NAVAL POSTGRADUATE SCHOOL

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THESIS

IMPLEMENTATION AND ANALYSIS OF THE CHROMAKEY AUGMENTED VIRTUAL ENVIRONMENT (CHRAVE) VERSION 3.0 AND VIRTUAL ENVIRONMENT HELICOPTER (VEHELO) VERSION 2.0 IN SIMULATED HELICOPTER TRAINING

by

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June 2005

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The focus of this thesis is the validation of ChrAVE 3.0 as an augmented trainer that can be adapted for use inside an actual aircraft cockpit. By placing the pilot in the most realistic simulation available ChrAVE 3.0 will enhance development of skills such as Terrain Appreciation, Crew Resource Management (CRM), and Situational Awareness (SA). Continuing past research, this thesis will analyze empirical data collected from training flights to further prove its value as an instructional tool. ChrAVE 3.0 is housed in three man-portable containers and can be set up within minutes with little or no prior experience.

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EXECUTIVE SUMMARY

The cost of the Global War on Terrorism has highlighted the need to maximize the use of every training dollar. Simulation has served to prepare pilots for actual aircraft flights for decades. Many systems have been developed for use in mission preparation, initial skills training, and skills refresher training. The MOVES Institute has worked with the latest technologies in order to research methods to economically train military personnel, including pilots and aircrew, using simulation. Chromakey Augmented Virtual Environment 3.0, using Virtual Environment Helicopter 2.0 as its application software, is the latest simulation system developed to investigate aviation training.

For deployed units and personnel, there has been a paucity of viable simulation systems for use in remote locations such as the ship environment or combat zones. As Operations Tempo (OPTEMPO) increases, more and more aviators and aircrew are finding themselves away from systems that can help them maintain proficiency or train for the next mission. The only option for these units is to use the actual aircraft to continue training and maintain proficiency. There are no options that carry more expense than the use of aircraft, aircraft parts, and aircraft fuel to train. Many times this is the only way to achieve training goals in a timely manner.

Mission preparation simulators such as TopScene and PFPS/FalconView are generally not realistic enough to be more than planning tools. While they do present a digital

depiction of route information, they lack the correct "environment" for adequate training and the result is similar to an aviation video game.

The need exists for a cost effective system that can be quickly deployed, is user friendly, is scalable, and is flexible enough to adjust to changing locations and training needs.

Initially developed to investigate the possible application as an embedded trainer in helicopter simulation, the ChrAVE combined live video feeds with a background "virtual environment". The bulky equipment requirements, time consuming set-up procedures, and the high level of expertise required to run the system made it untenable for deployment. The relative success of these experiments led to further testing with a more realistic "environment simulation" in a more portable package.

VEHELO, the second system in the ChrAVE series was successful at proving the viability of such a system for use in the initial stages of helicopter training. The overall size of the system components was reduced, but the footprint for deployment was still too large to make it useable. Multiple chromakey screens and the hardware to display them, bulky "mock cockpit" equipment, and a rolling case that weighed more than 200 pounds made the system "moveable", but not portable. The system in this second configuration was more useful and proved its value through experimentation. ChrAVE 3.0, the topic of this thesis, combines the past success of ChrAVE and VEHELO with new innovations in lighting and background screens to achieve as yet unmet goals. This thesis continues to validate the system as a trainer capable of initial, continued, and refresher training and introduces its possible use as a deployed mission preparation trainer. Use of NVG compatible lighting for simulation also introduces the idea of its possible use as an NVG introductory or proficiency tool.

Several training goals are associated with the use of ChrAVE 3.0. For purposes of experimentation, the system was designed to help improve Terrain Appreciation skills, Crew Resource Management (CRM) skills, and Situational Awareness (SA) skills.

Terrain appreciation encompasses several skills that must be mastered by helicopter pilots in order to achieve mission success on a regular basis. Pilots must be comfortable with reading and interpreting map and chart data. This is the first step towards developing terrain appreciation. Next, they must learn to analyze and determine where they are and where they need to go. This is accomplished mainly from scanning the terrain features around the aircraft, at varying distances from the aircraft, and finding the same terrain as depicted on the map they are using. Finally, the pilots must be able to accomplish the first two steps at varying altitudes and in varying weather conditions and illumination levels. The use of accurately depicted simulated terrain can help to hone these skills. A pilot that is able to “fly” through a digital depiction of the terrain around a planned route of flight is more likely to be comfortable during an actual mission flight. Repetition is an enabler for mastery of terrain appreciation skills. The more a pilot practices the better that pilot will become at interpreting and navigating through varying types of terrain. For a pilot getting ready for an actual mission, in combat or otherwise, the ability to “fly” the planned mission route before the actual mission and in the relative safety of a shipboard or garrison environment can mean the difference between success and failure. Although the experiments conducted involve flying the same routes in the simulator as in the actual aircraft, terrain appreciation skills developed through the repetition provided by simulation are universal and apply to all situations.

CRM is the new term to describe Aircrew Coordination. This term has its origin in the late 1970’s as civilian airline companies were tackling a number of crew issues that resulted in catastrophic failures of passenger aircraft crews, aircraft mishaps, and the significant loss of life. Analysis of communication skills, flight deck interactions, and breakdowns in procedures were all focused on reducing risk and reducing the bottom line. The United States Army took this early work and further developed it into a full-scale risk management program. The United States Navy and the Marine Corps followed suit and developed Aircrew Coordination Training (ACT) as a method to mitigate risk in naval aviation.

> The objective of the Aircrew Coordination Training (CRM) Program is to integrate the instruction of specifically defined behavioral skills throughout Navy and Marine Corps aviation training, and to integrate the effective application of these behavioral skills into operational aviation procedures wherever appropriate. CRM will increase mission effectiveness, minimize crew preventable error,

> maximize aircrew coordination, and optimize risk management.
>
> Commanders shall ensure that all personnel whose duties involve flying as an aircrew member in naval aircraft receive CRM. CRM shall be conducted annually in accordance with OPNAVINST 1542.7A, including an academic portion and a flight/simulator evaluation.
>
> From OPNAV Instruction 3710.7T

For many inexperienced pilots the first training they receive as part of the crew of a multi-place aircraft is in the Fleet Replacement Squadron (FRS). Here they are forced to communicate with, consider implications of their actions in reference to, and manage the different climate of a team of 3 or more. Some of these considerations are simply handled by the existing rank structure of the military, however, many are not. The ability to provide guidance and leadership to a crew is essential to mission success. The ChrAVE 3.0 system gives pilots the opportunity to practice those skills and develop as professional pilots.

SA continues to be the focus of all levels of training. The SA for younger, inexperienced pilots is generally a weakness and is addressed on every training event. Good SA is the ability of a pilot to know and understand what is happening inside and outside of the aircraft, where the aircraft is located in reference to the battlefield environment, and what future requirements or objectives are required for mission success. The true litmus test for any simulation system is ‘whether the simulated environment helps build SA and pilot confidence for use in the real environment’. For the purposes of experimentation this thesis used pilots with similar backgrounds, relatively low situational awareness, and little experience navigating in a low level environment. Repetition in the training environment is an important tool that helps pilots meet established training goals. By performing required skills in a simulated environment, new pilots can begin to master them and achieve improved performance during actual aircraft flights. For the instructor pilot tasked with meeting training and readiness objectives, a student with increased SA allows the focus of instruction to be on specific aviation skills at each level and not just on overall comfort level or the “basics”. The resultant effects of the use of a simulated environment can be found in maximizing use of aircraft instruction periods, reduced flight hour costs due to a lack of “re-fly” events after poor performances, and reduced maintenance costs associated with extra flight time. As a mission preparation tool, the simulated environment can help ensure future mission success, save lives, and reduce proficiency training dollars.

Terrain Appreciation, CRM, and SA can all be practiced in an environment that is realistic, consistent, and manageable with the current version of ChrAVE 3.0. The key to the success of a simulation system is providing the correct environment, one that is accurate and allows the pilot to be immersed in a pseudo-reality. This thesis will examine the ability of ChrAVE 3.0 to provide that realism and quality of instruction that will ensure credible training value.

This thesis will introduce the reader to the history of the ChrAVE/VEHELO visual simulation system and its possible role in aviation training. A description of the system and its components will allow the reader to visual the simulation environment. A description of the experiment and analysis of the associated results, along with the results from previous work, will allow the reader to quantify its use in a training environment. Testimony from instructor pilots and pilots under instruction along with surveys and recommendations will give the reader a non-biased opinion of the system's success or failure. Finally, recommendations and conclusions will help the reader frame the direction the ChrAVE program may be headed.

As in Kulakowski, experimentation will be based on introducing the simulation to novice pilots at the CH-46E FRS prior to their NAV-130 1:250,000 navigation training flight. The simulation will be used to enhance terrain appreciation, CRM, and SA skills that will be evaluated during the actual flight.

System configuration is based on commercially available components that are configured within two durable cases designed for ease of deployment. Some specific component replacements, modifications, and updates add the capability to further reduce overall size and weight while increasing performance.

Experimentation was conducted at HMM(T)-164, located at Camp Pendleton Marine Corps Base in Oceanside, CA. This squadron is the model manager for the CH-46E and produces and maintains the Standardization Manual. Empirical data was collected and evaluated according to the low-level navigation performance thresholds set forth by this publication. The Standardization Manual The Knightriders also participate in the annual Training and Readiness conference which makes changes, deletions, and additions to the requirements for training Replacement Aircrew (RACs).

I. INTRODUCTION

A. PROBLEM STATEMENT

> Models and simulations will provide a pervasive set of tools for operational units and also to support analysis, training, and acquisition throughout the Department of the Navy. To attain this vision, the following objectives will be vigorously pursued:
>
> a. Modeling and simulation and associated information technology will be applied consistently across each of the four pillars of naval Modeling and Simulation. These pillars are: operations and experimentation; training; acquisition; and analysis and assessment.
>
> b. Modeling and simulation technology shall be readily available to the naval warfighter.
>
> c. Modeling and simulation, and its underlying data, will be consistently applied across the Navy-Marine Corps Team afloat or ashore, at home or deployed.
>
> d. Investment in modeling and simulation technologies will be cost effective, have measurable benefits, and build on the Department of Defense (DoD) and commercial capabilities and standards.
>
> e. The DoN Science and Technology (S&T) efforts will ensure the development of technologies to meet the modeling and simulation needs of the Sailor, the Marine, and the Department of the Navy.
>
> (SECNAV Instruction 5200.38A (28 Feb 2002))

It is clear from reading SECNAV Instruction 5200.38A that simulation is and will continue to be central to training personnel. For decades “simulating flight”, from broomsticks and soup cans to PC-based applications and full-motion Weapons Systems Trainers (WSTs), simulation has been part of all levels of Naval Aviation training. Adapting pilots to new airframes, teaching basic aviation skills, and practicing missions which carry a significantly higher risk factor are all applications for simulators. Simulation systems have been viewed as a cost effective and safe method to manage the risks associated with preparing pilots and aircrew for aircraft sorties.

Over the years costs associated with operating aircraft have remained relatively low, keeping the ratio of simulated hours to actual flight hours rather low, roughly between five and ten percent of total training time depending on aircraft type. Since the late 1980s, these costs have been steadily rising for a number of reasons. First, "legacy" aircraft are aging and experiencing required life-extension upgrades and increased maintenance costs. Replacement parts are harder to find and more expensive to acquire. Secondly, the next generations of aircraft that are replacing current models are much more technologically advanced, designed with components that cost more to repair and replace. Finally, Operational Tempo (OPTEMPO) has driven costs up since the early to mid-1990s as aviation units have responded to crises around the world and have supported the Global War On Terrorism (GWOT).

The costs associated with operating new aircraft such as the MV-22, the F-22, and the Joint Strike Fighter are anticipated to be far greater than their predecessors. As an example, the cost per flight hour (CPH) to operate and maintain a CH-53D or CH-46E for the United States Marine Corps is approaching nearly $7,000. Their replacement, the

MV-22 Osprey, is projected to cost 2.5 to 3 times that much to operate (not including the per unit cost for initial acquisition and deployment).

On top of the pure dollar costs, the advanced systems that are being engineered into future aircraft designs require added adaptation and “practice” in order for pilots to attain familiarity and acceptable comfort levels.

The skills that pilots and aircrew are required to master have increased and changed dramatically with the recent deployments to Southwest Asia, Afghanistan, the Far East, and the Horn of Africa. Asymmetric threats, humanitarian relief missions, challenging terrain, extended ranges, and unfamiliar weather phenomena have all required new training and improved skills.

An aviator’s skill set includes things such as situational awareness and terrain association. In the past, systems have been fielded to assist pilots in preparing for missions, both training and real world. An example system is TOPSCENE (Tactical Operational Scene) which is a simulator designed for mission rehearsal purposes. Used with all branches, the system comes in two basic versions, one is a desktop model and the other is housed in a separate deployable console. Designed to provide personnel with a “digital mission area” and the ability to navigate from the line of departure to the objective area the graphics and flight characteristics (velocity and angular momentum) are realistic. However, the controls are standardized and the capability for environmental immersion does not exist. Limited unit availability and maintainability have made this system somewhat ineffective.

The Global War on Terrorism has seen an increase in units deployed and deployment duration. When away from home stations, simulation systems are usually unavailable. For Department of the Navy (DoN) personnel, ships have limited space and forward deployed units are normally in remote locations, away from established infrastructure. Perishable skills, such as navigation/terrain appreciation, communication, instrument flying, crew resource management (CRM), and night vision goggle (NVG) flying can quickly atrophy if not practiced. Mission requirements often preclude the ability to schedule flights designed to maintain these skills. Thus, the requirement exists for a deployable, scalable, maintainable, and usable system that simulates flight in an environment as close to the real world as possible.

B. MOTIVATION

The thesis work that follows builds on the previous research conducted by Joseph Sullivan (1998), Mark Lennerton (2004), and Walter Kulakowski (2004). (For simplification purposes these bodies of work will be referred to as Sullivan, Lennerton, and Kulakowski.) This thesis develops the concept of a truly deployable and adaptable system that augments pilot training by providing an environmentally accurate simulation for mission rehearsal. The current configuration can be adapted in order to train pilots at many differing experience levels and for several different mission types. In 2004, Kulakowski concluded that the ChrAVE (identified as VEHELO) system is capable of augmenting initial navigation instruction in order to increase the efficiency of early navigational training flights. This thesis will continue to support this conclusion through further experimentation and analysis of data collected from initial training flights. It will, however, go further in order to demonstrate the capability for immersion training that supports its use as a mission rehearsal and deployable skills maintenance trainer.

This thesis will also investigate the Knowledge Value Added (KVA) that can be achieved by using the dynamic ChrAVE environment to augment the relatively "technology free" navigation flight preparation that young pilots currently utilize. By replacing the static training that comes from classroom lecture and the study of publications with a virtual environment, significant increases in knowledge and decreases in training time will result.

C. THESIS OVERVIEW

The thesis work conducted and recorded here is the latest in a series of research projects devoted to studying virtual environment simulators for use in augmenting aviation training. This thesis will continue the work of Kulakowski, which presented data that concluded that there is substantial gain for initial training of pilots with the system.

The desire for a portable simulation system has focused the research on a reduction in footprint without any appreciable decline in simulation quality. Through the implementation of new technologies and improved design techniques, the research proved valuable in several regards. Applicability to all stages of aviation training, flexibility of use on all helicopters in the Navy and Marine Corps inventory, and possible applications in various types of mission preparation training are among the benefits of this research.

The experimentation portion of the thesis work was conducted in a similar way to that of Kulakowski, focusing on initial navigation training in the CH-46E. Twelve students were used for the research, six that participated in the simulation and a baseline group of six that did not. Errors measured in distance from particular checkpoints were used to compare the two groups and conclusions were based on these results. The same questionnaires for pre-flight and post-flight evaluation were used as they are appropriate. The data is presented in a simple way in order to maintain the focus on technology implementation, the real success of this work.

Instructor comments continue to be helpful to the conclusions and some will be included. The Return on Knowledge (ROK) that was determined through the Knowledge Value Added (KVA) Assessment also proved valuable in determining overall value of the system.

Kulakowski goes to some length to explain Lennerton’s idea about “machine-centered design” and “user-centered perspective”. It is important to note that the genesis of ChrAVE 3.0 is based on these concepts and stresses the user-centered perspective portion through application of the system to the actual aircraft students are learning to fly. The system configuration can be found in Figure 1.

The Instructor station is located directly behind the radio closet of the CH-46E which is right behind the copilot’s seat, the student or Pilot Under Instruction station.

Figure 1. Basic ChrAVE 3.0 System Implementation

Top Left: Chromatte sheets on outside of CH-46E
Bottom Left: ChrAVE 3.0 System behind radio closet
Top Right: ChrAVE 3.0 as seen from instructor station
Bottom Right: PUI navigating through ChrAVE 3.0 simulation

The earlier versions of the ChrAVE 3.0 system focused almost exclusively on validating the use of chromakey technology, but were unable to take the research to its natural ending point – the aircraft. The inclusion of “mock environments” like the portable cockpit in VEHELO fails to gain the desired results due to a lack of realism. ChrAVE 3.0 will continue to validate chromakey use in simulated virtual environments, but will go further to prove the system is truly deployable, scalable, and flexible enough to benefit the operating forces.

D. RESEARCH QUESTIONS

The central topic of this thesis is the validation of ChrAVE 3.0 and VEHelo 2.0 as a deployable, adaptable, and scalable trainer for use as an augment to all levels of aviation training. Validation will occur if the system can be adapted for use inside actual airframes. Support of the idea of its use as an instructional tool will be attained through the study of performance results from navigation flights in the Fleet Replacement Squadron (FRS).

This thesis will specifically address the following questions:

1. Can ChrAVE 3.0 and VEHelo 2.0, the virtual environment software, technology be adapted to and used within the actual helicopter airframe/cockpit in order to make the virtual helicopter simulation more realistic? What design modifications, deployability alterations, and useability advantages does ChrAVE 3.0 achieve compared to previous versions such as VEHelo 1.5?
2. Is there an increased level of proficiency afforded student pilots through the use of augmented training? What is the Knowledge Value Added (KVA) associated with adding this technology to the training syllabus?

3. What possible modifications can be implemented in the ChrAVE 3.0 system to improve levels of augmented training and student pilot performance in the aircraft?

Kulakowski built upon previous work by Lennerton and Sullivan to create an environment as close to ergonomically correct as possible without actually sitting in the aircraft. This was done for a number of reasons. First, by “practicing” skills in an environment that contains the same distractions as the actual cockpit, the pilot is forced to adapt her/his behavior to be successful. Secondly, Crew Resource Management skills accompany the acquisition of all other aviation skills and the correct environment is a critical piece of this. This thesis takes all previous work to the very nexus of development – placing the system aboard and within the actual designated aircraft during virtual environment simulation. The goal of such exposure is to improve the overall comfort levels and Situational Awareness (SA) in preparation for actual flights in the aircraft. The resultant exposure to the simulated flight environment is useful for initial training, refreshing of skills, and more advanced mission preparation.

Lennerton was able to successfully answer limited proof of concept questions as they related to the earlier version providing the tool for helicopter pilot proficiency. Kulakowski was able to prove the concept that an earlier version could be used for initial helicopter navigation training preparation. This thesis ties these two concepts together and advances the concept to total environmental immersion by using the ChrAVE 3.0 system in an actual aircraft cockpit during experimentation.

In all simulations, setting the correct environment is central to success. Full-motion simulators are designed to give pilots the “seat-of-the-pants” feel that only comes with physiological changes of angle and movement. Small arms simulators give the user the “kick” that comes when a weapon is discharged. Likewise, an application designed to simulate aircraft flight and practice navigation skills should be used in an environment that mirrors the real thing as close as possible. Past systems were built around a “mock cockpit” environment that included a pilot-like seat, non-functioning controls, and a simulated instrument panel. In the end, however, these environments lacked most of the realism that was desired.

ChrAVE 3.0 takes advantage of leading edge technologies to allow the simulation to actually take place in the cockpit that earlier versions tried to simulate. This full environmental immersion introduces the PUI to the limited space and many obstructions that get in the way of performing pilot duties. Cockpit management skills are honed and practiced as PUIs must decide where to put publications, which knee to strap their kneeboard to, how to fold the map so that it is manageable, and how scan around those obstructions that tend to get in the way.

For purposes of giving credit to contributors to this body of work, a few clarifications need to be made. This is the third thesis in a row on this subject matter. The source documents between the three theses are, for the most part, the same. The configurations between VEHELO and ChrAVE 3.0 are also very similar. The technical data for the components is essentially the same. Many of the

Appendices are also the same, for instance the NATOPS briefing guide and the questionnaires remained the same between thesis students. It is not uncommon to find reference data that is in Kulakowski in this thesis.

E. ORGANIZATION OF THIS THESIS

This thesis is organized into the following chapters:

1. Chapter I: Introduction. This chapter presents the problems that will be addressed in and the motivations, questions, and organization of the thesis.

2. Chapter II: Helicopter Navigation Training and Chromakey Augmented Virtual Environment (ChrAVE) Background. This chapter outlines the current methods for helicopter navigation training. Included in this are the relative experience levels of pilots that are studied, terrain appreciation skills definitions, and Training and Readiness Manual descriptions of specific skill sets. Discussed here are the current training methodologies for fleet pilots to maintain proficiency and the current mission preparation tools available. It also discusses the background of the ChrAVE training system. Work completed by previous authors is summarized and used as a starting point.

3. Chapter III: ChrAVE 3.0/VEHelo 2.0 Specifications and Configuration. This chapter covers the current physical configuration of ChrAVE 3.0 and VEHelo 2.0 as tested during this thesis. Included are the equipment specifications for the various components that make up the system. It also includes an updated User’s Manual to successfully employ the system in an experimental environment.

4. Chapter IV: ChrAVE 3.0 Knowledge Value Added (KVA) Assessment. This chapter describes the benefits associated with adding Information Technology, in the form of a virtual environment, to the training of novice and experienced pilots.

KVA will be defined and background information will be presented to help the reader understand its basic tenants.

5. Chapter V: ChrAVE 3.0 Instructional Experiment and Results. This chapter describes the experiment methodology and presents the analysis of data collected during the study.

6. Chapter VI: Recommended System Modifications and Improvements. This chapter outlines suggested modifications and alterations that would improve overall performance and enhance the usability for future development.

7. Chapter VII: Conclusions. This chapter describes conclusions reached via evaluation of the test results and input from the users, experienced and novice.

II. HELICOPTER NAVIGATION TRAINING, CHROMAKEY AUGMENTED VIRTUAL ENVIRONMENT (CHRAVE) 3.0, AND VIRTUAL ENVIRONMENT HELICOPTER (VEHELO) 2.0 BACKGROUND

A. HELICOPTER NAVIGATION TRAINING BACKGROUND

Learning to navigate in any type of aircraft is a critical skill. It is not enough to be able to control an aircraft, but pilots must be able to safely get their craft from point A to point B. Marine Corps helicopter aviation navigation training includes initial skills development, advanced techniques training, and refresher or proficiency training. Before this thesis introduces the experiment setup, experiment goals, and conclusions it is important to clarify some key navigation definitions and introduce the methods and standards used to develop the key skills required to successfully navigate.

1. Training Requirements by Stage

As Naval Aviators transition through various stages of training, training requirements increase based on the Training and Readiness Manual. The three general stages of training are undergraduate, Fleet Replacement Squadron, and Operating Forces.

a. Primary, Intermediate, and Advanced Training

During undergraduate flight training in Pensacola, Florida and Corpus Christi, Texas student pilots are introduced to a limited number of navigation training. Most of the training during these stages is based on Instrument Flight Rules (IFR) with only a few hours used to introduce them to Visual Flight Rules (VFR) concepts. In each stage there are usually one or two flights that rely on the student's ability to navigate using terrain features. While this is by no means a firm base with which to build the key skills upon, it does give the students a look at the future. One of the issues is the use of 1:25,000 maps as introductory navigation tools. This is not commonly used in the operating forces and may not be ideal for building experience.

b. Fleet Replacement Squadron (FRS) Training (Combat Capable Training)

Once newly winged pilots arrive at their Fleet Replacement Squadrons the real navigation training begins. Using the CH-46E FRS as an example, Replacement Aircrew (RACs) are taught navigation skills through four individual flights. They fly a 1:250,000 day (NAV 130), a 1:50,000 day (NAV 131), a night unaided 1:250,000 (NAV 132), and a Night Vision Goggle (NVG) 1:250,000 flight in order to meet Training and Readiness Manual requirements. For purposes of this thesis work, the NAV 130 T&R event was the flight used to evaluate the system's potential. See Appendix A for further details about the T&R Manual requirements.

c. Operating Forces Training (Combat Ready Training)

The training continues when the pilots reach their Fleet or Operating Forces squadrons. Advanced techniques are taught through 200, 300, and 400 level T&R coded flights. Progress on these flights is dependent upon the quality of training in the 100 level codes flown at the FRS.

2. Standardization Manual Navigation Definitions

Within the CH-46E Standardization Manual there are specific definitions of what navigation training is designed to achieve. These definitions are the basis for all other and more advanced training in such environments as low light level or shipboard operations.

From Chapter 4 of the Ch-46E Standardization Manual:

4002. **NAVIGATION STAGE**.

1. This stage is taught to develop the pilot's ability to navigate by terrain appreciation, dead reckoning (time/distance/heading), radio navigational aids, and global positioning system (GPS) aids. Further FRS programs are designed to acquaint the new CH-46E pilot with techniques required to perform future navigational duties in the Terrain Flight (TERF) environment. The flight techniques taught in this stage will be associated with low level flight.

a. Low level flight makes navigation difficult, because the flat visual angles distort contours when compared to the map. Vertical relief is the most suitable means of identifying checkpoints. Navigating with proficiency during low level flight requires training and practice. Identifying checkpoints is the critical task, requiring the pilot to be proficient in map reading, terrain interpretation, and the correlation of terrain features with map symbology. The pilot must be able to visualize from the map how the surrounding terrain around him should appear. The pilot must also be able to look at the terrain, identify the plane’s location, and locate that position on the map.

b. The flight route is a pre-selected, generally straight-line track and is flown at a constant airspeed and indicated altitude. Time-distance checks can be used to determine the limits of flight in a specified direction and confirm checkpoint identification. This is made possible because at these altitudes, direct legs can be plotted, avoiding most ground obstacles. Day navigation flights will be flown between 200-500 feet AGL climbing to 1000 feet AGL over heavily populated areas, and night navigation flights will be flown between 500-1000 feet AGL.

CH-46E Standardization Manual

The types of low altitude navigation flights or low level terrain flight fall into three basic categories: Low Level, Contour, and Nap-of-the-Earth (NOE). Use of each type depends on tactical situation, weather, and other mission elements. All of the types are generally flown below 200 feet above ground level (AGL). For purposes of initial training, altitudes are generally kept at 500 feet AGL or between 300 and 500. The NAV-130 syllabus event from which data is collected is flown on a 1:250,000 map at 500 feet AGL.

The purpose of navigation training during the Combat Capable stage as outlined in the CH-46E Training and Readiness Manual is “to develop navigation skills using maps and charts” with a secondary purpose of “a discussion of the seven critical steps of Cockpit Resource Management (CRM).

The following figures illustrate the three types of Low Level Terrain Flight.

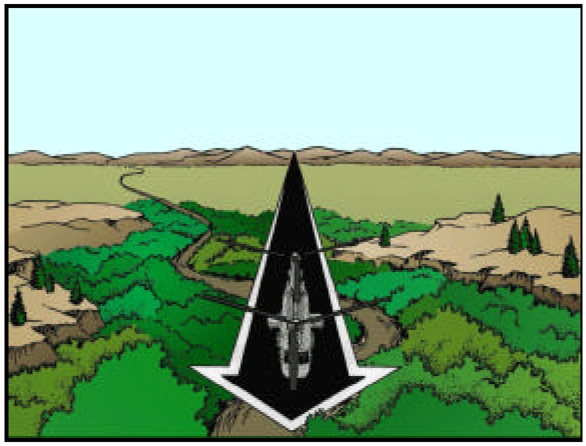

Figure 2. Low Level Terrain Flight

Figure 3. Contour Terrain Flight

Figure 4. Nap of the Earth Terrain Flight

3. Crew Resource Management

Crew Resource Management, Communications, and Coordination skills are practiced in all syllabus events. For the first time in their aviation training, the FRS presents the RACs with a multi-crew weapon system. Skills that they learn during this stage will apply to the rest of their careers. With that in mind, the ChrAVE 3.0 System presents a unique opportunity to introduce and practice these critical skills before the time comes when they have to use them for real.

Successful navigation requires coordination with all members of the crew. This coordination is best achieved through Crew Resource Management (CRM) training. The Standardization Manual and NATOPS Manual outline the requirements for training and the Navy philosophy regarding CRM. These references include lengthy explanations of how a crew must divide the labor and duties during missions, accepting responsibilities as required.

4. Situational Awareness

Situational Awareness is a critical skill that must be practiced during navigation training. Perhaps more than other syllabus flights, the student must know the location of the aircraft in relation to where the aircraft is headed and what elements are going to affect its continued efforts. A pilot uses all senses available to help build that SA. Radio communications, Intercom system communications, and other inputs need to be monitored and analyzed to continue with the mission.

Situational Awareness is a graded item on every flight and often is coupled with CRM goals.

B. CHROMAKEY AUGMENTED VIRTUAL ENVIRONMENT BACKGROUND

1. ChrAVE 3.0 Development

As discussed in Chapter I, chromakey technology has cleared the way for more creative uses of virtual environments. The evolution from a “blue-screen” system to the system called ChrAVE 3.0, the basic concept is the same. Leading technologies and proven signal mixing allow for realism that had not been achieved.

The live signal mixed with a background virtual environment was conceived by Sullivan and put into practice by Lennerton. Researched in 2004 by Kulakowski, the technology has reached the limit of development. As we close in on that perfect environment or a state of “near fidelity” the system must be upgraded with future development in mind.

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III. CHRAVE 3.0/VEHELO 2.0 SPECIFICATIONS AND CONFIGURATION

The latest configuration of the ChrAVE/VEHLO research project is designed to replicate the cockpit environment as closely as possible. This unique application of chromakey technology introduces the student pilot to the required communications exchanges that are inherent in navigation. By sitting in the copilot's seat, the navigating pilot or Pilot Not At the Controls (PNAC) interacts in a way that is similar to real conditions. The flying pilot or Pilot At the Controls (PAC). Through terrain association and interpretation and directive commands, the ChrAVE 3.0 System lets the student pilot practice skills that are required in an actual aircraft environment. Utilizing the standard terminology from the CH-46E Naval Aviation Training and Operating Procedures Standardization (NATOPS) Manual, the students can work out any problems prior to actual flight interactions. The Instructor Pilot is stationed aft of the CH-46E radio closet with the ability to follow the GPS track, see the digital background, or select the navigator's view which includes camera and background feeds.

During flight there are specific duties that each member of the crew is responsible for. These responsibilities fall under the roles of PAC, PNAC, Crew Chief, and Aerial Observer/Gunner. At times the basic crew can be augmented with a load master or jump master depending on the cargo type or mission type. Kulakowski went into great detail about the responsibilities and the communications techniques that are to be utilized. Other sources of complete information are the CH-46E NATOPS Manual, the Standardization Manual, and the Training and Readiness Manual. These are listed as References and some of the more useful information is included as appendices. Both Kulakowski and Lennerton talk to the workload experienced by each of these crewmembers. They both concluded that the pilot responsible for navigation is usually more focused on how the mission is progressing. For these reasons, the duties of navigation and aircraft control are often “swapped” several times each flight.

For purposes of experimentation, manipulation of the controls is not required. There is not a requirement for hydraulic power or even electrical power on the aircraft. During the simulation, the instructor manipulates the controls through keyboard commands. The control commands may be referred to in Chapter VI.

A. SCALABILITY

ChrAVE 3.0 introduced scalability to the Virtual Environment being researched at MOVES. Designed around a PC-based simulator, there are several methods for deployment and employment. From running the application on a desktop to the full implementation on an aircraft, flexibility is a central theme in the system.

Using COTS systems allows a certain number of options in deployment methods. At its most simple state, the user can operate the system without the HMD, LiteRing Assembly, and ChromaFlex sheets. Simply sitting at the monitor the pilot can practice terrain recognition and practice navigation. By loading a route into the PFPS laptop, mission rehearsals can be conducted fairly easily. For use in a ready room setting, the ChrAVE 3.0 equipment can be stored under a desk and peripheral devices such as a monitor, mouse, and keyboard can limit space required for employment. In this configuration, the system most closely resembles TopScene. This configuration is best for a single individual to practice navigation and conduct mission preparation.

The next configuration simply adds the HMD, lighting, and chromatte screens. This method requires, at a minimum, some structure to hold up the framed, foldable chromatte screens. This is the “mock cockpit” configuration that was tested during VEHELO by Kulakowski. While not required, a seat, mock controls, and an instrument monitor add to the realism. This method can be used with only one person, but two are advised for realism.

The final configuration is the one tested during the research that went into this thesis. It requires the user to mount the ChromaFlex “sheets” on the exterior of the aircraft windscreen. While it involves using less equipment, the setup is a bit more difficult and it requires coordination with the maintenance crew or the hangar chief. This method also requires two people to effectively conduct training.

B. DEPLOYABILITY

ChrAVE 3.0 is about 6 pounds lighter, has a smaller footprint, and is broken down into several units which makes it more manageable than VEHELO or ChrAVE. The savings in weight does not include the loss of the large light banks, multiple screens, seat, controls, and associated hardware.

C. SYSTEM HARDWARE AND SETUP

The ChrAVE Version 3.0 system configuration merges hardware components used during previous versions with some leading edge technology that has since emerged. In an effort to increase portability and deployability, the configuration has undergone some basic setup changes. The current configuration consists of the equipment listed in the inventory located in Appendix B.

1. Cockpit Configuration

The ChrAVE 3.0 system configuration has removed the need for a “mock cockpit”. By using the LiteRing assembly and ChromaFlex chromatte material from the Reflecmedia Corporation ChrAVE 3.0 the need for studio lighting has been eliminated. The small Light Emitting Diode (LED) light ring assembly emits a green light that is specifically tuned to the gray fabric that comprises the chromatte sheets. Without the studio lighting requirement the system is now adaptable to an aircraft cockpit and no additional equipment is required to simulate the cockpit setting. Included in the list of items that were deleted due to the new configuration were the multiple fluorescent studio light fixtures (as many as six large or small units), three blue chromatte screens, the pilot seat, the instrument monitor frame, and the simulated controls. Figure 6 illustrates the previous version’s “mock cockpit” footprint.

Figure 5. VEHELO Portable Mock Cockpit and Matting

With the acquisition of new technologies, ChrAVE 3.0 is easily configurable to current DoD aircraft cockpits. The ChromaFlex background sheets fit right over the windscreen and side windows of the CH-46E used for experimentation. Figure 7 shows the experiment configuration using the chromatte sheets.

Figure 6. ChrAVE 3.0 Chromatte Screen Configuration

Without the need to "simulate" the cockpit environment, the test subjects were able to sit in the actual cockpit in which they would fly the next day. This gave the highest level of realism possible, adding the distractions associated with the somewhat cramped environs of a CH-46E. Present were the instrument panel and glare shield, the flight controls, the harness, and the many support structures and beams that restrict the pilots field of view (FOV). The current system configuration also allows for the placement of the equipment directly behind the copilot, allowing ease of Instructor Pilot (IP) – Pilot Under Instruction (PUI) communications. Figure 8 shows both a view of the PUI in the cockpit and the equipment placement within the cargo area of the aircraft.

Figure 7. Internal Cockpit View and Equipment Configuration Behind Cockpit

By reducing the number and weight of the items required for simulation, ChrAVE 3.0 achieved new levels of portability and deployability. The system now only requires one person to load, transport, offload, and deploy on sight. Figure 9 displays several of the components that are no longer required for use with the system.

Figure 8. Various Equipment (Portable Pilot Seat, Flight Controls, Instrument Monitor Stand, Screen Support Poles, and Fluorescent Lamps) No Longer Required for Simulation

2. Cockpit Equipment

a. Reflecmedia ChromaFlex Chromatte Sheets

The use of flexible sheets of chromatte material has allowed, along with the light ring, ChrAVE 3.0 to be used within an actual CH-46E. The chromatte material is simply “draped” over the cockpit windscreen and left-side cockpit windows and attached to various attachment points using simple flexi-chords. There is no requirement for aircraft modification and a reduced threat of Foreign Object Damage (FOD) due to the small amount of hardware required for mounting.

Chromatte is a reflective fabric specifically designed to be used as a background for “chroma key” productions such as film and television news. The gray fabric appears as a blue or green background to the camera when it receives light from the LiteRing Assembly. The technology involved in the chromatte material is based on millions of what Reflecmedia calls “SateLITE Dish” reflective beads. These beads allow the fabric to be used at varying angles from the camera lens and in low light conditions. This is the key to allowing ChrAVE 3.0 the flexibility to be used on an aircraft frame.

Figure 9. Reflecmedia ChromaFlex Chromatte Material

Compared to conventional blue or green screens, chromatte does not require the large amount of studio lighting units. These units required a large amount of expertise and experience to produce the desired images. ChromaFlex, on the other hand, is the perfect material for the novice. There are no tuning or angular adjustments. Simply display the material, turn on the LiteRing Assembly, adjust the power output of the light source, and the user will get a near perfect rendering of a blue or green background.

b. Instrument Panel

The instrument panel used for ChrAVE 3.0 is the same as the last version. With the “in-cockpit” configuration, there is no power to run the actual cockpit instrumentation. Therefore, the external monitor is still used to display a representation of the SH-60 helicopter’s instrument panel. The purposes for use of the instrument display is to give the simulation an added degree of realism, continue scan technique training, and give the PUI reference with which to direct the flight inputs of the IP. The display includes an airspeed indicator, an attitude indicator, turn and slip indicator, radar altimeter indicating height Above Ground Level (AGL), a barometric altimeter indicating height above Mean Sea Level (MSL), Radio Magnetic Indicator (RMI) and a Vertical Speed Indicator (VSI).

Figure 10. ChrAVE 3.0 Instrument Panel

c. Lighting

ChrAVE 3.0 introduces a marked improvement in lighting requirements. The multi-unit fluorescent lighting configuration of past systems is replaced by a single ring of LEDs that produces the required illumination. Paired with Reflecmedia’s gray ChromaFlex fabric, overall system footprint was greatly reduced. Power requirements for illumination were cut from thousands of watts to just over ten. The need to constantly adjust lighting direction and distance in relation to the fabric is no longer required. Set-up and preparation time is reduced to a fraction of that of previous versions. The new light source is hard mounted to the HMD and constantly illuminates in the direction of the user’s scan.

3. Head Mounted Display Assembly

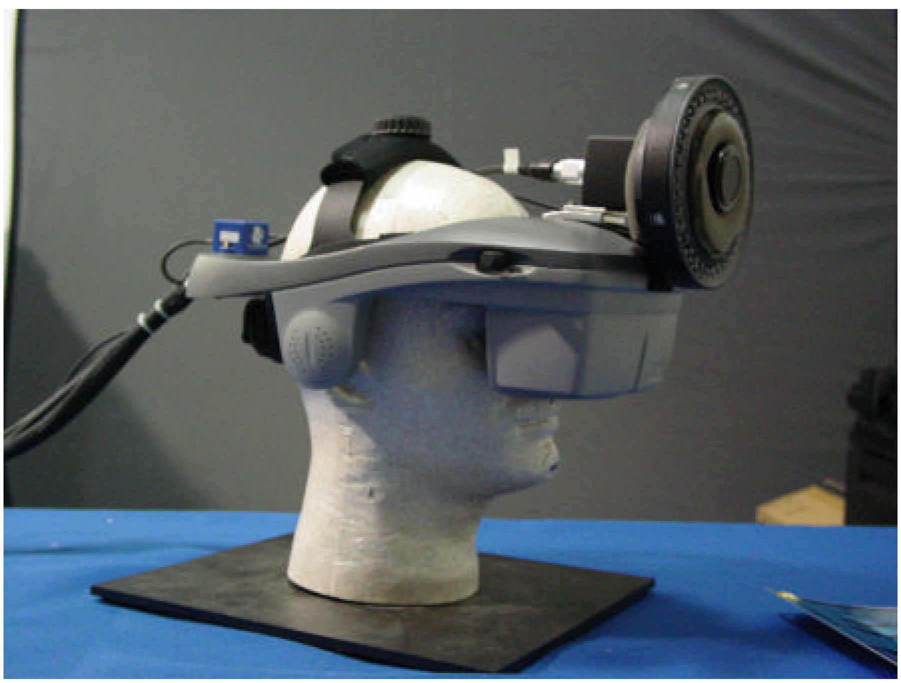

Figure 11. ChrAVE 3.0 HMD Assembly with Mounted Camera, Head Tracker, and LiteRing Assembly

a. *Head Mounted Display*

The Head Mounted Display (HMD) used for ChrAVE 3.0 is the nVisor SX manufactured by NVIS out of Reston, Virginia. The nVisor SX incorporates high-resolution color microdisplays with custom engineered optics. It utilizes a Liquid Crystal On Silicon (LCOS) display made by CRL Opto. It uses a 24 bit color display with a 1280x1024 60 Hertz analog or DVI resolution. This unit is quite an advanced step when compared to previous system components. It offers a wide field of view and increased visual acuity with relatively little weight. It is ergonomically designed to increase comfort and can be easily adjusted for fit, including inter-pupillary distance (IPD) adjustment and eye relief adjustment for proper eye position. In the current configuration, a head tracker was mounted to the existing external mounting point.

Inputs and outputs for video and power are handled through an external control box. Red and green Light Emitting Diodes (LED) indicate ‘Power On’ and ‘Clear Signal’. The unit accepts standard SXGA video in either digital or analog formats. An analog output is provided for driving a repeater monitor and a standard RS-232 port supports future upgrades. A standard 15 pin VGA type connector accepts the VGA (1280 x 1024, 60Hz) inputs.

Figure 12. NVIS nVisor SX Head Mounted Display (HMD)

The nVisor SX HMD, when coupled with the InertiaCube Head Tracker, allows the user to view all areas within the cockpit environment. Simply put, the pilot can look in all directions, viewing the specific terrain in that direction, see the relative motion of the aircraft, and scan both vertically and horizontally or any combination of the two. With an exchange of communications, the PUI practicing navigation can determine what direction in which to fly and send commands to the IP who manipulates the “controls”. The ability to see something and turn the aircraft toward it increases the realism of the simulation, benefiting instruction and skills development. This is a leap forward from the flat view available with monitors that a standard PC configuration offers. The HMD provides a constant angular FOV through the use of the head-tracking unit. The PUI can dynamically affect the view independent of the flight direction. With ChrAVE 3.0 the user can see all views that are normally available while flying the actual aircraft.

With the “on-aircraft” configuration, the user also experiences the obstacles to field of view (FOV) in the aircraft. Lennerton’s work developed the term “dynamic point of view” to describe this functionality.

The ability to utilize an HMD which gives accurate angular FOV information to the user lends this system to more advanced experimentation. Combined with the night vision goggle (NVG) compatible light source and an environmentally correct night environment database, it is not beyond reason that future use may include NVG training.

b. Camera

The camera used in the ChrAVE 3.0 is the same as that used by Kulakowski in his work with the VEHELO. The monocular vision attained from the camera requires some planning for lens selection to assure the user of a logical view. Borrowing from Kulakowski, “the lens is selected upon consideration of many factors.” Some of these factors as discussed in Lennerton’s work are the “visual requirements such as first-order parameters (focal length, FOV, and f-number), performance parameters (emphasizing limits of distortion), and other parameters (such as size, weight, shape, and zoom)”.

The Panasonic GP-US532H Digital Signal Processing (DSP) Color CCD micro-camera is a high performance micro-camera that is designed around three 1/3 inch Charge Coupled Devices (CCD). It uses one CCD for each color, red, green, and blue and is controlled via the Camera Control Unit (CCU). It has Automatic Gain Control (AGC) and Electronic Light Control (ELC). The camera used is compatible with the nVision SX HMD.

Figure 13. Camera Control Unit and Camera Head (Minus Lens)

Kulakowski outlines the additional problem of eye to lens displacement (ELD). Lennerton in 2004 described the ELD as it, “represents both a rotation and translation between the user and camera’s optical path origin”. This is simply the result of the off-axis mounting of the camera on the HMD and is insignificant in the current configuration.

c. Lens

A variable 6-13mm F1.8 manual camera lens is used in the VEHELO system. The lens has two adjustable rings; one is used for camera focus. The other is to adjust the aperture f/stop settings. Adjusting the aperture to a lower f/stop number will allow more light to reach the camera sensors. It will also reduce the depth of field of the camera.

Figure 14. Camera Lens

d. *Motion Tracker*

Head tracking and motion detection is accomplished via the InterSense Inertiacube[2]. It is a motion tracker that utilizes inertial sensing technology to provide 3-Degrees of Freedom (DOF). This is the same hardware used in the Kulakowski version. It obtains motion sensing by using a "miniature solid-state inertial measuring unit". This unit senses the angular rate of rotation, gravity and the Earth's magnetic field along three perpendicular axes. The angular rates of motion are combined to obtain the orientation (yaw, pitch, and roll) of the sensor.

Figure 15. Motion Tracker

The system utilizes the small InertiaCube[2], approximately 1.5 inches square, mounted to the top of the back of the HMD frame worn by the user. It is connected by a cable to the input of the CPU via the use of a serial port dongle and DC power connection. Use of this head tracking device is effective inside and outside of the actual helicopter cockpit with no noticeable interference from aircraft structure.

e. LiteRing LED Light Source

A significant advance in system design was made with the acquisition of the Reflecmedia products including the ChromaFlex screens and LiteRing LED assembly. The Chromatte fabric is designed to work in conjunction with the LiteRing. The footprint was dramatically reduced due to the deletion of the fluorescent light fixtures and accompanying hardware. The LiteRing assembly contains individual green LEDs arranged in a circular casing that is positioned around the camera lens. This configuration provides all the light required to illuminate the Chromatte background material. At just over 10 watts of output, the LiteRing assembly represents a significant decrease in power requirements over previous systems. Power is provided through a standard wall plug and runs through a regulator that offers brightness control via a rheostat. Figure 19 displays the current HMD configuration with the LiteRing Assembly mounted and powered on. Note the position of the camera inside the ring of LEDs.

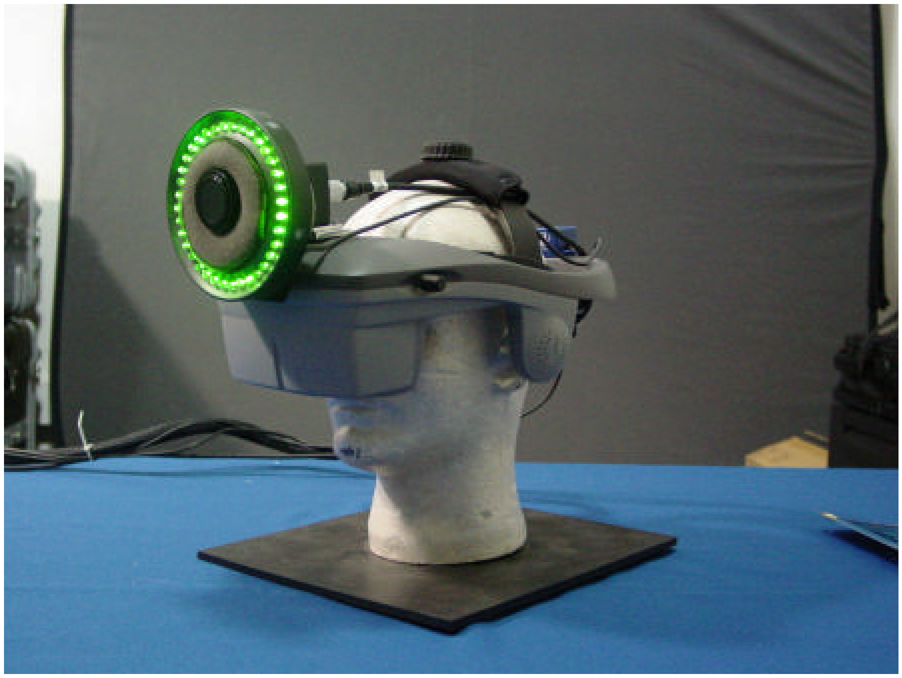

Figure 16. ChrAVE 3.0 HMD Assembly with LiteRing

(The following technical descriptions are adapted or taken directly from the descriptions found within Kulakowski's work. The only exceptions are the ADC-8033/DFR-8014A Signal Converter and Frame and the DVI to VGA Conversion Unit.)

4. Electronic Hardware and Software

ChrAVE 3.0 has yielded significant improvements in hardware and software used when compared to the previous versions tested by Lennerton and Kulakowski. There are five (5) improvements evident in the current version worth explanation. These five improvements fall into three (3) general areas: Portability/Deployability, Future System Expansion, and Instructional Improvement.

The improvements primarily focus on allowing the system to be more mobile and supportable. They also included changes to allow it to perform functions such as it being used as an instructional tool. The basic configuration of the VEHELO is depicted in Figure 16.

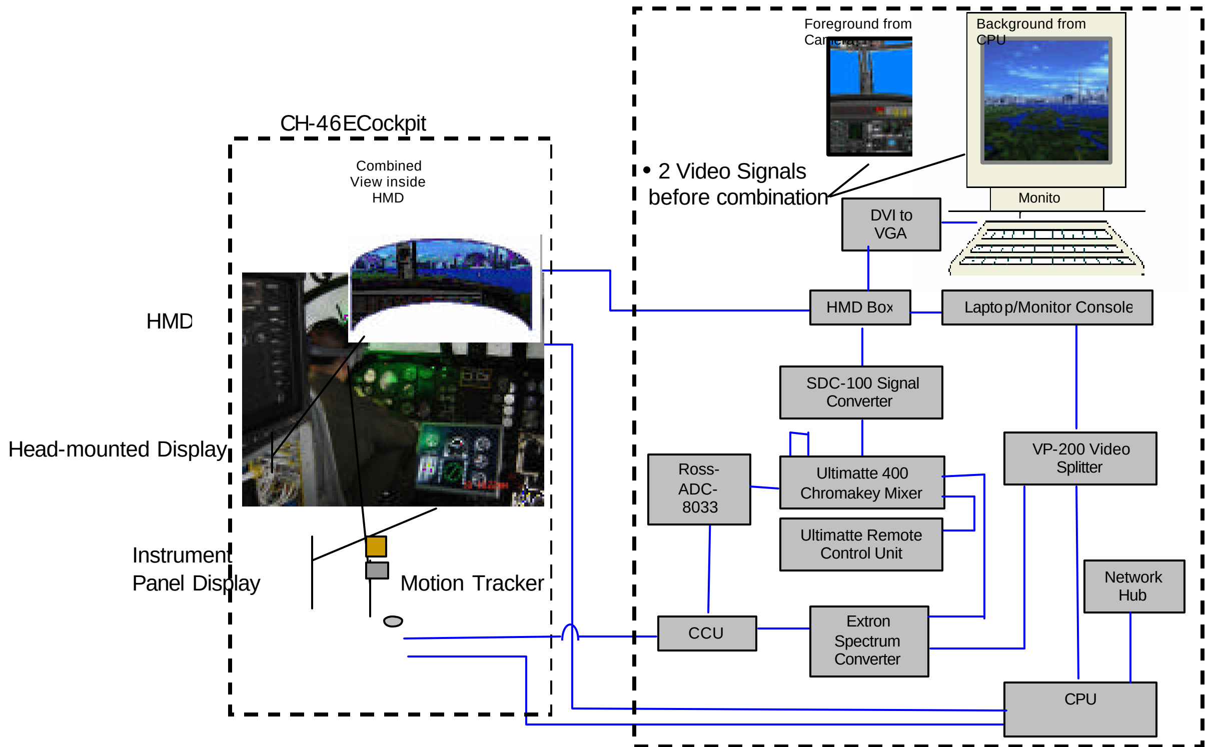

Figure 17. Schematic of the ChrAVE 3.0 System

a. *Ultimatte® 400 Mixer*

Ultimatte 400 Mixer is a fully linear matting system able to produces realistic composites. It accomplishes this even when the foreground contains smoke, shadows, soft edges, motion blur or other translucent and transparent qualities. It is used to produce composite signals (digital CCIR-601 signal) of two inputted video images. As used in the VEHELO there is a camera signal and a CPU Virtual Environment signal that the mixer combines.

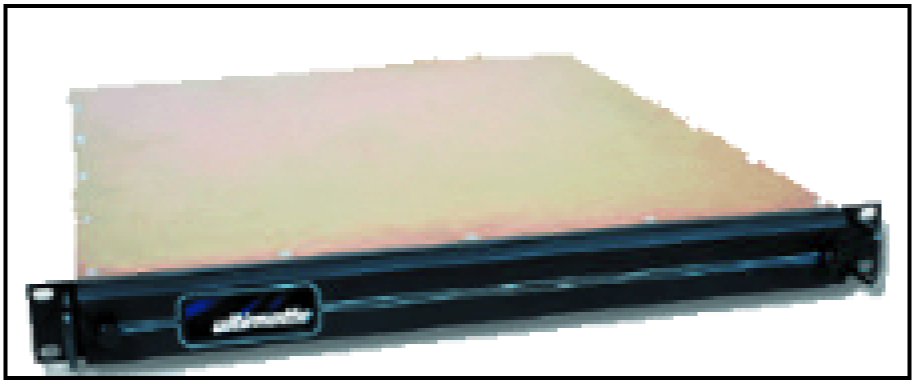

Figure 18. Ultimatte 400 Video Mixer

The Ultimatte mixer requires a controller to effectively manipulate the many variable encountered during set-up. The Ultimatte Company refers to this unit as the ‘Smart Remote’. This unit has 640 x480 VGA display for effective navigation through the available menus. Communication between the Ultimatte 400 Main Unit and the Smart Remote is through an RS-422 interface at a data rate of 115 Kbps.

At the completion of the experiment this unit was replaced by a software upgrade to the PC. Future versions of the VEHELO will include this software upgrade incorporated and be afforded a space saving in the equipment cabinet.

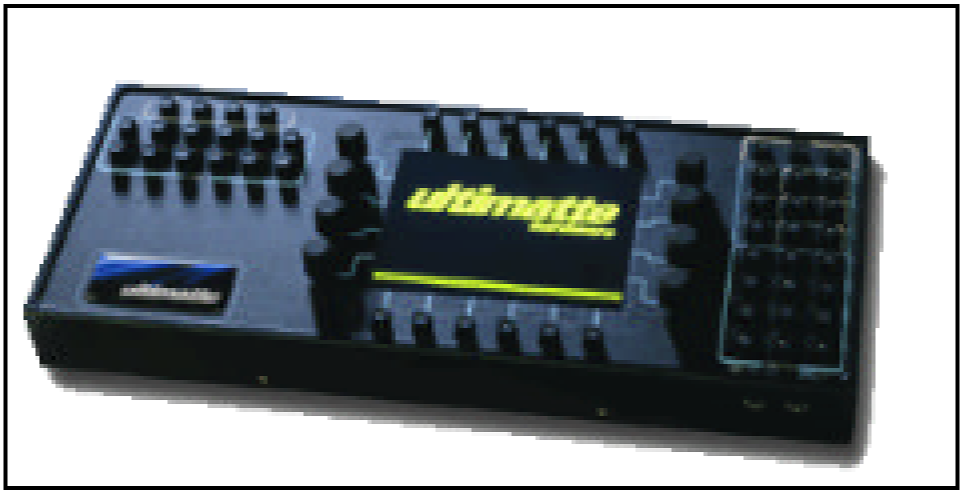

Figure 19. Smart Remote, Ultimatte Corporation

b. ExtronÔ VSC 200 Scan Converter

The system utilizes an Extron™ VSC 200 Video Scan Converter for VGA to Digital 601 Signal Conversion. It converts the video signal from the CPU into a digital CCIR-601 signal. The Extron™ unit has five levels of vertical filtering which assists in eliminating flicker. It also has four levels of horizontal filtering to accomplish scan conversion. The unit also has a 24 bit color sampling which provides 8 bits per color for a total of over 16 million colors. The unit has front mounted controls allowing it to be easily mounted in the VEHELO cabinet.

Figure 20. VGA-to-Digital Signal Scan Converter

(front and back shown)

c. Analog-to-Digital Signal Converter

The Ross™ ADC-8033 signal converter allows for 10-bit quality conversion of analog component signals into 270 Mb/s serial component 4:2:2 video. The ADC-8033 is a card that fits into several models of converter frames. The converter frame used in ChrAVE 3.0 is described below. It serves the purpose of converting RGB into digital signals. The Camera produces an RGB video signal that is required to be converted to a digital CCIR-601 signal. That digital signal is then inputted to the Ultimatte™ 400 Deluxe chromakey mixer.

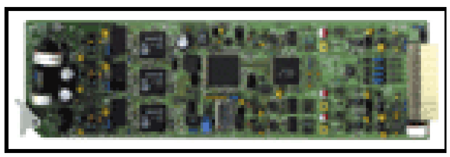

Figure 21. ADC-8033 Analog-to-Digital Converter

d. RossÔ DFR-8104A Converter Frame

The ADC-8033 signal converter is housed in the Ross DFR-8104A Converter Frame. The rack-mounted unit has space for four separate converter cards and allows for considerable expansion. With an easy to use/change system, the versatility and flexibility offered by the component will play a key role in the continued weight saving and space saving effort by replacing three other components with a light weight card.

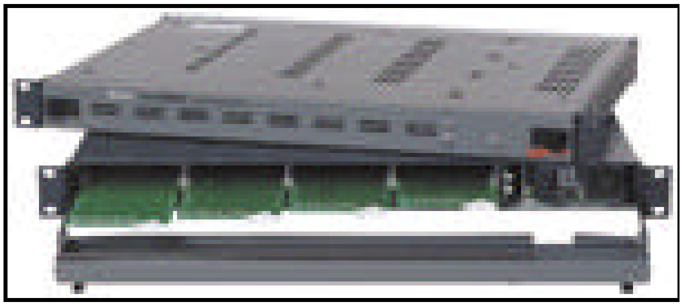

Figure 22. DFR-8014A Converter Frame

e. ExtendItÔ DVI-to-VGA Conversion Box

The ExtendIt DVI-to-VGA Conversion Box allows the signal coming from the HMD to be routed to the Laptop Monitor. The real advantage that comes from this configuration is the ability to switch to “cockpit” view, allowing the IP to gain insight into the student’s scan and correct any bad habits. The converter generates all the compatible digital to analog conversion signals to make the connection between the digital input and the analog output work.

Figure 23. Digital-to-VGA Converter

f. LeitchÔ SDC-100 Signal Converter

The Leitch™ SDC-100 converts the serial digital CCIR-601 signal (from the Ultimatte 400 mixer) to a ‘multi-pin’ VGA type cable. This allows the signal to be viewed on the V8 HMD.

Figure 24. Digital-to-VGA Converter

g. 1:2 Video Distributor (Splitter)

The VEHELO system requires that the video signal be split for multiple destinations (the Extron Spectrum Converter and the Stealth laptop monitor). The VP-200 is a high performance 1:2 distribution amplifier for VGA signals. The unit accepts one video input, provides buffering and isolation and then distributes the signal to two identical outputs using 15 pin D connectors. The unit requires a dedicated 12V power supply.

Figure 25. 1:2 VGA Distributor

h. Rackmount CPU

The Stealth SR-4500B is an industrial rackmount computer. The computer operates with Microsoft Windows 2000 with Service Pack 3 installed. The computer also has an 2.8 GHz Intel processor mounted on an ATX Mainboard. The unit installed in the VEHELO is configured with a hard drive, 1 Gigabit of RAM, floppy drive, CD-ROM, and 300 watt power.

Figure 26. Central Processing Unit (CPU)

i. Rackmount Laptop with LCD/Keyboard/Mouse

The single CPU is controlled through the use of a Stealth laptop, model FR-100, mounted in the equipment case. It has an integrated 17 inch LCD monitor with a resolution of 1280 x 1024. It also has a built-in keyboard and mouse mounted on a slide out tray. It has eight video/keyboard/mouse ports on the backside to support various configurations. The VEHELO configuration utilizes only two of the combination inputs in normal operation.

Figure 27. Laptop CPU Console

j. Equipment Cart

The Thermodyne Quadraflex™ was again used to house the equipment for the system. During ChrAVE 3.0, two cases were used in order to improve the mobility and protability by spreading the weight out. These cases are heavy duty, shock resistant, and waterproof. Inside the boxes the various pieces of equipment are mounted on custom configured shelving. For normal operation, the four covers are removed, the top case components are connected to the bottom, external power applied and the external connections (HMD, monitor etc.) made in approximately 15 minutes. The bottom unit is also configured with four removable heavy duty casters.

Figure 28. Thermodyne QuadraflexÔ Equipment Cart

5. Miscellaneous Hardware

a. Rack-Mounted UPS

Tripp Lite's SMART450RT UPS System provides the VEHELO system with a line-interactive battery backup. It is designed to be rack-mounted and has a 450 VA power handling capability and UPS battery backup. The unit has 5 AVR protected outlets, four of which are UPS and surge and one surge-only outlet. It also has diagnostic LEDs on the front and an accessory slot for use with optional SNMP card, network management, and connectivity products.

Figure 29. Rack-Mount UPS

b. Rack-Mounted Surge Protector

The transient surge protector for the equipment case is an industry standard. It is required to provide the needed number of outlets for all installed hardware and to easily connect the equipment case to an external power source. The unit is produced by the Leviton company.

Figure 30. Rack-mounted Surge Protector.

6. Overall System Goals

As with previous work conducted by Lennerton and Kulakowski, the goals for the system remain the same. There are two overall goals of the system.

- To exercise the task of navigation as “faithfully and rigorously’ as the task is accomplished in the real world utilizing an actual aircraft and
- To place the subject in an immersive and familiar environment, true in first person fidelity.

IV. CHRAVE 3.0 KNOWLEDGE VALUE ADDED (KVA) ASSESSMENT

Knowledge Value Added or KVA is a way for a business or organization to determine the value inherent in an investment in information technology. KVA is an information age methodology based on the Thermodynamics Complexity Theory. It views an organization as a portfolio of knowledge assets deployed to create value. KVA assesses the value of intellectual capital and information technology. The result of a KVA Assessment may be an entire Business Process Reengineering project or a simple adjustment to the way the process currently exists. The following is a definition taken from www.iec.org:

> Knowledge Value Added methodology provides a way to measure the value of knowledge assets deployed in core processes objectively. Valuation – the measurement of the value of knowledge embedded in company core processes, technology, and employees – is accomplished through two return ratios: return on knowledge (ROK) and return on process (ROP).

The basic premise is that by comparing the percentage of the revenue or dollar allocated to the amount of knowledge required to complete a task to that of the total amount of knowledge required to generate an organization’s total output we can assess the value of knowledge. This proportion makes up the numerator of a ratio that has as its denominator the cost to execute the knowledge process. This ratio is illustrated below.

$$\text{Return on Knowledge} = \frac{\text{Amount of Knowledge Required to Reproduce Process Outputs}}{\text{Cost to Use Knowledge to Produce Results}}$$

To begin the KVA process, an organization must take an internal look at how knowledge is used. This Knowledge Audit helps to establish a baseline from which to adjust. First, all of the core area Subject Matter Experts (SMEs) must be identified. By discussing with them the process that currently exists, the KVA can help to determine which direction an organization should move. Through interviews, observations, and process mapping, the assessment determines an ordinal ranking of key steps of the process and the Learning Time (LT) required to perform them.

In the case of augmented reality embedded trainers, there currently is no useable version. The FRS relies on a simple class, a relatively low tech process, and selected readings from several manuals to prepare the students for success in the cockpit during navigation training.

Next, a spreadsheet is created that maps out the "As-Is" process. This is a numerical "snapshot" of how the business is being conducted. Critical columns are Actual Learning Time, Hit Count, Percentage of IT in process, and IT Cost. The next Figure summarizes the KVA Process.

KVA in 10 Easy Steps

1. Define the AS-IS Process
2. Ensure that the sponsor concurs with the process as described.
3. Conduct the Knowledge Audit
    a. Determine Actual Learning Time (ALT)
    b. Determine Nominal Learning Time (NLT) 100 units of time
    c. Determine Ordinal Ranking (Optional) Rank 1-X

4. Determine number of organizations involved
5. Determine number of people/organization involved
6. Determine number of “times fired” per time period
7. Determine “working time” for each “time fired”
8. Determine cost per time unit for working time (if applicable)
9. Determine NUMERATOR:
    a. ALT or NLT times
    b. Number of organizations involved times
    c. Number of people involved times
    d. Times fired

10 Determine Denominator
    a. Time to complete times
    b. Number of people involved times
    c. Number of organizations involved times
    d. Times fired times
    e. Cost per unit of time (if applicable)

10. Determine ROK
Numerator/Denominator

Figure 31. Ten Steps In the KVA Process

For the scope of this thesis the following table is the “As-Is” process for simulation training in the FRS.

As-Is

Process Task	Task Owner	Level of Automation	Actual Learn Time (hours)	Times Fired / Year	Head Count	Touch Time (Hrs/ Year)	Hourly Salary	Total Cost
Navigation Class Preparation	RAC	0%	1	1	62	2	$31.68	$3,928
Navigation Lecture	Instructor	10%	100	15	4	30	$52.08	$6,250
Computer Based Training	RAC	95%	1	62	62	600	$31.68	$1,178,496
Map Study/Map Preparation	RAC	20%	2	62	1	2	$31.68	$63
Flight Brief	Instructor	0%	100	31	2	45	$52.08	$4,687
Flight	Instructor	25%	750	62	1	1.5	$52.08	$78

Knowledge Generated	Nrml Learning Time	Total Revenue (ALT x HC x TF)	Total Expense (Touch Time x HC X TF x HR)	ROK (Tot Rev/ Tot Exp)
1	0	62	3928.32	15.78
1500	15	6600	93744	70.40
62	1	7495.8	73066752	0.10
124	1	148.8	3928.32	37.88
3100	31	6200	145303.2	42.67
46500	465	58125	4843.44	12000.77
Correlation	85%			

Figure 32. KVA "As-Is" Process Worksheets (Divided into two parts for ease of viewing)

Now that we have determined the As-Is Process in navigation training, we have to leverage what our IT investment, in the form of ChrAVE 3.0 could be. It is important to note on the As-Is chart which processes might benefit from the introduction of IT. From the description of the tasks, Navigation Class Preparation and Map Study/Preparation lend themselves to acceptance of more IT investment.

Once the initial worksheet is completed, a determination is made of what IT investment is to be made and what task will be affected. In the case of the ChrAVE 3.0 System the initial assumption that class preparation and map study/map preparation would affected was correct.

To-Be

Process Task	Task Owner	Level of Automation	Actual Learn Time (hours)	Times Fired / Year	Head Count	Touch Time (Hrs/ Year)	Hourly Salary	Total Cost
Navigation Class Preparation	RAC	40%	1	1	62	2	$31.68	$3,928
Navigation Lecture	Instructor	10%	100	15	4	30	$52.08	$6,250
Computer Based Training	RAC	95%	1	62	62	600	$31.68	$1,178,496
Map Study/Map Preparation	RAC	95%	2	62	1	2	$31.68	$63
Flight Brief	Instructor	0%	100	31	2	45	$52.08	$4,687
Flight	Instructor	25%	750	62	1	1.5	$52.08	$78

Knowledge Generated	Normal Learning Time	Total Revenue (ALT x HC x TF)	Total Expense (Touch Time x HC X TF x HR)	ROK (Tot Rev/ Tot Exp)
1	0	86.8	3928.32	22.10
1500	15	6600	93744	70.40
62	1	7495.8	73066752	0.10
124	1	241.8	3928.32	61.55
3100	31	6200	145303.2	42.67
46500	465	58125	4843.44	12000.77
Correlation	85%			

Figure 33. KVA To-Be Process Worksheet (Divided into two parts for ease of viewing)

The overall effect of adding more technology, in the form of ChrAVE 3.0 results in an increased Return On Knowledge of nearly 25 percent for class preparation and almost 50 percent increase for map study/map preparation.

With these results, an increase in IT would further knowledge valuation and result in an overall increase in revenues. It should be noted that while the figures in the worksheets above included an embedded cost analysis, the figures were estimates and may not be completely accurate.

V. CHRAVE 3.0 INSTRUCTIONAL EXPERIMENT AND RESULTS

The procedures outlined in Kulakowski's research are sound and can be followed in order to obtain data on initial navigation training. With the scalability of the current system, other steps may be added or taken away depending on the mission. For purposes of ChrAVE 3.0 experiments, these steps will be followed almost without exception. The basic procedures are reproduced below with exceptions and additions outlined in italics. These steps are to be followed by the person "giving" the period of instruction.

1. Utilize the enroute portion of the first leg to familiarize the PUI with the system. The PUI will quickly learn the ability of the system to depict terrain and gain an appreciation almost immediately.
2. The proctor/IP will simulate calls from the PAC, Crew Chief (CC) and Aerial Observer (AO). The two-way communication dedicated to the mission is the primary method to teach CRM to the PUI.
3. The IP will also point out to the PUI distinct terrain features so that he may garner an appreciation of scale and speed of the helicopter towards or away from them.
4. The IP may vary parameters such as airspeed and altitude to ensure the PUI is maintaining a good scan under the HMD onto the instrument panel.
5. The Proctor or IP will manipulate the flight and the flight parameters via keystroke entry on the laptop keyboard. The commands are listed in Table 2.

   NOTE: Advanced commands are not required to complete a training session. They are intended more as system design and evaluation tools.

A. EXPERIMENT SETUP

1. Subject Pilots (PUI)

ChrAVE 3.0 was evaluated at Marine Medium Helicopter (Training) Squadron - 164 at MCB Camp Pendleton. Over a period of 6 months, 12 Replacement Aircrew Pilots participated in simulations and flights in which data was collected and compared. All subjects were male Marines with the same basic experience levels. These pilots were undergoing the Combat Capable Phase Helicopter Training in accordance with the U.S.M.C. Training and Readiness Manual (Appendix A). Upon completion of the Combat Capable phase of training the pilots are designated as Helicopter Second Pilot (H2P) in the CH-46E and execute orders to a fleet unit.

All participants had completed prerequisite in preparation for the NAV sorties. The T&R Manual mission criteria and performance standards can be found in Appendix A. Completion of FAM-113 and the navigation class make the pilots eligible for navigation flights.

The RACs have already practiced the skills required to aviate in a multi-tasked environment.

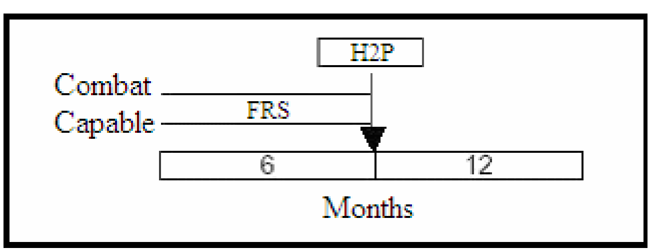

Figure 34. Fleet Replacement Squadron (FRS)Training Timeline

2. Treatment

Prior to the experiment simulations the twelve subjects received an introductory class on the research and their role in data collection. All participants were asked to complete both a preflight and post-flight questionnaire that recorded essential historical data along with perceptions of the experiment. Following the class and questionnaire, the students rotated through the simulation individually. A brief explaining communications and coordination in a crew-served aircraft along with a brief of the equipment and intended route was then conducted. A map study was completed by each pilot. Unlike Kulakowski, the author completed all of these steps. The only squadron personnel involved were those that flew with the participants in the NAV-130.

a. Entrance Questionnaire

Every pilot completed a pre-flight questionnaire prior to the flight brief. The preflight questionnaire is shown in Appendix D. The questionnaire is designed to gain insight into the test subjects.

b. Flight Briefing

Each flight and simulation event in the FRS require a flight briefing. This brief can cover safety issues, procedures, and other T&R items along with familiarization with the equipment. The brief should be performed by the instructor that will implement the simulation. The CH-46E NATOPS briefing guide, required Squadron Standard Operating Procedures (SOPs), and CH-46E Tactical Manual (TACMAN). The Briefing Guide is depicted in Appendix F and reflects those areas that are pertinent to NAV flights and CRM training. Once the subjects were briefed individually for the ChrAVE flight and the aircraft flight the flights were executed. Table 1 depicts the standard briefing items for a NAV-130 flight. Discussion items are ones in which the students should have memorized. Introduction items are the newest on the table, but the pilots should be able to discuss them in detail. Review items are standard knowledge requirements for each flight.

GOAL	▪ Introduce day visual navigation.	
DISCUSS	▪ CH-46E NATOPS Manual ▪ Standardization Manual CH-46E Flight ▪ CH-46E TAC Manual ▪ CRM ▪ Lost Plane Procedures ▪ Time/Distance checks ▪ Distance estimation and map legend information ▪ Map preparation ▪ METT-TSL considerations	▪ Comfort Levels ▪ Boundaries ▪ Wind correction for Dead Reckoning Navigation ▪ In-flight route changes
INTRODUCE	▪ Navigation procedures emphasizing the following to determine position. - use of terrain - contour features - triangulation ▪ Use of 1:250,000 and 1:50,000 maps	▪ Point to point navigation of at least 5 checkpoints at 200-500 feet AGL ▪ Remain +/- 500 meters of course line

Table 1. Preflight Brief Items as Per T&R

All briefing items were covered with each student individually and within a short time before executing the flight.

c. Debrief

In accordance with the Standardization Manual and NATOPS Manuals, all pilots should debrief in order to share a common experience and learn from all mistakes. For this experiment all flights were debriefed, to include aircraft flights.

d. Exit Questionnaire

Upon completion of the simulation event, all pilots were asked to complete a questionnaire to determine effects of the simulation experience and to determine where changes may be needed. The questionnaire is shown in Appendix F.

3. System Artificialities

The ChrAVE 3.0 System, in its current state, laid to rest some significant artificialities that were described in Kulakowski. The “mock cockpit” is no longer a factor for the system. By placing the simulation in the cockpit, artificiality is restricted to just some visual shortfalls and some lack of realism in pilot configuration due to the IP being behind the PUI.

a. Visual Artificialities

The virtual environment still lacks the clarity and diversity in image that is desired. This is more a result of a “home grown” database than anything else. The resolution of the image from the LiteRing and ChromaFlex components is far clearer than past attempts. Terrain diversity is also a bit of a shortfall. Some colors just didn’t make sense and should be adjusted.

b. Flight Profile Artificialities

There is a limited amount of flexibility built into the control of the aircraft. Due to some programming shortfalls, the pilots perceive the affects of riding a roller coaster. Once the altitude is registered, the simulation will fly a “contour” profile. In order to ensure a fair experience, airspeed and altitude are maintained essentially constant and according to the plan. The lack of movement in the flight controls does add some artificialities, but a lack of control manipulation is consistent with the duties of a copilot while navigating.

B. EXPERIMENT PROGRESSION AND RESULTS

1. Preflight Questionnaire Results

The preflight questionnaire used during Kulakowski’s research was more than adequate to gain insight into the experiences of the subject pilots. Table 2 summarizes the results.

With a single exception, all of the subject pilots were fresh from Advanced Training in Pensacola and a couple had experienced some difficulty with navigation in Primary Flight Training. The 12 pilots had an average of 246 hours total time. Of the 246 hours, very few were flown within the last six months. One of the pilots had been flying for several years and had a significant number of extra hours.

Many answers pointed to the fact that the pilots had done some studying prior to taking the questionnaire and proceeded to read the Tactical Manual and NATOPS Manual which may explain some of the spikes in performance.

Question #18 proved to be the best gauge as to the subject’s perception of skill required for proper navigation. The results show the varying degrees of instruction the subjects had received to the point prior to this experiment. Two of the subjects thought the most important item was voice communication between the aircrew. One subject thought knowing aircraft position in relation to a terrain feature was most important.

Question Number	Results	Question Number	Results
1	11 of 12 Subjects < 120 hrs.	12	N/A
2	10 of 12 Subjects < 280 hrs.	13	All requirements for Nav flights were completed w/in 30 days.
3	9 of 12	14	All subjects over 6 months (Flight School)
4	100% = NO	15	75% = Timing 25% = Distance
5	100% = NO	16	100% = NO
6	100% = NO	17	N/A
7	No subject had VE experience	18	Results described below
8	N/A	19	▪ Most answers: 200
9	100% = NO	20	▪ Most answers: 200
10	N/A	21	▪ 60% = NO ▪ 40% = YES
11	▪ 50% = NOVICE ▪ 50% = AVERAGE	22	100% = NO

Table 2. Preflight Questionnaire Results

2. Recorded Data from VEHELO System and Aircraft

The ChrAVE 3.0 System recorded the data onto its hardrive as the subject pilots flew the system. This is not a requirement as the collected data does not necessarily correlate to data profiles from the NAV-130 flight. The critical data comes from the NAV-130 flight. Additionally the subjects actual flight path in the aircraft were recorded via a handheld GPS which was carried onboard each flight by the Instructor Pilot (IP). A single file which showed the planned route and the flown route was recorded for each pilot. An example of this may be found in Appendix G. This data is what is used in order to support this thesis.

The data was then analyzed and plotted on a simple chart. *The bivariate analysis and anova charts from Kulakowski were cut do to inconclusive*. The data from Kulakowski was added to the results from this research to get a more precise feel for success or failure.

The evidence was very conclusive that using the virtual environment system resulted in the test subjects flying an average of 40+ meters closer than those without.

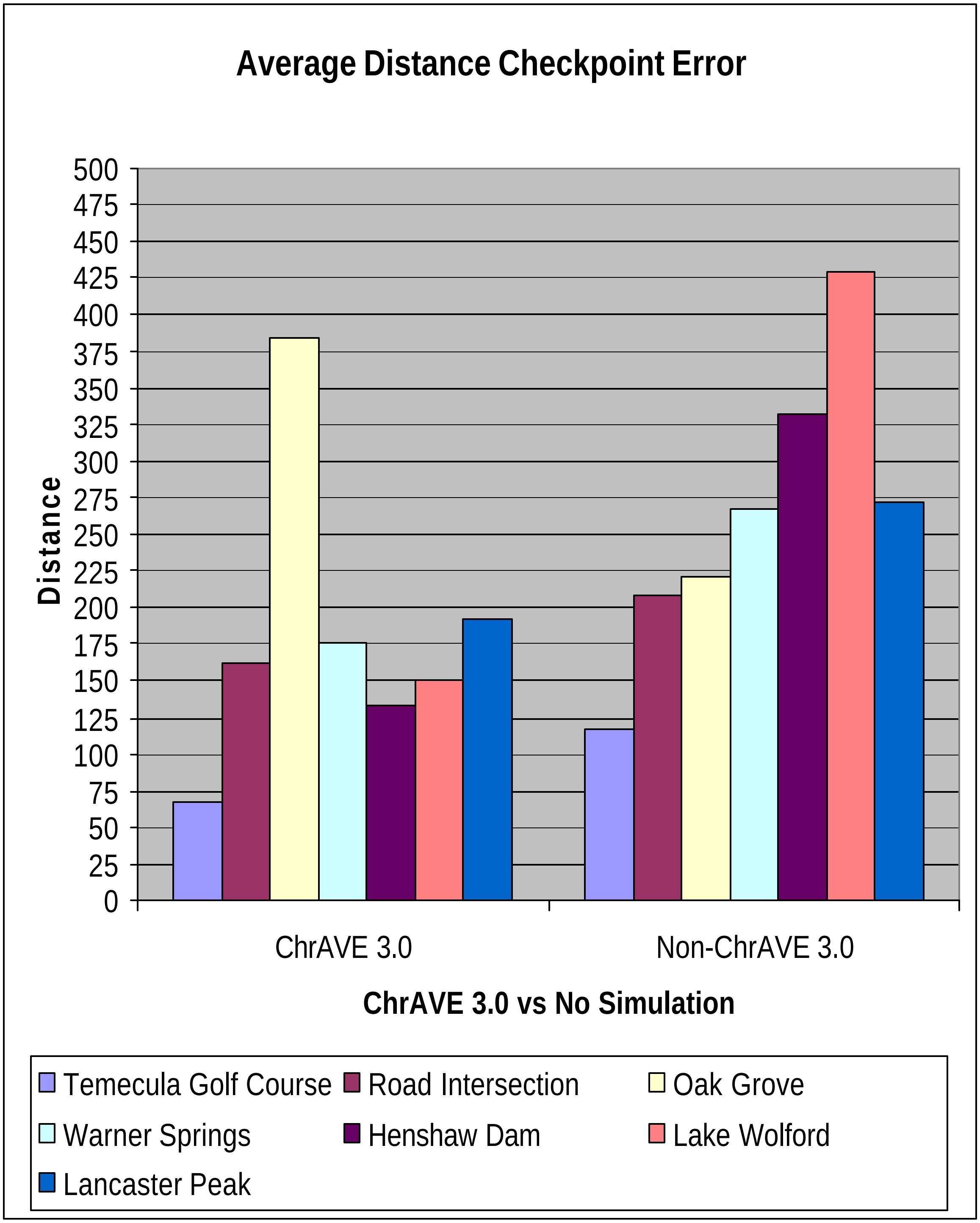

Figure 35. Graphic Comparison of Average Checkpoint Errors Among Those Receiving Simulation

Subject	Flight Mode	Checkpoints (distance in meters)							Avg. Distance from Ckpnt
		Temecula Golf Course	Road Intersection	Oak Grove	Warner Springs	Henshaw Dam	Lake Wolford	Lancaster Peak	
1	VEHELO	225	< 50	2000	550	300	1000	650	682
	Aircraft	< 50	< 50	< 50	500	< 50	200	500	221
2	VEHELO	< 50	< 50	500	< 50	550	1600	1000	543
	Aircraft	< 50	< 50	< 50	< 50	< 50	200	250	100
3	VEHELO	< 50	500	< 50	500	750	700	1350	557
	Aircraft	< 50	250	< 50	150	< 50	300	1000	264
4	VEHELO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Aircraft	400	500	1700	1100	400	400	450	707
5	VEHELO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Aircraft	300	450	1000	400	200	< 50	600	429

Notes: (1) Point Canyon checkpoint used for warm-up.

Table 3. VEHELO NAV-130 Results (Average Error) From Research by Kulakowski

Subject	Temecula Golf Course	Road Intersection	Oak Grove	Warner Springs	Henshaw Dam	Lake Wolford	Lancaster Peak	Avg. Distance from Ckpnt
	Distance from checkpoint (measured in meters)							
1	<50	200	800	150	<50	200	225	239
2	125	<50	225	200	<50	125	100	125
3	<50	150	100	<50	200	<50	200	114
4	75	100	450	100	150	225	200	186
5	<50	<50	125	300	<50	<50	125	107
6	<50	400	600	250	300	250	300	307
Average Distance Errors for ChrAVE 3.0 Students								180
7	100	200	<50	500	300	675	350	310
8	150	325	450	125	550	<50	300	279
9	<50	125	150	200	275	350	200	193
10	<50	300	250	275	450	400	375	300
11	125	200	75	200	<50	<50	350	150
12	225	100	350	300	375	1050	<50	350
Average Distance Errors for Non-ChrAVE 3.0 Students								263
Average Distance Errors from Kulakowski for VEHELO								195
Average Distance Errors from Kulakowski for Non-VEHELO								568
Average Distance Errors Hahn+Kulakowski Simulated								185
Average Distance Errors Hahn+Kulakowski Non-Simulated								340

Notes:
(1) Of the twelve (12) subjects studied, the first six (6) listed received ChrAVE 3.0 training in the ChrAVE 3.0 prior to the NAV-130 flight. * The last six (6) listed flew the NAV-130 flight only.
(2) Point Canyon checkpoint used for warm-up.
(3) GPS was not used by PUI during the recording of data.
(4) All distances from checkpoints are rounded to closest 25 meter segment.
(5) For purposes of simplicity, the distance errors from the ChrAVE 3.0 simulations were not included.

Table 4. ChrAVE 3.0 NAV-130 Results (Average Errors) Including Previous Research Results by Kulakowski

3. Debrief and Comments

The value of the data obtained was described in the earlier body of work by Lennerton. The metrics were also verified in that body of work. The empirical data is shown below in Table 5. It reflects the closest proximity to each checkpoint by each subject during t he simulated flight and the actual flight in the aircraft. The column on the right side depicts the average distance in meters from the checkpoint for all of the checkpoints on that pilot’s flight.

The squadron instructs each PUI to the USMC standard which is plus or minus 500 meters from course line. As can be seen in the table, subjects’ performance was notably improved after completing training in the VEHELO system. It can also be noted, when using the averaged data, that the two of the three students who utilized the simulator first were able to maintain navigation to within the standards described above. The two students who flew the aircraft with no VEHELO exposure failed to meet the minimum criteria set forth for this level of training.

4. Postflight Questionnaire Results

As in Kulakowski’s work the biggest complaint and the only item that really meant something from the questionnaires was that the visual environment. Details such as man-made items were lacking. The water looked like desert and sometimes the desert like water.

5. Instructor Pilot Comments

This thesis differed from prior work in that it was not possible to schedule a single pilot to fly each of the events. Instead, multiple instructor pilots flew the flights and allowed the author to view graded comments. All participating IPs were trained and experienced to conduct the flights.

The Academic Training Forms (ATFs) are the official grading sheets produced by the IP after the flight in the aircraft is completed. The following are comments taken from the ATFs of four of 12 subjects.

Subject #3 (conducted simulation

Seemed comfortable with communications required…All T&R items discussed thoroughly. Good scan and kept PAC's head out of the cockpit while subject continued to plot position. Could use more work with dealing with the two aircrewmen.

Subject #4

"Great flight. Appears comfortable in challenging terrain. Missed a couple of checkpoints, but found them and marched on."

Subject #10

Normal tendencies to not back up with time and include crewchief in discussions. Had some trouble at Henshaw Dam and finding Temecula Golf Gourse. No time for brickwork as we were occupied for a little longer than normal on fulfilling minimum.

Subject #12

"Tough flight. Circled several times to locate checkpoint. Tended to keep scan too close to the aircraft and missed the big pictue. CRM skills are average and needs to be more forceful when dealing with the enlisted aircrweman"

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VI. RECOMMENDED SYSTEM MODIFICATIONS AND IMPROVEMENTS

A. MODIFICATIONS COMPLETED

This thesis and the one prior have highlighted some continuing problems with the system. First, the items that Kulakowski recommended will be discussed and then items that need to get attention will follow.

1. Headgear Replacement

Problem – The headgear to support the V8 HMD was effective but unrealistic for the PUI to wear while training in the ChrAVE. Ideally the PUI should train with the same flight rated gear that he would wear in the aircraft. This will eliminate any ‘hotspots’ and PUI fatigue normally experienced by the existing headgear.

Solution - The HMD was replaced with a lighter, more capable unit. The associated cabling still poses a significant problem, especially with the LiteRing Assembly added. The HMD was modified at NPS in order to hard mount the camera and lens to the visor. The LiteRing Assembly was mounted around the camera. The HMD is much more comfortable and the wearers were able to fly longer while wearing it.

2. Smart Remote Replacement

The Smart Remote unit was brought back out for the ChrAVE 3.0 testing and experiment. This was done for several reasons, but most important was the ease of adjustment of the output. The software takes quite a bit of training.

3. LED LiteRing

The implementation of the LiteRing Assembly and sheets of ChromaFlex allowed the unit to be used aboard the CH-46E. This was perhaps the greatest advantage that ChrAVE 3.0 had over VEHELO.

4. Modified Equipment Case(s)

The equipment case configuration was modified during the re-building of the system. Two cases were purchased in order to distribute the weight more evenly and increase the value of the unit as deployable

B. RECOMMENDED IMPROVEMENTS

1. Component Replacement with Cards in DFR-8014A Frame

The Leitch ADC-8000 unit was replaced by the Ross ADC-8033. The card is housed in a DFR-8014A Conversion Frame which allows for three other conversion units.

A solution to the weight and space required for individual components is to replace components with cards that will fit in the conversion frame. The cards are actually competitive in price for purchasing. A reduction in weight and freeing up of critical space within the transport cases is the true payoff. reflected back at its source (with the camera lens in the center).

2. Virtual Environment Database Update

Almost to a pilot, the lack of a clear and colorful database is required to take the system to the next level. Particular attention to man-made structures/features should be made.

The solution can be an in-house one as before, but the researcher must provide credible opinions and guidance.

The software modification described above allows for a

3. Future Research

Future research should focus on validating the use of the system with the Litering and Chromatte material for matting. It should concentrate on the following areas;

- Testing using the flight rated hardware such as the flight helmet with ICS between the Proctor/IP and the PUI.
- Validate training of the unaided night navigation flights (100 level flights). This would involve the system being used in a blacked out cockpit configuration.
- Validate initial (100 level flights) NVG flight training. The configuration with the Litering will permit all of these training scenarios.

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VII. CONCLUSIONS

In the future, the Navy and Marine Corps team will face more fiscal constraints and a steady increase in Operations Tempo that will lead to even more dependence on simulation-based training. Adaptable, scalable, and deployable systems must be developed now to make way for that eventuality. Large scale acquisition programs like the Joint Strike Fighter and the MV-22 Osprey currently require nearly half of all initial flight hours to be simulated. This number could increase with an increase in advanced technology equipment designed into these systems.

Chromakey Augmented Virtual Environment 3.0 is the culmination of over six years of research into a system that helps to meet current and future simulation needs. Built around the concept of providing a mixed live video foreground with a software generated background in a simple to use head-mounted system, ChrAVE 3.0 is an economical option as an embedded trainer to augment and improve quality of training and mission preparation. Composed entirely of commercially available components or Commercial-Off-The-Shelf (COTS) products, ChrAVE 3.0 combines the versatility of a mobile virtual environment simulator with the latest in chromakey technology to provide an immersive simulation experience.

Creating the environment that is most familiar and comfortable for the pilot is essential to achieving the desired results of any simulation device. Familiarity with the environment allows a pilot to concentrate on the multiple tasks required by the mission profile without the added lack of comfort of foreign surroundings. Past system configurations failed to achieve this familiarity as all simulated environments were based on mock-ups of a helicopter cockpit. ChrAVE 3.0, in its most integrated mode, actually places the pilot in her or his aircraft cockpit. This is realism that has, historically, only been achieved by multi-million dollar Weapons Systems Trainers (WSTs) or Aircrew Procedures Traininers (APTs). ChrAVE 3.0 successfully reached the primary research goal by being adapted to the cockpit of a CH-46E helicopter. The actual cockpit provided the realism of cramped spaces, internal aircraft obstructions like controls and instrument panels, and aircraft structural framework. Multiple experiments in this environment proved the concept's usefulness and fulfilled the desired conditions of deployability, adaptability, scalability, and flexibility for its implementation.

Secondary research goals were achieved with conclusive data that provided insight into ChrAVE 3.0's ability to augment flight training and increase or maintain proficiency in some basic skill sets. The pilots that participated in the simulation were able to achieve some level of success in improving some or all of three goals of the navigation training: Terrain Appreciation, Crew Resource Management, and Situational Awareness. This primarily supported those conclusions from Kulakowski's previous work, but ChrAVE 3.0 achieved a higher level of usability, providing further insight into the system's possible use as a proficiency trainer in navigation, mission preparation, instrument, and NVG training.

Increasing proficiency in these areas in a low risk and cost effective environment is the ultimate achievement of ChrAVE 3.0.

Analysis of Knowledge Value Added (KVA) calculations provides evidence that the use of Information Technology, in the form of a virtual environment trainer, at the initial navigation training stage provides a significant Return On Knowledge (ROK) when compared to the current method of training. This leads to the conclusion that the injection of navigation simulation prior to the execution of the NAV-130 syllabus event can increase training efficiency and effectiveness with the end result being possible DoD cost savings.

Echoing the conclusions of Kulakowski's research, the most valuable data collected during the evaluation of ChrAVE 3.0 was the comments from the Instructor Pilots and Pilots Under Instruction. The insight provided led to many of the recommendations for further system development and experiment execution. The bottom-line to any method of training in naval aviation is that it is based upon human-to-human interaction and the opinions and observations expressed by those supporting this experiment give further evidence to this.

The research that was conducted using the ChrAVE 3.0 system answered all of the thesis questions. The system was adapted, successfully, to an actual aircraft cockpit. ChrAVE 3.0 surpassed previous versions in terms of ease of loading, transporting, unloading, and deploying. The simplified equipment requirements led to decrease in set-up and preparation time. With some minor modifications, the system can achieve higher levels of deployability and its use expanded to other areas of training and mission preparation. The system, again, proved itself as a quantifiable success for use in initial navigation training. With the injection of Information Technology into initial training, there is a significant increase in Return On Knowledge. Finally, a few small modifications will improve the system for use as an instructional tool, allowing increased interaction between pilots and even more associated training benefits. Adaptable to all levels of aviation training, an embedded training utilizing a virtual environment provides the force multiplier needed to keep aviators mission ready at home or while deployed. ChrAVE 3.0 offers a solution that is both economically and technically viable to the future simulation needs of the fleet.

APPENDIX A. CH-46E TRAINING AND READINESS MANUAL

Weapons Qualification
Mission Planning
NATTP 3-22.5-CH46E, CH-46E Tactical Manual, Volumes I and II
Academic Training Syllabus

120. FLIGHT TRAINING FOR BASIC AND TRANSITION PILOT

1. Combat Capable Phase

STAGE	NO. EVENTS ACFT/SIM	NO. HOURS ACFT/SIM	CRP ACFT/SIM
Basic Qualification	-	-.-	25.0
Familiarization	11/11	15.5/22.0	10.0/4.5
Instruments	4/3	6.0/6.0	4.0/3.0
Navigation	4/0	6.0/0.0	4.0/0.0
Confined Area Landings	2/1	3.0/2.0	1.5/0.5
Formation	2/1	3.0/2.0	2.0/0.5
External Loads	1/1	1.5/2.0	1.0/0.5
Terrain Flight	1/0	1.5/0.0	0.5/0.0
Review	1/1	1.5/2.0	1.0/1.0
Combat Capable Pilot Check	1/0	1.5/0.0	1.0/0.0
TOTAL FOR PHASE	**27/18**	**39.5/36.0**	**25.0/10.0**
COMBINED TOTALS	**45**	**75.5**	**35.0%**
ACCUMULATION FOR BASIC POI	**45**	**75.5**	**60.0%**

AIRCRAFT: CH-46E MOS: 7562 CREW POSITION: PILOT

STAGE	EVENT TRNG CODE	HRS	REFLY INTERVAL	CRP	C	R	M	E	REMARKS
COMBAT CAPABLE PHASE									
NAV	130	1.5	*	1.0					A
	131	1.5	*	1.0					A
	132	1.5	*	1.0					A N
	133	1.5	*	1.0					A N NS

3. Navigation (NAV)

a. Purpose. To develop navigation skills using charts and maps.

b. General. Conversion aircrews qualified and current in navigation in previous type aircraft are exempt.

(1) Pilots will be prepared to discuss the seven critical steps of CRM as applicable to each event.

c. Crew Requirement. IP/RAC/CC.

d. Flight Training. (4 Flights, 6.0 Hours).

NAV-130 1.5 1 CH-46E A

Goal. Introduce day visual navigation.

Requirement

(1) Discuss. (ref: CH-46E NATOPS Manual, CH-46E Flight Standardization Manual, CH-46E TAC Manual)

(a) CRM.

(b) Lost plane procedures.

(c) Time/distance checks.

(d) Distance estimation and map legend information.

(e) Map Preparation.

(f) METT-TSL considerations on route selection.

(2) Introduce

(a) Navigation procedures emphasizing use of terrain, contour features, and triangulation to determine position.

(b) Use of 1:250,000 maps.

(c) Point-to-point navigation to at least five checkpoints at 200 to 500 feet AGL. Remain within 500 meters of course line.

Performance Standards

Pilot shall perform a navigation route utilizing a 1:250,000 map remaining within 500 meters of course throughout the route that consists of a minimum of five checkpoints.

Prerequisite. FAM-113, FRS Navigation class.

Ordnance. None.

External Syllabus Support. None.

NAV-131 1.5 1 CH-46E A

Goal. Review NAV-130.

Requirement

(1) Discuss. (ref: CH-46E NATOPS Manual, CH-46E Flight Standardization Manual, CH-46E TAC Manual)

(a) Comfort level.

(b) Navigation techniques.

(c) Map preparation.

(d) Boundaries.

(e) Wind correction for DR navigation.

(f) In-flight route changes.

(g) Onboard navigation systems.

(h) Basic Survivability Concepts.

(2) Plan and navigate at 200-300 feet AGL to a minimum of six predetermined terrain features using 1:50,000 maps. Remain within 200 meters of course line. Use appropriate onboard navigation systems, if available.

Performance Standards

Pilot shall perform a navigation route utilizing a 1:50,000 map remaining within 200 meters of course for a minimum of six checkpoints.

Prerequisite. NAV-130.

Ordnance. None.

External Syllabus Support. None.

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APPENDIX B. HARDWARE INVENTORY

The following inventory documents the current physical configuration of the VEHELO.

	Nomenclature	Manufacturer	Model	Serial Number
1	CPU	Stealth Computer Corp.	SR-4500B	STL0304SR3235
2	Laptop Console	Stealth Computer Corp., USA		129-1911202629-6E
3	Video Splitter	Kramer Electronics, Israel	VP-200	N/A
4	Spectrum Converter	Extron	VSC-200	818525008E11072
5	Video Mixer	Ultimatte	Ultimatte 400	12182
6	Mixer Remote	Ultimatte Corp, USA	Smart Remote	11296
7	Camera and Camera Control Unit	Panasonic	GP-US532H	9Z2175
8	Lens	Pelco, USA	**12VA6-13**	1-12 8
9	HMD	NVIS	nVisor SX	N/A
10	HMD Control Box	NVIS	nVisor SX	V8EBY26 and USN 62271A2703
11	Head Tracker	Intersense	InertisCube^2	100-1MU00-0210 SC2-0210282-D
12	Instrument Panel Monitor	NEC	MultiSync	1880SX
13	Signal Converter	Ross	ADC-8803	
14	Signal Converter	Leitch	SDC-100	N/A (Qty 2)
15	Equipment Case	Thermodyne	Quadraflex™	One Case consisting of: ▪ Center Case w/internal racks ▪ 12107L Cover – Qty2 ▪ 12108R Cover – Qty 2
16	Rack-Mounted UPS	TrippLite	**SMART450RT**	9142ALCSM
17	Transient Surge Protector	Leviton		5500-190

* NOTE: All are quantity of one (1) except were indicated.

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APPENDIX C. HARDWARE SPECIFICATIONS

A. NVISOR SX HEAD MOUNTED DISPLAY

- From NVIS.

Display	- Dual 1.3” diagonal Active Matrix Liquid Crystal Displays - Resolution per eye: ((640x3)x480), (921,600 color elements) - Contrast ratio: 200:1
Optical	- Field of view: 60° diagonal - Multi-element glass, fully color corrected design - Interpupillary distance (IPD) range: 52mm to 74mm - Eye relief: Adjustable 10-30mm design accommodates glasses - Rubber eye cups prevent eyeglasses and lens contact - Overlap: Standard 100%
Audio	- Sennheiser HD25 high performance headphones - Headphones rotate above headband and snap off when not in use
Mechanical	- Single rear ratchet allows for quick, precise fit - IPD assembly moves fore/aft to accommodate glasses - IPD knobs accessible at sides of shell - HMD overall length/width/height: 17.5” x 8” x 6” (43 x 20 x 15 cm) - HMD Weight: 34 ounces (1.0 kg)
Cable	- Description: Custom molded cable - Length 13’ (3.9m) standard - Connector: 50 pin SCSI
Control Box	- VGA (640 x 480 60Hz) input format - Sync on green, separate H and V, or Composite (+ or - going) - Overall brightness and contrast - Stereo or mono input auto detected - Mono input drives right and left eye with one signal - Audio Input: 3.5mm mini stereo phone jack - Monitor Output: VGA (640 x 480 60Hz)
Electrical	- Power supply: Universal input (+5, +24, -12, VDC) output - Power consumption: 30W

B. PANASONIC GP-US532H CAMERA

- 3-CCD High Performance Micro Head Color Camera with DSP from Panasonic.

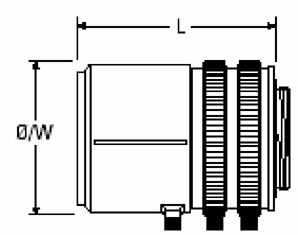
TV System	- NTSC (Available in PAL)
Pick-up System	- Micro prism optical system
Pick-up Device	- Pixels: 768 (H) x 494(V) Three 1/3" interline transfer (IT) supper high sensitivity CCDs
Scanning System	- 2:1 Interlace 525 lines, 60 fields, 30 frames Horizontal: 15.734kHz, Vertical: 59.94Hz
Synchronizing System	- Internal or External (Gen-Lock)
▪ **Internal**	- NTSC standard (Available in PAL as GP-US532E***)
▪ **External (Gen-Lock) Input**	- VBS, VS, HD/VD SC Phase for Gen-Lock (VBS): Free adjustable over 360 H Phase for Gen-Lock (VS): Adjustable
Video Outputs	-
▪ **Video 1,2**	- 1.0V [p-p] / 75 ohms NTSC composite video signal, BNC Connector
▪ **S-VIDEO (Y/C) Out**	- (Y) 0.714V [p-p] / 75 ohms (C) 0.286V [p-p] / 75 ohms, S-VIDEO Connector x 1
▪ **RGB/SYNC**	- (R/G/B) 0.7V [p-p] each / 750 (SYNC) 4V [p-p] / 75 ohms or 0.3V [p-p] 1750 selectable, D-SUB 9-pin Connector x 1
Required Illumination	- 2000 lx at F8.0 3200K
Minimum Illumination	- 9 Iux (0.9 foot candle) at F2.2 with +18db gain, 30 IRE level
Signal-to-Noise Ratio	- 62dB (Typical, Luminance) without aperture and gamma
Horizontal Resolution	- 750 lines at center (Y signal)
White Balance	- ATW (Automatic Tracing White Balance Control), AWO (Automatic White Balance Control) and Manual
Black Balance	- ABC (Automatic Black Balance Control) and Manual
Color Bar	- SMPTE color bar with 7.5% set-up
Electronic Shutter	- ELC (Electrical Light Control) and Manual STEP: Selectable 1/60 (OFF), 11100, 1/250,1/500, 1/1000, 1/2000, 1/4000, and 1/10,000 sec SYNCHRO SCAN: Selectable from 1/525 to 254/525 line
Gain Selection	- AGC, Manual Gain (0, +9, +18db Selectable)
Switches	- Power On/Off (POWER), Camera/Color Bar Selection

	(CAM/BAR), Gain UP Selection (OFF/LOW/HIGH (0/+9/+18dB), White Balance Selection (ATW/AWC/MANU), ELC (Electronic Light Control) On/Off, PAGE, ITEM (AWC) <(ABC) and> Scene 1/2
Controls	- R Gain, B Gain and ELC LEVEL
Computer Interface	- RS-232C Control, D-SUB 9-pin Connector x 1
Lens Mount	- C Mount
Power Source	- 12V DC
Power Consumption	- 8.4 W
Ambient Operating Temperature	- 32F - 113F (0C - 45C)
Ambient Operating Humidity	- 30%-90%
Dimensions	

	Ht	Width	Depth	Weight
▪ **Camera Head (Excluding Mounting Adapter)**	1 11/16 in (44mm)	1 5/16 in (34 mm)	2.0 in (52 mm)	0.24 lbs (110 g)
▪ **CCU (Excluding rubber foot & conn.)**	1 11/16 in (44mm)	8 1/8 in (206.5 mm)	9.50 in (250 mm)	3.74 lbs (1.7 kg)

C. PELCO CAMERA LENS

- 1/2-inch Format Varifocal Lens model 12VA6-13 from Pelco,



Model	- 12VA6-13
Type	- Varifocal
Format Size	- ½ inch
Mount Type	- C
Focal Length	- 6-13mm
Zoom ratio	- 2.2X
Relative Aperture	- 1.8~ close
Operation	-
▪ Iris	- Manual
▪ Focus	- Manual
▪ Zoom	- Manual

Min Object Distance	- 0.3 m
Back Focal Length	- 8.7 mm
Filter size	- N/A
Weight	- 0.20 lb
O/W	- 1.65 in (4.19 cm)
L	- 191 in (4.85 cm)

D. INTERSENSE INERTIACUBE2

- From InterSense, USA

Degrees of Freedom	- 3 (Yaw, Pitch, Roll)
Angular Range	- Full 360^0 , All Axis
Maximum Angular Rate	- 120^0 per second
Minimum Angular Rate	- 3^0 per second
Static Accuracy	- 1^0 RMS
Dynamic Accuracy	- 3^0 RMS
Update Rate	- 180 Hz
Latency	- 8 milliseconds
Angular Resolution	- 0.05^0
O/S Compatibility	- Windows 98/2000/NT
Interface	- RS-232 Serial
Power	- 6 VDC via AC to DC adapter
Dimensions	Ht: 1.2 in; Width: 1.06 in; Depth: 1.34 in; Weight: 0.98 lbs

E. EXTRON VSC 200D VIDEO SCAN CONVERTER

- From Extron Electronics (VGA to D1)

Video Input	
• **Number / Signal Type**	- 1 VGA, 1 Mac RGBHV, RGBS, and RGsB
• **Connectors**	- VGA 1 15-pin HD female + adapter cable - Mac 1 15-pin D female
• **Nominal Level(s)**	- Analog 0.7V p-p
• **Minimum / Maximum Level(s)**	- Analog 0V to 1.5V p-p with no offset
• **Impedance**	- 75 ohms or High Z (switchable)
• **Horizontal Frequency**	- Autoscan 24 kHz to 811 kHz
• **Vertical Frequency**	- Autoscan 50 Hz to 120 Hz

• **Resolution Range**	-	Autoscan 560 x 384 to 1280 x 1024
• **External Sync (Genlock)**	-	0.3V to 1.0V p-p
Video Processing		
• **Encoder**	-	10 bit digital
• **Digital Sampling**	-	24 bit, 8 bits per color; 80 MHz
• **Colors**	-	16.8 million
• **Horizontal Filtering**	-	4 levels
• **Vertical Filtering**	-	5 levels
• **Encoder Filtering**	-	3 levels
Video Output		
• **Number / Type / Format**	-	1 RGBHV / RGBS / RGsB or component video or - 1 digital component video (CCIR 6011 / ITU-R BT.601)(VSC 200D only), or 1 S-video, or - 1 NTSC / PAL composite video
• **Connectors**	-	5 BNC female - 1 RGBHV / RGBS / RGsB or component video - 1 BNC female - 1 digital component video --VSC 200D only - 1 4-pin mini-DIN female - S-video - 1 BNC female - composite video
• **Nominal Level**	-	RGBHV / RGBS / RGsB 0.7V p-p - S-video and composite 1.0V p-p
Impedance	-	75 ohms
Sync		
• **Input Type**	-	Auto detect RGBHV, RGBS, and RGsB
• **Output Type**	-	RGBHV, RGBS, and RGsB (all RGB formats are swith selectable)
• **Genlock Connectors**	-	1 BNC female genlock input - 1 BNC female genlock output (terminate w /75 ohms if unused)
• **Standards**	-	NTSC 3.58 and PAL
• **Input Level**	-	1.5V to 5.0V p-p
• **Output Level**	-	5V p-p
• **Input Impedance**	-	75 ohms
• **Output Impedance**	-	75 ohms
• **Polarity**	-	Negative

F. ROSS ADC-8033 SIGNAL CONVERTER

- From Ross (Analog to SDI).

Input		
• **Sampling Rate**	-	27MHz Y 13.5MHz Cr/Cb
• **Quantization**	-	10 bits
• **Input Standards**	-	SMPTE / EBU, MII, Betacam component or RGB at 525 or 625 lines rates
• **5 BNCs**	-	Ext. Sync, Loop Through G/Y, B/B-Y, R/R-Y
Component Analog Input		
• **Connector**	-	BNC per IEC 169-8
• **Impedance**	-	75 ohms unbalanced
• **Signal Level**	-	1 V
• **Adjustable Gain**	-	±10%
• **Time Adjustment Range**	-	±1.8μs
• **Return Loss**	-	>40dB to 5.5 MHz
Filtering As Per CCIR 601 Specifications		
• **Frequency Response**	-	Y channel ±0.1 dB to 5.5 MHz
	-	Cr, Cb Channels ±0.2 dB to 2.75 MHz
• **Signal to Noise Ratio on all Channels**	-	>64 dB RMS, relative to 0.714 V, 10 kHz to 5.5 MHz
• **Interchannel Crosstalk**	-	<-50dB
• **2T K factor**	-	<0.5%
• **Luminance Non-linearity**	-	<1%
• **Gain Alignment**	-	<1%, typically better than 0.5%
• **DC Clamping**	-	Typically within 1 quantization level on field average.
Output		
• **Output Standard**	-	4:2:2, two BNCs as per SMPTE 259
• **Input to Output Delay**	-	3.6μs

G. ULTIMATTE 400-DELUXE COMPOSITE VIDEO MIXER

- From Ultimatte Corporation.

Specifications	- Internal Foreground and Matte processing 4:4:4:4
	- Conforms to CCIR 601 - 10-bit or 8-bit SDI inputs and outputs - 525 / 625 Auto-selectable
Video	
• **I/O Resolution**	- 4:2:2
• **FG Input**	- 4:2:2
• **BG Input**	- 4:2:2
• **Matte In**	- 4:0:0
• **Digital Reference**	- 4:2:2
• **FG and BG Out**	- 4:2:2
• **Internal FG Processing and Matte Generation**	- 4:4:4:4
• **Inputs**	- Serial CCIR 601, BNC 75
• **Outputs**	- Serial CCIR 601, BNC 75

H. KRAMER 1:2 VIDEO DISTRIBUTER (SPLITTER)

- From Kramer Electronics, USA.

Specifications				
• Model	- VP-200			
• Video Bandwidth	- Exceeding 345 MHz			
• K-Factor	- <0.05%			
• Differential Gain	- 0.06%			
• Differential Phase	- 0.13 Deg			
• Coupling	- AC			
Dimensions	Ht 0.98 in (2.5 cm)	Width 2.95 in (7.5 cm)	Depth 4.7 in (12.0)	Weight lbs

I. ULTIMATTE 400 SMART REMOTE

- From Ultimatte Corporation.

Specifications	- RS232 and RS422 computer interface - Control up to 4 boards of Ultimatte 400 and/or Ultimatte 9 simultaneously - Internal Foreground and Matte processing - High contrast 640x480 VGA display - PC keyboard and mouse interface - User configurable menus - Quick save and recall
Dimensions	Ht 7.0 in; Width 17.0 in; Depth 1.75in; Weight lbs

J. LEITCH SDC-100 CONVERTER

- Serial Digital to VGA Monitoring Converter from Leitch (D1 to VGA)

Serial Digital Input	- BNC 75 ohm; 270Mb/s; 259M-C - Up to 100m automatic cable equalization
Input Return Loss	- 13.9 dB at 270 MHz
VGA Monitor Output	- Sub-D 15-pin female connector
RGB	- ±3 dB 0.7V, H+V TTL
Frequency Response	
• **Luminance**	- ±0.5 dB from DC to 5.25 MHz - ±3 dB up to 10 MHz
• **Chrominance**	- ±3 dB up to 4 MHz
• **Gamma Correction**	- Automatic
• **Standards**	- 525-line and 625-line auto switching
• **Signal-to-Noise**	- -64 dB
625 line / 50 Hz mode with line doubling	
• **Horizontal Frequency**	- 31.25 kHz
• **Vertical Frequency**	- 50 Hz
525 line / 60 Hz mode with line doubling	
• **Horizontal Frequency**	- 31.469 kHz
• **Vertical Frequency**	- 59.94 Hz

K. STEALTH SR-4500 RACK MOUNT CPU

Manufacturer / Model	-	Dell / Dimension 8100
CPU	- -	Intel® Pentium® 4 1300 MHz
Memory	-	128 MB RAM
Operating System	- - -	Microsoft Windows 2000 5.00.2195 Service Pack 2
Monitor	- -	Set to 640 x 480 for HMD compatibility 60 Hz
Power	-	Industry Standard for U.S. desktop computers
Dimensions		Ht: 7 in; Width: 19 in; Depth: 18 in; Weight: 35 lbs

Ht	Width	Depth	Weight
7 in	19 in	18 in	35 lbs

L. STEALTH VR100 RACK MOUNT LCD/KEYBOARD/MOUSE

Manufacturer / Model	-	Dell / FR-1000-15-KVM
Construction & Design	-	19” Rackmount steel chassis 1 U , 1.75” or 44.5mm high
Type	-	TFT Active Matrix Liquid Crystal
Screen Size	-	15.0"
Resolutions Supported	-	Auto Sync. from 640 x 480 to 1024 x 768
Native Mode	-	1024 x 768
Colors	-	Analog Input: 16.7 million
Contrast Ratio	-	300:1
Viewing Angle (typical)	-	+/- 80° in All Directions
Brightness	-	230 cd/m² White Luminance
INPUTS	-	ANALOG: 0.7 Vp-p/75 Ohms
INPUT (VAC/VDC)	-	90~220VAC Adapter 12VDC Input @5A
Keyboard	-	105 KEY
Mouse Touch Pad	-	2 Button Glide Point
Security	-	Built-in lock with 2 keys
Controls On-Screen Display	-	Built-in Controls for Brightness, Size, Contrast, H-V Position, Frequency, etc.
Dimensions		

Ht	Width	Depth	Weight
1.75 in (482.6 mm)	19 in (44.5 mm)	26.6 in (600 mm)	37 lbs (17.0 kg)

M. TRIPP LITE RACK-MOUNTED UPS

Manufacturer / Model	-	Tripp Lite / **SMART450RT**
Rack Units	-	**1 U (unit)**
Output Power Rating	-	450 VA / 270 watts
Voltage Capacity	-	120 volts/60Hz
Number of outlets	-	4 UPS - 1 Surge
Output Voltage Regulation	-	LINE MODE: Sine wave line voltage 120V (-12% +6%) - BATTERY MODE: PWM Sine wave output within 5% of 120V AC
Output Frequency Regulation	-	LINE MODE: Passes line frequency of 60Hz +/-10% - BATTERY MODE: Inverter output regulated to 60Hz +/-0.5Hz
Output Quantity/Type	-	5 NEMA 5-15R output receptacles ▪ 4 with UPS and surge suppression ▪ 1 with surge suppression only
Overload Protection	-	Resettable input circuit breaker
Battery Full Load Time	-	4 minutes (450VA)
Battery Half Load Time	-	14 minutes (225VA)
Battery Recharge Rate	-	2-4 hours (at 90%)
Dimensions		

Ht	Width	Depth	Weight
1.75 in (44.5 mm)	17.0 in (43.2 mm)	11.0 in (27.9 mm)	15.5 lbs (7.0 kg)

N. LEVITON RACK-MOUNTED SURGE PROTECTOR

Manufacturer / Model	-	Leviton / **5500 Series**
Rated Line Voltage (VRMS)	-	**120 Volts**
Load Current	-	20 Amps
Maximum Continuous Operating Voltage	-	135 Volts
Operating Frequency Range	-	50, 60 Hz
Circuit Type	-	Staged Multi-component
Outlets	-	10 Rear - 2 front
Dimensions		

Ht	Width	Depth	Weight
1.71 in (43.43mm)	19.0 in (482.6mm)	4.55 in (115.57 mm)	15.5 lbs (7.0 kg)

O. THERMODYNE QUADRAFLEXÔ EQUIPMENT CART

- **Manufacturer / Model**	- Thermodyne
- **Rack Units**	- **14**
- **Custom Frame Depth**	- 24 inches
- **Color**	- Olive drab Green
- **Unit Includes**	- Heavy Duty Hardware - Anodized Rack Frame - Footman Loops - Sliding Shelf - Stainless Hardware - Heavy Duty Removable casters
- **Power**	- Industry Standard for U.S. desktop computers

Dimensions	Ht in	Width in	Depth in	Weight Empty Lbs Weight Operational Lbs

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APPENDIX D. USER'S MANUAL

VIRTUAL ENVIRONMENT HELICOPTER SYSTEM (VEHELO)

SET-UP GUIDE AND PROCEDURES

I. SET-UP INSTRUCTIONS

1. Place the ChromaFlex sheet, gray side in, over the cockpit windscreen utilizing three to four elastic hooks that are in the shipping case. Using the edges of panels to attach the hooks, ensure that the material covers the windscreen and side windows on the side of the cockpit being utilized.

2. Set-up the 'instrument console' CRT on the center console of the cockpit. Be careful not to move the ECLs or manipulate any switches, rheostats, or circuit breakers in the cockpit. The aircraft should not have any power applied during simulation.

3. Position the ChrAVE 3.0 System cases behind the radio closet which is directly behind the copilot's (left) seat. If utilizing the pilot's (right) side position, then place the system behind the control closet.

4. Run power from hangar outlets to the power strip inside the aircraft.

5. Ensure all components are connected IAW Figure 29 and Table 1.

6. Connect external power to the equipment box and power strips.

7. Connect the PFPS laptop using the provided peripheral cable. Power the laptop on.

8. Start-up the system as per the steps in Section II of this Appendix.

HARDWARE DEVICE	CONNECTIONS
CPU	▪ In – from Head Tracker ▪ In – from Keyboard to Laptop Interface ▪ In – from Mouse to Laptop Interface ▪ Out – to Video conn Instrument CRT
Ultimatte 400 Mixer	▪ In - to Extron VSC 200 Converter ▪ In - to Ultimatte Smart Remote ▪ In - from ADC 6801 Mix Box ▪ Out – to SDC "A"
Ultimatte 400 Smart Remote	▪ Out – to Ultimatte 400 Mixer
VP 200 Video Splitter	▪ In - from CPU ▪ Out – to Extron VSC 200 Converter ▪ Out – to Laptop Interface
SDC 100 "A"	▪ In – from Ultimatte 400 Mixer ▪ Out – to HMD Box
SDC 100 "B"	Not Required for VEHELO
ADC 601 Mix Box	▪ In – Camera Control Unit (CCU) ▪ Out - Ultimatte 400 Mixer
Extron VSC 200 Converter	▪ In – from Camera Control Unit (CCU) ▪ In – from VP 200 Video Splitter ▪ Out – to Ultimatte 400 Mixer
HMD Box	▪ In - from SDC 100 "A" ▪ Out – to Laptop Interface Panel ▪ Out – to HMD
Camera Control Unit	▪ In - from Camera ▪ Out – to Extron VSC 200 Converter ▪ Out – to ADC 6801 Mix Box
Camera	▪ Out – to Camera Control Unit (CCU)
HMD	▪ In – from HMB Box
Head Tracker	▪ Out – to CPU
Instrument Panel CRT	▪ In – from CPU
Laptop Interface Panel	▪ In – VP 200 Video Splitter ▪ In – SDC 100 "B" – N/A ▪ In – HMD Box ▪ Out – CPU Keyboard connection ▪ Out – CPU Mouse connection
Uninterruptible Power Supply (UPS)	▪ Power Cords from equipment
Network Hub	▪ In – from CPU LAN connection
Power Strip	▪ To external power source

Table 5. VEHELO Connections

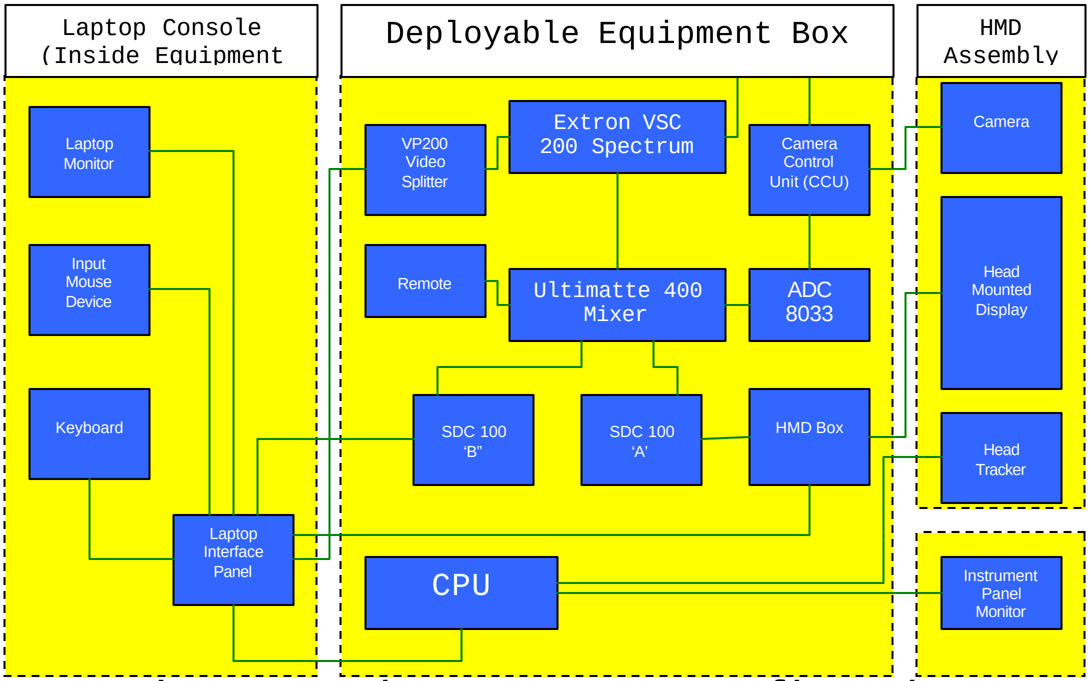

Figure 36. ChrAVE 3.0 Set-up Configuration

II. START-UP PROCEDURES

1. Turn the two (2) TripLite UPSs on. One is in the upper case, one in the lower. Ensure it is operating on AC power and not battery power.

2. Turn on Ultimatte 400.

3. Turn on CPU <u>after</u> step #2.

4. Turn the HMD Control Box on if it is not already powered up.

5. Turn on the LiteRing Assembly and adjust the rheostat as necessary. Setting 5 or 6 works best in the cockpit environment.

6. After CPU boots, log on with –

   Username: chrave
   Password: chrave

7. Start the desired ChrAVE 3.0 program via the veChrave (debug) shortcut on desktop.

    NOTE: Database for each specific application is assigned in software directory files.

8. Adjust rack mounted laptop monitor to display ‘flying view’ and the instrument CRT to reflect just the instruments. This is accomplished via the set-up menus for the system in the Microsoft Windows environment.

    NOTE: The system is configured to utilize two monitors simultaneously in the Microsoft Windows environment.

9. Test the system by checking that the HMD tracks with head movements. Also ensure that instrument displayed on panel reflect valid movements coinciding with the flight program.

10. Select FalconView on the PFPS laptop and, once loaded, open appropriate route, and finally, select GPS tool. If unable to get route loaded, utilize help tool.

III. EXPERIMENTAL INSTRUCTIONAL SESSION

The following steps are generalized procedure that could be used by a proctor/Instructor Pilot (IP). They would use these steps during a period of instruction for the completion of an initial navigation flight while using the ChrAVE 3.0. It is suggested that an IP from the local command instruct the simulator flights so that a maximum learning curved can be achieved.

They would have to be altered to fulfill the training requirements set forth in the Training and Readiness manual (T&R). The steps would also be altered to reflect local SOPs so that the student would not receive any negative training in standard operating procedures.

1. Utilize the enroute portion of the first leg to familiarize the PUI with the system. The PUI will quickly learn the ability of the system to depict

terrain and gain an appreciation almost immediately.

2. The proctor/IP will simulate calls from the PAC, Crew Chief (CC) and Aerial Observer (AO). The two-way communication dedicated to the mission is the primary method to teach CRM to the PUI.

3. The IP will also point out to the PUI distinct terrain feature so that he may garner an appreciation of scale and speed of the helicopter towards or away from them.

4. The IP vary parameters such as airspeed and altitude to ensure the PUI is maintaining a good scan under the HMD onto the instrument panel.

5. The Proctor or IP will manipulate the flight and the flight parameters via keystroke entry on the laptop keyboard. The commands are listed in Table 2.

   NOTE: Advanced commands are not required to complete a training session. They are intended more as system design and evaluation tools.

Keystroke	Command
- or +	Increase or Decrease Velocity
P	Pause or End Pause
⇧ ⇩	Climb = 500 fpm(VSI) Nulls to zero
⇦ ⇨	Once = ½ SRT Twice = SRT
Spacebar	Rollout
F	Minimize Screen
T	Remove Terrain Color
Shift T	Change direction of flight to 12 o’clock
Esc	Exit

* All turns are SRT or 90^0 of turn in 30 seconds.

Table 6. ChrAVE 3.0 Program Keyboard Instructions

APPENDIX E. PREFLIGHT QUESTIONNAIRE

Please read first: The following preflight questionnaire is completely confidential. Nothing you do or answer will be related to you in any manner. Please take a few minutes to complete this questionnaire prior to flying the VEHELO experimental trainer. This questionnaire is organized into three sections – Section A, Background Information; Section B, Navigational Skill/Knowledge; Section C, Comments.
Remember there is no time limit. Hand the completed questionnaire to the Instructor when you are done.

Subject Number _____________ (Instructor use only) Date (Sim flight): ____________

A. Background Information:

1) How many Flight Hours do you have in the past 12 months? ________Hrs

2) How many Total Flight Hours do you have? (approximately) ________ Hrs

3) Are you prone to simulator sickness? Yes/No

4) Do you require corrective lenses? Yes/No

5) If so, what is your uncorrected vision? ____/____

6) Do you have any other history of eye disease, surgery or injury? Yes/No

7) Have you ever used a virtual environment for training? Yes/No

8) If you answered yes to #7, where did you use the device? ___________________

9) Have you ever used a virtual environment for entertainment? Yes/No

10) If yes, did you use a head mounted display? Yes/No

11) As a designated aviator, how would you rate your low level navigational skills? (check one)
? Novice ? Average ? Advanced ? Instructor Level ? Expert

12) List all type, model, series aircraft you are or have been qualified to fly. (Disregard Flight School unless you were an instructor)
____
____
____

13) When was the last Navigation class you attended? ________________________

Page 1 of 3

Figure 37. Pre-Flight Questionnaire (page 1)

14) When was your last low level helicopter navigation map preparation? _________

15) What do you consider to be the more important? (check one)
? Timing along the route ? Distance from intended flight path

16) Are you familiar with the route you will be flying in today? Yes/No

17) If so, have you ever flown this route before? Yes/No

B. Navigational Skill/Knowledge:
The following questions ask your opinion of acceptable criteria for non-tactical low-level helicopter navigation based upon your current skill level. You may refer to your map at any time.

18) Number the following in order of importance (1-highest, 8- lowest):

_____ Maintaining the route of flight
_____ Accurately knowing your present location
_____ Accurately flying over your checkpoints
_____ Knowing your location by reference to a terrain feature
_____ Identifying (seeing) the checkpoint by not flying over it
_____ Being off the intended route of flight but correcting towards it
_____ Being off the intended route of flight and correcting by intercepting the follow-on checkpoint
_____ Voice communications between aircrew

19) The acceptable threshold between acceptable and substandard navigational performance is ______ meters of the intended route of flight.
? 200 ? 300 ? 400 ? 500 ? 600 ? 700 ? 800 ? 900 ? 1000

20) The acceptable threshold between acceptable and substandard navigational performance is ______ meters of the checkpoints.
? 200 ? 300 ? 400 ? 500 ? 600 ? 700 ? 800 ? 900 ? 1000

21) Do you have at this time any unanswered questions concerning low-level helicopter navigation? Yes/No

- If so address them to the Instructor

22) Do you have at this time any unanswered questions concerning the use of the VEHELO experimental trainer? Yes/No

- If so address them to the Instructor

Page 2 of 3

Figure 38. Pre-Flight Questionnaire (page 2)

C**. Comments**

Please use this section for any additional comments or suggestions you may have regarding your training and preparation for your experience with the VEHELO experimental trainer.

Thank you for your time and attention to this questionnaire. The information gathered from these questionnaires will be used to further develop and refine the VEHELO experimental trainer. Please ensure your Instructor collects them.

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Figure 39. Pre-Flight Questionnaire (page 3)

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APPENDIX F. CH-46E NATOPS BRIEFING GUIDE

Briefing Guide – Areas shown that are applicable for NAV 130/131 and VEHELO flights.

A. Administrative Information

1. Time hack
2. Local area weather forecast
   (a) Sunrise/sunset
   (b) Moonrise/moonset
   (c) Moon angle/ illumination.
3. En route weather forecast
4. Destination weather forecast
5. Helicopter assignment
6. Maps/charts/smart packs
7. Flight leader/alternate
9. Call signs.

B. Mission Information

1. Primary
2. Secondary/implied
3. Sequence of events.

C. Conduct of Flight

1. Times: man/APU/RJO/spin/ taxi/takeoff
2. Controlling agencies
3. Frequencies
4. Radio procedures (PAC/PNAC)
5. IFF procedures and codes (PAC/PNAC)
6. Formation instructions
7. Routes/checkpoint ID (PAC/PNAC/CC)
8. Operating and landing areas
   (a) Size and obstacles
   (b) Landing direction
   (c) Waveoffs (PAC/PNAC)
   (d) Alternates
   (e) Landing site lighting.
9. Fuel required (mission/minimum)

F. Special Considerations

1. Bump plan
2. Go/no go
3. Minimum operational weather
4. En route hazards
5. NVG considerations
6. Aircraft lighting (PAC/PNAC)
7. Loss of visual contact with flight
8. Friendly fire plans
9. Rules of engagement for onboard defensive weapons (PAC/PNAC/CC)
10. TRAP/SAR procedures
11. Debrief time and place.

G. Crew Coordination

1. Use of checklists (PAC/PNAC)
2. Control changes
3. Navigation procedures
4. Lookout doctrine (PILOTS/CC)
5. Copilot (pilot not at the controls) duties
   (a) Takeoff (PAC/PNAC)
   (b) En route (PAC/PNAC)
   (c) Approach/landing

10. Fuel availability.

D. Flight Planning and Operational Data

1. Navigational aids available and utilization
2. Load computation card
3. Mission essential equipment
   (a) Personal
   (b) Aircraft
   (c) Passengers.

E. Emergency Procedures

1. Aborts (PAC/PNAC/CC)
2. Downed aircraft (controlled/ uncontrolled) (PAC/PNAC/CC)
3. Loss of communications (PAC/PNAC/CC)
4. Inadvertent IMC procedures (PAC/PNAC)
5. Aircraft emergencies (actual/simulated)(PAC/ PNAC/CC)
6. Aircraft system failure (actual/simulated)(PAC/PNAC/CC) (PAC/ PNAC)

H. Training Information

1. T&R requirements
   (a) Discussion items
   (b) Demonstrate
   (c) Introduce
   (d) Review.

n. Crew coordination

(1) Pilot at the controls — terrain obstacles, clearance, radio calls, emergencies

(2) Pilot not at the controls — navigation barriers, monitor performance instruments, gauges, normal duties, emergencies

(3) Aircrew — lookout, navigation, obstacles clearance, emergencies.

APPENDIX G. POST FLIGHT QUESTIONNAIRE

<u>Please read first</u>: The following post flight questionnaire is completely confidential. Nothing you do or answer will be related to you in any manner. Please take a few minutes to complete this questionnaire, which is organized into two sections – Section A, Evaluation of System and Section B, Comments. Remember there is no time limit. Hand the completed questionnaire to the Instructor when you are done.

Subject Number _____________ (Instructor use only) Date (Flight in AC): __________

A. Evaluation of System:

1) Navigating in the VEHELO resembled the actual task in the aircraft?
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

2) Voice commands used in the VEHELO resembled those actual voice commands used in the aircraft?
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

3) The VEHELO performs as well as visual simulators you have used in the past with regard to flight navigation.
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

4) The VEHELO is more valuable as a flight preparation tool than desktop simulators that you have used in regards to flight navigation.
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

5) The VEHELO require you to use cockpit management skills similar to management skills required in the aircraft.
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

6) You would use the VEHELO simulator if it were made available in the Squadron's spaces.
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

7) Viewing of your map through the Head Mounted Display (HMD) was acceptable.
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

8) Viewing of your kneeboard through the Head Mounted Display (HMD) was acceptable.
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

Page 1 of 3

Figure 40. Post-Flight Questionnaire (page 1)

9) Viewing of the instrument panel through the Head Mounted Display (HMD) was acceptable.
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

10) The terrain depicted in the VEHELO appeared realistic in size and dimension.
Yes/No

11) Encountered no problem distinguishing the required level of ground detail for successful route navigation. Yes/No

12) The VEHELO made you feel queasy or nauseous. Yes/No

13) The VEHELO was disorienting because it is a motionless platform. Yes/No

15) The VEHELO currently provides a 60-degree field-of-view (FOV). Would it be more beneficial if a wider FOV was provided by the system? Yes/No

16) If a wider FOV were available by the system would it induce less discomfort or nausea?
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

17) The weight or complexity of the headgear was a factor in any discomfort that resulted from using the system?
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly agree

18) In your opinion, the VEHELO simulator system may help reduce pilot workload during the actual flight after having flown the route in the simulator.
? Strongly disagree ? Disagree ? Neutral ? Agree ? Strongly Agree

Page 2 of 3

Figure 41. Post-Flight Questionnaire (page 2)

B. Comments

Please use this section for any additional comments or suggestions you may have regarding your experience with the VEHELO simulator system. Please include any comments on a specific question and include the question number.

Thank you for your time and attention to this questionnaire. The information gathered from these questionnaires will be used to further develop and refine the VEHELO experimental trainer. Please ensure your Instructor collects them.

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Figure 42. Post-Flight Questionnaire (page 3)

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APPENDIX H. CHRAVE 3.0 EXPERIMENT PLANNED AND FLOWN ROUTE EXAMPLES

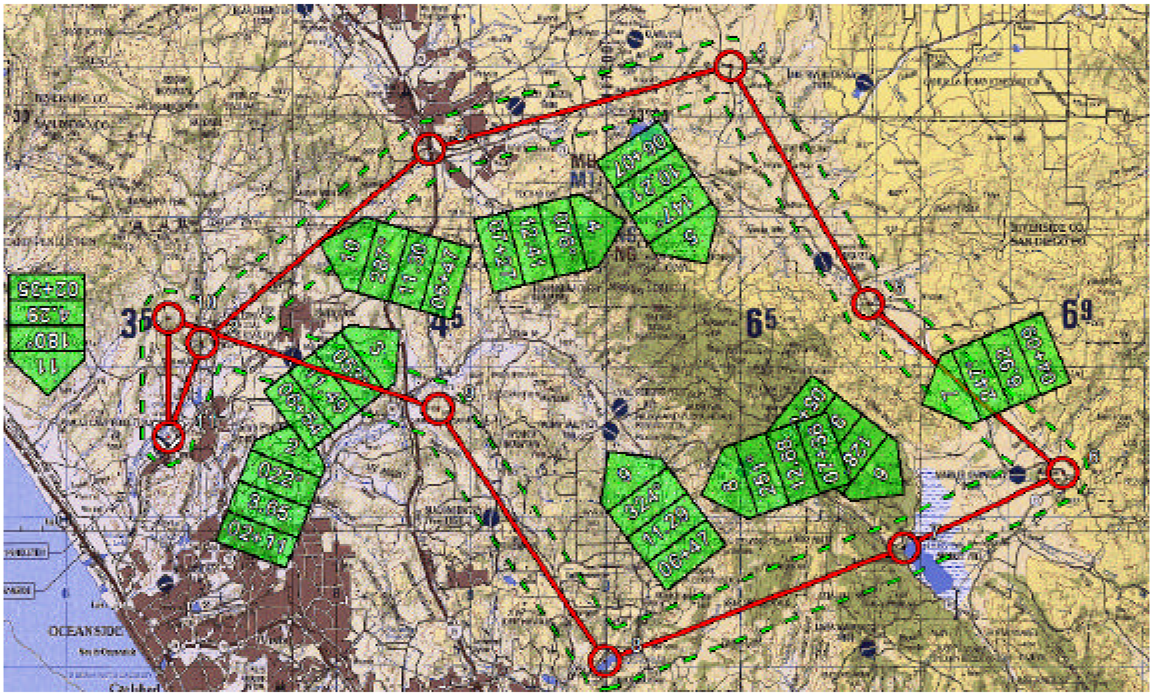


Figure 43. Planned Route for ChrAVE 3.0 Experimentation

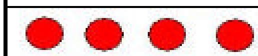
	Proposed route of flight to be flown in ChrAVE 3.0 and aircraft.
	Route of flight flown by student pilot in aircraft.

Table 7. FalconView Data Legend

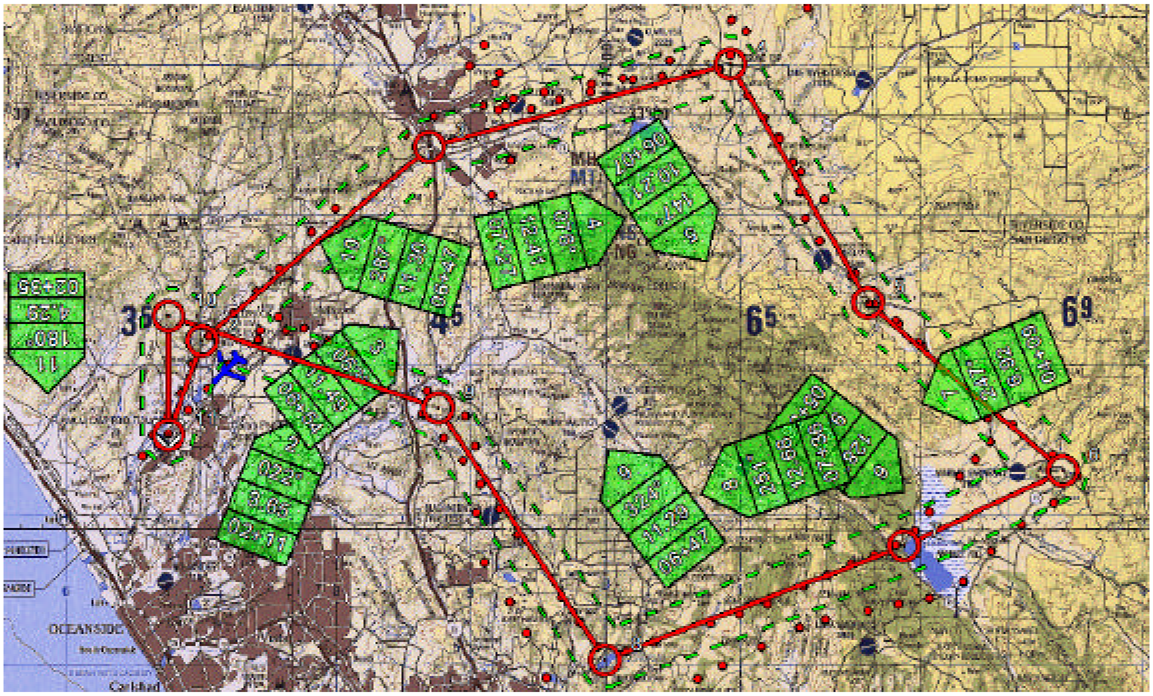


Figure 44. Example of GPS Track Data Collection for PUI

	Proposed route of flight to be flown in ChrAVE 3.0 and aircraft.
	Route of flight flown by student pilot in aircraft.

Table 8. FalconView Data Legend

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