VIRTUAL ENVIRONMENT DEPLOYABLE SIMULATION (VEDS)

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ABSTRACT

Military training and exercise budgets are continually challenged. Training airtime cannot be afforded at a level consistent with the desires of our fighting troops. The next best training method is simulation, allowing the aircrew to manipulate equipment as close to the “real thing” as possible. The drawback is the expense of high-fidelity simulators in fixed facilities constrained by rigid training schedules.

An avenue now open to exploration is leveraging use of the actual aircraft as a simulation device, either in the hangar or on the ramp. One approach being pursued by Lockheed Martin in an ongoing Internal Research and Development (IRAD) project allows a powered-down aircraft cockpit to be transformed into a simulated training environment. This would permit a simulator training capability to be taken into the field with the warfighter, and do much to advance the state-of-the-art in cost-effective, deployable simulation training.

The research centers around combining a minimal amount of equipment: a COTS high-fidelity helmet-mounted display (HMD), commercially available “blue screen” video-mixing equipment, blue window placards, and a commercial image generator, along with several custom enhancements. By covering the cockpit windows and instrument faces with a blue material, images can be mapped and registered to specific cockpit locations. This results in a layered image of computer-animated instruments as well as out-the-window (OTW) scenery displayed through the HMD. Plans for CY97 include the addition of a VEDS data glove to permit the manipulation of aircraft switches and knobs in the training exercise. The cockpit can be mapped as a 3-D environment and through use of glove-tracking sensors, switches can be selected in the virtual simulation. This paper describes results to date.

ABOUT THE AUTHORS

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INTRODUCTION

Market Focus

With military training and exercise budgets continually being tightened, training airtime cannot be provided at a level consistent with the desires of our fighting troops. The next best training method is simulation, allowing the aircrew to manipulate equipment as close to the “real thing” as possible. Simulation’s drawback is the expense of high-fidelity simulators in fixed facilities constrained by rigid training schedules.

One avenue open to exploration is leveraging use of the actual aircraft as a training device, either in the hangar or on the ramp. The approach described in this paper is an ongoing IRAD project titled Virtual Environment Deployable Simulation (VEDS). VEDS is a new class of device technology that brings embedded training closer to reality than ever before.

VEDS has combined the best HMD technology with innovative scene-compositioning techniques. This technology allows trainees to participate in interactive, single or multi-participant missions. Fitted with this new class of device, crew members can experience all the visual, aural and tactile cues required for high-fidelity training. Further, the equipment required is small enough to fit inside the actual aircraft, enabling its use wherever troops or aircraft are deployed. Training is accomplished on the ground, without powering up engines or avionics, reducing wear and tear on the aircraft and maintaining low observability during forward deployment.

This method holds much promise in advancing the state of the art in *cost-effective* deployable simulation training. However, the VEDS concept also raised a number of issues, technical and human factors, the solutions for which are detailed below.

System Description

Research has centered around combining a minimal amount of equipment to perform training. VEDS uses a COTS high-fidelity HMD, commer-cially available “blue screen” video-mixing equipment, blue window placards, a commercial image generator, and a few modifications to COTS equipment.

The VEDS system approach is unique in that it employs a simple blue-screen approach to produce the canopy visual presentation. Dark-blue placards are attached to the inside of the cockpit window surfaces by the pilot in a matter of minutes. This special color is then viewed by miniature video cameras attached to the pilot’s HMD. The miniature (stereo) cameras convey the dark-blue images and orientations to the image fusion system, which in turn replaces the dark-blue areas with synthetically generated and augmented OTW scenery for viewing in the HMD. The view the pilot sees is very realistic, and preserves the “normal” look and feel of a clear cockpit. Figure 1 shows the cockpit as it appears to the naked eye, without benefit of the augmented reality HMD. The blue placards are easily attached to the inside window surfaces of the aircraft, and are quickly stored when not in use. With the placards in place, imaging computers create the correct window scenery and substitute it in their place (Figure 2).

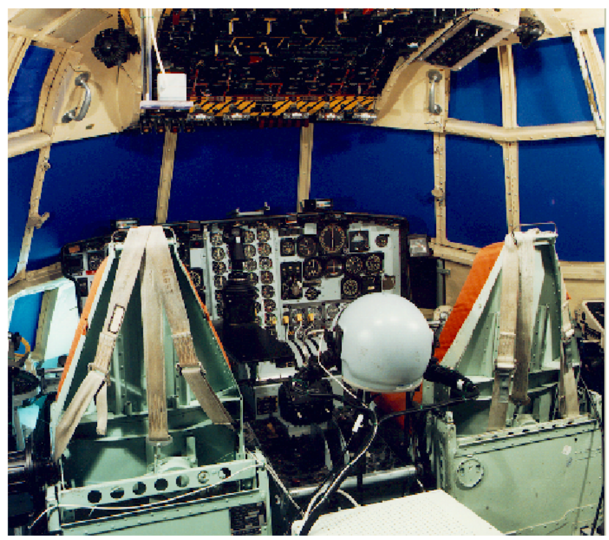

Figure 1. *Actual C-130 cockpit converted into a VEDS simulator using blue window placards.*

By covering the cockpit instrument faces with blue material, the same technique can be used to animate gauges and EFIS-type displays. The result is a layered image of computer-animated instruments as well as OTW scenery displayed through the HMD. With the addition of a VEDS data glove, aviators can manipulate aircraft switches and knobs in the training exercise. The cockpit can be mapped as a 3-D environment and through use of glove-tracking sensors, switches can be activated in the virtual simulation.

Figure 2. *Actual HMD image as seen by pilot using VEDS system.*

APPROACH / IMPLEMENTATION

Historical

The VEDS project started with the knowledge that the computing power of the early '90s was not then adequate to perform the tasks of VEDS-type simulation. But the approach was sound enough to proceed and develop the project fundamentals in parallel with computing advances. Early in the project it was decided to not develop items like HMDs or specialty video mixing equipment, but to buy the best commercially available equipment. A rapid prototype approach was taken to allow a demonstrable capability and to continually upgrade and enhance the system.

System Elements

The system is comprised of four elements: motion tracking, display devices, video layering, and image generation devices.

Tracking

The recent popularity of "virtual reality" in the commercial marketplace has produced numerous commercial tracking products. Current VEDS head and hand tracking systems make use of low-cost magnetic systems from companies such as Polhemus, Inc. and Ascension, Inc. The VEDS team modified their data output to overcome the issues commonly associated with their use inside a cockpit, e.g., problems with speed, accuracy, and non-linearity have been overcome by the use of special proprietary post-processing and correction techniques. Tracking of the pilot's head and hand movements with accuracy better than 1/100 inch is achievable. With this technology (Figure 3), no avionics electrical interfaces are necessary to relay pilot hand-movements to data fusion or imaging computers. Cockpit switch positions and control stick positions are all known to the computers in real time.

The concept is to track the glove-encased hand within the 3-D mapped cockpit environment and to select/deselect switches by simply touching their location in the cockpit.

Figure 3. *Tracking sensors are easily attached to control sticks in a typical aircraft cockpit.*

A COTS CyberGlove model has been purchased and is being integrated into the VEDS system (Figure 4).

Display Devices

Currently, VEDS uses high-end COTS technology for head-mounted and HMD devices. Our strategy of modifying existing equipment to improve performance has met with good success in past programs. In addition, the team has developed business relationships and teaming agreements with several of the major HMD device manufac-turers.

In the areas of emerging new technology, such as direct retinal scanning, maturation is needed only in the areas of packaging and weight reduction to make these units an excellent solution for future HMD use. In the meantime, products from Kaiser Electro-Optics, Inc. (Carlsbad, CA) such as the

Figure 4. *Commercial CyberGlove*

SimEye 60, 75, and 90 series color display helmets have proven very effective (Figure 5). The predecessor of the Kaiser helmet is being used by pilots in daily flight operations as deliverable equip-ment on the US Army's Comanche helicopter.

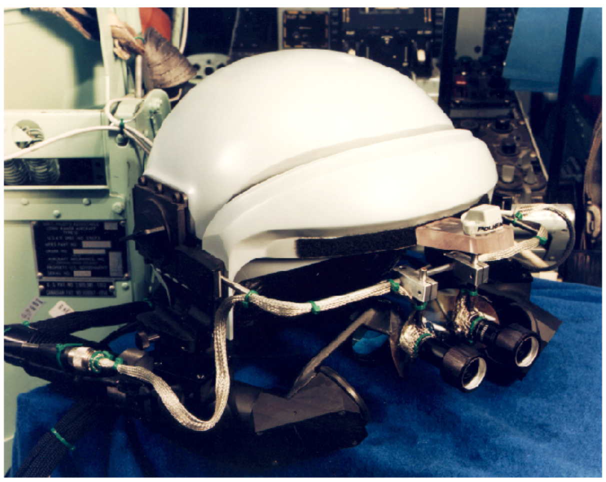

Figure 5. *Modified Kaiser SimEye 60 helmet with miniature video cameras*

The advent of new markets such as robotic vision, laparoscopic surgery, and digital cameras has driven the development of super-small video cameras. These cameras are now available in resolutions exceeding 2k x 2k pixels. Low weight and small size make them ideal for head-mounted use. The VEDS program strategy in the past has been to modify the equipment as needed to accommodate the helmet mounting field of view.

Video Layering

VEDS has successfully demonstrated the ability to electronically "mix" additional information into these pilot images. For example, to train effectively, a pilot should see his own hands, real controls, and his copilot. Figure 6 illustrates the concept of compositioning multiple layers of imagery to create this effect.

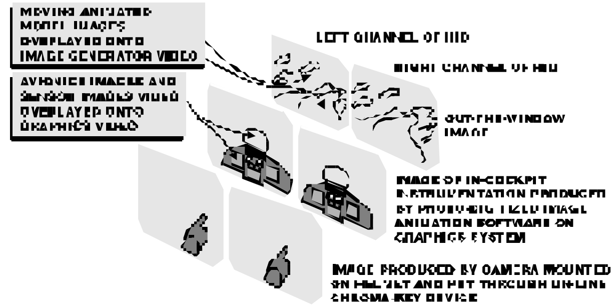

Figure 6. *VEDS image layering concept*

Image compositioning occurs in real time, using Lockheed Martin-developed software and specially modified COTS Chroma-keying video equipment. Care is taken that the images are layered in the correct order (foreground to background). The pilot's hand, for example, correctly occults both instruments and OTW images as viewed by the pilot (Figure 7).

Figure 7. *Image layering capability, with correct foreground-to-background ordering. Note that pilot can read his own wrist watch with VEDS.*

Some instrument displays may appear blank (due to being powered off) or frozen (in the case of a mechanical altimeter). Both situations are eliminated with the addition of computer-generated insets. The technique can prove extremely effective in bringing to life an actual, powered- down aircraft (e.g., sitting in a hangar or deployed in the field). Both air-data instruments and blank EFIS-type CRT displays can be made to appear fully operational to the pilot. For example, in Figure 8, the altimeter has been inserted by computer. All other instruments are real, as seen through the video camera eyes of the pilot. The altimeter hands move correctly according to the aircraft flight path. Any number of instruments can be animated or modified in real time with the VEDS system.

Figure 8. *Photo showing computer-generated and animated instrument.*

Image Generation

The VEDS system currently uses an SGI Onyx that was repackaged to fit into the back of an OH-58 helicopter. Newer SGI computers are significantly smaller and are being reviewed for suitability to future VEDS applications. The terrain database used is PerformerTown with a helicopter dynamic flight model (HLSIM) providing control of the aircraft. The system is not dependent on the selection of a particular IG, but requires a database which will run at 60 HZ to maximize the effectiveness of the HMD.

CHALLENGES ENCOUNTERED

Packaging

To fit into an aircraft, the VEDS system had to be small enough to be portable. An OH-58 helicopter was selected as a candidate platform for design requirements. A custom hardside enclosure was built to fit in the rear door of the aircraft and loaded with an SGI Onyx, video mixing boards, Chromakey boards, camera control boxes, and a power supply. The box is powered by a single 110-V power input. Additional control boxes are needed to perform the headtracking and cyclic/collective pedal tracking and for the HMD. The final integration footprint is approximately 3 cubic feet. Extreme care was taken to integrate most of the system equipment into this case, including power requirements.

Tracking System

The first tracking system used was the Polhemus Fast Track magnetic tracking system. The product yielded good accuracy and ease in connecting transmitters to the aircraft controls, at a relatively low cost. The negative attributes were the system's limited range and susceptibility to tracking errors due to proximity of metal. Investigations are underway to evaluate the latest 6-DOF tracking system based on an inertial system exhibiting no problem with proximity to metal.

Dynamic Instruments

The dynamic instrument overlay was another area of concern. The computer must have the computing power to keep the dynamically generated instruments centered in the instrument panel. As the tracked HMD turns left, the computer instrument needs to shift right. Due to delays and the IG clock rate, slight instrument swimming occurs. Several approaches to correct this problem are being researched: a faster IG, specialty video equipment, and improved tracking algorithms.

RESULTS TO DATE

VEDS' reception by users has been promising, especially in the rotary wing community. Since helicopter pilots wear helmets with NVG equipment, the 6-lb weight of a simulation HMD is not as noticeable as it is with fighter pilots who have lighter flight gear. User evaluations of VEDS are scheduled for this year at Fort Rucker, AL.

One very important constraint discovered early in the research was the user's reluctance to power up any part of the aircraft, even the pneumatics assisted controls which start the system hobbs meters. Since maintenance is periodic and carefully monitored, any single system incurring operational hours throws the maintenance cycle off. With this knowledge, an approach maintaining total aircraft shutdown, by the use of auxiliary power supplied, has been taken.

The pilot's field of regard is unlimited since head movement is tracked. A powerful computer is required to keep up with head motion. One negative aspect of HMDs has been "sim sickness," most of which can be attributed to systems running less than 60 Hz and system frame delays. VEDS has a miniature camera video input with instantaneous head motion response. This results in the user viewing another "layer of imagery" in the display. The intermediate camera imagery layer moving with the user's head seems to overcome the delay effects of the terrain database due to an IG running at less than 60 hz.

Helicopter pilots also look through chin windows which are easily handled by VEDS. Additional blue material is all that is required. All cost is borne in the initial system and does not effectively increase due to additional instruments or window views.

APPLICATIONS

Deployable Aircraft Simulation

The real power of VEDS is that it allows the creation of *augmented reality.* The real world, as seen normally, can be used selectively or replaced with "substitutes" as desired. Miniature cameras provide the user with a synthetic form of vision. In the electronic-look-through (ELT) mode of use, the pilot's normal optical vision is completely blocked out using an opaque visor. The technique can be extremely effective in animating an aircraft sitting in a hangar or deployed in the field.

Visual Modification to Legacy Simulators

If the opaque visor is removed from the helmet, and the pilot is allowed to see through the display screen, a new application is born. This mode is referred to as optical-look-through (OLT). The OLT mode is used when a situation requires the pilot to see his actual flight instruments and controls optically. The cameras are still used, but only to provide the window inset information previously described. Optical beam splitters allow light from the display device to be projected to the eye, while permitting the eye to see forward past the display.

Many older simulators are not equipped with OTW visual systems. In this instance, a VEDS system operating in OLT mode is the perfect solution for a visual upgrade. The OLT mode allows the trainee to "see" the inside of the simulator cockpit with his normal optical vision, through glass optics. Only the windows of the aircraft are affected in appearance, with the blue color replaced by an outside visual scene. The rest of the simulator is not modified and continues to function as before. This visual-only VEDS system can replace costly domes and projectors. The only physical modification required to an existing simulator is the addition of window placards and, in some applications, simple lighting fixtures.

NVG or HUD

VEDS can also be adapted for NVG and heads-up display (HUD) use. Selected channels with appropriate sensor imagery from an IG are piped into the display system. The HUD is modeled as a virtual instrument with the scene imaging and tracking strategies as other cockpit systems.

SUMMARY

Deployable simulation for pilot training and mission preview is very near to being a reality. VEDS exhibits capabilities critical for mission success.

a. SVGA resolution or better - larger FOV is always preferred
b. Stable head tracking - Polhemus seems acceptable
c. OLT dashboard instruments viewing - chromakey instrument insert approach requires next-generation computer power to be cost-effective
d. "Blue screen" OTW mapping - highly lighting-dependent to maintain image integrity, but very good once obtained
e. 30-Hz minimum refresh rate aircraft flight model adequate for training

The integrated components of our system have yielded excellent results. VEDS research is producing results that can be formed into useful recommendations for meeting combatants needs in the field.

Performance and comfort improvements, cost reductions, and technology updates have been demonstrated through rapid prototyping over the last 18 months.

Acknowledgment

The authors would like to thank all those who have worked on the program in the last few years, most especially Pete Lutikoff, whose ingenuity and dedication have taken VEDS from an intriguing idea to a working system.