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ADP010624

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DISMOUNTED WARRIOR NETWORK EXPERIMENTS

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INTRODUCTION

The Dismounted Warrior Network (DWN) project began in November 1995 with the publication of the STRICOM Individual Combatant Simulation Technology Transfer Plan [1]. Sponsored by the US Army Infantry Center (USAIC) and the US Marine Corps (USMC), the purpose of the first phase of DWN was to provide a means of understanding dismounted infantry simulation requirements. A series of experiments and exercises were planned, to include an assessment of the cost and benefits associated with the technologies to immerse the individual combatant within the virtual battlefield. One of the most important products of DWN is a Simulation Task Analysis, which was developed to support simulation for IC in the Training, Exercises, and Military Operations (TEMO), Advanced Concepts and Requirements (ACR), and Research, Development and Acquisition (RDA) domains. A preliminary technology analysis was conducted to assess and select current representative IC simulation technologies for inclusion in the DWN experiments and exercises.

APPROACH

DWN is a STRICOM-led project executed under an Advanced Distributed Simulation Technology (ADST) II delivery order, with Lockheed Martin Corporation as the prime contractor. In January 1996, STRICOM assembled a team of technical experts from Government and industry to evaluate the current state of the art in IC simulation. The team visited several technology providers and assessed the maturity of the simulations as they supported the DWN needs.

As the focus for the DWN experiments was on virtual simulation, the systems were required to be real-time, man-in-the-loop, and DIS compatible so that several platforms could be networked. Among the system components reviewed and assessed were: body movement tracking, visual animation of human figures, directional sound, surrogate weapon systems, locomotion simulation, human gesture recognition, natural language processing, SAF capability and analytic modeling. Several contractors proposed innovative solutions for inserting the individual into the synthetic environment. However, based on budget and time constraints, STRICOM preferred that the systems be developed and actively funded. The technologies selected were grouped into four Virtual Individual Combatant Simulators (VIC), each capable of providing a single individual the ability to interact within the virtual battlefield with other VIC and platforms in a DIS exercise.

In addition to the VICs, a Dismounted Infantry (DI) Semi-Autonomous Forces (SAF) capability was required to support more than a fireteam level battle (i.e. to round out the squad/platoon with computer generated forces). The DWN team investigated a number of different SAF systems that model DI. Among the technical capabilities reviewed during the SAF evaluations were: the SAF development language, platform on which the SAF runs, support of DIS protocols, human figure animation, ModSAF basis, voice recognition, gesture recognition, and interaction with 3D terrain.

Following the technology assessments and selection, the DWN delivery order was awarded in June 1996. Several Technical Interchange Meetings were held among the Integrated Product Team (IPT) to design the experiments and exercises. Following a brief integration period, the engineering experiments were conducted during a three-week period in April-May 1997 at the Orlando, FL Lockheed Martin facility. The VICs were relocated and the user exercises were conducted during a three-week period in May-June 1997 at the Land Warrior Test Bed, Ft. Benning, GA.

OBJECTIVES

Simulation Task Analysis. Among the key objectives of the DWN project is to develop a Requirements Document for US Army and USMC IC simulation. The DWN experiments and exercises were conducted to provide a proof of concept for the technologies that enable the individual to interact within the virtual battlefield. The DWN Simulation Task

Paper presented at the RTO HFM Workshop on "The Capability of Virtual Reality to Meet Military Requirements", held in Orlando, USA, 5-9 December 1997, and published in RTO MP-54.

Analysis was developed to assist the Army and USMC soldiers in defining the requirements for IC simulation in the ACR, RDA and TEMO domains. A Functional Definition Process was developed, based on the Army's Close Combat Tactical Trainer (CCTT) Program, with changes necessary for the ACR and RDA domains. Linkage was provided to existing Army and USMC doctrine and tactics. Individual to squad, squad to platoon, and platoon to company organization level tasks were analyzed for the domains.

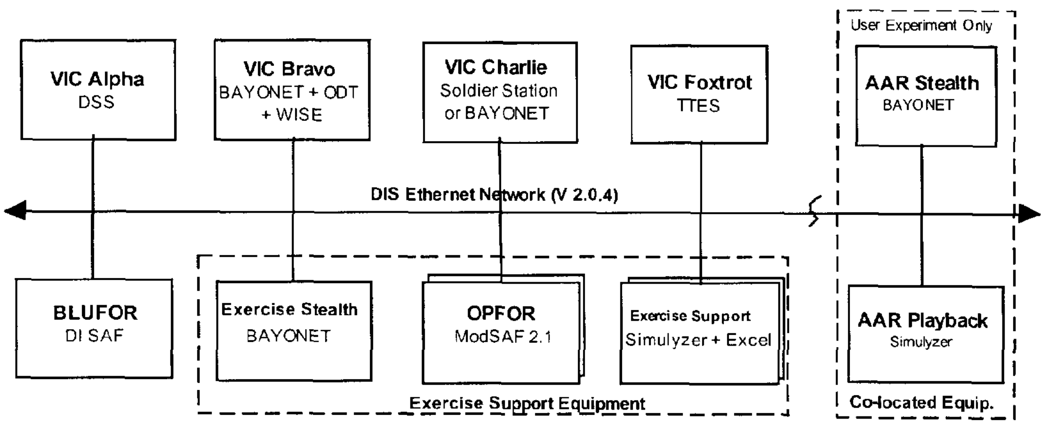
An extensive series of documents were systematically developed as part of the Simulation Task Analysis and became the basis for the DWN Requirements Document. This documentation provides traceablility back to doctrine. A relational database was developed to allow direct Validation, Verification and Accreditation functionality. The documents include the following: Functional Definition Process, ACR/RDA Functional Definition, TEMO Functional Definition, ACR/RDA Functional Fidelity, TEMO Functional Fidelity and Requirements Document. The information can be viewed and downloaded by accessing the DWN home page at http://www.rciorl.com./htms/warrior.htm. The intent of the Requirements Document is to form the basis for follow-on virtual IC simulations and simulators required by the Army and USMC.

DoD Defense Technology Objective (DTO). DWN directly supports DTO IS.40.01, Individual Combatant and Small Unit Operations (IC/SUO) Simulations in the Synthetic Environment. This joint DTO is led by the STRICOM Engineering Directorate. Among the objectives is to develop and demonstrate technologies for creating real-time simulations to immerse the individual soldier and allow for interaction in the synthetic environment. The products that will evolve within the DTO include simulations which are High Level Architecture (HLA) compliant and that support low cost solutions for mission rehearsal, materiel development and training of individual soldiers and marines. There is also potential application of these technologies to training and rehearsal for the FBI and law enforcement communities. DWN and its results will form the basis of the virtual simulation capabilities for the IC/SUO DTO.

EXPERIMENTS AND EXERCISES

Technologies

Four VICs and DI SAF were integrated and evaluated on two digital terrain databases during the DWN engineering experiments and user exercises. As mentioned above, these technologies were chosen based on maturity, capability, availability and their contribution to form a representative and complementary sample of existing technical approaches. Figure 1 provides a System Block Diagram for DWN.



Notes:
(1) DIS Compatible virtual radios supplied with each system for operator coordination, but connected together on a separate ethernet network ("admin net");
(2) Separate wireless radio net between soldiers using the four VIC's and the Exercise Stealth ("tactical net");
(3) Second ModSAF and second Simulyzer provided as back-up and to provide additional PVD for Exercise Director and Battlemaster

Figure 1. DWN Block Diagram

As shown, the system consisted of four VICs, a BLUFOR station comprised of DI SAF, Exercise Support equipment, and an After Action Review (AAR) capability. All systems were connected via an ethernet network and communicated

with each other via DIS 2.0.4 PDUs. A wireless radio was provided for communications between the soldiers on the operating VICs.
The four VICs provided a wide variety of techniques for accomplishing the basic functions of locomotion, display, and weapon aiming as shown in Table 1.

Function	VIC Alpha	VIC Bravo	VIC Charlie	VIC Foxtrot
Locomotion	Human Joystick	ODT	Joystick	Foot Pedal + Head Orientation
Visual Display	Wireless HMD	4 Projection Screens (WISE)	Desktop Monitor	Single Projection Screen
Body Motion Capture	Video	Magnetic	N/A	Magnetic
Weapon Tracking	Video	Magnetic	N/A	Acoustic
Weapon Aiming	Video thru HMD	Video thru IHAS	Video crosshairs on CRT	Rifle sight on rear projection screen
Directional Sound	SOUNDSTORM 3d	SOUNDSTORM 3d	Yes	Yes
Human Animation	Biomechanics	DI-Guy	JackML	DI-Guy

Table 1. VICs Comparison Matrix

VIC Alpha is the Dismounted Soldier Simulation (DSS) system developed by Veda, Inc. under a STRICOM Broad Agency Announcement contract [2], [3], [4]. Unique technologies utilized by this system are the optical (camera) based full-body motion capture system, the use of a wireless head-mounted display (HMD) and the 'human joystick' paradigm for locomotion. VIC Alpha is the only completely untethered DWN system that allows the soldier to freely maneuver in a pre-defined space.

VIC Bravo is a combined system consisting of Virtual Space Devices, Inc. (VSD) Omni-Directional Treadmill (ODT) mobility platform combined with Reality By Design's (RBD) Bayonet visual simulation system. Bayonet is based on NPSNET-IV from the Naval Postgraduate School with additional RBD enhancements, extensions and optimizations specifically for IC operations [5], [6], [7]. Unique technologies presented by this system include an omni-directional, force-feedback mobility platform allowing full 360-degree operation. The Bayonet system presents a 270 degree field-of-view visual display using a Walk In Synthetic Environment (WISE), combined with a monocular monochrome HMD simulating the video camera from the Land Warrior (LW) system. Bayonet utilizes magnetic based tracking for weapon aiming.

VIC Charlie is the TRAC-WSMR Soldier Station [8], [9]. Soldier Station is a combined virtual/constructive simulation solution focused on analytic modeling and evaluation. Unique technologies include the use of a joystick and touchscreen user interface, with a computer monitor display. Soldier Station uses validated constructive algorithms from Janus combined with an enhanced version of NPSNET-IV for visuals, networking and the user interface. The fully functional Soldier Station was used during the user exercises only.

VIC Foxtrot is the USMC Team Tactical Engagement Simulator (TTES) developed at the Naval Air Warfare Center (NAWC-TSD). TTES presents a high-resolution virtual image via a large rear-projection screen. Locomotion velocity is controlled using a pressure sensitive foot pedal. The user's head is tracked with a magnetic sensor and is used to control steering through the environment. A de-milled rifle is used for aiming and firing and is tracked using an acoustic sensor.

Based on the data collected and analyzed during the technology assessment, a DI-oriented SAF system did not exist with Army behaviors suitable for the DWN experiments. An Army DI SAF capability was therefore developed by SAIC based on the USMC IC SAF, which had supported Leathernet as part of the DARPA STOW program [10]. The USMC IC SAF behaviors were modified to reflect standard Army doctrine and an additional twelve behaviors were added to the original set of maneuvers. The DI SAF will be integrated into ModSAF 4.0.

Two digital terrain databases were selected based on the high fidelity requirements for IC operations. The Range 400 database of 29 Palms, CA was selected based on its dense resolution and open terrain features. The McKenna Military Operations in Urban Terrain (MOUT) database of Ft. Benning, GA was also selected based on its high resolution and representation of a built-up area. Both databases are Government furnished managed by the US Army Topographic Engineering Center (TEC). All VICs used a visual representation of the databases in the industry standard Multigen Flight format. DI SAF used a correlated version 5 Compact Terrain Database (CTDB) format database of the same regions.

ENGINEERING LEVEL EXPERIMENTS

The engineering experiments were conducted at the Lockheed Martin Information Systems facility in Orlando, Florida from 19 April-10 May 1997. The purpose of the experiments was to assess the capabilities of current IC simulation technologies in support of future training, virtual prototyping and evaluation of new weapons systems.
Eight soldiers from Ft. Benning, GA served as subjects for the experiments. Each soldier utilized and experienced all VICs and scenarios. Three days of training and testing per soldier were conducted per VIC. The U.S. Army Research Institute (ARI) collected data and provided an independent evaluation of the experiments. Data was collected by the following means: DIS PDU data logging, Pre- and Post-exercise subject debrief and rating assessments, and videotaping. Measures of performance were specified for each experiment and were augmented by subjective ratings and questionnaires. Data from the experiments was analyzed using Excel and statistical analysis software [11].

A number of IC simulation issues were examined during the experiments. Table 2 provides a summary of the functions, issues, performance measures and tasks for the specific variables tested and analyzed.

Function	Issues	Performance Measures	Tasks
Locomotion	• Time to acquire proficiency • Level of proficiency	• Errors over time (collisions) • Task completion times • Movement rates	• Move through building; maneuver around obstacles
Visual Display	• Lag • Resolution • Object detection/identification • Facilitation of locomotion (Distance estimation)	• Time to detect/identify object • Range at object detection/i.d. • Location of object relative to self/other object locations • Engineering measurements	• Locate and identify vehicles, DI (friendly and foe)
Body Motion Capture	• Accuracy • Lag • Reliability	• Engineering measurements	• No man-in-the-loop component
Weapon Tracking/Aiming	• Sighting Ease • Tracking Accuracy • Lag	• Accuracy of shooting at static and moving targets • Time to engage • Engineering measurements	• Shoot at static and moving targets
Directional Sound	• Object localization	• Speed and accuracy of assessment of object direction and location	• Locating noisy objects in environment
Human Animation	• Lag • Realism	• Engineering measurements • Subjective assessments	• Observe DI figures walking, running, crawling, etc.
Miscellaneous	General Issues: • Comfort, Simulator sickness • Noise, Safety • Immersion	• Engineering measurements • Subjective assessments • Questionnaires	• Observe during execution of all tasks

Table 2. Engineering Experiment Design

The intent of the Engineering Experiments was to compare the various component technologies represented in the four VICs over different tasks. The results were documented in order to be matched against functional fidelity requirements flowing from the simulation task analysis portion of DWN. The results will provide the beginnings of a database that will match existing technologies and capabilities against simulation requirements, and the identification of areas where future technology development is required.

User Level Exercises

The user exercises were conducted from 27 May-13 June 1997 at the USAIC Dismounted Battlespace Battle Lab (DBBL) using the Land Warrior Test Bed (LWTB) facilities, Ft. Benning, Georgia. The purpose of the user exercises was to focus on the system level capabilities of the technologies, whereas the engineering experiments focused on the technology components. The ability of the soldiers to operate on the VICs to support collective and individual dismounted infantry tasks was evaluated.

Two basic scenarios were conducted -- an open terrain attack/defend operation on the Range 400 database and a building clearing operation on the McKenna MOUT database. All operations involved a platoon of friendly forces consisting of the VICs operating as a four-man fireteam, together with a second fireteam of SAF. All friendly entities were commanded by a platoon leader using a joystick-driven version of Bayonet. All operations were simulated under daylight conditions. During each exercise, one of the VICs would serve as the fireteam leader.

The open terrain scenarios involved two basic variations -- an attack on an opposing force (OPFOR) site and the defense of a friendly site against an advancing OPFOR. Minimal cultural features are available on the Range 400 desert database so the soldiers were forced to make the most use of the terrain features for cover and concealment. Standard Army doctrine was used to conduct the operations including the use of bounding overwatch and suppressive fire. The end of an exercise was declared to occur when either all enemy or friendly forces were eliminated.

The MOUT scenarios involved the friendly forces clearing opposing forces from a village. Operations were conducted with enemy placements both inside and outside of the structures. Several scenarios involved an enemy sniper located in multi-story buildings thus requiring the friendly soldiers to enter the structures, advance down narrow hallways and proceed up and down stairways. The sniper was played by a man-in-the-loop using a Bayonet station. The end of an exercise would be declared when all enemy had been eliminated as a threat or the friendly forces were unable to continue due to casualties.

An After Action Review (AAR) was conducted at the conclusion of each exercise, including data logged playback of the scenario. ARI collected anecdotal data during the exercises and subjective data during the AARs.

RESULTS OF DATA ANALYSIS

PDU Data Analysis. DIS PDUs, specifically Entity State, Fire, Detonation, and Collision PDUs, collected at the exercise support station served as source data for the majority of the analyses conducted after the engineering experiments. The experimental tasks were intended to investigate VIC performance in the areas of locomotion, visual system performance, and weapon aiming/shooting accuracy (see Table 2). The results of these tasks are described below.

Locomotion. All VICs were set with identical maximum sustained rates of locomotion. Based on course completion times, Bravo was the slowest VIC because the soldier had to expend real energy to move through the environment. Foxtrot was the fastest of the VICs, but at a cost of significantly more collisions with building structures. Bravo, along with Alpha, had the fewest number of collisions.

Visual System. VICs Charlie and Foxtrot had the highest resolution visual systems, followed by Bravo, with Alpha's HMD providing the lowest resolution of all the VICs. Performance in the target search, recognition, identification, and animation detection tasks generally reflected these differences in resolution. In decreasing order of performance, the VICs ranking for these tasks is Charlie, Foxtrot, Alpha, and Bravo.

Secondary performance measures included target range and azimuth estimation and the detection of target motion. For the estimation tasks, VIC performance rankings were reversed from the primary performance measures (Bravo, Alpha, Foxtrot, Charlie from best to worst). A more spatially constant representation of azimuth heading in Bravo and Alpha is proposed to explain the performance differences in this measure; better range estimation performance is believed to be an artifact of fewer long-range detections. Finally, VIC Alpha and, to a lesser degree, Foxtrot performed worst at target motion detection. It is hypothesized that these head-coupled systems made it more difficult to isolate target motion from self motion.

Weapon Employment. None of the weapon tracking/aiming technology implementations provided an adequate weapon aiming solution. VICs with more natural aiming methods (i.e., Bravo and Foxtrot) were better at target acquisition, but Foxtrot's acoustic sensors proved the least accurate weapon tracking system.

Subjective Data Analysis. ARI researchers collected a variety of subjective data through the administration of questionnaires, by observation, and by soldier interviews. Some of the primary findings include the following:

- Simulator sickness was not a problem for the soldiers using the VICs.
- Task difficulty ratings generally followed the pattern of results found in the PDU data: VICs that performed better were judged easier to use.
- Bravo was ranked as the overall best VIC in supporting tactical realism by soldiers during the user exercises; Foxtrot was generally second in the various ratings
- Coordinating movement among the VICs was considered difficult
- Alpha's ratings were negatively affected by a lack of system reliability
- Charlie had some good features but was generally considered the most unrealistic

Other issues concerning database correlation between the SAF and VICs (and between VIC Charlie and the other VICs), VIC virtual figure identification, extraordinary SAF lethality, and communications difficulties were noted during the user exercises.

Discussion. The experimental results point out the relative strengths and weaknesses of the VICS and DI SAF. Weapon tracking is still problematic – none of the three technologies used provided the required accuracy. The case was made once again for better display resolution and field of view. Locomotion technologies need to provide for rapid transverse of open terrain as well as precise maneuvering inside of buildings. VICs need to appear natural, easy to use, and reliable to gain soldier acceptance. These lessons learned provide the evolutionary forces to shape future VICs and SAF development efforts.

FUTURE EFFORTS

Follow On Enhancements

Based on the preliminary technology assessment and observations made during the experiments and exercises, several components or technologies are missing that are needed for realistic dismounted infantry operations. Some clear deficiencies have been identified and others have been revealed by the analysis of the experimental data.
None of the VICs utilized in DWN have the ability for the soldier to command and control SAF directly using voice or gestures. All SAF operations must be controlled with an additional man-in-the-loop 'battle master' to issue instructions and orders to the SAF entities. An intuitive and direct interface to allow command of SAF by a real soldier-in-the-loop is desired to enhance the reality of scenarios.

Communication between the soldiers on the VICs was accommodated by a wireless radio technology. While this approach did allow the soldiers to talk, it simulated a basic radio capability that individual soldiers do not have today in the field. In addition, the soldiers were not able to sense distance or location to the originator of the transmission as they would in the real world. As soldiers become more equipped in the future, the capability is needed to more accurately simulate communications between individual soldiers and link the soldiers with higher command, including digital messaging.

As noted, individual combatants need to perform several activities that are not currently fully supported by any of the current VICs. Some of these activities include: throwing a grenade, setting and detonating explosive charges to gain entrance to a building, scaling walls and rappelling down ropes. These tasks and others are identified by the simulation task analysis and warrant further research and development. STRICOM, together with other Government and industry partners, is continuing to identify and work toward solutions for individual combatant RDA, ACR and TEMO simulation requirements for the future.

SUMMARY

The STRICOM Dismounted Warrior Network program is designed to identify the requirements and capabilities related to man-in-the-loop, networked systems to support individual combatant simulation. The simulation task analysis phase is oriented toward defining a set of validated requirements and functional fidelity needed for soldiers using technology to support the RDA, ACR and TEMO domains. The engineering experiments and user exercises were an attempt to gather relevant data to determine which technologies and systems are useful today and identify areas where significant future work is needed. Several representative technologies were integrated to provide technical insight regarding issues concerning IC simulation. Based on analysis of the data collected, the US Army is focusing future efforts on the identified technologies that require enhancements to meet realistic IC simulation capabilities.

AUTHOR' S BIOGRAPHY

TRACI A. JONES is the Lead Systems Engineer for Individual Combatant (IC) Simulation at the U.S. Army STRICOM. Mrs. Jones leads the DoD Defense Technology Objective for Individual Combatant and Small Unit Operations Simulation in the synthetic environment and the STRICOM Science and Technology Objective (STO) for IC Simulation . Mrs. Jones is the lead for modeling and simulation (M&S) for the MOUT ACTD and is actively involved on the MOUT ACTD Technology Task Force. Previously, Mrs. Jones represented STRICOM on the 21st Century Land Warrior M&S project. Prior to her work at STRICOM, she was responsible for development of numerous training devices for the U.S. Navy. She served as co-chair of the DIS Human Figures in Virtual Environments Special Interest Group. Mrs. Jones has a B.S. in Electrical Engineering from the University of Central Florida and is pursuing her Masters in Simulation and Training.

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