Developing and Evaluating Advanced Technologies for Military Simulation and Training

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ABSTRACT

As the military continues to focus on reducing the overall cost of training while increasing the efficiency with which this training is provided -without sacrificing quality- Virtual Environment (VE) systems will become an increasingly attractive alternative. While current VE development efforts typically focus on supporting the individual user, rather than a broader, integrated collaborative environment, it is precisely this type of distributed, integrated and cross-platform environment within which the military typically operates and for which such VE systems must be developed. The VIRtual Technologies and Environments (VIRTE) research program was developed, through the Office of Naval Research, to support a solid Science and Technology base from which to expand this narrow development focus. VIRTE's research thrusts unite elements from the Modeling and Simulation communities with those from the Human Factors and Experimental Psychology fields in order to develop VE systems that are both technologically sound and performance enhancing, within a distributed virtual battlespace.

VIRTE's component systems are based on real-world operational requirements and are designed to easily transition. The systems include: a Virtual Environment Landing Craft, Air Cushion (VELCAC), a Virtual Environment Advanced Amphibious Assault Vehicle (VEAAAV), and a Virtual Environment Helicopter (VEHelo). These domains were selected precisely because military doctrine for Expeditionary Warfare including Marine Corps Strategy 21 and Sea Power 21 rely on elements from each of the real world vehicle analogues in order to be effective, thus forming a natural collaborative, integrated environment. The virtual systems are designed with the dual purpose of supporting training at the individual level, as well as at the level of distributed, team-based events, operating within a shared synthetic battlespace. This paper will describe the human centric process that was applied to the simulation development, the role of continuous training effectiveness evaluation, and key findings from this program that should be considered for future simulation development efforts.

ABOUT THE AUTHORS

Peter Muller is the deputy development manager on ONR's Virtual Environments and Technologies (VIRTE) program. He has extensive experience in DoD modeling and simulation. On the Defense Advanced Research Projects Agency (DARPA) Synthetic Theater of War Program (STOW) Advanced Concept Technology Demonstration (ACTD), Mr. Muller was responsible both for management of the development and transition of technology. Unlike most ACTDs, which do not go beyond their demonstration, STOW software was transitioned to Joint Forces Command (JFCOM) and the Navy and is in use today. In addition to his work as a Systems Engineering and Technical Assistance (SETA) contractor, Mr. Muller has worked in the aerospace industry in systems engineering and program management for both large and small companies. After graduating Syracuse University as a Distinguished Military Graduate, Mr. Muller served in the U.S. Army as an Air Defense Artillery Officer. Mr. Muller has a MS in Systems Management from USC and is a graduate of the U.S. Army Command and Staff College. He has received the Defense Acquisition University Level III certification for Science and Technology Management.

LT Joseph Cohn, PhD. is a designated Aerospace Experimental Psychologist. He received his Ph.D. in Neuroscience from Brandeis University's Ashton Graybiel Spatial Orientation Laboratory and completed his postdoctoral studies at Florida Atlantic University's Center for Complex Systems. While serving as the Lead, Training Effectiveness Evaluation, at the Naval Air Warfare Center Training Systems Division, LT Cohn co-developed a time series analysis technique for evaluating training transfer in VE-based Military training systems. Currently, LT Cohn serves as the Lead, Requirements and Training for VE at the Naval Research Laboratory where he is directing the evaluation of deployable VE systems for the Naval Aviation and Expeditionary Warfare communities.

Dr. Denise Nicholson is a Senior Research Engineer at the NAVAIR Orlando, Training Systems Division. She leads basic, exploratory and advanced R&D programs for ONR, DARPA, DMSO and NAVAIR. In her current capacity as ONR Human Systems Department Detailee she is a principal agent for development of S&T programs in response to the SEA WARRIOR Initiative. Her areas of research include Virtual Technologies and Environments, Augmented Cognition, Improved Behavioral Representation of Computer Generated Forces, Advanced Embedded/Deployable Training Systems, Synthetic Cognition for Operational Team Training and Intelligent Training Support Tools for Air Warfare Training. Prior to 1997 she conducted bench level research at the Air Force Research Lab, Rome NY where she developed and patented a Diffractive Optic Imaging Spectrometer for Visual and IR applications. Denise received her B.S. in Electrical Computer Engineering from Clarkson University and holds both M.S. and Ph.D. degrees in Optical Engineering from the University of Arizona. She has over 15 years of experience in research and development for military applications.

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BACKGROUND

In 1999, the Department of the Navy adopted a new process for concentrating its science and technology assets to achieve Future Naval Capabilities (FNCs). Capable Manpower is one of thirteen FNCs, with the stated goal of providing Sailors and Marines the tools they need to succeed by giving them affordable human centered hardware and systems developed out of a thorough knowledge of human capabilities, limitations, and needs.

VIRTE (VIRtual Technologies and Environments) represents Capable Manpower's largest single investment. Although the program officially began in FY 02, it leveraged work from ONR's Virtual Environment Training Technology (VETT) and the Small Unit Tactical Trainer (SUTT) programs. As the VIRTE concept was being developed, the Marine Corps finalized their Capstone Concept of Expeditionary Maneuver Warfare in support of Marine Corps Strategy 21. Expeditionary Maneuver Warfare training provided a natural fit with VIRTE goals.

EXPEDITIONARY MANEUVER WARFARE

Expeditionary Maneuver Warfare (EMW) … "is the union of our core competencies; maneuver warfare philosophy; expeditionary heritage; and the concepts by which we organize, deploy, and employ forces." (Department of the Navy, 2001)

Naval Expeditionary Maneuver Warfare consists of military operations mounted from the sea, usually on short notice. They are carried out by forward-deployed or rapidly deployable, self-sustaining naval forces tailored to achieve a clearly stated objective. The future primary platforms for Expeditionary Warfare, known as the "Amphibious Assault Triad", are the Landing Craft, Air Cushion, or LCAC, the Advanced Amphibious Assault Vehicle (AAAV), and the Osprey MV-22 tiltrotor aircraft. VIRTE focused on these diverse vehicles since they present unique simulation and training challenges. These vehicles, and their Virtual Environment Counterparts, are depicted in Figure 1.

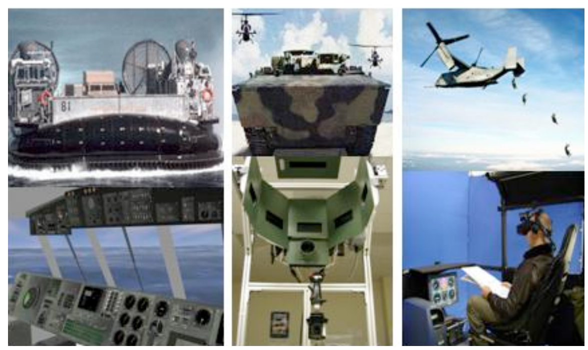

Figure.1: VIRTE focuses on providing training solutions that support performance on Expeditionary Maneuver Warfare's Amphibious Assault Triad platforms. The elements comprising this Triad include air, land and sea components. *Left column:* Landing Craft, Air Cushioned (LCAC) and, beneath it, Virtual Environment LCAC (VELCAC). *Middle Column:* Advanced Amphibious Assault Vehicle (AAAV) and beneath it one of the Virtual Environment AAAV (VE AAAV) crew member stations; *Right column:* MV-22 (Osprey) tilt-rotor aircraft and beneath it the setup for the Virtual Environment Helicopter (VEHelo). See text for detailed description of system specifications and requirements definitions.

LCAC

The LCAC is the only member of the triad that is currently fielded. The LCAC is a high-speed, over-the-beach fully amphibious landing craft capable of carrying a 60-75 ton payload. It is used to transport weapons systems, equipment, cargo and personnel from ship to shore and across the beach. The Navy has 76 LCACs in service. The LCAC crew consists of three positions, the Craftmaster (pilot), the Navigator, and the Engineer who work closely together to operate the vehicle.

Currently, there are two LCAC Full Mission Trainers (FMTs), one at Assault Craft Unit (ACU) 4 in Dam Neck, Virginia, and one at ACU 5 in Camp Pendleton, California. While these provide excellent high fidelity training, they are expensive to procure and operate.

The LCAC fleet is just beginning to field a Service Life Extension Program (SLEP) which completely changes the operator interface to the vehicle. It will be several years until there are sufficient SLEP LCACs fielded to transition the FMT to the SLEP configuration. VIRTE is delivering a desktop SLEP LCAC training system that can be used as an interim training system.

AAAV

The Advanced Amphibious Assault Vehicle (AAAV) is currently in the prototype stage and it is scheduled to enter Low Rate Initial Production in FY 07. The AAAV will provide the capability to move a combat loaded USMC rifle squad at over 20 knots on the water and maneuver cross country with the speed and agility of the M1 tank. It will replace the AAV7A1. The AAAV crew consists of the driver, the gunner, and the vehicle commander.

The AAAV is in the System Development and Demonstration (SDD) phase and second generation prototypes are being matured and prepared for production. The AAAV will be supported by a significant investment in training systems. VIRTE is focusing on transferring technology to two of these, the schoolhouse training system and the vehicle embedded training system.

MV-22

The MV-22 Osprey is a tilt-rotor aircraft that will provide airlift in support of Expeditionary Maneuver Warfare. The tiltrotor design combines the speed, range, and fuel efficiency normally associated with turboprop aircraft with the vertical take-off/landing and hover capabilities of helicopters. The MV-22 crew consists of a pilot and co-pilot.

The MV-22 is currently in Low Rate Initial Production (LRIP) and in the USMC will replace the CH-46E and CH-53D. As with the AAAV, there is a significant investment in training systems. Rather than try to insert technology directly in the MV-22 program, we are concentrating on demonstrating technologies that are applicable to all aircraft trainers.

REQUIREMENTS DEFINITION

One of the unique features of Capable Manpower is the requirement to identify a transition customer for the Science and Technology. In order to formalize the transition, the technology developer and the customer must execute a Technology Transition Agreement (TTA). Although the format of the TTA has changed several times, the purpose of the document is to get a commitment from the transition customer that they will transition the technology if it meets agreed upon metrics.

While formal requirements definition is used in DoD acquisition programs, it is rarely applied to Science and Technology thrusts. The VIRTE program worked with its customers early on to define requirements that could form the basis of the TTA. Naively, it was thought that requirements definition with each customer would be a one-time exercise. As each customer saw the level to which VIRTE's technologies had developed through demonstrations scheduled at Intermediate Feasibility Experiments (IFEs), they often elected to add new requirements and, in some cases, chose to radically alter what they wanted.

VIRTE Requirements

One of VIRTE's overarching program goals was to insure that all of our training systems would share a common Joint Synthetic Battlespace (JSB). This was done despite the fact that none of the customers had a requirement to interoperate with the other training systems of the Amphibious Assault Triad. Nevertheless, it was expected that as the mission goals for each platform became more entwined with each other, the benefits of being able to jointly practice missions, tactics and strategies in the relative safety of a JSB would be enormous. Along these lines, a single After Action Review System was developed for all three systems.

In *Serious Play,* Michael Schrage of the MIT Media Lab writes, "When talented innovators innovate, you don't listen to the specs they quote. You look at the models they've created." What interests Schrage is not the model itself, but the behavior that playing with it inspires (Schrage, 1999). This underlying design philosophy, which is essentially human or user-centric, forms the core of VIRTE's Research and Development effort. By getting early prototypes to the potential users, VIRTE was able to jump start the requirements process and gain valuable insight into how to design systems that would both be used by the intended community and provide them with a valuable training experience.

Within the Department of the Navy, there is a two two-tiered framework for defining training system requirements. On the one hand, the Program Management (PM) team ensures that each new requirement falls within the overall goals and mission of the acquired platform. On the other hand, the Fleet User provides a direct push to the PM to develop better and more accessible training tools. In developing requirements for each VIRTE component, both communities were involved early on in the design process to ensure that the final requirements –and the ensuing VE training system- were satisfactory to both.

PMS 377 Requirements for VELCAC

The Amphibious Warfare Program Office (PMS 377) is assigned responsibility for management of LCAC Acquisition and Life Cycle Management.

The Virtual Environment LCAC (VELCAC) simulator will provide the capability to train all three LCAC positions, Craftmaster, Navigator, and Engineer, by modeling the various crew stations interfaces and vehicle systems. PMS 377 identified that the objective of VELCAC was to provide an interim training solution; a schoolhouse simulation training of crews transitioning from baseline to SLEP LCACs prior to the availability of SLEP configured training systems.

Prior to VIRTE, NAVAIR Orlando had several years experience in Virtual Environment applications for the LCAC. Since Virtual Environment technologies are relatively new, it was critical to let the LCAC crews "play" with the LCAC and find out how they could best be used to accomplish real world training tasks. By providing members of PMS 377 with initial exposure to VELCAC they were better able to understand our subsequent requests for information and crewmember participation.

Direct Reporting Program Manager, Advanced Amphibious Assault (DRPM, AAA) Requirements for VEAAAV

The Direct Reporting Program Manager, Advanced Amphibious Assault (DRPM, AAA) is responsible for the acquisition of the new Advanced Amphibious Assault Vehicle (AAAV).

VIRTE's focus for VEAAAV was on developing a prototype schoolhouse trainer to train the "New Equipment Training Team" (NETT) and to transfer component technology for use in the Embedded Training (ET) system that will be embedded in the actual vehicles. Unlike the LCAC, the AAAV is not in production and changes to the operator interface are constantly being made. As with the LCAC, there was an early prototype developed under a previous program. This allowed the customers a hands-on experience that was invaluable in assisting them in forming a clearer picture of how VEAAAV would be able to support their future training needs.

PMA 205 Requirements for VEHELO

In discussions with the MV-22 program office, it became clear that their technology requirements did not fit well with VIRTE's goals. Rather than abandon the effort, we found sponsorship with NAVAIR's PMA 205. PMA 205 is responsible for managing Naval Aviation Training Systems from concept to disposal. The transition program for VIRTE identified by PMA 205 is the Naval Aviation Simulation Master Plan (NASMP). NASMP consolidates program efforts for aviation training, linking all major contributing factors necessary for effective training.

Areas of research were identified that fit NASMP requirements including low-cost deployable training systems and methods for effective implementation of simulation tools for simulation based training including; pre-brief, mission rehearsal and debriefing/after-action review. VIRTE has been focused on addressing these needs by developing a general VE rotary wing/helicopter aircraft training system or VEHelo.

User-Centric Requirements Definition

The initial exposure of the transition customer's program management to their respective VIRTE platform served as a first step towards defining system requirements. Nevertheless, it is the service member who is the intended end-user and it is from them that more specific sets of requirements must be derived. In order to more fully identify a set of requirements for each VIRTE system, a comprehensive Training Effectiveness Evaluation (TEE) was undertaken.

The philosophy underlying the VIRTE TEE derived from the overarching mission goal of ensuring that Fleet training requirements are identified and supported throughout the R&D cycle. This mandates a three-pronged approach. First, up-front analyses must be undertaken to provide critical input in order to better understand overall training goals and objectives, required level of simulator fidelity, scenario components and performance measures. In parallel with this effort, Intermediate Feasibility Experiments (IFEs) must be undertaken at key points within the development cycle to evaluate progress-to-date and, if necessary, to propose alternate development solutions. Finally, a back-end analysis must be undertaken once the development cycle has been completed, in order to provide the end-users with a comprehensive understanding of what the system can and can't train.

In practical terms, this effort can be parsed into five elements. The first element, the *Task Analysis (TA)*, seeks to identify the training objectives and the scenario elements that must be included in a simulation to support these objectives as well as providing an assessment of whether currently available training can be modified so that a technology solution is not necessary. For TEE purposes, a contextual task analysis is performed, which focuses on the behavioral aspects of a task as performed in a given operational setting, resulting in an understanding of the general structure and flow of task activities (Mayhew, 1999; Nielsen, 1993; Wixon & Wilson, 1997). The second element is an assessment of *Human-Computer Interactions (HCI)*, identifying the requirements for sensory modality integration, as well as evaluating current hardware/software technologies supporting these interactions, and providing guidance for integrating them into a simulation. The next area, *System Usability*, evaluates how accommodating the overall VE design is for use by the layperson (Stanney, Mollaghasemi, & Reeves, 2000). *VE User Considerations* addresses both evaluations of the side effects encountered during exposure to VE, as well as aftereffects arising following this exposure. Perhaps the most important element of TEE, which validates all the efforts described thus far, is an evaluation of the degree to which *Training Transfers* from the VE to the real world scenario (Carretta & Dunlap, 1998; Lathan, Tracey, Sebrechts, Clawson, & Higgins, 2002; Waller, Hunt, & Knapp, 1998).

Table 1. TEE elements supporting requirements definition.

Platform / *TEE Element*	LCAC	AAAV	MV-22
TA	X	X	X
HCI	X		
Usability	X		
VE User Considerations	X	X	X
Training Transfer			X

Since each simulator carried with it a distinct set of requirements, the TEE objectives of VIRTE were structured so that, while each VE platform utilized aspects of each TEE component, each platform was also singled out to highlight, from a requirements perspective, issues within these elements most germane to their respective applications. Table 1 illustrates this allocation.

Task Analysis

One of the most critical issues that any VE developer faces, prior to undertaking the design of a new VE simulation is *How to design a system that will support the users' training needs?* Recent trends in simulator development have suggested that the optimal approach is to determine the information (world-based knowledge, perceptual cues/stimuli) that enables task performance (Gross, Stanney & Cohn, 2001), then develop a model for task performance based on *task elements* and, finally, to design a simulation to support these task elements (Cohn, Breaux, Nguyen & Schmorrow, 2001). The accepted approach for identifying these elements is via a task analysis. Specifically, since VIRTE is concerned with providing experts with training on abstract concepts rather than with training novices to perform specific perceptuomotor tasks, for each platform a *cognitive task analysis* (CTA) was performed (Card, Moran, & Newell, 1983; Corbett, Koedinger, & Anderson, 1997). The outcome of each CTA includes the training objectives, the elements that support these objectives, and notions of how to incorporate these elements into a training scenario.

The VELCAC system's primary use was determined to be a teaching supplement to acquaint highly skilled crews with a new cockpit instrumentation layout and corresponding upgraded features (the Service Life Extension Program, or SLEP LCAC configuration).

The elements supporting this objective included providing an interactive, 3-D environment with "live" instrumentation supporting each crewstation. Training scenario definition was determined through multiple evaluation sessions with Subject Matter Experts (SMEs) who had received preliminary training on the new instrumentation layout.

The key training objective for the VEAAAV was determined to be the provision of a stand-alone training system, integrated with a Human Behavior Representation (HBR) capable of acting as an Intelligent Agent (IA). The elements supporting this objective included the simulation of each of the three AAAV positions and the development of an IA that operates as a separate federate in the VIRTE federation. The IA supports both Immediate Feedback and After Action Review components by monitoring, assessing and recording trainee performance during scenario execution (Lyons, Schmorrow, Cohn & Lackey, 2002). The training scenario definition included a comprehensive curriculum consisting of five levels: Orientation, Novice Gunnery, Intermediate Gunnery, Advanced Gunnery, and Expert Gunnery.

The intended use of the VEHelo is, among other things, to support low level, navigation training for such exercises as Non-Combatant Evacuation Operations (NEO) and Nap of Earth (NOE) flight. The key elements supporting this objective included the development of a system that could import environments from commonly used Navy Mission Planning software tools, as well as the development and validation of metrics targeted at quantifying level of Navigation proficiency. Specific navigation scenarios were identified in conjunction with Helicopter Squadron-10 and the Naval Postgraduate School, with an effort towards developing tools that could be handed to newly designated Naval Aviators joining the squadron and needing exposure to the local terrain.

Human Computer Interface

The objective of the HCI evaluation was to identify those sensory modalities that must be represented within the VE, to provide an evaluation of current technologies supporting these sensory modalities, and, based on these analyses, to recommend devices for integration into the final VE system. Since the VELCAC system was the one most likely to require hi-interface fidelity, due to the unique nature of its training objectives, VIRTE's HCI effort focused on issues relating to this system.

One of the most important results to derive from this effort was the focus on only two of the sensory systems, vision and haptics (touch). Adding to this, an analysis of the requirements document suggested that key factors included: cost-effectiveness of training and portability. Field observations revealed that of the three crew positions under consideration, only the Craftmaster (the crewmember who flies the LCAC) would need physical controls (yoke, foot pedals, and throttle) in the VELCAC. The other two crewmembers (the Navigator, who monitors position, and the Engineer, who monitors LCAC system function) spend the majority of their time observing and interacting with touch screen interfaces on the instrument console. Thus, the Craftmaster would require a wide field of view (FOV), while the Engineer and Navigator, who spend the majority of their time looking at their respective instrument console, would not need this enhanced FOV.

Together, these findings suggested that the VELCAC system had to have minimal setup/calibration time; that the system had to be compact in size; and that the component hardware had to be ruggedized in order to withstand environmental stressors found in a range of operational settings. These factors, in combination with cost effectiveness and the need for a wide FOV for the Craftmaster, eliminated all visual display system options except for HMDs or multiple monitors. The haptics requirements suggested that the Craftmaster needed to physically touch the control interfaces to 'feel' the craft's performance while the other two positions (Navigator and Engineer) - which do not receive information that is as critical from their control surfaces (primarily knobs and switches)- required only touch screen interfaces.

System Usability

System usability provides a comprehensive indication of how accommodating software and hardware are for use by the layperson. The ultimate goal in performing a system usability analysis is to work with system developers and domain experts to establish usability objectives that then serve as the metrics against which iterative builds can be evaluated. These metrics encompass:

- <u>Effectiveness:</u> How successfully tasks can be achieved at acceptable proficiency levels
- <u>Intuitiveness:</u> How easy/difficult it is to learn to operate and to interact with the System
- <u>Subjective perception</u>: How comfortable and satisfied users are with the system.

In order to derive these metrics, a series of clearly defined, logical steps must be undertaken. First, system-wide design weaknesses are identified through expert evaluation. Next, user interaction is assessed through observation by trained evaluators. Based on these efforts, usability experts can then identify key usability concerns in the VE system design.

Ultimately, the results of these analyses are a set of rank ordered redesign recommendations, which include novel approaches for resolving identified usability concerns as well as providing conceptual designs to guide the proposed redesign effort (Figure 2). VELCAC's usability assessment was performed by two usability engineers, working together with LCAC crewmembers from the Craftmaster and Engineer stations. The results from this effort were used to provide redesign recommendations, as well as to establish usability testing metrics and their associated acceptability criteria for future usability testing of VELCAC when more mature iterations of the system are developed.

Usability Concern	User Impact	Recommendation	Priorit y
Cockpit Instrument Interface is not organic to the task	**L**	**Replace interface with touch screen**	**L**
Point of View is difficult to change	**M**	**Develop intuitive interface too change Point of View**	**M**
Zoom function leads to disorientation	**H**	**Modify Zoom feature**	**H**

Figure 2: Sample Redesign Recommendation Matrix for interface components of VELCAC. *From Left :* Usability Concern presents key issues identified as potentially affecting user acceptance; User Impact identifies the impact these concerns are predicted to have on the user, presented as a rank order Low (L), Medium (M) or High (H); Recommendation provides system developers with a proposed solution; Priority provides the system developers with a rank ordered indication (Low, Medium or High) of how critical it is to implement the proposed recommendation.

VE User Considerations

An important consideration, from the User's perspective, when developing a VE is the degree to which exposure to the actual VE system negatively impacts training and warfighter readiness. Cybersickness is a collective set of symptoms that can develop during VE exposure. Symptoms of cybersickness range from the merely distracting, such as eyestrain and blurred vision, to the performance detracting, such as depression and apathy. It is expected that the quality of the overall training imparted by a VE will be negatively impacted by these symptoms. Aftereffects, resulting from VE exposure must also be evaluated and their potential for negative impact on real world performance determined (Stanney, Salvendy et al., 1998). Such impact typically includes recalibration of both reflex motor behaviors, such as changes in the resting point of accommodation (the eye's optical power) (Fowlkes, Kennedy, Hettinger & Harm, 1993) as well as more complex behaviors, such as an inability to remain in place while running following treadmill exposure.

In VIRTE, there are three parallel efforts addressing these issues. The first focuses on developing a *Warfighter Readiness Toolkit* to quickly identify users who may be suffering from either Cybersickness side effects or aftereffects. This toolkit includes cognitive, perceptual and motor tests that are currently being validated against a range of existing training simulations (Cohn, Muth, Schmorrow, Brendley & Hillson, 2002). The second effort focuses on applying these metrics during the development of the component VIRTE systems, to provide developers with yet another yardstick by which to measure progress.

The first two efforts provide information that allows developers to make informed decisions in terms of developing hardware and software requirements. The third effort focuses on developing technologies –and quantifying how best to integrate them into existing training systems- to reduce motion sickness in individuals already experiencing some of the Cybersickness symptoms. Specifically, this effort capitalizes on the notion that artificial horizons may provide a re-orienting effect in individuals, such as pilots, who may be exposed to disorienting cues (Rolnick & Bles, 1989). Previous results, in which users were exposed to a provocative environment either with or without this device, suggest that this approach may hold promise (Cohn, et al, 2002, Brendley, Cohn, Marti, Muth & Stripling, 2003). Current work is focused on developing a seamless interface for providing this reorienting effect in users *while* they are training in VE systems, thereby enabling them to continue their training session.

Training Transfer

The ultimate goal of *any* VE simulation training system is to provide enhanced performance in the real world environment (Ford, et al, 1998; Lathan et al., 2002). Despite the many benefits that VE systems have over real world training (cf Rose, et al, 2000) concrete illustrations of the transfer of complex skills to real-world applications from VE training, or of real-world performance enhancement through exposure to VEs, are few and far between (Cohn et al., 2000). More often, positive transfer of component sub-skills, such as those that are *spatial* (Witmer, Bailey, & Knerr, 1996; Witmer & Sadowski, 1998) or *procedural* skills (Brooks, Attree, Rose, Clifford, & Leadbetter, 1999) is demonstrated. Yet, many of these demonstrations are likely simulation-specific. When demonstrations of positive training transfer for complex tasks are indicated, these evaluations may rely on more anecdotal evaluations or perceptions of training utility rather than statistically determined measures.

In a sense, training transfer provides the testing arena within which all previous design decisions are evaluated, *en masse.* Capitalizing on the CTA, the VEHelo scenario was developed with a focus on spatial knowledge/terrain association task, which is ideally suited for Virtual Environment training (Darken & Banner, 1998; Bone & Lintern, 1999). Information derived from the CTA provided the background for developing metrics, to more fully understand the processes leading to successful transfer. These metrics encompassed both *process* and *outcome* variables, and are currently under development. Many of these metrics are questionnaire-based and required extensive validation before being used. All were selected with the intent of quantifying a user's 'spatial knowledge landscape' before and after training, in order to pin-point where, in the learning process, VEHelo proved most effective.

The actual training transfer design involves assigning users to one of two groups (1) the current training regimen plus an extra exposure to 'best practices' for performing the task or (2) the current training regimen plus VE training. After training, all groups will navigate a real world flight with an instructor pilot. All groups will be equalized in terms of the current classroom training regimen. The component of training that is being tested, then, is whether or not VE exposure is better than receiving additional non-VE based training. The fundamental training transfer hypothesis is that groups who receive the current training regimen and additional VE training flights will perform more effectively with lower perceived workload/stress than those who receive the current training regimen and best practices component, precisely because the VE training session provided the means through which spatial knowledge can be consolidated..

PROTYPE DEVELOPMENT

Before Training Transfer can be established, we have to turn the requirements into a functioning system. In addition to all of the requirements explicitly stated by the customers and all of those gleaned from the Training Effectiveness Evaluation, there were a number of requirements that were added by the program manager, LCDR Dylan Schmorrow as part of his vision for the program. First, the program must be HLA compliant and each of the simulations had to share the same battlespace. This led to the selection of JointSAF as the simulation environment. We chose OpenFlight as the visualization database standard and allowed each of the development teams to choose their own tools. Second, we tried to minimize program license costs with the vision that we would be able to hand out free CDs of the applications to anyone that wanted them. While we made significant progress in that direction, we still haven't achieved the vision. We came the closest with the VELCAC which uses a commercial gaming engine, Gamebryo (formerly NetImmerse).

For deployability and cost factors, we chose high end PCs with "gamer" quality graphics cards. While we tried to make maximum use of COTS, when the TEE told us that we needed to replicate certain items of hardware, we did.

As we mentioned previously, early prototypes were the key to the program. In a two-year span, we went from concept to deployable prototypes. We employed a Spiral Development process and held a series of Intermediate Feasibility Experiments (IFEs). The four IFEs were events where developers deployed their latest configurations in realistic testing environments with typical users. IFE 1 and 2 were in San Antonio at the SwRI facility (the developer of VEAAAV). IFE 3 was at various customer locations. IFE 4 is here at I/ITSEC.

Summary of Requirements Definition and Their Implementation

The discussion thus far has mapped out a path for developing system requirements in what can be considered both a top-down (Program Management level) and bottom-up (End-user level) approach. In a sense, the top-down requirements can be considered as providing the boundary values for what will be acceptable additions to a given community's already large training technology 'toolbox.' In a similar manner, the bottom-up requirements can be treated as providing the underlying details that will fuel system designers as they develop the actual training system. Through planned, iterative development demonstrations, necessary corrections to these requirements –and to their implementation- can be made. The results of these efforts are reviewed, briefly, below.

CONCLUSIONS

The principles underlying the development of VIRTE's simulation platforms are not intended to be program-specific. Instead, they are meant to serve as a concrete illustration of how any simulation development team might endeavor to guarantee that their efforts meet with the highest possible acceptance among the intended customer.

It is critical to the program success to understand who the customer is. Although we listened to potential end-users, our agreements are with our transition partners. Another important lesson is flexibility. You can't be too tied to a specific technical or scientific solution. If it doesn't meet customer requirements, then don't transition it.

Finally, even if you understand your customers, it is crucial to get the system out to the Fleet in regularly scheduled events. There is no substitute for Sailors and Marines "kicking the virtual tires."

While the actual details of transition may vary from effort to effort, the basic user-centric philosophy that cuts through VIRTE's development is one that will continue to prove itself across a range of simulation development efforts.

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