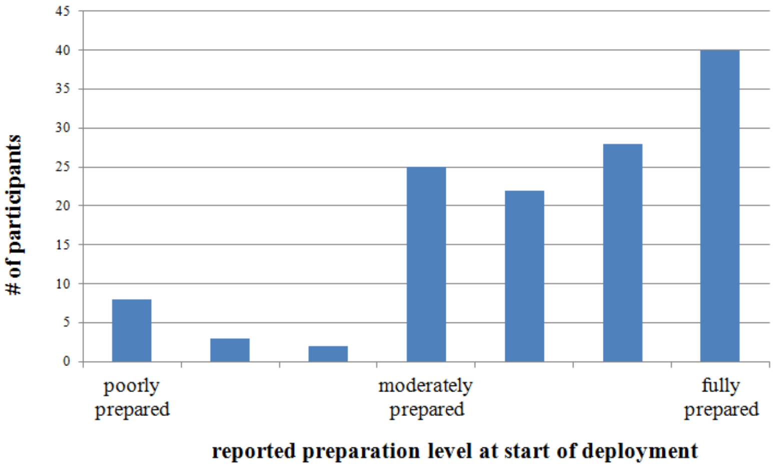

Figure 3-2: Preparation Level of Participants.

When asked about their frequency of training in theater, 72.4 percent reported that they trained daily in their specialty areas, and an additional 12.6 percent indicated that they trained at least weekly. Over 83 percent of the participants indicated that their frequency of training while deployed was adequate to maintain competency in their occupational specialties. The combination of reported preparation and frequency of training in theater indicate participants were ready to do their assigned duties, and continued to maintain a high level of proficiency through frequent training. The survey data does not indicate the costs of deploying this training capability, nor does it indicate its level of effectiveness.

When asked about the type of training in which they participated, 61 percent of the respondents participated in live training only, 6 percent participated in computer-based/simulator-based training only, and 31 percent reported that they participated in both live and computer-based/simulator-based training exercises. This may be indicative of low availability of computers/simulators for training in theater. If this is true, consideration should be given to enhance the availability of computer-based/simulator-based training in theater to maintain skills and to train for missions that might otherwise not be practical/safe in a live training environment. Embedded training solutions are a viable alternative to deploying a separate simulator infrastructure.

3.0 EMBEDDED TRAINING SURVEY RESULTS

The participants were asked if they had any type of embedded training capability available while deployed; 77 percent responded ‘no’ and only 23 percent responded ‘yes’. When the 23 percent who reported that embedded training was available were asked if they used the embedded training, 59.5 percent of the 23percent said ‘yes’ and 40.5 percent said ‘no’. This group of embedded training users translates to only approximately 14 percent of the total survey participants.

In the embedded training user group, the type of embedded training available used in theater included individual only (21 percent), collective only (58 percent) and both (21 percent). The participants rated the usefulness of the embedded training they used in theater as highly useful (mean = 6.32 on a 7 point Likert scale where 7 was defined as very useful). The distribution of usefulness scores is shown in Figure 3-3. The data shows that over 86 percent of the participants rated the embedded training they used as at least moderately useful. Given the experience level and recent deployments of the participants, the usefulness data indicates that embedded training solutions would be a welcome addition to the training regimen in theaters of war.

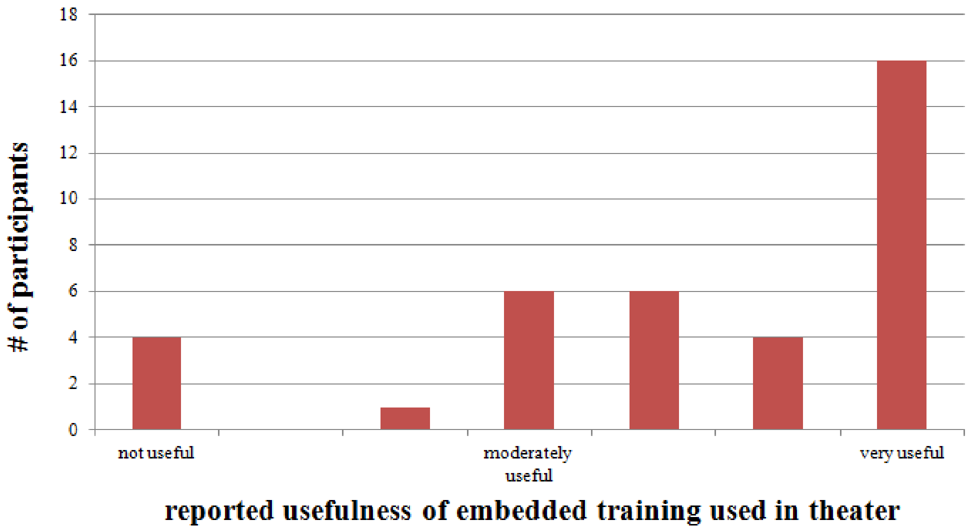

Figure 3-3: Usefulness of Embedded Training in Theaters of War.

4.0 DISCUSSION

The most glaring facts uncovered during this study were the current lack of embedded training solutions for use in theater, and the high level of understanding of what embedded training was and how it could help. Only 23 percent of survey participants had access to embedded training capabilities during deployment, yet the same group was able to provide relevant recommendations about the relevant features they expected to see in an embedded training solution. Most respondents noted that a realistic environment was important in simulating the stress of the operational environment, and many included automation as an important feature of an embedded training environment. Automation included capabilities that respondents described as automated data collection, intelligent tutoring systems, automated After Action Review systems (AARs), and virtual non-player characters to represent the roles of non-trainee participants.

Even those with little or no exposure to embedded training shared positive thoughts on how embedded training might be used. Some quotes are included below:

- ‘If all units were equipped with embedded training, it might make it easier for those who are ‘disconnected’ due to location, to stay current, or get more up to date information/training while deployed in remote areas.’
- ‘Although I have no experience with it, I think embedded virtual training is an excellent concept and very useful for increasing experience in combat related situations.’
- ‘It is much better to use pre-deployment training – you MUST arrive ready for war, but In-theater training (embedded) could be used for currency, trying new tactics, etc.’
- ‘Although my experience is a bit dated, embedded training would allow more realistic scenarios.’
- ‘Stress is the key. Simulators can be used for training tactics, but proximity to another aircraft, actual shaking and immense ground rush cannot be simulated. You only get that in the aircraft.’

5.0 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

As noted in the introduction, embedded training concepts have been in use for over 30 years, but are not the ubiquitous training solution envisioned. The low percentage of embedded training users (14 percent) in our survey results can be attributed to the low availability of embedded training systems and direct competition with existing training programs in theater. Based on the survey results, it was obvious that exposure to embedded training concepts was low.

Still, our survey hints at the utility of embedded training. Those in the survey who used embedded training were overwhelmingly positive with over 86 percent of users rating their training at least moderately useful and over 43 percent rating their training very useful.

The practicality and utility of embedded training concepts have yet to be exploited on a large scale. It will be important moving forward to share the results of this survey and to provide success stories on the deployment of embedded training solutions to educate users, developers and policy makers about the usefulness of embedded training capabilities.

5.1 Acknowlegments

The HFM-RTG-165 membership extends their thanks to Dr. Paul Roman for his efforts in supporting this study.

5.2 APPENDIX A

Embedded virtual simulation survey

1) Are you now or have you been a member of the: Army, Navy, Air Force, Marine Corps, Other?

2) Have you been deployed to Afghanistan or similar areas:
   a) within the last 2 years
   b) 2-4 years ago
   c) 4-6 years ago
   d) 6-8 years ago
   e) 8-10 years ago
   f) more than 10 years ago

3) What was your specialty or your job duties while deployed?

4) While deployed, did you consider yourself (select one):
   a) a novice in your specialty?
   b) a journeyman in your specialty?
   c) an expert in your specialty?

5) How did you prepare for your individual duties within your specialty before you were deployed?

6) How did your unit/collective/team prepare for your missions before you were deployed?

7) How well prepared for your duties do you feel you were when you arrived in theatre?

8) In theatre, how often did you perform tasks relevant to the specialty you trained for?

9) Were you able to do any training while in theatre?

10) What did the training consist of? Please elaborate (e.g., computer-based, simulator-based, live training).

11) How frequently were you able to train in theater? Daily? Weekly? Monthly? Hardly ever?

12) Did you feel the frequency of training was adequate?

13) Did you feel the quality of the training was adequate?

14) Did your military equipment have any type of embedded training capability?

15) Did you use this embedded training capability in theater?

16) On a scale of 1 (not useful) to 7 (very useful), please rate the usefulness of the embedded training capability you used in theater.

17) Do you think that an embedded training capability is needed to train your specialty in theater?

18) In your opinion, which capabilities/features need to be included in embedded training systems to be worthwhile as training tools? (e.g., realistic environment, simulation of stress, intelligent tutors, automated after action review, mission editor.)

19) If you had embedded training in theatre, how do you think it should be used? For example, should it be used just before doing an actual mission, for refresher training, individual training, collective training, or other?

20) Are there any other thoughts on the topic you would care to share with us?

Chapter 4 – TRAINING MANAGEMENT IN EMBEDDED VIRTUAL SIMULATIONS

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1.0 INTRODUCTION

1.1 The Relevance of Training Management for EVS

Training management is the continuous process in an organization, e.g., an operational unit, to develop, implement, deliver, evaluate and improve training programs. The goal of training management is to optimize the available resources, materials, guidance, and time to meet specific training requirements. Relevant functions of training management for EVS are for example:

- Defining Training Needs: define specific competency needs, in first instance for trainees, but also for related personnel such as senior personnel overlooking the EVS exercises and staff that prepares the EVS scenarios, identify training exercises which address these needs.
- Designing and planning of EVS exercises, including facilitating of mission planning, careful consideration of training objectives and instructional strategies, planning of briefing and debriefing, planning of data collection.
- Training Implementation, including management of EVS related materials, scenarios, instrumentation and other resources.
- Training Evaluation: course, instructor, and trainee evaluation including analysis and reporting.
- Safeguarding: making the necessary safety provisions for the execution of EVS, including sufficiently clearing the environment in which ET exercises are carried out from safety threats and ensuring safe transitions between ‘training mode’ and normal ‘operational mode’ and vice versa.

For the purposes of this paper, the authors do not distinguish between the term ‘training management’ and the term ‘learning management’. However, the term learning management is more commonly associated with the term ‘learning management system’ or ‘learning content management system’. These terms are restricted to software applications which are mostly used for a limited set of management tasks related to on-line training; e-learning programs and/or computer based training programs. Since this paper deals with management of EVS based learning and Embedded Training in a broader sense, the term training management will be used.

Cannon-Bowers (2010) argues that Embedded Training (i.e., training enabled through EVS) is in fact scenario-based, and the supposed training value is based on realistic scenarios as an effective means to accelerate the development expertise. An important training management task in such training is to record trainee performance and use that information to guide future training exercises. However, Cannon-Bowers contends that in the operational environments in which ET is intended to be used, this management task is often accomplished informally, rendering subsequent training sessions less effective than they could be. An important requirement for training management in EVS should therefore be the precise detection and registration of the trainees' level of expertise such that subsequent ET sessions and scenarios can be adapted to the appropriate level, yielding the highest training value. This also highlights the requirement that trainee performance during ET exercises should be carefully recorded for the purpose of selecting subsequent training activities.

1.2 Senior Personnel Functions and Required Competencies in Managing an Embedded Training Environment

Because the EVS is embedded in - or appended to - real equipment (e.g., to an aircraft, a ship or a vehicle), ET typically does not have a human instructor in the classical sense. The instructor function in virtually-based ET is most often performed by an embedded instructor which resides in software. In some cases there is no instructor function and the trainee1 must learn from whatever feedback the ET provides in an unorganized manner. In those cases the trainees must function as their own instructor. In most cases, while there is not a human instructor in the traditional sense in ET, there will need to be a senior person who can perform some of the training management functions a traditional instructor would perform.

1.3 Instructor Function Competencies

The International Board of Standards for Training, Performance and Instruction (IBSTPI) has established standards that are useful in determining how senior personnel can best interact with EVS. They have described competencies necessary for instructors, training managers and training evaluators. (IBSTPI, 2010). A supervisor with warfighters using ET might have to perform some, or all of the following competencies depending upon the sophistication of the EVS being used. In Table 4-1 to Table 4-3, a sub-set of IBSTPI competencies are listed that apply to the training management functions that will have to be addressed in any embedded training system, either by the automatic system or the supervisor of the warfighter receiving training.

Table 4-1: Instructor Competencies (IBSTPI, 2010).

Competency	**Behavior**
Communicate effectively. Planning and Preparation	Prepare for instruction. The supervisor might need to show the trainee how to use the ET
Instructional Methods and Strategies	Stimulate and sustain learner motivation and engagement Demonstrate effective presentation skills Demonstrate effective facilitation skills Demonstrate effective questioning skills Provide clarification and feedback Promote retention of knowledge and skills Promote transfer of knowledge and skills
Assessment and Evaluation	Assess learning and performance Evaluate instructional effectiveness
Management	Manage an environment that fosters learning and performance Manage the instructional process through the appropriate use of technology

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[1] While the term 'trainee' is used in this section, it should be construed to mean the actual Warfighter who is in the field or garrison. While these warfighters may not be trainees in the formal schoolhouse sense, when they are receiving embedded training in the field they are trainees for that short period.

Table 4-2: Training Manager Competencies (IBSTPI, 2010).

Competency	Behavior
Communicate effectively in visual, oral and written form	Maintain networks to advocate for and support the training function
Design and Development	Evaluate training and performance interventions
Assessment and Evaluation	Assess learning and performance Evaluate instructional effectiveness
Administration	Apply leadership skills to the training function Apply management skills to the training function

Table 4-3: Evaluator Competencies (IBSTPI, 2010).

Competency	Behavior
Communicate effectively in visual, oral and written form	
Implementing the Evaluation Plan	Collect data. The supervisor might be called upon to collect data, both analytical and empirical, for evaluators of the ET
Managing the Evaluation	- Monitor the management plan - Work effectively with personnel and stakeholders.

In addition to the IBSTPI-competencies, the supervisor might have to make use of the additional instructional/management functions. These functions are listed in Table 4-4.

Table 4-4: Additional Supervisor Competencies needed to Manage EVS.

Competency
Providing additional feedback from the training session, via a formal or informal After Action Review
Remediation prescriptions
Record keeping
Planning the training path forward for the trainee(s)
Reporting individual and aggregate progress up the chain of command\
Determining if the trainee(s) are ready for operations on their weapon system

While many of these functions might be performed by automated systems within the EVS, a human may need to perform them for the following reasons:

- the EVS developers are not able to produce a system that handle those functions automatically, and/or
- the unit is more comfortable having a supervisory human in the loop.

Even if the EVS is completely automated, and the functions shown above are done without need of a human supervisor, the supervisor will still need to be informed of the results of the training. This would include information about the strong and weak points of the trainee's performance in the training. In addition, remediation suggestions to the supervisor would be warranted so that the supervisor could construct, in some cases with the trainee, a plan for improving performance.

ET developers should carefully consider the potential supervisor functions and competencies that their EVS designs will require. Generally, due to supervisor workload and lack of instructor training, it might be a goal to automate as much as possible.

During the workshop of the RTG current issues and practices with EVS were examined. These included policy and user requirements, human effectiveness, human interaction, and learning technologies. Some of the presented papers considered training management issues. Additionally 'mind-mapping exercises' were organized during this workshop. One of the mind mapping themes was training management. The facilitators asked the workshop participants to consider the following questions as a means of stimulating discussion:

- What are viable instructional strategies for EVS?
- What categories of metrics can be used to manage EVS?
- How do you manage training sessions?
- How do you envision tasks currently accomplished by 'white-cell' personnel?

The following sections attempt to provide answers to these questions.

2.0 WHAT ARE VIABLE INSTRUCTIONAL STRATEGIES FOR EVS?

Over the last twenty years or so, a substantial body of research has been devoted to instructional strategies in simulated environments. This led to a substantial advance in our knowledge about principles of training in simulated environments. Relevant literature considers part and whole task training, adaptive training, intelligent tutoring, task loading effects, specialized skills training, and generalized skills training.

Clearly, the identification of a suitable instructional strategy for Embedded Training is a matter of applying a methodology such as Instructional System Design or Training Analysis (see e.g., Farmer, van Rooij, Riemersma, Jorna, and Moraal, 1999). A related question is, whether all theoretically suitable instructional strategies are practically implementable in EVS, or is implementation constrained by technological or more fundamental issues? The approximately twenty research papers that were presented at the NATO HFM-169 workshop highlighted a relatively small subset of the endless range of possible instructional strategies as currently considered for embedded training.

During the mind-mapping exercises it was brought forward that the simplest instructional strategy seems to just confront the trainee with a scenario (Scenario-Based Training) using EVS, i.e., involving some degree of simulation. Thus, constructing an appropriate scenario is the minimum effort that needs to be made in terms of devising an instructional strategy. This however, can be a major effort in the complex skill domains we are looking at for ET in the military.

Additional instructional strategies that were mentioned are: whole-task training with injection of virtual entities into the training scenario, instructional strategies based on intelligent tutoring (replacing the human instructor), instruction strategies that are based on remotely monitoring of the exercise and providing instructor feedback via radio (e.g., emphasis training), adaptive training, in which parameters of the training environment (level of complexity, speed, etc.) will change depending on progress of the trainee.

Depending on the nature of the 'host equipment' on which the EVS is implemented (which may range from a handgun to a navy vessel), the instructional strategy may be based on part-task training (e.g., individual training of marksmanship) with any combination of part-tasks, with or without the whole-task context or may be based on whole-task training in the operational environment (e.g., team training of fire-fighting on a ship).

Cannon-Bowers (2010) elaborates on the important consideration that ET is generally Scenario-Based. Although learning may occur spontaneously in such a scenario-based training environment, it is important to optimize learning by embedding instruction in the scenario-based training. Instructional decisions may influence the difficulty of the tasks presented to the trainee, the form and timing of feedback, the nature of hints and cues provided to trainees and the spacing of practice opportunities. Some of the instructional approaches were based on intelligent tutoring.

In this context of intelligent tutoring, Sottilare, (2010) made a case for machine perception of trainee affect to aid learning and performance in EVS. The perception and analysis of affects, such as moods or emotions, should compensate for the lack of human instructors in the EVS environment. In addition, in the context of intelligent tutoring, Heuvelink, van den Bosch, van Doesburg and Harbers (2010) present intelligent agent-supported training in an on-board naval ship application. Teams onboard ships are large and training of team skills is performed, with many of the team members being intelligent agents. Heuvelink et al. introduce the notion of a 'director agent' to keep the behavior of all other agents carefully controlled, particularly in their goal-directedness. A director agent can be a surrogate for a supervisor, capable of diagnosing task performance, instructing intelligent agents and steering the simulation, thus offering training tailored to the needs of the trainee.

A current implementation of EVS in the Joint Strike Fighter F-35 fighter aircraft (Bills, Flachsbart, Kern., & Olson, 2010) provides for fighter pilot tactical training in temporary reserved airspace, without the need of having real (mock) threats in the air or on the ground. This implementation features scenario-based training in an almost fully operational whole-task context. The airborne enemies, their air-air missiles and ground-based surface-to-air missiles are however virtual agents and can be programmed into a variable scenario. Also, the missiles shot by the F-35 are simulated and performance outcomes are based on real-time kill assessment. This implementation allows for team training through implementation of a special datalink that connects the aircraft in a formation. The traditional role of the expert-instructor is limited, since the trainees obtain more direct feedback from the EVS.

It can be helpful if ET developers structure Advanced Organizers for the training. David Ausubel (1960) posited that it is important to present to learners a cognitive scaffold of the material to be learned before they begin learning the details. Ausubel's advance organizer can best be classified as a deductive method. Deductive methods or reasoning provide the rule to follow, then the example, leading to the correct answer or learning (Mayer, 2003). This is the opposite of inductive methods of reasoning that provide the example to follow and then the rule.

Advance organizers are also highly useful in the process of transferring knowledge. Because of the deductive reasoning, students are able to use the rule then the example for learning to occur. Mayer writes in his text, ' … the effects of advance organizers should be most visible for tests that involve creative problem solving or transfer to new situations, because the advance organizer allows the learner to organize the material into a familiar structure' (Mayer, 2003).

Part of the instruction strategy could be that while being deployed, e.g., in Afghanistan, that trainees can ‘reach back’ to their home country, e.g., a school or any other training resource. Finally, cross-training was mentioned, i.e., team training in which team members take on other team members’ roles and responsibilities, resulting in shared awareness of the teams tasks, roles, responsibilities and capabilities.

A more general remark was that the selection of EVS as a training medium should not be done before an appropriate instructional strategy had been selected and that the appropriate instructional strategy depends on the instructional objectives and the training program as a whole.

3.0 WHAT CATEGORIES OF METRICS CAN BE USED TO MANAGE EVS?

Based on the notion of Scenario Based Training, Cannon-Bowers (2010) emphasizes that generally, performance measurement is challenging in high performance environments where situations are unfolding rapidly and significant behaviors run simultaneously, such as in team situations. Also, establishing standards of performance, i.e., a set of criteria that describe desired performance, is hardly feasible in uncertain, ambiguous decision making situations where there are many possible ways to solve a problem.

In the mind-mapping exercise, distinction was made between: (1) outcome measures (*how well* the mission/task goals have been achieved); and (2) process measures (*how* mission/task goals were or were not achieved, e.g., frequencies of certain behavior, communication, mutual support in teamwork, etc.). At the same time, because ET relates to complex task performance, there is a need for multiple measures, covering multiple aspects of behavior (behavioral measures, psycho-physiological measures). In addition, the need for analysis of performance- or learning curves was mentioned, an issue that also has been considered under the heading of training management/learning management systems.

Behavioral measures that were mentioned were eye-movement measures (EPOG, blink frequencies, pupil diameter). It was realized that certain performance measures may not be applicable to ET, for example those collected by a human instructor for feeding back immediately to the trainee, because human instructors are not always present in an ET concept, which highlights the need for Intelligent Tutoring Systems. Finally, the need was expressed for getting a measure (cues) for the level of expertise of a trainee before starting the ET session, in order to set the appropriate scenario.

Supervising personnel must have valid and reliable measurement from the ET system in order to make proper decisions about learning diagnosis and remediation. Regardless of whether the ET has an automatic instructional management system, or that function is performed by a supervisor, or the management system is a hybrid of the two, it is necessary to have a quality performance measurement system to provide proper diagnosis and remediation.

To construct a quality performance measurement system the designers must first determine what the types of learning outcomes are being assessed. Gagne and Briggs (1979) tell us there are five main learning domains (Table 4-5):

Table 4-5: Five Main Learning Domains (Gagne and Briggs, 1979).

Learning domains	Sub domain
1.Verbal	
2.Intellectual	i. Discriminations ii. Concrete Concepts iii. Abstract Concepts iv. Rule Using v. Problem Solving
3. Psychomotor domain	
4.Cognitive strategies domain	
5. Attitude domain	

In ET we can expect there to be training objectives for all of the five learning domains. Designers must have capabilities within the performance measurement system to assess these domains and provide supervisors and automated parts of the training management system with clear learning assessments, diagnoses and remediation prescriptions.

The assessments must be both reliable, that is, repeatedly consistent, and valid. In this case, validity refers to measurements that mimic closely the Warfighter performance in the training system that we would expect to see when the Warfighter employs the weapon system in the actual combat setting. The measures should have congruence to the measures used for training in the formal schoolhouse. In the addition the measures should have face validity to the supervisors and Warfighter leaders up the chain of command. The leaders must feel that the performance measurement system is giving them an accurate picture of how well prepared their charges are to take on various missions.

Undoubtedly, it is imperative for performance measurement to diagnose the causes of observed performance. Clearly, it is insufficient to say that a trainee performed inadequately. In order to mediate such that performance has the chance to improve, it is essential to understand why inadequate performance was shown. A certain inadequacy may be attributable to a lack of skill, such as lack of team coordination, suggesting a certain type of instruction or intervention, while another inadequacy in performance may be attributable to inadequate mission planning, which would suggest an entirely different intervention in training.

3.1 Feedback (e.g., After Action Review)

Feedback is an essential element in Embedded Training as it is in all forms of training. ET feedback must be succinct if it is to be useful in the field. Generally, the number of feedback items should be kept to a minimum if trainees and supervisors are to make use of them on a regular basis. The number of feedback items should be kept to no more than a dozen, less if possible. There are at least two methods for providing training feedback to the users of ET systems.

- From on-board ET systems- Trainees and supervisors are shown feedback displays via the weapon system’s operational displays. Ideally, the same information can be is shown through multiple on-board displays so that supervisors and trainees can see the feedback at the same time for discussion purposes.

- From off-board systems – The feedback information can be shown on displays off-board the weapon system as they are relayed from the ET system via cable or RF signal. The advantage of this approach is that the supervisor can review performance for an entire team with the team that has trained on multiple weapon systems (a tank platoon). In addition, the team can review their performance without a supervisor present.

Obviously, a key design decision is how much the supervisor should be involved in the feedback to the trainee. The supervisor interaction can range from a completely automated system that provides all the feedback to the trainee and merely gives the supervisor a summation of performance, to a system that requires all feedback to be given to the supervisor and he/she provides the feedback to the trainee.

Frequency and rapidity of feedback is a key issue. As is the case with any simulation-based training system, providing feedback in a timely fashion can greatly aid the training process. However, research shows that delaying feedback for a day for higher order cognitive skills like decision making can result in better learning retention. The theory behind this phenomenon is that the trainee will have more time to mentally rehearse their performance and the feedback will help them instantiate lessons learned optimally.

In Scenario Based Training, feedback is a primary mechanism for imparting targeted objectives; hence, it must be carefully developed and implemented (Cannon-Bowers, 2010).

4.0 HOW DO YOU MANAGE TRAINING SESSIONS?

During the mind-mapping exercises, the notion that ET seems to diminish the role of the human instructor was elaborated upon. It was suggested that this was simply because simulation hard/software is attached to real systems hardware/software, resulting in a training medium that most often doesn’t provide physical space for a human instructor. Thus feedback from a human instructor will often be delayed to some point after the mission exercise, e.g., during an After Action Review (AAR) or a mission debriefing. The dual role of the supervisor was mentioned, probably meaning that he is both supervisor of the trainee (senior person) and has an instructional role in deciding what to do next.

An obvious remark is that the instructor could be replaced by an intelligent tutoring system. At a meta-instruction level, the training sessions could be managed by a Learning Management System (LMS). How would it interface with the EVS?

Functional requirements imposed upon such system are:

- record keeping of exposure to specific training events (counting);
- scheduling trainee events in order to optimize the learning process;
- scenario configuration management (which scenarios are updated and ready for use);
- persistent trainee profiling (possibly throughout his career) on the basis of performance measures.

5.0 HOW DO YOU ENVISION TASKS CURRENTLY ACCOMPLISHED BY ‘WHITE-CELL’ PERSONNEL?

‘White-cell’ personnel are the support personnel during live exercises, e.g., fulfilling role-playing tasks, exercise performance scoring, refereeing, and control of opposing forces (semi-automated forces). Some participants in the mind-mapping sessions hypothesized that ET implementations could make ‘white-cell’ personnel superfluous by automating their tasks. This is certainly dependent on the level of intelligence and autonomy of the various entities in the ET virtual scenario. The question was raised whether exercise planning software packages exist, presumably to allocate tasks in ET scenarios to ‘white-cell’ personnel, or rather: Do scenario management systems for real or simulated exercises currently support entities for ‘white-cells’?

6.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Embedded training presents the ET designer with both opportunities and challenges when designing the training management system. The urgency and immediacy of the training is easily impressed upon the trainee and supervisor because the actual weapon system is being used as the training medium. Gaining and keeping the learner's attention should not be a problem. However, because the training is taking place in the field, the normal procedures for training and feedback we would expect to see in a formal schoolhouse will be significantly affected. Capabilities to record and store training data may not be seen as a priority and therefore important learning trend data that is captured in a schoolhouse may be lost. This loss can make it difficult to plan for training progress as the automatic ET system or the supervisor plans the next steps.

It may well be that both trainees and their supervisors will need to receive training in how to manage the training when ET is the medium. This training could either be provided before the trainees depart for their combat theater, or it might be provided as part of the ET on board the weapon system. However, particularly if the unit is going to a combat zone the preparations for that deployment may prevent any time being devoted to this type of training.

Embedded training via virtual means is steadily improving in quality and coming down in cost. Many of the past reasons that ET did not have widespread success are now being overcome. However, continual progress must be made both conceptually and technically on the training management systems if ET is to have large scale success. We have provided a few ideas about those areas of improvement in this brief paper.

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Chapter 5 – THE HUMAN INTERFACE TO EVS

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1.0 INTRODUCTION

The purpose of embedded training (ET) is to make use of operational equipment so that operators can train effectively. The implementation of ET requires fundamental capabilities, including the presentation of scenarios, operator inputs, performance assessment, and feedback (Morrison & Orlansky, 1977). Embedded Virtual Simulation (EVS) is the name given to the technologies that allow an operator to sense and interact with the operational equipment and a virtual environment (VE) that is different from the real one in which the operator is physically present. The VE could be a three-dimensional computer-generated environment or it could consist of both computer-generated and real components within or outside the operational equipment. For example, a tank gunner could look through his real sight and see computer-generated targets superimposed on the local landscape. This combination of real and synthetic imagery is called augmented or mixed reality.

The human interface to EVS systems could stimulate several human senses at the same time to promote the perception of immersion within the VE. This effect could be achieved or enhanced with sensors and controls that allow self-directed movement within the spatial environment, gestures and natural real-time interactions, including spoken interactions, with animated virtual characters or avatars. Recent and emerging technologies now provide opportunities for enhancing the uses and efficacy of ET by providing new ways of interfacing operators with EVS systems.

This chapter considers some issues of human interaction with EVS by summarizing papers that were presented at the workshop of the RTG and the discussions that surrounded them. It is based on a report that was presented at ITEC 2011 (Magee, Sottilare & Roessingh, 2011); the proceedings of that conference are not openly available, so much of the ITEC paper has been reproduced here. This chapter also adds discussion of the implications of EVS for military readiness.

2.0 WORKSHOP PRESENTATIONS

2.1 Human-Robot Interaction

Neuhoefer, Kausch and Schlick (2010) addressed the need for human-in-the-loop, immersive simulation technologies as a means of accelerating safety assessments in the control of industrial robots. They noted that optical, see-through Head-Mounted Displays (HMDs) provide an attractive solution since they have a small footprint, are less expensive than alternatives visual display systems (e.g., CAVES) and are very immersive, but that the size, weight, and resolution of see-through HMD are problems for usability. An additional problem is that it is difficult to make use of see-through HMDs if virtual objects need to occlude real objects in the visual scene. Development efforts to address this problem were described; they make use of addressable focal planes for combining images of real and virtual objects. The industrial application involved handling and cleaning heavy parts with a blasting tool that shot pellets. Neuhoefer, Kausch and Schlick determined that visual depth, haptic, and auditory cues were important for the simulation. They compared two implementations of the human interface with a stereoscopic HMD. In an augmented reality (AR) condition, the operators were able to see their hand and the real tool. In a VR condition, only computer-generated images were provided. The performances of 40 users, and the workloads that they experienced, were measured for each condition. Significantly more virtual pellets were used to perform the task with augmented reality. The participants reported that more pellets were needed because their aim was affected by mismatch in the orientation of the pellets and the blasting tool. No significant difference in any measures of workload, using the NASA-TLX questionnaire, was found. In comparison, the participants preferred the interface that used augmented reality as a potential solution because they could immediately see their hand move.

2.2 Spatial Perception

Sandor et al (2010) also considered the advantages and disadvantages of HMDs. They noted the benefit of HMDs for conveying three-dimensional information and the problems of a reduced field-of-view and a head-fixed, visual frame. They were concerned that these characteristics would negatively affect visual orientation, particularly the perception of the direction of gravity. They first conducted a study to determine if a tilted, large-scale, immersive, virtual environment would affect judgments of verticality in the same way as tilted real environments. Variations of the Rod and Frame Test (RFT) were used. Three different virtual environments were presented: one replicated the traditional RFT, one provided wall paper on the walls, and another added furniture and objects to enhance depth cues. In addition, two methods were used to adjust the rod. One required use of a computer mouse to adjust the vertical orientation of the rod; the other used a real, hand-held rod. A typical sinusoidal relationship between the amount of frame tilt and rod tilt was found for the real and the virtual environments. Within the virtual environments, the amplitude of the sine wave grew with scene detail. In turn, these functions were affected by the adjustment method. The condition that allowed the participants to hold the rod reduced misperception of the gravitational direction. Hence, there is evidence that haptic control and feedback reduce the misleading effects of greater scene detail. This evidence provides an argument for multi-modal cueing in ET applications involving spatial orientation.

Sandor et al also reported the results of a second study that investigated the spatial relationship between visual and auditory cues. In a dark room, a spot of light and a sound were presented at the same time, at the same location or in different locations, on a flat, frontal plane. The participants judged whether a light and sound were fused, that is, whether or not they appeared to be coming from the same position in space. The limits for fusion were found to be greater in height than in width (at eye level) and progressively greater for stimuli as they moved away from straight ahead. To determine if gaze direction affects fusion, the investigators required the participants to make judgments when gaze and head orientation were aligned and misaligned. They found that the fusion limits were influenced by both gaze direction and head orientation in an equal manner.

These results, obtained in a darkened room, replicate results in a lighted room where the other visual cues for orientation are available, and they show that fusion accuracy varies with the relative alignment of the eyes and ears.

2.3 Dismounted Soldier Requirements

A third presentation in the workshop session on human interfaces was made by Dyer (2010) who was concerned with the impacts that embedded training could have on soldier systems. Dyer noted that US Army policy states that embedded training should not adversely impact a system's operational capability and that embedded training needs to provide systems-related training and feedback. Dyer also noted that size, weight and power are critical considerations affecting feasibility of embedded training for soldier systems, especially for fully embedded, go-to-war capability. Dyer described the requirements for embedded training for the Ground Soldier System (GSS) and the investigation of alternative architectures for embedded training, which included virtual training in a facility and a "stand-alone" mode. The principal components of the GSS are a wearable computer and a GPS coupled to a helmet-mounted display system. The conclusion was that only a few tasks were amenable to virtual simulation and that an approach for identifying the tasks and skills that are most appropriate for embedded training with the GSS was needed.

Dyer described a funneling approach for identifying the tasks; it first considered psychological dimensions, such as the memory decay for the task, and task characteristics, for example, its frequency. A second step considered military criteria that consisted of questions focused on sustainment, rather than initial skills training. Dyer described some tasks to illustrate the use of the questions to identify tasks appropriate for embedded training, but acknowledged that the process has not been validated. Dyer advanced the notion that memory aids might be a better and more acceptable means of maintaining skills than virtual exercises. Dyer provided a few examples of the challenges that embedded virtual environments need to address for dismounted soldiers. One example of the challenges is that many cues and signals are used by a fire team getting ready to clear a room. Touch and gesture are used by the team members. Hearing is used to locate hostiles and non-combatants. The soldier's acceptance of EVS as a means of training and rehearsal was identified as a problem by Dyer, who noted that soldiers gain confidence by practicing on ground similar to the operational setting and that their preference is for live training.

3.0 DISCUSSION

3.1 In-Flight Training

The presentations at the workshop helped to inform and stimulate the group discussions that followed as the participants considered the limitations and capabilities of EVS as an enabling technology for embedded training. The discussions were also informed by the preceding addresses of the keynote speakers and several presentations that were also relevant to issues of the human interface. Among these was the keynote of Verhaaf (2009) who provided a user's perspective on the need to maintain high proficiency for air combat while deployed. He described successful exploratory use of EVS by the Royal Netherlands Air Force (RNLAF) Command. It was used for training F-16 combat skills as a precursor for application to the F-35 Joint Strike Fighter. Simulated threats were fed to the sensor systems of the aircraft in flight, thus allowing several pilots to engage virtual targets in tactical manoeuvres Beyond Visual Range (BVR).

The virtual world included the threats and targets, their electronic signatures, weapons and dynamic behaviours, involving strategies, tactics, manoeuvres and counter measures corresponding with their real-world roles. This achievement demonstrates that it is technically feasible to include BVR engagements in an EVS training exercise. However, simulated engagements Within Visual Range (WVR), that is within about 10 nautical miles (depending on visual conditions) provide major technical challenges since they require the overlay of virtual objects upon the real world as viewed by the pilot.

The visual requirements for training target identification exceed the capabilities of state-of-the-art HMDs; pixel resolution and (colour) contrast are now inadequate for visual target identification (VID). HMDs or suitable alternatives do for displaying realistic, virtual opponents in an EVS do not yet exist (Roessingh, van Sijll, & Johnson, 2003). Roessingh, van Sijll and Johnson identify 12 visual requirements for WVR embedded simulations. These include the following:

- An image update rate and a display refresh rate of at least 80 Hz, but possibly much more than 80 Hz.
- The time delay of the WVR-target visualisation system should be less than 20 milliseconds. In other words, the position in the display of simulated targets should not lag more than 20 ms behind on simulated target motions, actual aircraft motions, and actual head motions.
- A field size (Field of Regard) of the simulated scene in the range of 300 degrees horizontally and 150 degrees vertically.
- A field depth in the range of 10 to 18.5 km.
- Scene management must be based on point-of-gaze measurement. Specification of the type of head- and eye- movements that must be measured would need to be determined and depend on other requirements.
- Occlusion of virtual targets by real world objects must be managed, that is, the hiding of virtual targets or part of a virtual target behind real world objects which are at closer distance to the observer, such as clouds, mountains and aircraft structures, must be managed. For safety reasons the operational community may be concerned about the occlusion of a real target by a virtual target, since a mid-air collision could be possible.
- Shading and illumination of virtual targets by real world objects (sun and clouds) must be managed.
- Quickly varying luminance levels, ranging from a few feet-Lambert to several hundreds feet-Lambert, in a sufficient number of luminance steps, should be supported by the display system.
- A resolution of the foveal image of 86 pixels per degree visual angle (in both horizontal and vertical direction) should be supported. However, a decreasingly lower peripheral resolution would be needed.
- A bi-ocular display with hundred percent overlap between the field of view of each eye is required. When targets come within a range that is less than 160 meters, support of stereopsis must be considered. The latter implies a binocular display with different images for each eye corresponding with retinal disparity.
- The display method should avoid potential conflicts between accommodation and other monocular depth cues if simulated targets are displayed at a short observation distance.
- The mechanical and optical properties of a device that enables projection of virtual targets superimposed on the real world should not compromise pilot safety (e.g., in high-g manoeuvres, in an ejection or in a crash).

Roessingh, van Sijll and Johnson note that when only a subset of fighter aircraft WVR tasks need to be trained with ET, some of these requirements could be relaxed. Roessingh and Verhaaf (2010) later provided evidence of the positive training effectiveness of the approach and discussed how EVS addresses user needs. They identified the visual display of simulated entities within visual range as a current, technological limitation and thus conclude that EVS is now applicable only to training scenarios that do not depend on visual sight of the threats or friendly forces. However, when compared to full mission simulation, EVS in the air provides important sensory cues that are expensive, or difficult to provide on the ground with full fidelity. These include accurate physical motion, control loading (force reflection) and aerodynamic cues.

Since displays (e.g. for radar and radar warning receiver) in the cockpit can contain both real and virtual information at the same time, operators should always be aware which information is real and which is virtual. This helps them to make the appropriate trade-offs and decisions during the training scenario. It is clearly not desirable to perform a potentially unsafe manoeuvre or action in response to a virtual entity, while this may be totally justified in an operational situation. A potential implementation for symbols on a display is to give the virtual entities a dedicated supplementary tag. In the fighter aircraft EVS that was used by the RNLAF, this was accomplished by attaching a small "v" to each virtual symbol on all displays where they could appear. Naturally such information should be designed carefully in order to guarantee positive transfer of training. Another effective strategy in the design of displays is to give symbols related to real entities a higher display priority. This way, symbols related to virtual entities do never obscure those related to real entities. More advanced means are also possible. Automatic monitoring of aircraft and its interaction with the real environment can prevent unsafe situations. This can be accomplished by the continuous evaluation of a number of safety rules by the EVS itself. The simulation immediately stops when one of the rules is violated, that is, when it detects an unsafe situation. Naturally this should be properly announced to the operators. As an example, the system can monitor that an aircraft remains in a temporary reserved airspace during the training. It could also automatically detect potential collisions with real entities or real terrain. In an overview of the use of embedded training for the F-35, Bills, Flachsbart, Kern & Olsen (2010) emphasized safety of flight as a consideration within and following a TRAIN mode.

3.2 Ground Vehicles

Schmidt (2009) provided a keynote address that presented an EVS solution for the Infantry Fighting Vehicle (IFV), and Shiflett (2009) provided a keynote that presented embedded training as key performance parameter for the Future Combat System. Schmidt described the use of head-mounted displays with the IFV, and Magee (2009) cited the development of special vision blocks by the US Army Research, Development and Engineering Command (RDECOM) as a development that enables armoured crew the ability to observe computer-generated imagery of the external world. These examples indicate that embedded visual system technologies are technically ready for use with ground vehicles, but Schmidt also cautioned that safety concerns would likely constrain the movement of ground vehicles and thus the use and effectiveness of EVS if physical motion cues are needed for human learning.

3.3 Dismounted Soldiers

The act of embedding training simulations on dismounted soldiers may be one of the most challenging operational environments in which to implement EVS. The ability to stimulate the soldier's senses and to respond to his touch is not only limited by the simulation, but also by constraints that include power, weight, processing power and communication bandwidth. Power consumption is already a major concern in the world's military. Battery power is not yet efficient enough to support dismounted soldiers over long periods of time. Any proposed EVS solutions would have to be fully embedded and not add to the already heavy load carried by dismounted soldiers. These fully embedded solutions will likely tax the processing power, communications bandwidth and battery power of the operational systems they are contained within.

Soldiers in the modern military move, shoot and communicate, but they also are expected to act as sensors in the environment and to negotiate with indigenous people. An EVS for dismounted soldiers must be able to present the visual world in sufficient fidelity to allow them to train in an environment that recreates the operational environment. Soldiers need to detect the movement of threats at a distance. They need to be able to identify potential targets as friend or foe, and to interact with other avatars and non-player characters to allow recognition of emotions and body language during negotiation tasks.

In Schmidt's (2009) keynote address, he presented an EVS solution for the Infantry Fighting Vehicle that included a dismounted capability. This was limited in that it was tethered to the vehicle and it provided a fully virtual training environment. This dismounted EVS did provide an effective power solution in that it drew power from the Puma vehicle. However, it did not incorporate the live environment as part of the EVS which Dyer (2010) has suggested is critical to effective training. A more effective, but also more complex and costly alternative to all virtual or all live is mixed reality. The near term potential exists to implement virtual targets.

3.4 Observations and Opinions

The following general observations and common opinions were reported by the groups:

- New EVS technologies, such as augmented reality, create opportunities for expanding the usefulness and range of applications of embedded training. The applications that were identified included air, ground and sea systems involving vehicles, command and control centers, and dismounted combatants.
- EVS can be a cost-effective alternative to more traditional simulator-based training for vehicle-based tasks and command centers, but is not technically ready for training dismounted combatants.
- Safety issues associated with vehicle use can constrain the application of EVS; there was much concern about the interplay between training and operational modes, and the movement of operational equipment in an ET mode.
- There was a general concern about the need for realism, to allow soldiers to train as they fight. Many human factors were identified, including the following:
    - Sensory cue fidelity.
    - Multi-modal interactions.
    - Sensitivity to interactions between simulated and real worlds.
    - Sensitivity to interactions among multiple players in team training applications.
    - Consequences for human performance in the EVS and subsequently for training transfer.
    - Human adaptation.
    - Unwanted side-effects, e.g., simulator-induced sickness.
- EVS technologies were considered to be the most advanced for vision, but limitations were identified for night vision simulation systems, depth cueing, and peripheral vision (i.e., wide field of view). The participants thought that flexible, transparent displays may soon provide a solution to the problem of presenting computer generated targets within visual range for in-flight fighter training.
- For hearing, sound effects and three-dimensional rendering are thought to be well developed, but limitations exist for simulating the location of a sound source in three-dimensional space, especially if head-phones are not used, and wide variation of abilities among humans was noted.
- For speech recognition, there is much concern about the masking effects of the often noisy environments of ET, although success has been achieved (e.g., for the F-35).
- For motion cueing, the physical stimuli can be real and uncompromised, e.g., as EVS was used for in-flight training, or completely absent, e.g., as EVS was used for the infantry fighting vehicles or tanks that do not move because it would be unsafe to operate them in a training mode. Consideration was given to the use of motion seats as a means of providing physical motion cues in vehicles that are stationary, but the costs and bulk of these systems was thought to be prohibitive and of doubtful utility since much of the literature on motion cueing says that it is not necessary for effective training transfer, for most tasks. Tactile vests and belts are also a possible, more affordable alternative, but their effectiveness is unknown.

- For haptic and vibration cueing, like motion cueing, the physical stimuli can be real and uncompromised, as EVS was used for the in-flight training demonstration for the F-16, or it can be absent or seriously compromised, in the way that EVS was implemented as a Virtual Reality (VR) experience for robot control. Consideration was given to the use of force loaders in a training mode for vehicles, but the costs and bulk of these systems was again thought to be prohibitive.
- For smell, odors can be simulated, but are difficult to remove from the training environment. Emergency medicine was one area where the user's needs might justify the use of a chemical simulator, but few other tasks were thought to need this type of sensory cue for effective training.
- Inter and intra modal consistency was recognized as a challenge. For instance, the relationship between simulated images, provided to a HMD with head-movements, and the real world present a challenge for head-tracking technology. The sensitivity of human operators to conflicting information within or between sensory systems was identified as human factor that could lead to unwanted side-effects, such as simulator-induced sickness.
- Additional challenges exist in developing and interacting with intelligent agents (e.g., virtual humans and intelligent tutoring systems) within EVS. The inherent remoteness of EVS (especially in deployed settings) poses a challenging environment for instruction and feedback to trainees. It is impractical to envision EVS in the future where human instructors/tutors would be available to support either individual or collective training on the scale required. It is more likely that tutors will be intelligent agents with adaptive algorithms to provide tailored training to both individuals and teams in remote locations.

4.0 CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

The workshop revealed several successful applications that provided effective human interfaces to EVS systems. These included interfaces for robot control, fighter training, and combat ground vehicles. In comparison, effective human interfaces for dismounted combatants were not revealed. For all types of systems, concerns about weight, size, and safety, as well as technological constraints were found to restrict the design and use of the human interface to an EVS system. For example, the cues of physical motion are limited with embedded training in a tank because it could be unsafe if movements of the vehicle are unrestricted during an ET exercise. In an ideal EVS implementation, the user will not be able to tell the difference between the real and simulated environment. Thus, it will be unclear to the user if a failure is real or simulated. Unlike traditional simulation, EVS needs to include a method to remind the soldier about its mode.

Human perception is multi-modal. The psychophysical study (Sandor et al, 2010) of the visual perception of gravitational direction, its susceptibility to scene detail and haptic input, and the psychophysical study (Sandor et al, 2010) of the fusion of light and sound in space, and its susceptibility to head and eye orientation, illustrate the interplay within and between the senses in determining our perception of the environment and our place in it.

The workshop participants concluded that the relationship between training and real environments, that is, the fidelity of the EVS and the consequences for training transfer, remain a concern due to technological limitations and a lack of behavioural information about the efficacy of EVS.

Many weapon platforms are operated by teams, and platforms operate with other platforms in many missions. Obviously, team training is an important area of application for EVS. Human Interface requirements need to allow coordination among team members and platforms. This may require dedicated communication channels. The use of EVS for team training could promote unity in operational procedures and doctrines and help train effective communication techniques. Training scenarios could, inter alia, be based on actual battlefield incidents involving factors related to teamwork.

As discussed above, artificially intelligent agents are more likely to be deployed with operational equipment to support EVS in the future. It is envisioned that part of the human interaction problem space for making intelligent tutoring systems and virtual humans practical for EVS will include low cost, unobtrusive methods for sensing behaviors (e.g., actions, gestures) and physiology (e.g., heart rate and galvanic skin response). Behaviors and physiology (observable trainee states) will then be used to predict cognitive states (e.g. unobserved trainee states). Predicted cognitive states that are relevant to learning could include affective variables like frustration and confusion or others like attention and engagement. Methods to accurately predict these cognitive states will determine the adaptability of any computer-based tutor and either limit or enhance the trainee's perception of the tutor's persona, credibility and supportiveness. In other words, the tutor's effectiveness (in terms of learning) is likely to be limited by the acceptance of the artificially intelligent tutor and acceptance (or lack thereof) will be limited the tutor's ability to predict the state of the trainee at least as effectively as a human tutor.

The costs of simulation have long been hypothesized to grow exponentially with fidelity while training transfer has been hypothesized to increase monotonically with fidelity, but with diminishing returns (Miller, 1954). This is the problem facing decision-makers who must decide how much to spend on a simulator, or how much to include in an EVS. The plots of these relationships could be very useful if they were based on actual data since they could be used to identify the amount of fidelity that yields the most training value for cost. However, there is no objective method for measuring the overall fidelity of a training device or EVS system. There are few studies and many different measures of training transfer. Thus, there is a need to develop measures and to determine their relationships. In addition, subjective opinion, human adaptation and simulator-induced sickness are outcomes that further complicate our understanding of the human factors associated with the design, use and evaluation of EVS.

On the basis of the presentations and discussions, a number of the workshop participants concluded that EVS should be considered as an extension to traditional training methods and that it is not yet their replacement.

Although the implications of this view were not explored further at the workshop, a subsequent meeting of the RTG considered the impact that EVS could have as an extension of traditional training methods. The RTG considered the impact that EVS could have on military readiness by discussing it within the context of VR as a potentially disruptive technology (Schlick & Alexander, 2011). Recent studies within NATO are directed toward the identification of emerged or emerging disruptive technologies. VR can sometimes provide an accessible and affordable alternative to full mission simulators, which have been the traditional means of exploiting modelling and simulation (M&S) for training. While a VR system may not provide all the functionality of a traditional simulator, it can sometimes provide a more compelling means of achieving immersion within a training environment. Immersion is often sought to promote situational awareness and training transfer. These are also principal goals of an EVS system.

Although VR training systems are generally less reliant on physical reproductions of the operational equipment than traditional simulators and are much less reliant on the use of operational equipment than EVS (by definition) systems, they are sometimes better suited to specific training objectives than full mission simulators because the human interface of a VR system can be more easily customized to match a particular training objective and its requirements, for example, the presentation of stereoscopic images for making accurate visual judgements of the distance to an object or a surface. Hence, VR is well-suited to part task training, mission planning and mission rehearsal applications where specific, rather than comprehensive, learning objectives can be identified. Since many VR technologies could be used to interface an operator with an EVS system, EVS systems could also provide a better human interface to a simulated environment than traditional simulators, and like VR, EVS systems could sometimes be better suited to part-task training than full task training. Safety concerns, such as limits on the motion of operational equipment when the EVS systems is in use, or technological limitations, such as the current inability to display simulated targets within visual range of a fighter in the air, will sometimes limit EVS to part-task training. However, the use of VR or EVS systems for part-task training does not necessarily limit the impact that they can have on subsequent task performance since part-task training can be very effective and disruptive when the training they provide is put to use. Consider, for example, the training needed by the terrorists of 9/11; they did not need to know how to complete take-off or landing with the aircraft that they used as weapons.

EVS systems could also afford significant benefits for mission planning and mission rehearsal since they could allow last minute, just in time training that could take advantage of the latest intelligence data for scenario development, presentation and human interaction. The use of EVS systems for mission rehearsal has at least two important benefits difficult to achieve with conventional training technologies. One is that EVS provides a means to exploit immediate, intelligence information, another potentially disruptive technology, to aid mission readiness beyond what could be achieved with traditional training technologies, which are usually apart in space or time from the operational setting. Another training advantage of EVS is that it provides a means to minimize human memory decay by closing the gap between learning, mission rehearsal and training transfer to the operational task.

In conclusion, the impact EVS systems could have on military readiness, as an extension of existing methods, should not be overlooked. EVS is a means to exploit other potentially disruptive technologies and provides a potential means to gain a training advantage over adversaries without this capability. Advances of the human interface to EVS systems will grow this advantage.

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Chapter 6 – THE APPLICATION OF INTELLIGENT AGENTS IN EMBEDDED VIRTUAL SIMULATIONS (EVS)

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1.0 INTRODUCTION

During the NATO HFM research workshop, a special session was dedicated to learning techniques. The discussion following the presentation was guided by the following questions:

- What are the factors enabling/limiting learning in EVS?
- When is the optimal time to provide feedback in EVS? On error, on trainee request, other?
- How much human involvement is required to support learning in EVS, and how much can be delegated to intelligent agents?
- How is feedback provided to trainees during embedded training?

A significant part of the discussion on learning technologies centered on intelligent agents for embedded training and how they might support the constraints (e.g., lack of availability of a human tutor) inferred by the questions above. Also discussed was how they differ from conventional technology-based training environments.

So why might intelligent agents be important to embedded training? In September 2010, IBM asserted that ’66 [percent] of new products have some kind of intelligence built in’. Less than a year later, 66 percent is likely a low estimate of new products that take advantage of Artificial Intelligence (AI) techniques. The need for artificial intelligence for the masses highlights the expectation for user-friendly products with ‘on demand’ support. This expectation translates well to training applications where human interaction and support (e.g., tutors) are either limited, not available, or impractical (e.g., embedded virtual simulations). IBM’s statement also parallels a need for new equipment training in the military, where expectations are growing for products that use AI to ‘teach’ the user about their capabilities and how to exploit them.

Intelligent agents take many forms, but the NATO group explored three primary classes of intelligent agents for EVS applications: learning agents, Non-Player Characters (NPCs) and process managers.

Learning agents are functional elements of computer-based tutors and support the trainee’s learning process. Agent functions might include the development/maintenance of trainee and expert models, the prediction of the trainee’s cognitive state (e.g., affect or motivation), assessment of trainee performance and the optimization of instructional strategies (e.g., hints, questions or pumps) employed by intelligent tutors.

NPCs represent real people or weapon systems, including their behaviors and cognitive states (e.g., decision-making capabilities). NPCs can be fully automated representations of friends, adversaries, or neutral characters.

Process management agents could be used to automate laborious processes including: the development of training content; management of interfaces and network loading; and the collection and analysis of data during a distributed EVS training exercise.

Intelligent-agent capabilities, including the evaluation of the trainee's 'readiness to learn', agent feedback delivery and frequency, the degree of automation, learning enablers, and the limitations of agent technologies, are reviewed, along with examples of successful implementations of intelligent technologies within a sample of NATO countries. Recommendations for future embedded training capabilities driven by intelligent technologies are also discussed.

2.0 INTELLIGENT LEARNING AGENTS

As noted above, learning agents are autonomous functional elements of computer-based tutors that observe and act upon an environment and direct their activity towards achieving goals (Russell & Norvig, 2003). In computer-based tutors, learning agents observe and act upon information about the trainee and his/her performance relative to an ideal trainee model, also known as an expert model.

Learning agents might use behavioral and physiological sensors, past performance and other competency measures, demographic information, human observations and/or self-reported data to assess the trainee's current 'readiness to learn', predict their future performance or cognitive state. Learning agents might also use trainee data to build expert models or to determine optimal instructional strategies used by intelligent tutors. Instructional strategies include, but are not limited to: pace of instruction, challenge level of instruction, frequency of direction and support, questions and pumps. Examples and frameworks for learning agents were presented and discussed during the 2009 workshop.

Sottilare (2009 & 2010) asserted that the lack of human tutors within operational platforms limits the understanding of each trainee's cognitive state (e.g., emotional state) and the completeness of the trainee model within computer-based tutoring systems. Tutor technology is not sufficiently mature to provide accurate, portable, affordable, passive, and effective sensing and interpretation of the trainee's cognitive state and limits the adaptability and effectiveness of the instruction in today's embedded training systems and other computer-based tutor-dependent environments.

Jensen, Mosley, Sanders and Sims (2009) reviewed two case studies of embedded training prototypes developed for the U.S. Army that employ structured training methods to optimize learning without direct instructor involvement. These prototypes include a man-wearable trainer for dismounted operations, and a robotic vehicle control station trainer.

3.0 INTELLIGENT AGENTS AS NPCS

Heuvelink, van den Bosch, van Doesburg, and Harbers (2009) utilized intelligent agents as non-player characters in a stand-alone low-cost desktop simulation used by a single trainee who played the role of the Officer of the Watch (OW) in shipboard fire fighting training scenarios. The Chief of the Watch (CW), Machinery Control Room Operator (MCRO), Confinement Team Leader (CTL), and the Attack Team Leader (ATL) are all agent-based characters. This allows individuals to train in realistic and complex environments in the absence of other human team members.

Bell & Short (2009) advocated the utility of speech-interactive synthetic teammates for training, mission planning and rehearsal. They identified the following issues with human role-players: many training exercises use trainees as training aids; human role-players introduced unwanted variability into the training; sometimes instructors were also trainees and this complicated performance assessment; and costs for human role-players were recurring (e.g., compensation and transport). Non-player characters were seen as a viable option to overcome these issues. As an example, they created a set of CAS scenarios, focusing on dialogue between the pilot and a Joint Terminal Attack Controller (JTAC), which was played by an intelligent agent.

4.0 INTELLIGENT PROCESS AGENTS

As noted above, process management agents could be used to automate laborious processes associated with training. There is potential for intelligent agents to supplant painstaking cognitive task analyses used to develop expert models for computer-based tutoring systems (Williams, 1993). Advances in sensor technology (e.g., unobtrusive physiological and behavioral sensors) and machine learning techniques make it possible to produce more expansive and accurate expert models automatically, but additional research is needed to standardize processes and improve the accuracy of these models.

5.0 DISCUSSION

Morrison & Orlansky (1997) noted that ‘provision of individualized instruction by embedded tutors, requiring little or no supervision’ as a common positive feature of embedded training systems evaluated at that time. This is based on the assessment of trainee performance as part of a simplified trainee model. The systems noted in this study did not consider physiological sensors, past performance or other inputs to assess the trainee’s cognitive and affective states, and therefore were limited in optimizing instructional strategies (e.g., feedback or scenario adaptation). This limitation could be seen as a negative attribute of these systems and should be considered in the design of new EVS.

An analysis of EVS requirements by the HFM-165 RTG highlighted significant technical challenges in the development and deployment of EVS within operational platforms. Among those challenges were communication and interaction with the trainee to support real-time feedback as well as an after-action review of their performance during embedded training exercises. This involves more than just movement of information to and from the trainee, but also includes intelligent observation. In live simulations, performance data is collected via sensors on an instrumented range and/or by human observers, but the use cases identified by the RTG included deployed scenarios in un-instrumented areas and without specialized observer personnel.

The RTG evaluated technology-based solutions and more specifically intelligent agents and their potential to: overcome the EVS lack of knowledge about the trainee state; and answer some of the guiding questions posed below:

- How should information (e.g., feedback, instructional content, etc.) be provided to the trainee in EVS?
- When (and how often) should feedback be provided in EVS and is it different than in conventional training simulations?
- What level of human involvement is needed in EVS? Can it be a fully automated or semi-automated process?
- What are learning enablers and limitations in EVS?

The following provides discussion of the application of intelligent agents to EVS in aircraft. Examples of embedded training in the aviation domain are primarily onboard fighters. The predominant type of intelligent agents in aviation EVS applications is NPCs.

The literature on EVS in the aviation domain is generally mute on the use of intelligent process agents. Process management functions, such as starting and stopping the EVS, data logging, data analysis and safeguarding functions (which take care of e.g., automatically terminating the EVS when flight safety requires) are generally not implemented as intelligent agents. A brief description of the architecture that is used for such functions can be found in Krijn and Wedzinga (2004), which deal with an early implementation of EVS for the F-16 aircraft. The latter implementation is of the 'single-ship' type, which means that aircraft equipped with such EVS have no dedicated EVS-communication link with other live aircraft. As a consequence, these aircraft can only engage in an EVS scenario in which they are the only live asset, i.e., they can only act as a single ship, not in a team.

This is a significant restriction because nearly all tactics training of fighter aircraft is done in formations of at least two aircraft. Lemmers (2009) and Keuning (2009) describe a multi-ship implementation of EVS for F-16 aircraft. Bills, Flachsbart, Kern and Olson (2009) describe a multi-ship implementation of EVS under development for the F-35 aircraft. The current review of the literature in the airborne domain doesn't mention the application of aforementioned 'learning agents' either. No documents in the public domain were found that revealed operational user requirements relating to specific functions in EVS that support the trainees' learning process, let alone the implementation of these functions in the form of intelligent agents.

Hence, the description of the use of intelligent agents for EVS in aircraft must currently be limited to the use of Non-Player Characters. Current efforts seem to focus on the development of adversary NPCs (Harrison, et al., 2010). One obvious reason is that the inclusion of synthetic adversaries in EVS is highly relevant to tactical training of fighter pilots and is cost-effective in the sense that fewer live-assets in the adversary are needed. Also, synthetic adversaries do not need to be equipped with complex communication architecture as would be the case with other relevant NPCs in a supportive or friendly role. After all, there is usually no communication through voice or datalink between fighter pilots and their advisories. Communication between, for example, a live flight lead and a synthetic wing man would be difficult to capture in an EVS architecture and would require a high quality and robust implementation for the cockpit environment, even in the least ambitious scenarios, as was discussed by Roessingh and Verhaaf (2009). Intelligent synthetic team mates in fighter formations will probably first be applied for ground-based virtual simulations, before being applied in EVS.

EVS for fighter aircraft applications is a relatively recent development, with the first concepts emerging in the late nineties of the last century. The first implementations concerned two types of NPCs: adversary aircraft and adversary ground threats in the form of Surface-to-Air-Missiles (SAMs). The adversary aircraft NPCs reduce the need to train against live mock enemies, or 'red air' in jargon. The SAM NPCs reduce the need to train at specifically instrumented flying ranges. Both types of NPCs are considered to contribute to substantial cost savings, as is further detailed by Bills et al (2009).

The first generation of adversary aircraft NPCs is further characterized by a virtual range from the EVS equipped 'ownship' which is beyond the visual range of the pilot. Those NPCs will never enter the visual range of the pilot during an EVS scenario. Hence, the training application of those adversary aircraft NPCs is limited to Beyond Visual Range (BVR) scenarios. According to Roessingh, van Sijll and Johnson (2003) this is mainly for technological reasons: to realistically visualize virtual adversary aircraft in the cockpit environment, when these aircraft come Within Visual Range, is technologically complex. As a result, the behaviour of these NPCs will only be observed directly via cockpit displays of on-board sensors (radar, radar warning receiver, possibly infra-red sensors). Hence, the behavior that these NPCs need to demonstrate only needs to be intelligent insofar observable via cockpit displays in the EVS equipped aircraft.

However, even intelligent behaviour BVR is far from trivial. Real enemies are, at least to some extent, unpredictable. They seek to maneuver themselves into a better position as the tactical situation changes. They react to friend and foe. They are adaptable. In other words, they are smart. The smart element in the behavior of these virtual opponents involves a number of factors. For instance, they should be able to detect and identify targets to attack, but should also be capable of defending themselves against enemy action. And just as the individual characters of people may vary, the variety in individual pilots and their personal style and preferences should also play a role. The eventual objective of NPCs into EVS is to create training scenarios where the threat is realistic, both in the air (adversarial aircraft) and on the ground (SAMs). This requires advanced cognitive modeling and the modeling of domain expertise. To reach the level of proficient behavior, NPCs could be 'trained', using machine learning algorithms, to instill the expertise that meets the requirements of the scenarios and the live participants. Harrison et al. (2010) propose genetic programming to train NPCs for EVS. However, the maturity level of machine learning applications for EVS has not been demonstrated as yet.

6.0 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Five critical areas were identified for additional intelligent agent research: technology (tools and methods) to assess of the trainee's learning needs and tutor feedback based on those learning needs; methods for automated scenario selection and adaptation based on trainee's competency and learning needs; methods for automated instructional strategy selection; methods to optimizing performance and retention; and automated data collection and assessment for after-action reviews.

Based on the RTG's research, discussions and workshop outputs, the following conclusions are offered relative to trainee feedback in EVS, the application of intelligent agents in EVS, their limitations and recommendations for future research.

Feedback (e.g., direction, support) should be presented when the trainee's actual performance varies sufficiently from their expected performance. The measurement of expected performance is largely based on experience and previously demonstrated competency in the domain being trained. The determination of current performance is critical to adapting training. Given the isolation of the trainee in an EVS from human observers, performance assessment will be largely left to computer-based techniques.

Feedback frequency should be driven by the trainee's competency, their levels of engagement, and their motivation. Accuracy, interference, calibration, and human variability will likely complicate the assessment of engagement and motivation through sensor technologies. Feedback should also be task dependent in that tasks involving high risk and consequence might involve more frequent feedback. Feedback should be triggered by trainee mistakes and trainee requests for help or clarification.

Intelligent agents may enable training: in situations where human tutors and human role players, such as mock-enemies, are either unavailable or not practical/cost effective; by reducing support costs via automated tutors, scenario directors, coaches, Non-Player Characters and simulation process management agents; by increasing availability of training through EVS as training goes with the Warfighter to the theater of operation. As they exist today, intelligent agents have limited adaptability and ability to motivate trainees, limited interfaces/interaction within virtual simulations and limited capability to perceive and understand a trainee's cognitive and affective states. This limits the ability of computer-based tutoring systems within EVS (or other training environments) to optimally select instructional content and strategies.

NPCs are viable as tutors, directors and coaches within EVS and other simulation environments, but additional research is needed to develop their interaction design (e.g., natural language understanding and generation) and cognitive modeling.

Elements of trainee models within computer-based tutoring systems may include demographics, input from behavioral and physiological sensors, self-reported and observed data and/or historical performance data. Physiological sensors are limited by human variation and electromagnetic interference (EM). EM is a concern in ground vehicles and naval platforms where EVS is likely to be deployed. Additional research is needed to assess what the essential elements of trainee models are and how they can be used to determine the trainee's cognitive state and optimal instruction in EVS.

In air applications, most notably EVS for fighter aircraft such as F-16 and F-35, NPCs are more often employed as adversarial NPCs (either ground threats, SAMs, or air threats, adversary aircraft). Currently application is limited to BVR scenarios, in which adversarial intelligent agent behaviors are observable via on-board sensor displays (e.g., radars) only.

Some research challenges include display of Within Visual Range (WVR) behaviors, cognitive modeling of entities (e.g., weapons platforms), tactics modeling of entities and multi-agent collaboration/interaction. Machine-learning approaches (e.g., decision trees, Bayesian networks, genetic algorithms) are growing tools of choice.

Intelligent learning agents show promise in spanning the gap between human and computer-based tutoring capabilities in one-to-one tutoring domains, but additional research and development is needed to make agents practical for use in fully autonomous training environments such as EVS.

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Chapter 7 – CURRENT AND FUTURE DIRECTIONS FOR VIRTUAL SIMULATION IN OPERATIONAL PLATFORMS

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This report summarizes the main results and outcomes achieved during the period of operations of NATO HFM-165 RTG on 'Enhancing Human Performance through Embedded Virtual Simulation' and the associated HFM-169 Research Workshop on 'Human Dimensions in Embedded Virtual Simulation'. The primary goal of the group was to address Human Factor's aspects specific to Embedded Virtual Simulation (EVS) for training applications in the military domain. This involves the effective and efficient use of virtual and augmented simulation technologies for integrating training functionality into operational equipment. RTG-165 explored the potential of virtual simulation technologies for Embedded Training (ET) since many enabling technologies have been developed within the past few years and many innovations are on the horizon. The recommendations contained in this report are provided to support embedded virtual simulation as a tool to enhance deployed training and improve overall military effectiveness.

Early on, RTG 165 reviewed and analyzed the concept of ET and the lessons-learned from previous implementations of ET in military systems. Embedded training is a concept, which tightly integrates training functionality into operational equipment. It allows military personnel to train and rehearse while deployed. ET allows skills to be developed, maintained and adapted with deployed military equipment. It allows a greater coherence between the operational environment (climate, geographic area, coalition forces, and cultural aspects) and the training. It also allows a wider range of training opportunities while systems are employed in military exercises. This enables scheduling and adapting training anywhere and anytime with a unit's own resources. It enhances accessibility of training.

ET is a concept that has been actively considered as an alternative for providing training on combat systems for many years, however, because of technology and cost implications the main applications of the ET concept has been in air defence and naval systems. A review of ET's history indicates that it is a concept that has been popular with senior military decision makers, as noted by the letter signed by the Vice Chief of Staff and Under Secretary of the U.S. Army in the late 80s addressed to weapon system program managers telling them that ET was to be the first alternative for providing training for new weapon systems. Despite this policy decision, very few systems have implemented ET and those that have failed to go much beyond the capabilities of existing simulators.

To be effective in deployed settings ET has to be able to accomplish the functions that a simulation centre staff and instructional infrastructure perform but perform them on-board with the members of the training unit. This goes well beyond requirements for incorporating simulation capabilities into combat systems since it addresses how training delivery and management should occur. One possibility would be incorporating intelligent tutor technology as means for governing what training is delivered to meet training needs.

The RTG adopted the definition of ET used by the U.S. Army Research Institute (Finley et al., 1988) in their ten volume description of ET requirements and processes. It defines ET as that training which results from features incorporated into the end item of equipment to provide training and practice using that end item equipment. It also differs between three types of ET systems:

- Fully embedded systems: ET system is an integral part of the operational system. It is also a part of its system architecture and has to be considered during the design of the operational system.
- Umbilical systems: System can be physically connected to the operational equipment when training is being conducted and later disconnected at the conclusion of the training.
- Appended (strap-on) systems: System can be appended or strapped onto the operational equipment when training is being conducted and later removed. With regards to the required technology and interfaces, the term “embedded virtual simulation” has been defined by the RTG as follows:

‘Embedded Virtual Simulation is an enabling technology that provides an interface to interactive simulations that reside within or are appended to the operational equipment. It can provide links to local and/or geographically distant trainees and instructional resources. It enables a full range of capabilities for aiding, learning and practicing individual and team knowledge and skills.’

The RTG reviewed the state of the art of ET supporting technologies. The group concluded that appropriate application of Virtual Reality (VR), Augmented Reality (AR), and Intelligent Agent (IA) technologies could provide the means to effectively incorporate EVS into ground and air systems for training both individual and collective skills. VR and AR have both been proposed as Emerged and Emerging Disruptive Technologies (E2DT) by the NATO RTO HFM Panel. Relevant human factors issues associated with these two technologies have been extensively explored by various RTGs under different Panels. In the early 90s VR systems became a new and important subject for research and development in several NATO Nations. Cooperative research efforts were initiated in 1991 and 1992. As one of the first, HFM-028 provided detailed information about the state of the art (user interface design, displays, multimodal dialogue, etc.) and important human factors issues (simulator sickness, immersion, etc.). Another RTG of the Information Systems and Technology (IST) Panel, IST-011, recommended a more active exchange of information with civil/academic organizations in the field, and maintained a technology watch on other innovative technologies. IST-011 concluded that a comprehensive human model embedded in intelligent agents would not be possible in the medium or the long term. They felt that training developers and researchers should look closely at “intelligent” behaviors in VR, which can be simulated on the basis of well-known rule-based cognitive architectures in conjunction with kinematic and dynamic models. Subsequently, HFM-121 concluded that VR technology was becoming mature enough to support specific applications in education and training. That RTG recommended continuing research and development efforts in that area. Recommendations of RTG-121 narrowed the range of applications of VR/AR and the results of this work served as the initial impetus to look into the potential of embedded virtual simulation.

AR/VR allows trainees and human operators to experience synthetic environments that prepare them for the tasks they will need to be able to perform in the real world. Those training in a virtual or augmented reality environment should be presented with the same cues in the synthetic world that they would experience in the real world. They should be able to react to complex synthetic stimuli as if they were real. In this connection, AR/VR provides a technological approach that can provide a realistic training environment and a natural human-system interface by applying new interaction techniques and interface technologies.

Their effectiveness depends on human perception, cognition and motor response demands of the tasks to which they are applied. Although VR is capable of accomplishing real time full and part task training that rely primarily on visual perception, research is still needed to help specify the displays and interfaces needed for the other senses. For example, training for tasks that rely on manual dexterity is limited due to poor haptic feedback and interface devices. Poor interfaces can lead to negative side effects like physical exhaustion and simulator sickness.

Current representations of virtual environments do not include the “mud and dirt” experiences that soldiers experience in the real world. Therefore, AR/VR technologies can contribute to effective training strategies but they will not totally replace other education and training methods or environments, particularly, live training. While tactics and maneuvers can be performed in VR, soldiers will always need to experience the physical demands and conditions of the real world. Virtual simulation can support the effectiveness of live training with the introduction of AR targets and virtual humans. VR will help prepare soldiers for live training by broadening the spectrum of the situations the soldiers have encountered prior to training on live ranges.

As noted above, effective ET is not just dependent on displays and interface devices. To be effective, ET systems also need to include effective pedagogy, training strategies, and record keeping. Advances in the development of computer-based tutoring systems and serious games have prompted scientists to consider their combined potential for providing effective ET. The development of authoring tools to facilitate integrated game-based tutors will significantly alter the utility, affordability and accessibility of quality, self-directed learning curriculum that is both engaging and effective. Research is ongoing to evaluate game-based tutoring methods to accelerate learning and retention. Maturation of tutor and game technology will provide powerful tools for creating effective ET systems.

In order to get the perspective of the military user community and the defence industry, RTG-165 conducted a workshop in 2009. During the workshop, presentations addressed ET and EVS military requirements, operational constraints, training and mission support requirements including intelligent tutoring, training management, performance measurement and feedback. Additionally, relevant topics from the domain of human-technology interfaces, intelligent agents and directions for virtual simulation in operational platforms were discussed. Subsequent brainstorming sessions captured the main results from interactive discussions following each session.

The user requirement presentations and discussion concluded that there are different users of EVS systems: trainees, supervisors, instructors, and other personnel. They have different tasks and requirements that must be taken into consideration. The analysis of training requirements session identified mission characteristics, task analysis, analysis of trainees and target groups, and training objectives as relevant topics. User requirements focused on realism of the training environment, realistic behaviour of synthetic players, team training and general usability of the EVS system. Training management discussions determined that training sessions have to be managed, methods and technological means for instruction and feedback have to be provided, and the overall performance has to be evaluated. Workshop discussion of cost/benefit analyses concluded that they are required in order to determine affordability of EVS solutions.

The RTG surveyed military users and potential users of EVS and ET capabilities. Results of the survey indicated that users felt that the concept of EVS was promising, although the survey showed that many service members were not aware of the ET/EVS concept or its capabilities. Those survey respondents who were aware of ET thought it provided distinct benefits. Clearly one conclusion derived from the survey is that potential users require education about the benefits of ET and EVS. Another conclusion is that an educational program should be undertaken through both international and national forums. The RTG started to do so by participating in ITEC 2011 where the results of the workshop were presented to researchers, military users and decision makers in the field of simulation and training.

Training management has been identified as a core topic for successful use of EVS. Because training takes place in the field and not at a designated training area or schoolhouse, new procedures for training and providing feedback will be needed. Recording, storing and keeping track of training data are required for training that is tailored to individual needs. Training on actual weapon systems adds to the urgency and immediacy of the training. Management of ET will also have to address how training should fit in with the other demands of deployed units. Training will have to compete for priority with operations, maintenance time, and rest cycles.

The human interface between the weapon system mediated training system and the user is a key element of an EVS system. ET and EVS systems must be careful to ensure that users understand that they are either in an operational or training mode. Physical motion cues may be limited by safety concerns involved with the movement or vehicles or their components (e.g., a tank turret) in a confined space. Flight rules for aircraft must be carefully thought through to ensure that safety is not compromised. Because of the multimodal character of human perception it is important to stimulate senses appropriately to enhance the training effectiveness of the EVS. Compared to other modalities, visual displays are well developed. But there are serious limitations in the capabilities of helmet-mounted displays, especially when used in daylight outdoor environments. Presentation of sound is possible and supported since many military jobs require the wearing of headphones. An ET/EVS advantage was the potential positive effect by minimizing memory decay by closing the time gap between learning, mission rehearsal and training transfer.

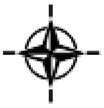
With regard to EVS, which applies AR/VR technology to education and training, some of the most mature applications have been in command and control domains. This includes command centres for missile defence and shipboard AEGIS systems. In these cases the EVS systems can be used without restriction for weight and space. Computational resources are also available. In addition, operational C2 displays can simply be applied and there is no need for sophisticated display and presentation technologies in order to create a virtual environment. Because the technological development in these areas has led to tremendous advances, EVS becomes applicable for ground and air platforms. They are typified in the development of the U.S. Army Future Combat System (FCS), the Puma infantry fighting vehicle and the F-35 fighter, all of which explicitly required embedded training in their overall design concepts.

In comparison to these applications, embedded training systems for dismounted warfighters remain a difficult challenge. This is primarily caused by physical restrictions, especially the extra load and energy requirements added by the training system. It would also require new technologies for augmenting the real view with computer-generated stimuli. A limiting factor is the insufficient brightness of current displays in outdoor settings. Existing prototype systems use an appended ET approach in order to enable training at special indoor locations.

A continuing challenge of the training community in support of EVS and ET will be to push for the integration of these technologies into the design of current and future operational platforms. To do this, ET and EVS should be integrated in the system design cycle as early as possible. The retrofit of existing platforms with ET systems might cause additional technical problems and costs. Retrofits may be difficult to integrate properly with the operational platform. Even appended or umbilical EVS systems require a consideration within system design for optimal performance. Since system acquisition designers are often separated from simulation and training designers, a more coordinated approach for the total system design may be needed.

The RTG concluded that EVS has the potential for maintaining the currency of training. As already pointed out above, human-centered design and integration of embedded virtual simulation technologies requires thorough review and analysis at the conceptual, functional, and technical levels. EVS covers a wide spectrum of human-system integration spanning from novel pedagogical concepts to innovative techniques of human-computer interaction. ET and EVS are promising concepts with a lot of benefits for enhancing military effectiveness. EVS is currently maturing. As technology becomes improves and becomes more affordable the likelihood of ET/EVS being implemented in ground and aviation systems will increase. The goal of having ET in the U.S. Army's FCS is an indication of this trend. In other domains, e.g., dismounted soldier training, the technologies to provide virtual full mission embedded training are not yet available.

Finally, the RTG would like to reiterate that for successful application of ET/EVS to future military systems user requirements (including characteristics of the user, task, and environment) and training management will have to be considered early in the design process. While training in both institutional and unit settings today requires an instructor that may not be possible for ET/EVS systems. An integration of an intelligent tutoring system might be able to successfully automate the instructor’s role. Given the key potential role of intelligent tutor technology in the success of ET, the RTG feels that further study should be undertaken to determine the maturity and promise of tutor technology. EVS could become a disruptive technology by providing NATO forces a training readiness advantage on the battlefield, particularly if EVS systems can exploit the advances now being made in other fields, such as secure, wide broadband, wireless networking and intelligence gathering.



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14. Abstract

Present and anticipated NATO missions require highly trained and capable military personnel. Units need to be able to deploy with little or no notice and to adapt to evolving situations. This places them in locations where they do not have the facilities needed to train, plan and rehearse complex missions.

The use of embedded virtual simulation (EVS) is seen as a potential tool to provide more effective deployed training. EVS is a concept that tightly integrates training and mission functionality into operational equipment. Applications for EVS are deployed settings that provide little support to users. To meet this challenge embedded simulation will have to include capabilities such as an intelligent tutor, integrated virtual environments, intelligent adversaries, friends and neutrals, an after action review system and training management capabilities. For live training an EVS system could support Augmented Reality capabilities as well. This report summarizes the outcome of the activities of a Research Task Group (RTG) whose objective was to explore from a human factors perspective the state of the art of EVS, evaluate its potential military applications and determine the directions for needed research and development.

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