



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

**EXPLORING THE FEASIBILITY OF THE VIRTUAL
ENVIRONMENT HELICOPTER SYSTEM (VEHELO) FOR USE AS
AN INSTRUCTIONAL TOOL FOR MILITARY HELICOPTER
PILOTS**

by

W.W. Kulakowski

September 2004

Thesis Advisor:

Rudolph Darken

Thesis Co-advisor:

Joseph A. Sullivan

This thesis done in cooperation with the MOVES Institute.

Approved for public release; distribution is unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.				
1. AGENCY USE ONLY(Leave blank)		2. REPORT DATE September 2004		3. REPORT TYPE AND DATES COVERED Master's Thesis
4. TITLE AND SUBTITLE Exploring the Feasibility of the Virtual Environment Helicopter System (VEHELO) for Use as an Instructional Tool for Military Helicopter Pilots			5. FUNDING NUMBERS	
6. AUTHOR Kulakowski, Walter W				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the U.S. Department of Defense or the U.S. Government.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (maximum 200 words) The requirement for low-level navigation flight conducted between 200 and 500 feet above ground level is something unique to the military helicopter pilot. Each novice helicopter pilot is introduced to this skill early and in a limited number of flights or flight hours. A low situational awareness (SA) is historically noted among the novice pilots during their first few flights within this flight regime. To that end, this thesis continues with the work conducted earlier to develop a trainer that places the pilot in an immersive and familiar cockpit environment for training through the use of chromakeyed technology as employed in the Virtual Environment Helicopter System (VEHELO). The pilot will then be able to learn and exercise required piloting tasks and multi-place aircraft communications as authentically and as meticulously as in actual flight. The focus of this thesis is to continue validation of the ChrAVE/VEHELO system. This will be accomplished by comparison of data obtained from data collected by pilots flying the ChrAVE and flying the actual aircraft during initial navigational training flights. Additionally this thesis will attempt to show that the latest version of the system has a previously unrecognized ability to improve pilot performance. The system is capable of teaching novice pilots the important skill of Crew Resource Management (CRM) and the appropriate communication skills. The original Chromakey Augmented Virtual Environment (ChrAVE) helicopter flight simulation system was developed to substantiate the feasibility of having embedded trainers for helicopters. Both the ChrAVE and VEHELO are comprised of commercial off the shelf (COTS) equipment in a mobile wheeled box. To determine the effectiveness of the ChrAVE as an instructional tool, the opinions of pilots and pilot instructors will be collected for analysis. The subject pilots will be tasked with numerous realistic piloting tasks. Empirical data will be collected and evaluated according to the low-level navigation performance thresholds set forth by Marine Medium Helicopter Training Squadron 164 (HMMT-164) which is the CH-46E Model Manager.				
14. SUBJECT TERMS chromakey, chromamat, Fleet Replacement Squadron (FRS), helicopter, human-computer interface, mission rehearsal, navigation, route rehearsal, spatial orientation, Litering, Refresher Aircrew Training (RAC), terrain association, virtual environments, VEHELO,			15. NUMBER OF PAGES 159	
17. SECURITY CLASSIFICATION OF REPORT Unclassified			16. PRICE CODE	
18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified		19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified		20. LIMITATION OF ABSTRACT UL

THIS PAGE INTENTIONALLY LEFT BLANK

**Approved for public release; distribution is unlimited.
This thesis was done in cooperation with the MOVES
Institute.**

**EXPLORING THE FEASIBILITY OF THE VIRTUAL ENVIRONMENT
HELICOPTER SYSTEM (VEHELO) FOR USE AS AN INSTRUCTIONAL TOOL
FOR MILITARY HELICOPTER PILOTS**

Walter W. Kulakowski
Major, United States Marine Corps
B.S., University of Florida, 1992

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN COMPUTER SCIENCE

from the

**NAVAL POSTGRADUATE SCHOOL
September 2004**

Author: Walter W. Kulakowski

Approved by: Rudolph Darken
Thesis Advisor

Joseph A. Sullivan
Thesis Co-advisor

Peter Denning
Chairman, Department of Computer Science

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The Chromakeyed Augmented Virtual Environment (ChrAVE) system was initially developed to validate the feasibility of using embedded trainers for helicopter simulation.

The ChrAVE Helicopter Simulation System was an initial attempt to produce an effective tool to suit a common yet important need. That need was the lack of an available simulator. That need becomes critical while military helicopter pilot is deployed away from the continental United States (CONUS) in support of worldwide operations. There has always been a deficiency in maintaining the level of pilot proficiency while away from CONUS. While deployed aboard ship or overseas the only available training platform available is the actual aircraft. The aircraft is an expensive option but provides the only means by which deployed pilots can maintain an acceptable level of proficiency and readiness. This thesis continues with the development of the ChrAVE implementation of the VEHELO and achieves a more useful and updated configuration of the system. This thesis also validates the possible capability of the modified system to support instructional level of training versus the proficiency level addressed in earlier work

The original ChrAVE system has been modified for the purpose of it being used as an instructional device. In this newer configuration the system can address a known training weakness involving the training of new pilots or Replacement Aircrew (RAC) at the Fleet Replacement Squadron (FRS). The new pilots lack the level situational awareness (SA) required during the initial low level navigation

flights. The VEHELO can be used to increase the new pilot's SA prior to that first flight in the aircraft. This will in turn provide an opportunity for increased pilot performance during the flights in the aircraft. And that in turn could manifest itself in the form of increased pilot performance and a savings of flight time, aircraft maintenance time and flight hour costs.

In addition to the required SA there are a number of other discrete new skills the novice pilot must learn. The two most important are terrain appreciation at low level flight and inter-crew communications and Crew Resource Management (CRM). The unique communications arise from the novice pilot flying a multi-crewed position aircraft for the first time. Currently there is not a system to facilitate this type of training. The VEHELO would provide a means for the novice pilot to learn and practice these required skills prior to the first flight in the aircraft. The net result would be that the novice pilot would enter the aircraft with a higher level of SA thus allowing the instructor to maximize the effectiveness of the limited flight time allowed for each training flight.

Irregardless of the format in which the VEHELO is used, instructional or proficiency, it will place the pilot in an immersed and familiar environment. While the pilot is immersed in this environment he will be free to exercise and practice a large number of tasks normally assigned to the crew position called pilot not at the controls (PNAC). The pilot under instruction (PUI) is given the ability to complete these tasks in a simulated environment that is as realistic as any he would encounter during an actual flight.

The focus of this thesis will assess the feasibility of the system being used in a configuration that supports it being used as an instructional tool for terrain appreciation and CRM. The system will be utilized to instruct RACs prior to their first low level navigation flight in the CH-46E aircraft IAW the CH-46E Training and Readiness Manual (T&R).

The current version VEHELO tested for this thesis, as well as the original ChrAVE, is comprised entirely of affordable, commercial off the shelf (COTS) equipment. The equipment is mounted in a boxed electronic equipment stack that is capable of being deployed and/or embarked aboard ship. The original configuration was modified to afford the system a higher level of mobility and usability.

The opinions of inexperienced RACs (novice pilots) and experienced Instructor Pilots (IP) were collected for analysis in this thesis. The subject pilots were tasked with numerous realistic PNAC tasks both while flying the VEHELO and the aircraft. Their performance was used to validate the feasibility of the VEHELO as an instructional. Empirical data was collected and evaluated according to the low-level navigation performance thresholds set forth by the CH-46E Standardization Manual. That publication is produced by Marine Medium Helicopter Training Squadron 164 (HMMT-164) which is the Model Manager authority.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I.	INTRODUCTION	1
A.	PROBLEM STATEMENT	1
B.	MOTIVATION	3
C.	THESIS OVERVIEW	5
D.	RESEARCH QUESTIONS	7
E.	ORGANIZATION OF THIS THESIS	8
II.	TRAINING TASKS AND VEHELO BACKGROUND	11
A.	HELICOPTER TERRAIN FLIGHT AND NAVIGATION	11
1.	Low Level Terrain Flight	14
2.	Contour Flight	15
3.	Map of the Earth Flight	16
B.	CREW RESOURCE MANAGEMENT	18
1.	Division of Duties	19
a.	<i>The Pilot at the Controls (PAC)</i>	19
b.	<i>Navigator or Pilot Not at the Controls (PNAC)</i>	21
c.	<i>Crewchief/Aerial Observer/Gunner</i>	22
2.	Communications and Situational Awareness	23
C.	VEHELO BACKGROUND	24
1.	VEHELO Development	24
III.	VEHELO SPECIFICATION, CONFIGURATION AND USE	27
A.	EXPERIMENTAL OPERATING MODES	28
B.	SYSTEM FEEDBACK	30
C.	SYSTEM HARDWARE AND SETUP	31
1.	Mock Cockpit Configuration	31
2.	Mock Cockpit Equipment	32
a.	<i>Portable Pilot Seat and Flight Controls</i>	32
b.	<i>Mock Cockpit Walls</i>	33
c.	<i>Instrument Panel</i>	34
d.	<i>Lighting</i>	35
3.	Headgear	36
a.	<i>Head Mounted Display</i>	36
b.	<i>Camera</i>	38
c.	<i>Lens</i>	39
d.	<i>Motion Tracker</i>	40
4.	Electronic Hardware and Software	41
a.	<i>Ultimatte™ 400 Mixer</i>	42
b.	<i>Extron™ VSC 200 Scan Converter</i>	44
c.	<i>Analog-to-Digital Signal Converter</i>	45
d.	<i>Leitch™ SDC-100 Signal Converter</i>	45
e.	<i>1:2 Video Distributor (Splitter)</i>	46
f.	<i>Rackmount CPU</i>	46

g.	<i>Rackmount Laptop with LCD/Keyboard/Mouse</i>	47
h.	<i>Network Ethernet Switch</i>	48
i.	<i>Equipment Cart</i>	49
j.	<i>CPU Software</i>	50
5.	Miscellaneous Hardware	50
a.	<i>Rack-Mounted UPS</i>	50
b.	<i>Rack-Mounted Surge Protector</i>	51
6.	Overall System Goals	51
D.	USER'S MANUAL	52
E.	EXPERIMENT SETUP	58
1.	Subject Pilots (PUI)	58
2.	Treatment	59
a.	<i>Entrance Questionnaire</i>	59
b.	<i>Flight Briefing</i>	59
c.	<i>Debrief</i>	61
d.	<i>Exit Questionnaire</i>	61
3.	System Artificialities	62
a.	<i>Visual Artificialities</i>	62
b.	<i>Ergonomic Artificialities</i>	63
c.	<i>Flight Profile Artificialities</i>	64
d.	<i>Task Artificialities</i>	65
F.	EXPERIMENT PROGRESSION AND RESULTS	66
1.	Preflight Questionnaire Results	66
2.	Recorded Data from VEHELO System and Aircraft	69
3.	Debrief and Comments	75
4.	Postflight Questionnaire Results	75
5.	Instructor Pilot Comments	76
IV.	MODIFICATIONS AND RECOMMENDED IMPROVEMENTS	81
A.	MODIFICATIONS COMPLETED	81
1.	Poor Communications	81
2.	Headgear Replacement	82
3.	Smart Remote Replacement	82
B.	RECOMMENDED IMPROVEMENTS AND RESEARCH	82
1.	LED Litering	82
2.	Modified Equipment Case(s)	84
3.	Equipment Selection/Modification	85
4.	Equipment Transportability	85
5.	Future Research	85
V.	CONCLUSIONS	89
	LIST OF REFERENCES	91
APPENDIX A.	CH-46E TRAINING AND READINESS MANUAL	95
APPENDIX B.	HARDWARE INVENTORY	99

APPENDIX C.	HARDWARE SPECIFICATIONS	101
A.	VRS V8 HEAD MOUNTED DISPLAY	101
B.	PANASONIC GP-US532H CAMERA	102
C.	PELCO CAMERA LENS	103
D.	INTERSENSE INERTIACUBE ²	104
E.	EXTRON VSC 200D VIDEO SCAN CONVERTER	104
F.	LEITCH ADC-6801 SIGNAL CONVERTER	106
G.	ULTIMATTE 400-DELUXE COMPOSITE VIDEO MIXER	106
H.	KRAMER 1:2 VIDEO DISTRIBUTER (SPLITTER)	107
I.	ULTIMATTE 400 SMART REMOTE	107
J.	LEITCH SDC-100 CONVERTER	108
K.	STEALTH SR-4500 RACK MOUNT CPU	108
L.	STEALTH VR100 RACK MOUNT LCD/KEYBOARD/MOUSE	109
M.	TRIPP LITE RACK-MOUNTED UPS	110
N.	LEVITON RACK-MOUNTED SURGE PROTECTOR	110
O.	THERMODYNE QUADRAFLEX™ EQUIPMENT CART.....	111
P.	NETGEAR HUB	111
APPENDIX D.	USER'S MANUAL	113
APPENDIX E.	PREFLIGHT QUESTIONNAIRE	119
APPENDIX F.	CH-46E NATOPS BRIEFING GUIDE	123
APPENDIX G.	POST FLIGHT QUESTIONNAIRE	125
APPENDIX H.	SUBJECT'S SIMULATOR AND FLIGHT DATA	129
INITIAL DISTRIBUTION LIST		139

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

Figure 1.	Basic VEHELO Implementation	6
Figure 2.	Low Level Terrain Flight	14
Figure 3.	Contour Terrain Flight	16
Figure 4.	Nap of the Earth terrain Flight	17
Figure 5.	Effective Communication.	24
Figure 6.	Student in Mock Cockpit with Blue Screen Matting.	32
Figure 7.	Flight Controls and Seat	33
Figure 8.	VEHELO Portable Mock Cockpit and Matting	34
Figure 9.	VEHELO Instrument Panel	35
Figure 10.	Fluorescent Lamp	35
Figure 11.	VEHELO Headgear	36
Figure 12.	V8 HMD	37
Figure 13.	Camera Control Unit and Camera Head (Minus Lens).	39
Figure 14.	Camera Lens	40
Figure 15.	Motion Tracker	41
Figure 16.	Schematic of the VEHELO System	42
Figure 17.	Ultimatte 400 Video Mixer	43
Figure 18.	Smart Remote, Ultimatte Corporation	44
Figure 19.	VGA-to-Digital Signal Scan Converter	44
Figure 20.	Analog-to-Digital Converter	45
Figure 21.	Digital-to-VGA Converter	45
Figure 22.	1:2 VGA Distributor	46
Figure 23.	Central Processing Unit (CPU)	47
Figure 24.	Laptop CPU Console	48
Figure 25.	Network Switch	49
Figure 26.	Thermodyne Quadraflex™ Equipment Cart.....	49
Figure 27.	Rack-Mount UPS	50
Figure 28.	Rack-mounted Surge Protector.	51
Figure 29.	VEHELO Set-up Configuration	53
Figure 30.	Fleet Replacement Squadron (FRS) Training Timeline	59
Figure 31.	Experiment Flight Route Card.	66
Figure 32.	Subject's Checkpoint Proximity	70
Figure 33.	One-way Analysis of AVG(A) by Group.	72
Figure 34.	Bi-Variate Fit of AVG(V) by AVG(A).	73
Figure 35.	Relfecmedia's LED Litering	83
Figure 36.	VEHELO Set-up Configuration	115
Figure 37.	Pre-Flight Questionnaire (page 1)	119
Figure 38.	Pre-Flight Questionnaire (page 2)	120
Figure 39.	Pre-Flight Questionnaire (page 3)	121

Figure 40.	Post-Flight Questionnaire (page 1)	125
Figure 41.	Post-Flight Questionnaire (page 2)	126
Figure 42.	Post-Flight Questionnaire (page 3)	127
Figure 43.	Subject 1 Results	129
Figure 44.	Subject 2 Results	131
Figure 45.	Subject 3 Results	133
Figure 46.	Subject 4 Results	135
Figure 47.	Subject 5 Results	137

LIST OF TABLES

Table 1.	VEHELO Connections	54
Table 2.	VEHELO Program Keyboard Instructions	57
Table 3.	Preflight Brief Items as Per T&R	61
Table 4.	Preflight Questionnaire Results	68
Table 5.	Subject's Checkpoint Proximity	71
Table 6.	One-way ANOVA	72
Table 7.	One-way ANOVA (cont.)	73
Table 8.	Linear Fit	74
Table 9.	IP/Proctor Summarized Results	78
Table 10.	VEHELO Connections	114
Table 11.	VEHELO Program Keyboard Instructions	118
Table 12.	VEHELO Data Legend (Subject 1)	130
Table 13.	VEHELO Data Legend (Subject 2)	132
Table 14.	VEHELO Data Legend (Subject 3)	134
Table 15.	Aircraft Flight Data Legend (Subject 4)	136
Table 16.	Aircraft Flight Data Legend (Subject 5)	138

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

This research would not have been possible without the knowledge and dedication of several individuals. I would like to start with a show of appreciation to co-advisor, CDR Joe Sullivan. His contagious enthusiasm and incredible knowledge was really the genesis behind the whole idea of embedded environments and the VEHELO for training.

There are some other individuals that I would like to thank for all of their assistance as well. First is LtCol. Hahne, Commanding Officer of HMMT-164 at Camp Pendleton California. He was a great help in providing the environment in which to test. He hosted our effort on numerous trips and was always enthusiastic in his support. This experiment would not have been possible without his efforts.

I would also include the support of Major Mark Lennerton for his work and support in bringing this idea to fruition. He accomplished this via his previous vast amount in creation of the ChrAVE and his continued interest.

I would also like to thank Captain 'Preacher' Gwynne and Major Mark 'Otter' Welch, both instructor pilots and the remainder of the Marines at HMMT-164. All of these Marines were of immense help in setting up the logistics of the experiment, assisting in the conduct of it and supporting it at a variety of levels.

Lastly, although it is currently beyond their comprehension, I would like to thank my two sons Richard and Adam. They likely have no idea how much their love

means to me and how it is actually a framework of support
for me to completing this body of work

I. INTRODUCTION

A. PROBLEM STATEMENT

The Weapons Systems Trainer (WST)/Aircrew Procedures Trainer (APT) should be used in those flights designated "S" or "S/A" within the syllabus. Demonstration and exercise modes of the flight simulator shall be used within the training syllabus. If the flight simulator is not available, simulator periods designated as "S" may be waived. Crew Resource Management (CRM) shall be stressed in the training of all pilots.

From MCO 3500 Ch 1 (2004)

Low cost, availability and usability - three things that are required of all simulation systems to be effective. Today's systems can be significantly more useful and realistic than any systems that pilots have had access to in the past. Today's systems also come at varying costs. The costs go beyond the basic facet that the systems are inherently expensive and difficult to maintain. Today's systems are extremely large and complicated pieces of hardware and they must also remain stateside when the military pilot is required to forward deploy. This puts the deployed pilot into a situation in which extremely perishable piloting skills can quickly degrade over the length of the deployment. The skills referred to here are not the basic 'stick and rudder' skills. They are the skills or tasks that are accomplished in an automatic fashion by the pilot. These could include the pilot's ability to navigate, communicate and interact with the various crew members onboard the aircraft.

In the past it has been proposed to utilize personnel computers (PCs) to replace or augment pilot training. As

discussed in previous work by Lennerton (2004) the PC's limitations far outweighed any observed gains. "PC applications remove the pilot user from his normal environmental interfaces" and "require additional learning on the part of the pilot". The 'additional' learning was actually a form of negative training and provided no net gain to the level of proficiency if the pilot using the system.

When it comes to advanced training today military pilots are being taxed more than at any time in the past two decades. Today's military pilot is experiencing extended deployments in often hostile environments. These environments, whether sea-based or land-based, do not afford the deployed pilot any opportunity for simulated training. This lack of training also extends to the Fleet Replacement Squadrons (FRS).

There are three levels of training required for all novice pilots in the CH-46E helicopter. The template for this training is defined in each aircraft's Training and Readiness Manual (T&R). There are three levels of required training; Combat Capable, Combat Ready and Combat Qualification Phases. The completion of the Combat Capable Phase is required before the student can proceed to a Fleet squadron. This training cannot be abbreviated in an effort to reduce the time before the pilot reaches the Fleet squadron. But it can be improved in an attempt to increase pilot performance. Increased pilot performance could reduce FRS time to training (TTT). This in turn could assist the fleet via pilots arriving and deploying in a more timely fashion.

The Fleet Replacement Squadron is responsible for completing the Combat Capable Phase of training for novice pilots. The primary purpose of this phase is to develop the student's preliminary flight skills in the CH-46E. It also is where the student will become familiar with flight characteristics, limitations, and emergency procedures of the helicopter. Lastly they will develop proficiency in all maneuvers contained in the familiarization (FAM) stage of training as defined in the T&R Manual.

Current training requires no simulated navigational training and does not provide an atmosphere in which Crew Resource Management (CRM) and communication skills can be learned or practiced. This thesis will address that need by proposing a product to address this need of the fleet. The product is an affordable simulation system that a pilot can utilize to maximize the effectiveness of his training flights in preparation for deployment. The new version of the system will be mobile and will be easy to use by personnel with minimum training. The VEHELO will allow deployed pilots to maintain acceptable levels of proficiency. It will also provide the pilot the ability to train and prepare for training flights while in an immersive and familiar flight environment. The pilot is able to apply piloting tasks, to include multi-place communications, as "faithfully and rigorously" as if he were flying in the actual aircraft.

B. MOTIVATION

This thesis concerns the training deficiencies related to the military helicopter community. The previous body of work by Lennerton concerned an in depth discussion of the

limitations involved with simulated pilot training. That work concentrated on the limitations of the current generation simulation systems, user perspectives and possible solutions. It also discussed the need for a deployable training system to support pilots that are deployed in support of military operations worldwide. It spoke of the tendency of a pilot's abilities to atrophy while deployed. It discussed why navigational training was a good area to begin exploring the feasibility of a simulator using chromakey technology, such as the VEHELO system, that utilized immersion of the pilot into the environment. The pilot skills in the Lennerton experiment will be referred to as the proficiency level of the in this thesis.

This thesis will expand upon the previous suggestion of low level or terrain flight navigation research. The focus of this thesis will be to concentrate on using the immersed environment to increase the efficiency of early navigational training flights. The training is more involved than just point to point navigation in the aircraft. In addition to navigational skills, the pilot must learn proper CRM and how to properly use and communicate with the other crewmembers in the aircraft.

This discussion will begin with the skill of aircraft low level navigation. The ability for a pilot to effectively navigate is a skill that most other flying responsibilities build upon, "Navigation is one a fundamental underlying function to most every task of helicopter aviation". The requirement for a pilot to be able to effectively navigate has not been negated with the

advent of modern navigational aids such as embedded Global Positioning Satellite (GPS) systems. Additionally this thesis will also address the ability of the VEHELO to be used as a Crew Resource Management (CRM) and communications resource platform.

The previous work by Lennerton presented research into many different simulation systems. They all were described as having to proceed through three basic steps. The steps are (1) research into the psychology and potential of training via the use of embedded simulators, (2) the production of a fully operational embedded trainer and (3) verification of the results of using an embedded trainer.

The first step was researched and reported upon in the works of Lennerton (2004) and of Sullivan (1999). The work completed by Lennerton proved the feasibility of the training via the use of embedded simulators which used the chromakey technology. This thesis will demonstrate and attempt to prove that the scope of the VEHELO system can be expanded to include many more functions. The system has the capability of being modified to allow it to satisfy it being used as an instructional tool. This functionality compares with earlier work in which it was suggested to be used to maintain levels of pilot proficiency. To summarize it will be a step closer to achieving Lennerton's step two mentioned above.

C. THESIS OVERVIEW

Embedded training systems must fulfill more than one or two basic needs in the training environment to justify their existence. They must be designed from a user-centered perspective and from a machine-centered design. This thesis

continues the work completed by Lennerton (2004) which used the chromakey technology to address this simulation need. It will take the VEHELO system beyond the simple tasks required during its initial testing and validation. It will also attempt to validate its usefulness as an instructional tool. It will accomplish this by comparing data obtained from simulation and from aircraft flights by students with that of students who fly in the aircraft only. The basic configuration of the system is shown below in Figure 1.

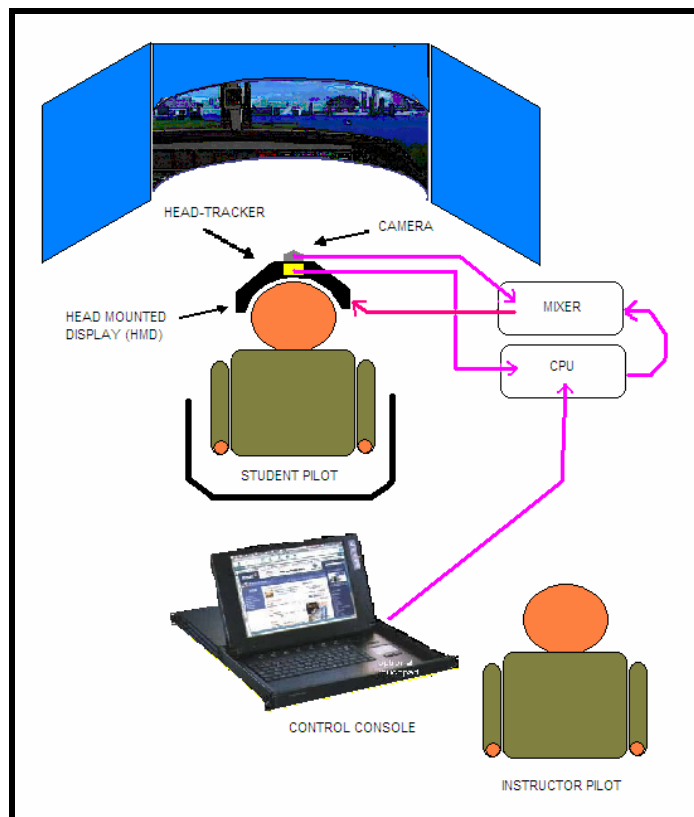


Figure 1. Basic VEHELO Implementation

The initial version of the ChrAVE system was successful at validating the basic concept of using the

chromakey technology for static helicopter simulations. In essence it could have been described as a tool used to maintain pilot proficiency. The focus of this thesis will be one of the suggested uses from the Lennerton work. The system, through slight modifications, has the ability to increase the performance of the novice pilot during their initial navigational training flights. The increased performance will be realized by the higher levels of Situational Awareness (SA) achieved by the novice pilot prior to the aircraft flight. The modified system will also have the ability to be used as an effective tool in teaching Crew Resource Management (CRM) to the novice pilot.

D. RESEARCH QUESTIONS

The primary focus of this thesis is to validate the VEHELO being used as an instructional tool in the training of novice pilots during the navigation phase of their flight training. The viability of the system's instructional potential will be proven if pilot performance improves during the navigational flight in the Fleet Replacement Squadron (FRS).

This thesis will specifically address the following questions:

1. Can augmented training using the VEHELO be expanded to improve initial training instruction of student pilots while still being used to increase proficiency amongst experienced pilots?
2. Is there an increased level of proficiency afforded student pilots through the use of augmented

training? What is the value of the savings in terms of reduced flight hours or increased proficiency during instructional flights?

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

The earlier work by Lennerton proved the system viability as a helicopter pilot proficiency tool. This thesis used the latest modified version of the system for further evaluation.

As discussed by Lennerton, "cockpit management skills conform to the cockpit environment and can only be practice in such an environment". This thesis continued to experiment at immersing the novice pilot in an ergonomically correct environment to learn and practice critical skills. By being confined in an ergonomically correct environment, the novice pilot could learn and practice terrain appreciation as well as crew coordination skills. All of this will be directed at improving the level of Situational Awareness (SA) and cockpit management skills of the novice pilot prior to his first navigational flight in the actual aircraft.

E. ORGANIZATION OF THIS THESIS

This thesis is organized into the following chapters:

1. Chapter I: Introduction. This chapter is an introduction to the problems and motivation for the problems stated earlier.

2. Chapter II: Training Tasks and VEHELO Background. This chapter explains the basis and emphasis of helicopter navigation training. It also delves into the background of the VEHELO training system. Work completed by Lennerton is explained and used as a stepping off point for this thesis.
3. Chapter III: VEHELO Specification, Configuration and Use. This chapter covers the current physical configuration of the VEHELO as tested during this thesis. It also includes a suggested User's Manual to successfully employ the system in an experimental environment. Lastly this chapter describes the setup and execution of the experiment as it was conducted for this thesis.
4. Chapter IV: Modifications and Recommended Improvements. This chapter describes the possible modifications to be made to the current system. It explains ideas that could further the training potential of the system as well as its increase its and ease of use and ability to deploy for testing.
6. Chapter VI: Conclusions. This chapter describes conclusions reached via evaluation of the test results and input from the users, experienced and novice.

THIS PAGE INTENTIONALLY LEFT BLANK

II. TRAINING TASKS AND VEHLO BACKGROUND

A. HELICOPTER TERRAIN FLIGHT AND NAVIGATION

The task of helicopter navigation is the foundation upon which all other pilot skills are built upon. Experienced helicopter pilots are accustomed to successfully navigating over terrain as it is seen with the visual perspective afforded by flight at or above an altitude of 500 feet above ground level (AGL) altitude or higher. The skills that are successful for navigation at higher altitudes are not useful at the lower altitudes dictated by terrain flight. The flat visual angle during terrain flight appears to distort terrain relief when compared to the two dimensional maps thus making the task of navigation much more difficult. Also the vertical relief, which is the most suitable means of identifying checkpoints, is also distorted from the 'sight picture' afforded the pilot at lower altitudes. For a military helicopter pilot to develop the required level of proficiency requires that he train and practice terrain flight navigation repeatedly.

Historical analysis of initial navigational training has shown that the amount of training required to meet requirements varies from student to student. This leads to some flights in the aircraft that are fruitless in terms of student training. This is because the student has already attained the required level of navigational skill. Yet other students require more flights than those scheduled in the Training and Readiness Manual for the navigational stage of training. The lack of some students to attain the minimum acceptable level of proficiency requires additional

flights or 'reflys' to be scheduled. These additional flights increase the training and maintenance burden of the training squadron. Additionally, more flights are required in order for the student to proceed adequately through the remainder of the training cycle.

The pilot that is doing the actual navigation is required to be proficient in reading a map, terrain appreciation and the correct correlation of terrain features with map symbols. Identifying checkpoints is the critical task requiring the aforementioned tasks.

For a pilot to succeed at navigation he must be able to anticipate how the surrounding terrain should appear from conducting a good map study prior to the flight. If successful, he will be able to look at the terrain during flight, orient the map correctly and identify the position of the aircraft. An experienced pilot will be meticulous during his map preparation for the flight.

Novice pilots lack many of the skills that are gained only from experience. They are taught from the first days of their flight training to aviate, navigate and communicate. These three skills must be mastered and must always be executed in order to succeed at becoming a military helicopter pilot. After learning how to actually fly the aircraft, novice pilots are next taught to navigate the aircraft from 'point A to B' in the accomplishment of the mission.

The requirement to be able to properly navigate while piloting a helicopter provides more than just knowing where the aircraft is 'on the map'. The skill of navigation is more than the aircraft transitioning from point A to point B. It involves the pilots maintaining a high level of

Situational Awareness (SA). Maintaining a high SA allows the pilots and aircrew to remain 'ahead of the aircraft'. This in turn allows the aircrew to effectively use the aircraft to accomplish the assigned mission.

The task of navigation is not the work of one individual in the aircraft. It is the compilation of effort from all members of the aircrew. In military aircraft there are numerous aircrew positions and each has its own set of responsibilities. The Pilot at the Controls (PAC) is the crewmember actually manipulating the flight controls of the aircraft to accomplish it being able to fly. The Pilot not at Control (PNAC) is the crewmember responsible for navigation. He is also responsible for many other tasks involving crew coordination and aircraft system employment.

There are also other crewmembers on board certain types of military helicopters. The CH-46E helicopter used for evaluation in this thesis has an additional two crewmembers. The crew chief and aerial observer both provide input to the pilots from their vantage point in the rear of the aircraft. A multi-place aircraft such as this is a prime example of the importance of good crew coordination. For the helicopter to successfully navigate a given route of flight the aircrew must work in a cohesive fashion.

Helicopter flight is normally flown at lower altitudes for a multitude of reasons. Not the least of which is a tactical necessity. Altitudes of 200-300 feet are considered the normal for most missions. But the altitude flown is always threat dependent and can vary throughout any given mission. It is for the above reason that training is also conducted at that altitude.

1. Low Level Terrain Flight

Terrain flight consists of three basic forms below 200 feet above ground level. The Assault Support Helicopter Tactical Manual (CNO, 1992) defines three different profiles or levels in this environment. The different forms are predicated by the altitudes flown for each. The levels are Low level, Contour and Nap of the Earth (NOE). Figure 2 below depicts a simplified example of each level of terrain flight.



Figure 2. Low Level Terrain Flight

The first and most commonly utilized flight profile used by military helicopter pilots is Low Level Flight. Low Level flight provides for the flight is pre-selected and is to be conducted at a selected altitude. That altitude is one at which detection and observation of the aircraft or of the points which, or to which, it is flying are minimized or avoided. Low Level flight is flown at minimum altitudes of 100 feet above ground level (AGL). This altitude profile provides the pilot with the ability to follow a pre-selected route. It also affords the pilot the opportunity to maintain a constant altitude and constant

airspeed. The airspeed can be any that is required for safe and successful accomplishment of the mission.

This thesis will focus on flights in the Low Level flight profile. In actuality, the aircraft will most likely transit between various flight profiles. But for the ability to assess effectiveness in the instructional environment, Low Level flight will be the only evaluated profile.

2. Contour Flight

The next flight profile is that of contour flight. It is a flight conducted at low altitude. It allows for the aircraft to be flown at an altitude that conforms generally and in proximity to the contours of the Earth's surface. It takes advantage of available cover and concealment to avoid an enemy's observation or detection of the aircraft, such as when departing and landing from a landing zone.

This level is usually flown at altitudes of 50 to 100 feet AGL. Again it requires the helicopter pilot to conform to contours of the Earth's surface in order to maintain a level of tactical necessity as vegetation and obstacles permit. It is normally flown at varying airspeeds. The minimum airspeed for this profile is 40 knots. The altitudes flown can also be varied throughout this flight profile.



Figure 3. Contour Terrain Flight

3. Nap of the Earth Flight

The final flight profile is Nap of the Earth (NOE). It is normally flown for much shorter distances than the previous two flight profiles. This profile allows the aircraft to fly as close to the Earth's surface as vegetation and obstacles permit. It is accomplished while generally following the contours of the Earth's surface. Altitudes for NOE flight permit the aircraft to fly as close to the terrain as conditions permit. The NOE profile allows the aircraft to be flown at varying airspeeds below the maximum of 40 knots. It also allows the aircraft to be flown at varying altitudes but the minimum altitude is 10 feet AGL.

The pilot preplans a broad corridor of flight operations based on known terrain features with a longitudinal axis pointing towards his objective. While flying NOE, the pilot will use a weaving and varying route within the corridor. He will also remain oriented along the

axis to take advantage of the cover and concealment afforded by available terrain, vegetation, and manmade features.



Figure 4. Nap of the Earth terrain Flight

The military helicopter pilot must follow certain fundamentals to successfully conduct terrain flight regardless of which flight technique is employed. They are different than the fundamentals of conventional flight because terrain flight is conducted close to the Earth's surface at speeds that vary from a hover to maximum mission permissible airspeed. The fundamentals are as follows: navigation, aircrew coordination, pilot techniques, tactical movement, flight safety, and weather.

It is the first two fundamentals that are addressed through effective use of the VEHELO system. Previous versions of the system did not allow the opportunity for novice pilots to learn any Aircrew coordination skills. Nor did the previous version allow novice pilots to build levels of proficiency involving the task of low level flight navigation.

B. CREW RESOURCE MANAGEMENT

Aircraft today are very complex machines and to successfully fly a modern aircraft requires the combined effort of more than one member of the aircrew. As mentioned earlier, there are normally four aircrew positions onboard the CH-46E helicopter that was used for evaluation in this thesis.

Terrain flight and navigation are some of the most demanding activities a helicopter pilot will encounter during most missions. To be successful it requires precise aircrew teamwork and coordination. This is particularly true with respect to pilot and copilot/aerial observer flight duties and cockpit coordination. Crew Resource Management (CRM) is a philosophy that addresses the requirement for crew coordination. CRM is has been defined as management of human error. This arises from the fact that error is 'universal' and in some instances it is 'unavoidable'.

Previous research has indicated that pilots are able to perform two tasks, even if familiar with each, at a time only in certain circumstances. Humans have two thought process systems, cognitive, with which they complete tasks. One uses conscious control. The other is an automatic system that operates separately from the conscious control. The conscious system is slow and effortful, and performs one sequential task at a time. The automated cognitive processes develop as the pilot obtains skill. These processes are task specific and they operate rapidly requiring little of the pilot's effort or attention.

The actual tasks required of a helicopter pilot require a combination of both types discussed above. An

experienced pilot can complete the flight via the automatic system. This provides the experienced pilot enough surplus conscious capacity to carry on a conversation. Cognitive process, without conscious supervision, is vulnerable to error. That error is called "Habit Capture". An example of this type is if the pilot intends to take a different route than that briefed and is then distracted by conversation in the aircraft. The pilot stands a chance of performing the automatic response and taking the briefed route.

Aircrew coordination is fundamental and a prerequisite for the safe and effective mission accomplishment while flying in the low-level environment. The automatic systems processes of the pilots must be constantly monitored by the pilot's cognitive system. This allows the automatic system to be updated with current information thus preventing the above scenario. Additionally research has indicated that pilots can combine the two systems simultaneously. They can accomplish this if they practice the assigned tasks together and regularly.

CRM and aircrew coordination is used to establish a division of pilot responsibilities. It is also used to organize required cockpit duties. The specific cockpit duties and responsibilities will vary with each mission's tactical situation, and which terrain flight profile is utilized. Each air crewmen's duties and responsibilities will be assigned and discussed thoroughly by the Helicopter Aircraft Commander (HAC) during the preflight brief.

1. Division of Duties

a. The Pilot at the Controls (PAC)

The pilot at the controls of the helicopter has two primary responsibilities. They are controlling the

helicopter and avoiding all obstacles. He must concentrate on keeping his vision outside the helicopter, maintaining an effective scan pattern. He must also avoid any distractions, particularly those that are cockpit related that could hinder his scanning pattern. The Pilot at the Controls will also report key terrain and landmark information to the non-flying pilot and other crewmembers to assist in navigation of the aircraft. He will accomplish this coordination through the use of standardized terminology.

Standardizing terminology is a skill that becomes automated through practice and often only reaches a mature level with experienced pilots. On the other hand the skill is not automated for the novice pilot. In fact it is historically one of the more difficult tasks for the novice pilot to master. The skill requires the novice pilot to actively think of each term to be used and the steps required to deliver it to the rest of the aircrew. This entails mentally rehearsing the term and then delivering it without disturbing the flight controls as set by the Pilot at the Controls. He must also not interrupt any communications already in the process of being exchanged between members of the crew.

He also retains control of the helicopter during any aircraft or system emergencies. He will also execute the emergency procedures required in accordance with appropriate aircraft publications. Lastly he is responsible for accomplishment of any instructions received at the preflight briefing.

b. Navigator or Pilot Not at the Controls (PNAC)

The Pilot Not at the Controls is referred to by different titles amongst the various references; for the purposes of this thesis, entry level navigation instruction, the title PUI will apply to the PNAC. The tasks and responsibilities of the PNAC are of particular interest to this thesis. The VEHELO overall system goals are tailored to the needs of the PUI and each task has been faithfully emulated for evaluation in the experiment phase. The primary duty of the PUI is accurate navigation. To be successful he must remain oriented at all times during the flight. He must inform the PAC of the proper direction of flight and appropriate airspeed adjustments for the purpose of correct mission timing. He also assists the PAC by monitoring aircraft instruments and the performance of the other crewmembers. He will additionally complete any assigned procedures during aircraft emergencies and those assigned to him during the preflight brief.

The duties and responsibilities of the navigator or PUI (PNAC) during most tactical missions would be as follows:

- Navigating from checkpoint to checkpoint via the intended route of flight.
- Maintaining aircraft orientation.
 - Utilize terrain appreciation as the primary means of monitoring aircraft location.
 - Utilize timing as a secondary means of monitoring aircraft location.
 - Dead Reckoning.
 - Utilize Time/Distance/Heading.

- Associate 3-D terrain outside aircraft with the 2-D map representation.
 - Utilize key terrain features to include;
 - Limiting features.
 - Channeling Features.
 - Vertical relief.
- Provide timely directional voice commands to the Pilot at the Controls.
 - Standard directional voice commands.
 - Standard terrain feature terminology.
- Monitor and manage radios.
 - HF/VHF/UHF
- Monitor instruments.
- Monitor and manage navigational equipment.
 - GPS/PLRS/ADF/TACAN/UHD-DF

c. Crewchief/Aerial Observer/Gunner

The remaining members of the aircrew aboard most flights in the CH-46E helicopter are those positioned behind the cockpit, in the passenger cabin. Crewmembers other than the two pilots have two primary responsibilities during flight. They are responsible for monitoring the mechanical function of the helicopter. They also assist in terrain recognition and ensure the aircraft has the required clearance from obstacles during hovering and landed. Crewchief/Aerial Observer/Gunners within the helicopter should be positioned where they can best observe outside, often requiring them to move about the cabin while

in flight. This requires effective communication between the pilots in the cockpit and the crewmembers in the aft section.

2. Communications and Situational Awareness

Communication is defined as the ability to clearly and accurately send and acknowledge information, instructions or commands. It is also the ability to provide useful feedback. In general there are two types of communication

- Verbal
- Nonverbal

Verbal communication involves words that are either spoken or written. Nonverbal communication is everything else but words. It can be in the form of gestures and voice intonation. The sender or receiver of the communications both have the responsibility to ensure that the communications are concise, clear, provide useful feedback and are completed in a timely fashion.

Communications between all members of the aircrew are essential to any successful flight. Terrain flight requires an exchange of information between all crewmembers on board the aircraft. The copilot or Pilot Not at the Controls (PNAC) furnishes the pilot with information required to for the aircraft to remain on the intended flight path. To assist the copilot/PNAC, the pilot will communicate approaching terrain features to him.

Effective communications between the crewmembers will raise the Situational Awareness (SA) of all crewmembers. It will also increase` the chance of mission success. SA is defined as the degree of accuracy by which a crewmember's perception of the current environment or situation mirrors reality.

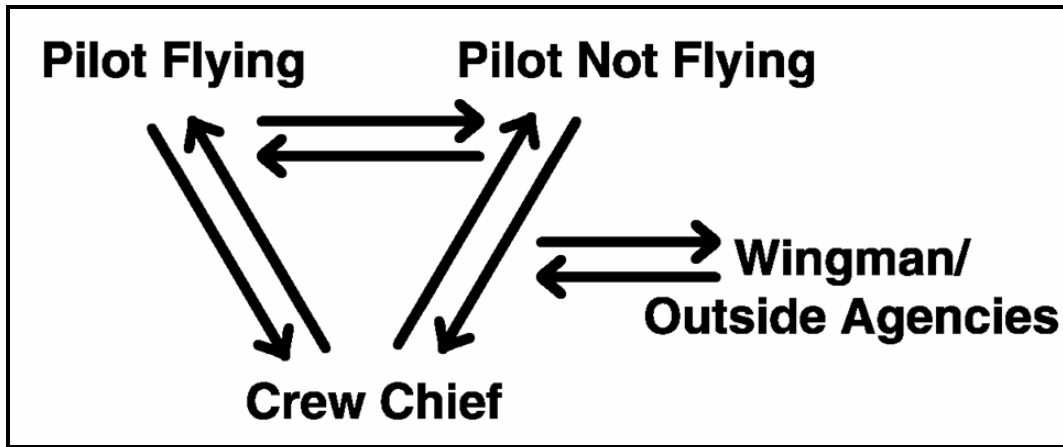


Figure 5. Effective Communication.

The crewmembers will utilize standardized terms to identify terrain features. For example, a body of water called a creek in some parts of the country is called stream or brook in others. Standardized terms will help to prevent misinterpretations and reduce cockpit conversation (brevity).

C. VEHLO BACKGROUND

1. VEHLO Development

Motion simulators today have 'near-full fidelity' of the aircraft's cockpit environment. Instrument displays in current systems provide flight information that replicates that from the actual aircraft. The simulator's flight control response and feedback have improved greatly over the past 15 years but still fall short of replicating those in the aircraft. It is an ongoing effort to improve simulators by improving the interactive graphics of the virtual environment or display that the user sees.

Simulator improvement will involve the use of user-centered design. This design approach takes into account the way in which a pilot interacts with the cockpit

environment. It accomplishes this by creating motion parallax with the dynamic head movements of the pilot. Traditionally simulators alone cannot replicate the feedback required for developing or maintaining the skill required to manipulate the flight controls of an actual helicopter.

The original Chromakeyed Augmented Virtual Environment (ChrAVE) research attempted to focus on the pilot task of low level navigation. This is an extremely critical skill required of all helicopter pilots. The skill of navigation requires none of the dexterity, when compared to the flying pilot, from the manipulation of the flight controls. Lennerton's work showed that the task of low level navigation was a viable task that could be effectively simulated in the ChrAVE. This in turn allowed further research using the VEHELO system into the more complex tasks that might include successfully emulating the flight control feedback. That ability could be used to maintain the level of pilot dexterity or skill proficiency.

The ChrAVE was built around the use of the chromakey technology. The technology has been around for many years and is often used in the entertainment industry. The basic chromakey process combines two different video signals, a foreground and a background, by overlaying one video signal over another. The areas of overlay are defined by using a specific range of color, called chrominance, on the background signal.

An even simpler description is like having an individual stand in front of a blue or green screen (background). A device, hardware or software, is then used to remove every area of that color and replace it with

another image or video source. This gives the observer the illusion of the individual being 'somewhere he is not'. The individual then is being 'keyed' in front of a green screen or Chromakeyed.

The Chromakey Augmented Virtual Environment (ChrAVE) was an idea that was first explored in the body of work completed by Lennerton in 2004. His work followed the work by Sullivan (1998) and evaluated the basic idea of using this method of simulation for helicopter training. Lennerton created the first ChrAVE system which was used for initial the evaluation. The work by Lennerton validated the usefulness of using the Chromakeyed technology to overcome the many drawbacks of current simulation systems. It successfully showed the effectiveness of immersing the pilot in an environment similar to that in which he would encounter in actual flight. It showed the effectiveness of virtual environments for use in stationary simulations. It also showed that the system is a viable training tool for navigational training and the 'acquisition of spatial knowledge'.

In this body of work, that previous system will be referred to as ChrAVE. The system was modified from lessons learned by Lennerton and to accommodate ideas for its future use. The current version of the ChrAVE is now known as the Virtual Environment Helicopter or VEHELO and it is that nomenclature that will used for the remainder of this thesis.

III. VEHLO SPECIFICATION, CONFIGURATION AND USE

The VEHLO was intended to be used in a manner that replicated actual pilot performance in the aircraft. That said the navigating pilot or pilot not at the controls (PNAC) will direct the flight path of the aircraft by giving appropriate voice commands to the pilot at the controls (PAC) or Instructor Pilot (IP). Standard terminology will be in accordance with (IAW) the aircraft Naval Air Training and Operating Procedures Standardization Program (NATOPS) Manual. This standardization between the simulated and 'real world' environments negates the need for any additional learning to accomplish the task in the VEHLO.

In Lennerton's work he discussed the workload of the navigational pilot (PNAC). He concluded that "the navigator is generally mentally more 'active' than the pilot at the controls". He also correctly concluded that "while it is a crew coordination task to maintain situational awareness and knowledge of the aircraft's whereabouts at all times, it is the navigator, who through use of the map and the outside world challenges the certainty of the aircraft's place in space. Successful navigation requires vigilant uncertainty management, the degree to which uncertainty is minimized and considered acceptable".

As was the case with the earlier ChrAVE experiment, manipulation of the flight model is accomplished via the keyboard. Thus it will be done by the IP.

A. EXPERIMENTAL OPERATING MODES

The VEHELO can be used as a proficiency tool. This was discussed in the work by Lennerton. It can also now be used as an instructional tool.

Human learning, once acquired, is not stored permanently in the mind. Human information retention is selective. Skills and knowledge can both be retained in proportion to their use and importance. The Federal Aviation Administration conducted various studies in the area of pilot proficiency. The studies were designed to track the retention and/or loss of pilot skills over a given period of time. One study found that newly certified pilots who do not fly regularly underwent 'rapid and significant deterioration' of their ability to perform given flight tasks. The study did not quantify what was meant by 'fly regularly'. Skill retention or skill loss can be divided into two types. The first is cognitive or procedural. The second is control oriented. The two types can more easily be described as mental tasks versus manual tasks. The study confirmed the widely held belief that the most serious skill loss is in the mental area. Ideally, skill retention is best reinforced through completion of proficiency training. Proficiency training is when the pilot is permitted continued flight practice, training, and evaluation.

An instruction is defined as "a form of information which is communicated in order to explain how an action, behavior, method, or task is to be begun, completed, conducted, or executed". Instructional training is initial training conducted by the instructor pilot towards the student. It can be accomplished by various and situational

methods. The instruction of any given skill can be presented to the student in the following ways:

- Instructor describes and instructor demonstrates.
- Student describes and student demonstrates.
- Student demonstrates and instructor evaluates.
- Integrated flight instruction. Flight instruction during which the student is taught to perform a flight task. The student will utilize outside visual references and inside reference to the flight instruments.

When used as a proficiency tool the system can supplement proficiency training that is already being conducted via the aircraft. When used as an instructional tool the VEHELO can accomplish all of the above when related to low-level navigation.

The VEHELO system can be used in many different operating modes for instructional or proficiency training. For the purpose of this thesis the system was tested in only two instructional modes. The two types of instructional operating modes used in this experiment were the Instructor-PUI (Instructor Pilot or proctor-student) and route rehearsal.

The Instructor-PUI mode of operation will be used to teach and practice navigational, CRM and other crew coordination skills required in a multi-place aircraft. This method allows the IP to devote the entire period of instruction to increasing the PUI's level of skill in any and all of the areas.

The route rehearsal method allows a navigational route to be practiced. This will provide the PUI with "an

acquired spatial knowledge of that area of flight" without ever having actually flown there in an actual aircraft.

B. SYSTEM FEEDBACK

The PUI (PNAC) will have a merged view of the real world and the virtual world displayed in the Head Mounted Display (HMD). The real world consists of the mock cockpit, objects within that cockpit, and the PUI's views of himself. The virtual world will consist of a computer generated world. Head movements of the PUI will affect viewpoint changes in both the real and virtual worlds displayed. Head movements will allow the PUI to have natural interaction with and investigation of both the real and virtual worlds.

Feedback will also be provided to the PUI via the instrument panel display. The instruments it displays are all important tools for successful navigation. The RMI is most useful for determining and maintaining aircraft heading. The attitude indicator assists in determining the aircraft's orientation relative to a virtual world's pitch, roll and yaw axes. The VSI displays information pertaining to the aircraft rate of climb or descent. The turn rate indicator provides information about the aircraft's orientation about its roll axis. In normal flight these instruments are all cross referenced to maintain normal and controlled flight. The VEHELO systems, all versions, are motionless platforms. This causes a mismatch between the visual perception and physiological percepts.

C. SYSTEM HARDWARE AND SETUP

The VEHELO consists of some new hardware and the deletion of other units. The current configuration consists of the equipment listed in the inventory located in Appendix B.

1. Mock Cockpit Configuration

The VEHELO configuration has been modified from that of the earlier version used by Lennerton. The portable VEHELO attempts to mock the left half of a side-by-side dual piloted helicopter, in this case the CH-46E. It was created to be easily reconfigured to generically represent many different helicopter cockpits. The system employs three collapsible blue screen curtains mounted on portable stands. The screens represent the left, front and right side views. Additionally it uses a smaller blue screen sheet to represent the view out the left chin bubble. It is this three sided configuration (4 when the chin bubble is included) that provides the immersive visual aesthetics to the pilot under instruction (PUI). An obstruction was installed over the right screen to represent the viewing area that would normally be hindered by the PAC, if he were sitting in the seat on the right side.



Figure 6. Student in Mock Cockpit with Blue Screen Matting.

2. Mock Cockpit Equipment

a. Portable Pilot Seat and Flight Controls

A cyclic, collective and rudder pedals are also employed to represent normal obstacles in the helicopter cockpit. A PNAC of an aircraft would normally be impeded by these structures at some point during the flight. The items are used for ergonomic considerations (learning to work around) and are not connected for flight model manipulation.



Figure 7. Flight Controls and Seat

b. Mock Cockpit Walls

A backdrop made of standard entertainment industry chromakey blue cloth panels. The walls consist of the panels being set-up on three sides of the mock cockpit. The collapsible curtains were set-up in such a fashion as to represent a virtual reference from the PUI's 8 o'clock to his 2 o'clock.



Figure 8. VEHLO Portable Mock Cockpit and Matting

c. Instrument Panel

There is also an instrument panel included in the mock cockpit. Its purpose is to continue the PUI efforts to improve scan technique. The CRT displays a fairly accurate representation of a SH-60 helicopter's instrument panel. It 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).

Future variations of the system should include a more specific instrument panel to alleviate any negative

training from the PUI having to learn a 'new' scan. The modified display should accurately reflect the instrument panel of the aircraft in which the PUI will be flying.



Figure 9. VEHELO Instrument Panel

d. Lighting

Lighting proved to be the most critical aspect of the previous version of the system. The chromakey technology requires very discrete lighting conditions. The mixer unit must perceive the blue background or matting. It must do this under ideal lighting conditions to prevent any noise arising from shadow or it being unevenly lit.

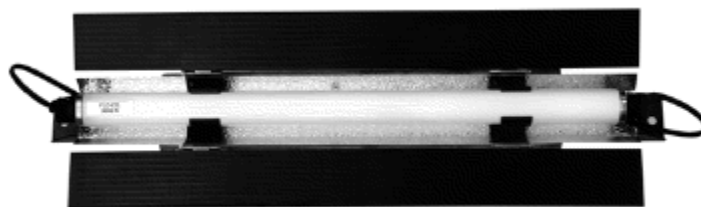


Figure 10. Fluorescent Lamp

The portable system required fluorescent lamps be placed in various positions to properly light the matting. Two portable light fixtures, each four feet in length and mounted vertically. One additional fixture, two feet long, was mounted horizontally forward of the instrument display. Each light fixture included a specular reflector and two adjustable lamp barn doors to control the direction and amount of light.

3. Headgear

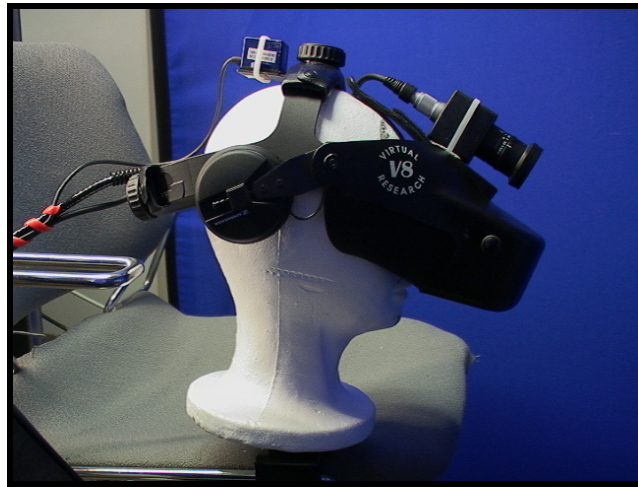


Figure 11. VEHELO Headgear

a. Head Mounted Display

The Head Mounted Display (HMD) is the same unit employed in the previous version of the system. The Virtual Research Systems Model V8 utilizes an active matrix Liquid Crystal Displays (LCD). It has a Video Graphics Array (VGA) pixel resolution of ((640x3)x480). This is not cutting edge technology but budgetary constraints prevented the purchase of a unit with higher resolution. Future versions of the system will have an up graded HMD display. Still the V8 HMD provides a CRT quality image when properly worn and

adjusted by the user. The V8 HMD allows for inter-pupillary distance (IPD) adjustments as well as eye relief adjustments (fore and aft).

Inputs and outputs for audio, video, and power are handled through an external control box. Red Light Emitting Diodes (LED) indicate 'Power On' and 'Stereo' modes. A standard 15 pin VGA type connector accepts the VGA (640 x 480, 60Hz) inputs.



Figure 12. V8 HMD

With normal systems that utilize a monitor for viewing, the PUI wanting to inspect specific area of terrain would have to fly in 'that direction' to see the terrain. 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. Lennerton referred to this as the dynamic point of view. Head movements in the VEHELO provide all views out of the cockpit that would be available in the actual aircraft.

The training afforded from using HMD is more than just immersing the PUI in a realistic simulated

environment. The use of the HMD may lend itself to training the military helicopter pilot in the proper use of Night Vision Goggles (NVGs).

b. Camera

The camera used in the VEHELO is different from the one that used in initial version of the system. The camera selected for the VEHELO system continues to utilize monocular vision. The lens is selected upon consideration of many factors. Some of these factors as discussed in earlier 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 was chosen as the best fit for the current application. It 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 an Automatic Gain Control (AGC) and Electronic Light Control (ELC). The camera used in the VEHELO was selected to balance all of theses to include budgetary considerations and is compatible with the V8 HMD.



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

An additional area of concern when selecting which camera to use was the eye to lens displacement ELD. The ELD, Lennerton 2004, "represents both a rotation and translation between the user and camera's optical path origin". The ELD affects the user's ability to interact with and manipulate objects. The weight and balance of the HMD, with camera and lens mounted, can create user fatigue and interferes with his ability to effectively use the system. Future modification will involve mounting the hardware on the user's flight rated helmet for simulation flights.

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

The InterSense Inertiacle² was chosen to be used for all motion detection in the VEHELO. It is a motion tracker that utilizes inertial sensing technology to provide 3-Degrees of Freedom (DOF). This is a major simplification from the earlier ChrAVE which used 6 DOF and additional hardware. 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 InertiaCube², approximately 1.5 inches square, mounted to the top of the headgear 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. It is nearly immune from interference in the area of the mock cockpit.

4. Electronic Hardware and Software

The VEHELO system includes many modifications from the previous version tested by Lennerton. 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.

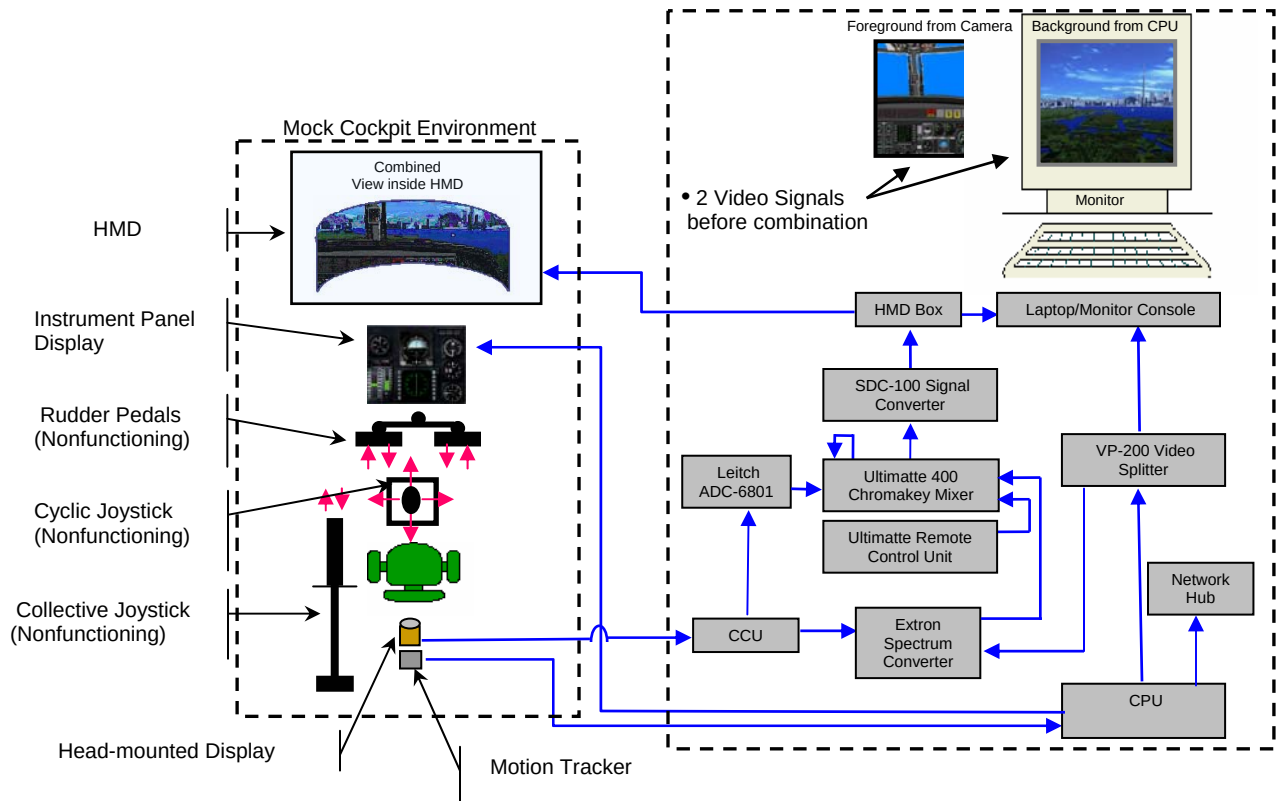


Figure 16. Schematic of the VEHELO System

a. *Ultimate™ 400 Mixer*

Ultimate 400 Mixer is a fully linear matting system able to produce 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 17. 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 18. Smart Remote, Ultimatte Corporation

b. Extron™ 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 19. VGA-to-Digital Signal Scan Converter
(front and back shown)

e. 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 22. 1:2 VGA Distributor

f. 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 a 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 23. Central Processing Unit (CPU)

g. 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 24. Laptop CPU Console

h. Network Ethernet Switch

The system built upon software that is itself installed on top of embedded HLA architecture. The HLA architecture is responsible for the helicopter or 'helo flight model'. The software has internal defaults to search for and expect a network switch or connection. For simplicity and future expansion, the software was not modified to operate alone (without the network capability). Thus the network hub must be connected to the LAN port of the CPU for proper operation. The switch utilized in this version of the VEHELO is manufactured by Netgear and allows expansion of up to four additional network stations to be installed.



Figure 25. Network Switch

i. Equipment Cart

The Thermodyne Quadraflex™ was selected to be the easily deployable yet heavy duty mobile cart for the VEHELO configuration. Inside the box the various pieces of equipment are mounted on custom configured shelving. For normal operation, the two covers are removed, external power applied and the external connections (HMD, monitor etc.) made in approximately 10 minutes. The unit was also configured with four removable heavy duty casters.



Figure 26. Thermodyne Quadraflex™ Equipment Cart
(shown without casters removed)

j. CPU Software

MultiGen-Paradigm's Vega virtual environment software is used in the CPU. This software was evaluated by Lennerton and selected for it being a "fairly intuitive API application called Lynx that allows connectivity between objects (observers, models, terrain, effects, etc.)".

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 27. 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 28. Rack-mounted Surge Protector.

6. Overall System Goals

As with the work completed by Lennerton, 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.

D. USER'S MANUAL

VIRTUAL ENVIRONMENT HELICOPTER SYSTEM **(VEHELO)**

SET-UP GUIDE AND PROCEDURES

I. SET-UP INSTRUCTIONS

1. Place the three collapsible Blue Screens to represent the 8 to 2 o'clock perspective of the PUI. Additionally place the 'loose' piece of matting in a position to represent the chin bubble view. Ensure all seams are covered and material is flat and taut.
2. Place the Flight Link Flight Controls and Seat in the center of the three collapsible screens.
3. Set-up the 'instrument console' CRT on its wooden base centered in front of the pilot's seat position.
4. Position the two vertical light fixtures to attain the required amount of light reflected from the blue matting.
5. Ensure all components are connected IAW Figure 29 and Table 1.

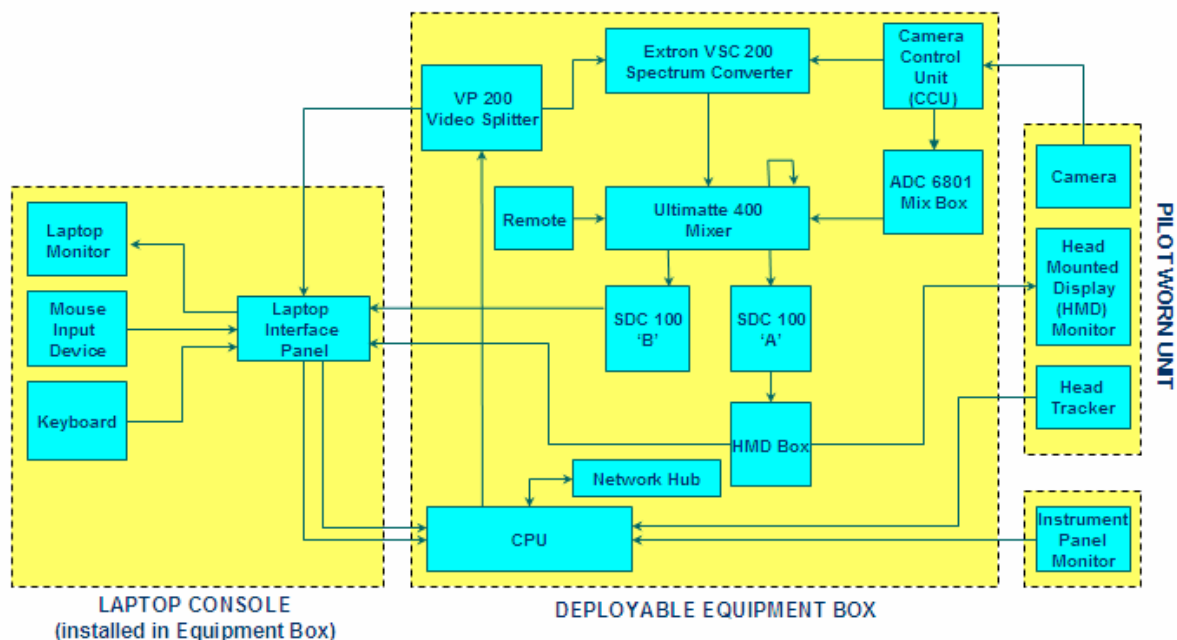


Figure 29. VEHELO Set-up Configuration

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 HMD 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 for current version of VEHELO ▪ 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 1. VEHELO Connections

6. Connect external power.

II. START-UP PROCEDURES

1. Turn the UPS and Ultimatte 400 on.
2. Turn CPU after step #7.
3. After CPU boots, log on with -

Username: Seahawks
Password: Seahawks
4. Start VEHELO program via shortcut on desktop.
5. NOTE: Database for each specific application is assigned in software directory files.
6. Adjust laptop monitor to reflect 'flying view' and instrument monitor to reflect just the instruments. This is accomplished via the set-up menus for the system in the Microsoft Windows environment.

7. NOTE: The system is configured to utilize two monitors simultaneously in the Microsoft windows environment.
8. 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.

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 VEHELO. 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	Keystroke	Command
F1	30 ⁰ turn to the right		
F2	60 ⁰ turn to the right		
F3	90 ⁰ turn to the right		
F4	120 ⁰ turn to the right		
F5	150 ⁰ turn to the right		
F6	180 ⁰ turn to the left		
F7	150 ⁰ to the left		
F8	120 ⁰ to the left		
F9	90 ⁰ to the left	Advanced Commands	
F10	60 ⁰ to the left	w	toggle wire frame display
F11	30 ⁰ to the left	'	Frame Rate/Geometry Data
F12 or 'Q'	EXIT Program	l	toggle graphics state lighting (on/off)",
[or]	Decrease Airspeed by 5 kts.	m	cycle motion model type
- or +	Zoom 'in' or 'out'	p	toggle transparency (on/off)
f	Toggle fog (on/off)	s	cycle statistics
t	Toggle texture (on/off)	u	toggle backface display (on/off)
x	Pause program	b	toggle buffer mode (single/double)
SHIFT 'p'	VNE / Max Climb	j	toggle channel rendering (on/off)
SHIFT 'd'	Toggle Day/Night	k	toggle channel state (on/off)
⇐ ⇨	Once = ½ SRT Twice = SRT	P	print current eye point location
↑ ↓	Climb = 500 fpm(VSI) Nulls to zero	z	toggle Z-Buffer (on/off)
SHIFT 't'	Change direction of flight to 12 o'clock	'?'	toggle runtime key display in overlay (on/off)

* All turns are SRT or 90⁰ of turn in 30 seconds.

Table 2. VEHLO Program Keyboard Instructions

E. EXPERIMENT SETUP

1. Subject Pilots (PUI)

This experiment was designed around the evaluation of seven novice helicopter pilots with the U.S. Marine Corps. The experiment was conducted at the CH-46E Fleet Replacement Squadron, Marine Medium Helicopter Training Squadron 164 (HMMT-164) located at Marine Corps Air Station (MCAS) Camp Pendleton California. The novice pilots will be referred to as Replacement Aircrew (RACs) for the remainder of this work. The test subjects were previously designated military helicopter pilots after completion of initial helicopter training with the U.S. Navy at Training Air Wing 5 in Pensacola Florida. All subjects were male novice pilots and were undergoing the Combat Capable Phase Helicopter Training in accordance with the U.S.M.C. Training and Readiness Manual (Figure 30). Upon completion of the Combat Capable phase of training the pilots are designated as Helicopter Second Pilot (H2P) in the CH-46E and transferred to the Fleet Marine Force (FMF) for operational duty.

The subject pool was all eligible for the NAV 130 and NAV 131 day navigation flights IAW the CH-46E T&R Manual. Mission criteria and performance standards are shown in Appendix A. All the students had completed all required prerequisites for these flights. Those prerequisites consisted of completing a one hour academic navigation class and at least FAM 113 (Familiarization).

The ability to dynamically prioritize tasks is a critical yet learned skill required for all helicopter flight regimes. All test subjects were previously

designated pilots and thus they meet the expert criteria with regard to the knowledge about, and skills involved in, the activities of a multitasked cockpit environment.

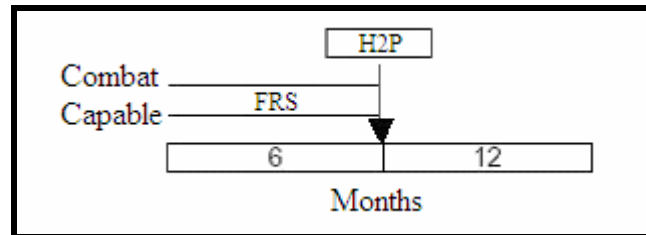


Figure 30. Fleet Replacement Squadron (FRS) Training Timeline

2. Treatment

Subjects were all issued a preflight questionnaire prior to beginning the experiment. Each participant was then briefed by the common Instructor Pilot (IP). The IP used in this experiment was a Standardization pilot and is in charge of qualifying all new student pilots and Instructor Pilots. Additionally he was in charge of the Academics Department at the training squadron.

a. Entrance Questionnaire

Each novice pilot completed a pre-flight questionnaire prior to the flight brief. The preflight questionnaire is shown in Appendix D. The questionnaire was an attempt to gauge the subject pilot's level of training, proficiency and simulator experience of any type. It was also used to ascertain the subjects perception of criteria used to evaluate low level navigation flight.

b. Flight Briefing

The preflight brief is important for safety and to have effective aircrew management. The preflight brief for the VEHELO flight was conducted with the same resources

and in the same manner as the brief conducted for the aircraft. It was performed by the Instructor Pilot (IP) using the CH-46E NATOPS briefing guide and required Squadron Standard Operating Procedures (SOPs). The Briefing Guide is depicted in Appendix E and reflects those areas that are pertinent to these NAV flights and CRM training. Each subject was briefed individually for the VEHELO flight and the aircraft flight. It is the IP's responsibility to verbalize the plan. He is also responsible for ensuring that each pilot understands and acknowledges the plan.

The preflight brief covered standard flight parameters such as airspeeds, angle of bank, altitudes and flight path to name a few. The brief provides a basis on which to build a higher level of teamwork that will be required during the flight. The IP would normally use numerous resources from which to brief the PUI and set up the training environment for the flight. Some of these resources are the Standardization Manual, T&R Manual (Appendix A) and the CH-46E NATOPS Manual (Appendix E). The brief included discussion of, but was not limited to, the following items.

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	- Comfort Levels - Boundaries - Wind correction for Dead Reckoning Navigation - In-flight route changes

	▪ METT-TSL considerations	
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 3. Preflight Brief Items as Per T&R

The above table uses some terms that are not universally defined. Use of the terms terrain, contour features and triangulation are considered 'skills' for the purpose of this thesis. There is much work to be done to properly establish definitions for the two terms. Ongoing research has yet to properly define a skill, that which can be learned and improved upon versus a trait, that ability which already exists in the pilot.

c. Debrief

A debrief was conducted by the Instructor Pilot (IP) after the completion of all flights, simulated and actual. A thorough debrief is required after all flights. It allows both pilots, IP and test subject, to go over the flight details. This step was completed prior to the subject completing the post flight questionnaires. Again the Standardization Manual, T&R Manual and NATOPS Manual are normally used for debrief guidelines.

d. Exit Questionnaire

Each novice pilot completed a postflight questionnaire after the flight debrief with the IP. The questionnaire is shown in Appendix F. The questionnaire was

an attempt to gauge the subject pilot's opinion of the VEHELO system. The questions were created to appreciate the fact that the subject pilots were new to this aircraft type and had yet to acquire any fleet experience.

3. System Artificialities

The VEHELO maintains some of the same built-in artificialities that had been noted in the previous version (ChrAVE). As with that earlier system some of the artificialities were desired while others were not. The following descriptions refine previously noted aspects as well as introduce those that were found while using VEHELO.

a. Visual Artificialities

The subject pilots were exposed to a system in which the colors deviated slightly from the real world. As discovered in the earlier testing it proved to be negligible as perceived by the subject pilots.

Also the camera used for the VEHELO in this thesis was one of the models used during the evaluation of the ChrAVE. The camera had an inherent ability to display to the user varying levels of brightness during rapid head movements of the user. This arises from the camera's automatic gain control not compensating effectively and giving the variations on the HMD that the views. The camera also uses a fixed focal length which gives rise to the user perceiving anything beyond approximately 36 inches as being blurry. This was not a serious problem as the majority of the User's scan was through the HMD (viewed beyond the 36 inches interval). Items viewed under the HMD were easily identifiable with no distortion.

The basic design of the VEHELO system and the earlier ChrAVE involves a 60 degree field of view (FOV). This limited FOV causes the user to have a limited (unrealistic) periphery view displayed in the HMD. Each user easily compensated for this by utilizing more head movements. As a side note, this additional motion proved to be extremely similar to that required during flight involving the use of Night Vision Goggles (NVGs). NVG simulation will be discussed in the last chapter.

The user's FOV of the VEHELO (cockpit) was set-up to represent a left seat pilot's perspective. This included the view through the left chin bubble of the mock cockpit. It allowed the blue screen background to approximate the pilot's 8 o'clock to his 2 o'clock. This accurately represented the left seat limitations of not being able to see past the pilot in the right seat of the aircraft.

b. Ergonomic Artificialities

The cockpit was set-up to represent a generic configuration and not specifically the aircraft used for testing. This still accurately provided the subject with the ergonomic restrictions encountered in the actual cockpit of the aircraft. Restrictions such as pedal movement, cyclic stick and kneeboard interference with navigational products prove to be educational to the novice pilots.

The weight of the combined HMD and tracker unit was comparable to what is actually worn in flight but the unit's balance was different. User's reported the unit was weighted too heavily in the front and, although adjustable, proved to be bothersome during each flight. In flight a helmet would evenly distribute the weight to avoid 'hot

spots' on the subjects head. Future modifications will involve mounting the system on actual flight rated helmets to be worn by the test subjects.

The instrument panel CRT was designed to accurately represent the instruments of the aircraft, the Ch-46E, utilized during this experiment. It did not represent all the instruments but just those required for normal completion of navigational tasks.

c. Flight Profile Artificialities

Again as in the previous version, airspeeds were preplanned by the subjects. 100 knots was used for this experiment. The airspeed was able to be varied by the proctor, or IP, via keyboard inputs. This allowed the subject to communicate the need to vary airspeeds to accommodate changing flight profiles.

The simulated flights were all flown during 'windless' conditions. This allowed subject performance to be evaluated much easier in relation to time, distance and heading.

The lack of any pitching moment or change in pitch during changes in flight profiles proved to provide a very 'artificial' feel for all participants.

Turns were restricted to standard rate turns (SRT) and $\frac{1}{2}$ SRT. SRT are conducted by 6° of heading change per second using a 45° angle of bank. The $\frac{1}{2}$ SRT is conducted with 3° of heading change per second and a 22° angle of bank. The system is designed in this fashion to prevent any disorientation on the part of the subject. This also provided artificiality in that many pilots are familiar with turns that are much tighter. This created a need for all turns in the simulated flight to be much wider than in

the actual aircraft. It did however provide a smooth transition into and out of all turns thus providing a steady platform that is required for effective navigation training.

d. Task Artificialities

Many of the task artificialities from the previous version of the VEHELO were addressed and overcome. This experiment concentrated on the system being used in the navigation syllabus and represented the NAV 130 and NAV 132 flight IAW the Training and Readiness (T&R) Manual as shown in Appendix A. This afforded the proctor, or IP, to conduct user's map preparation exactly as would be required for an actual flight in the aircraft. The preparation included manual map products produced by each subject. It also included the use of normal squadron assets such as the Falconview flight planning system. The subjects were all given the task of preparing a route card IAW the IP's route selection, using all available assets within the Squadron. The route card is depicted in Figure 31 below.

Turn Pt	Type	Fix/Point	Latitude	Elev	Aspd	Altitude	Temp	MH	Leg Time	Leg Dist	Leg Fuel
	DTD	Description	Longitude	MV	Bank	Wind	FF	MC	Clock Time	Total Dist	Total Fuel
1	ST	KNFG 21/RVW	N 33 18.4	78FT		0A	+15C	212	00+00+00	0.0	200
		CAMP PENDLETO	W117 20.9	13.2E			0	212	00:00:00	0.0	4200
2		PT CANYON/L	N 33 21.8	141FT	100T	500A	+14C	008	00+02+09	3.6	42
			W117 19.3	13.2E			1163	008	00:02:09	3.6	4158
3		.TEMECULA	N 33 28.8	1010FT	100T	500A	+12C	040	00+06+55	11.5	132
			W117 08.4	13.1E			1146	040	00:09:04	15.1	4026
		.level off	N 33 29.5	1158FT	N/A	1658A	+9C	063	00+02+37	3.1	45
			W117 04.7	13.1E			1028	063	00:11:41	18.2	3981
4		.RD INTERSEC	N 33 31.8	2316FT	100T	500A	+9C	063	00+05+33	9.2	103
			W116 54.0	13.1E			1117	063	00:17:14	27.5	3878
5		.OAK GROVE	N 33 23.2	2762FT	100T	500A	+9C	134	00+06+07	10.2	113
			W116 47.4	13.1E			1105	134	00:23:21	37.7	3765
6		.WARNER SPRI	N 33 17.1	3143FT	100T	500A	+8C	115	00+05+56	9.9	108
			W116 38.1	13.0E			1094	115	00:29:17	47.5	3657
7		.HENSHAW DAM	N 33 14.4	2635FT	100T	500A	+9C	234	00+04+08	6.9	76
			W116 45.7	13.0E			1102	234	00:33:25	54.4	3581
		.descent pt	N 33 11.6	1850FT	100T	1285A	+9C	238	00+05+06	8.5	93
			W116 55.2	13.0E			1099	238	00:38:31	62.9	3488
8		.LAKE WOHLFO	N 33 10.3	1470FT	N/A	500A	+11C	238	00+02+20	4.2	44
			W117 00.0	13.1E			1143	238	00:40:51	67.1	3444
9		.LANCASTER M	N 33 19.4	1417FT	100T	500A	+11C	310	00+06+48	11.3	127
			W117 08.0	13.1E			1122	310	00:47:39	78.4	3317
10		.NORTH INT/L	N 33 22.7	823FT	100T	500A	+12C	284	00+04+27	7.4	84
			W117 15.9	13.2E			1128	284	00:52:06	85.9	3233
11		KNFG 21/RVW	N 33 18.4	78FT	100T	500A	+14C	211	00+03+35	6.0	68
		INDLETON MCAS	W117 20.9	13.2E			1139	211	00:55:41	91.8	3165

Figure 31. Experiment Flight Route Card.

F. EXPERIMENT PROGRESSION AND RESULTS

1. Preflight Questionnaire Results

The preflight questionnaire contained some questions that proved useless for the data collection required for this thesis. Many of the questions they contain proved valid for this body of work. Table 4 summarizes the results.

There were a few of the questions that were worth further discussion. The results showed that the subject pool was really a novice group with all having less than 120 hours in the past 12 months and less than 280 hours total. The overall trend noted was that most thought that timing was more important than distance from the intended flight path.

Also the subjects would most likely benefit from standards by the IP/proctor being addressed while flying the VEHELO. This is because the whole group believed that aircraft could be further off of the intended flight than at the checkpoint. They missed the correlation that quality navigation enroute allows the aircraft to arrive within an acceptable distance from the checkpoint.

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.

<u>Question Number</u>	<u>Results</u>	<u>Question Number</u>	<u>Results</u>
1	All Subjects < 120 hrs.	12	N/A
2	All subjects < 280 hrs.	13	All subjects rcvd Navigation academic class w/in 30 days.
3	100% = NO	14	All subjects over 6 months (Flight School)
4	▪ 66% = YES ▪ 33% = NO	15	66% = Timing 33% = Distance
5	One subject required corrective lenses (20/40 corrected to 20/20)	16	100% = NO
6	▪ 33% = YES ▪ 66% = NO	17	N/A
7	No subject had VE experience	18	Results described below
8	N/A	19	▪ 66% = 500 meters ▪ 33% = 400 meters
9	100% = NO	20	▪ 33% = 500 meters ▪ 66% = 200 meters
10	N/A	21	▪ 66% = NO ▪ 33% = YES
11	▪ 66% = NOVICE ▪ 33% = AVERAGE	22	100% = NO

Table 4. Preflight Questionnaire Results

All the subjects stated that accurately knowing present position was the second most important item on the list. The remainder of the answers reflected a sense of not knowing USMC requirements and lack of experience in using CRM.

Additionally the results cumulatively reflect the advantages of having a tool such as the VEHELO to first teach the skills of terrain appreciation and CRM. These skills are normally introduced in the aircraft thus making the flights less effective.

2. Recorded Data from VEHELO System and Aircraft

The VEHELO system recorded the data onto its hard drive as the subject pilots flew the system. 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). The two data files were overlaid upon the preplanned flight route as shown in Appendix G. It is from this GPS data that the conclusions for flight path deviation were made.

Results were tabulated and quantified as described in the following section. The data depicts the VEHELO group, those that flew the VEHELO and the aircraft against the AIRCRAFT group, those student pilots that flew only the aircraft.

Comparing the VEHELO group to the AIRCRAFT only group on a measure of average proximity to checkpoints along the route, it can be seen that the VEHELO group performs significantly better than the AIRCRAFT only group ($P=0.059$, $F=8.785$) suggesting that VEHELO had a strong positive effect on navigation performance.

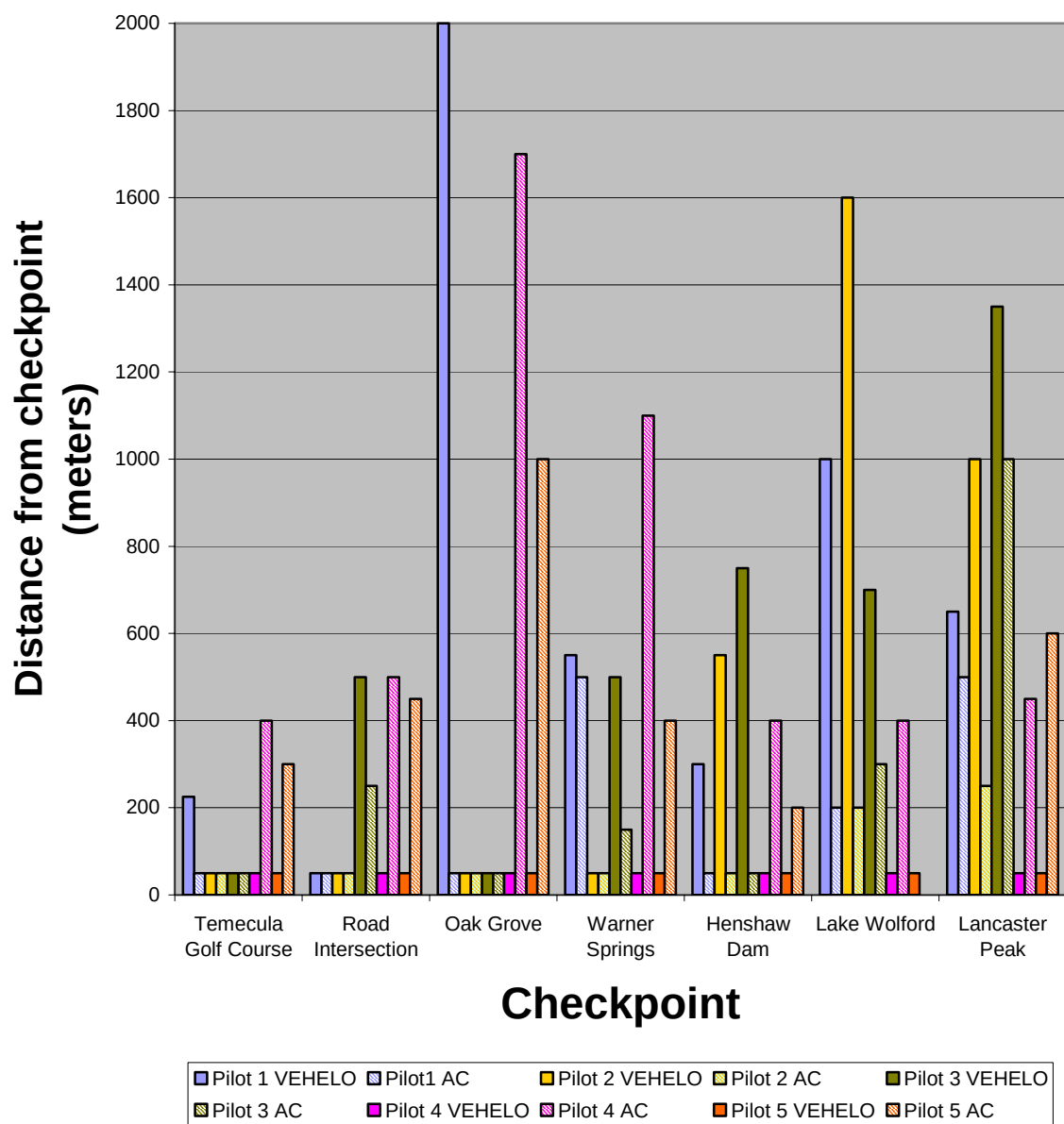


Figure 32. Subject's Checkpoint Proximity

Subject	Flight Mode	Checkpoints (distance in meters)							Avg. Distance from checkpoint
		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
6	VEHELO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Aircraft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	VEHELO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Aircraft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes: (1) Subjects 6 and 7 had flights in aircraft cancelled. Timeline did not permit inclusion in this study.

(2) Point Canyon checkpoint used for warm-up.

Table 5. Subject's Checkpoint Proximity

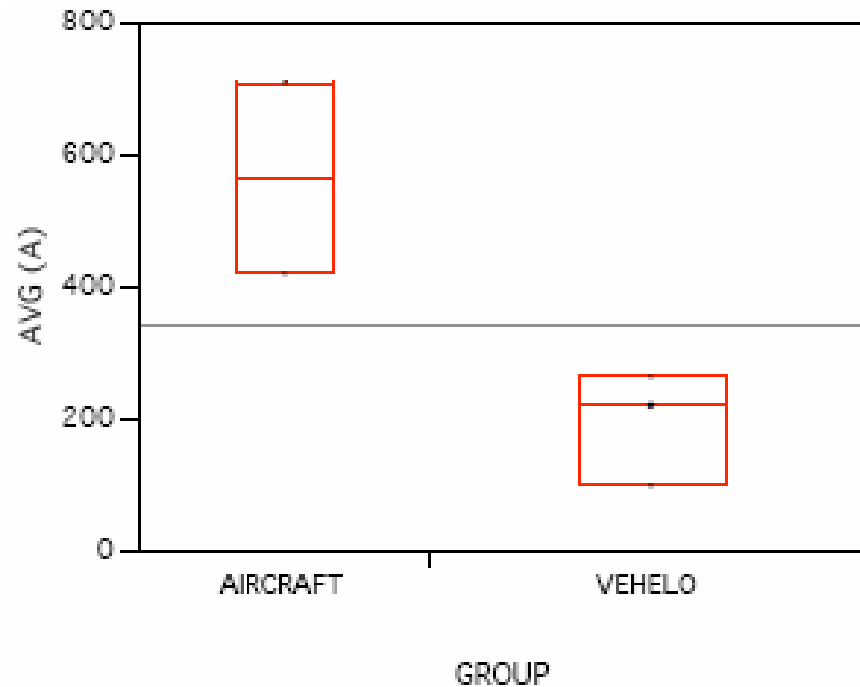


Figure 33. One-way Analysis of AVG(A) by Group.

Quantiles							
Level	Minimum	10%	25%	Median	75%	90%	Maximum
AIRCRAFT	420	420	420	563.5	707	707	707
VEHELO	100	100	100	221	264	264	264
Oneway Anova							
Summary of Fit							
Rsquare		0.745438					
Adj Rsquare		0.660584					
Root Mean Square Error		136.1941					
Mean of Response		342.4					
Observations (or Sum Wgts)		5					
t Test							
Assuming equal variances							
	Difference	t Test	DF	Prob > t			
Estimate	368.500	2.964	3	0.0594			
Std Error	124.328						
Lower 95%	-27.166						
Upper 95%	764.166						
Unequal Variances							
	Difference	t Test	DF	Prob > t			
Estimate	368.5	2.430	1.23931	0.2080			
Std Error	151.7						
Lower 95%	-645.0						
Upper 95%	1382.0						
Analysis of Variance							
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F		
GROUP	1	162950.70	162951	8.7850	0.0594		
Error	3	55646.50	18549				
C. Total	4	218597.20					

Table 6. One-way ANOVA

Oneway Analysis of AVG (A) By GROUP					
Oneway Anova					
Means for Oneway Anova					
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
AIRCRAFT	2	563.500	96.304	257.0	869.98
VEHELO	3	195.000	78.632	-55.2	445.24
Std Error uses a pooled estimate of error variance					
Means Comparisons					
Dif=Mean[i]-Mean[j]					
	AIRCRAFT	VEHELO			
AIRCRAFT	0.00	368.50			
VEHELO	-368.50	0.00			
Alpha= 0.05					

Table 7. One-way ANOVA (cont.)

A plot of the average deviation from checkpoints for the VEHELO (AVG (V)) against the same measure for the AIRCRAFT (AVG (A)) is shown below in Figure 33. It depicts a high positive correlation suggesting that VEHELO may be a good predictor of performance in the aircraft. Ideally, the VEHELO could be used as a measure of readiness to perform a mission. Because of the small subject population in this study, the results are inconclusive but a trend is suggested. This issue will require further research for verification.

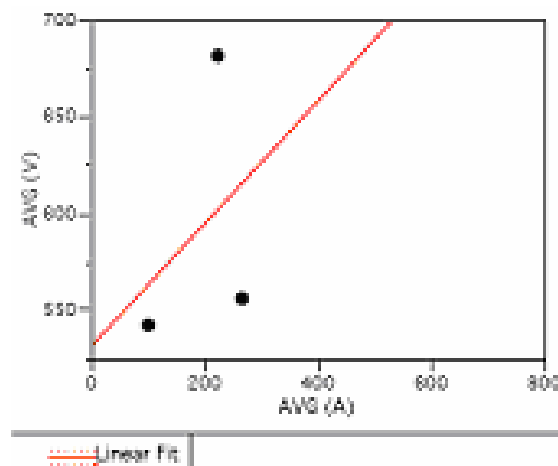


Figure 34. Bi-Variate Fit of AVG(V) by AVG(A).

Linear Fit				
AVG (V) = 532.24506 + 0.316692 AVG (A)				
Summary of Fit				
RSquare		0.123822		
RSquare Adj		-0.75236		
Root Mean Square Error		101.3092		
Mean of Response		594		
Observations (or Sum Wgts)		3		
Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1450.449	1450.4	0.1413
Error	1	10263.551	10263.6	Prob > F
C. Total	2	11714.000		0.7711
Parameter Estimates				
Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	532.24506	174.3766	3.05	0.2016
AVG (A)	0.316692	0.842432	0.38	0.7711

Table 8. Linear Fit

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 the 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

The postflight questionnaire proved to have a few answers from which some valid assumptions could be made. The first was that the majority of subjects thought the system was good as a 'rehearsal tool' before flying the route in the aircraft. Second was that the majority of subjects believed the voice communications introduced and practiced in the simulator were very much like those

experienced in the actual aircraft. And lastly was that the group overwhelmingly appreciated the terrain appreciation the system afforded them but all disliked the level of detail from the database.

Although it was not the intent of this experiment, they all disliked the lack of manmade cultural features. They detailed items to add such as more roads, buildings and structures like power lines. The results also included a natural phenomenon to add such as weather and time of day changes.

5. Instructor Pilot Comments

The intent was for the Squadron's Instructor Pilot (IP) to fly the students in the VEHELO and in the aircraft. This experiment deviated from that intent because of scheduling issues. The VEHELO portion of the experiment utilized me in the capacity of the IP. My qualifications include my recently having been the Standardization Pilot and a Instructor Pilot at the FRS for three years (1999-2002).

The Instructor Pilot (IP) for this experiment was an experienced standardization pilot with the Fleet Replacement Squadron (FRS). He was responsible for the training of not just the student pilots but also that of the Instructors Under Training (IUT). I briefed the IP prior to the experiment and we ran both portions of the experiment, VEHELO and aircraft, in the same manner.

With minimal training an IP can be taught to use the VEHELO in a manner in which they can run the experiment.

After all this is the goal of any system developed for the fleet. It must be easily used by the intended audience for it to be effective.

His overall statement was "The VEHELO trainer seemed beneficial in several areas." The summarized comments from his After Action report are shown in the following Table 7 below.

Preparation	▪ All subjects received the same route via checkpoints circled on a map. ▪ All prepared their own cockpit maps for both flights.
Standard terminology	▪ The instructor in the VEHELO device can teach standard terminology (right, hard right, easy right, creek, saddle, etc). ▪ If the pilot can practice this on the ground, he will be much better prepared to navigate.
Timing	▪ Students got a feel for how fast the aircraft will move across the map at the selected airspeed. ▪ This could be great when flying routes that switch from one map scale to another (IP inbound).
Crew Resource Management	▪ Students were not shy about giving commands to the pilot at the controls (PAC) and when they practice in the trainer, they are forced to tell the operator where to fly, and they get used to directing the aircraft. ▪ Lastly they were better at using the crew chief to aid in navigation, perhaps because the operator of the simulator was pretending to be the crew chief on the opposite side of the aircraft, pointing out things from the map.
Summary	▪ Overall these students navigated a little better

	than normal, particularly in general terrain orientation and crew coordination. At this level and at flight school, this device would be a great instructional tool. If attached to a better database, compatible with NVGs, this could be a great tool for real world missions.
--	---

Table 9. IP/Proctor Summarized Results

The Academic Training Forms (ATF) 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 three subjects (1,2,and 3) who flew the VEHELO prior to the training flights in te aircraft.

Subject #1

Dead reckoning type navigation worked fairly well. He used time tick marks to keep himself oriented, and was able to identify all checkpoints. Had trouble initially identifying one road intersection, and picked the wrong town for another checkpoint. Back yourself up with altitude if you are using a prominent terrain feature to identify a checkpoint (picked the wrong mountain top).

"Overall, pretty good job of terrain associating and dead reckoning, a little trouble with cultural feautres. Would have successfully completed the mission if he was actually going somewhere."

Subject #2

Was able to plug the route into PFPS, make a route card, and load a brick by the time we launched. Demonstrated GPS navigation. Dead reckoning navigation worked fairly well to keep him oriented, with timing tick marks to keep him on track. Had a little trouble with one road intersection, and then the Lancaster Mtn. checkpoint. Back yourself up with altitude when using a hilltop as a checkpoint. Good crew coordination. Gave the crew specific things to look for, and gave good commands to the PAC.

"Overall- effective navigation, will get better at map/ground comparison with time."

Subject #3

Managed to get PFPS and a brick loaded by launch time, so we were able to demonstrate GPS navigation. Navigation- AA. Good terrain association and dead reckoning. He was on track the entire route, and seemed to know where he was throughout. Good use of limiting features and vertical relief. Good crew coordination, gave the crew specific tasks and kept the flying pilot's eyes outside the aircraft.

"Overall- effective navigation skills, ready for more challenging routes/conditions."

THIS PAGE INTENTIONALLY LEFT BLANK

IV. MODIFICATIONS AND RECOMMENDED IMPROVEMENTS

A. MODIFICATIONS COMPLETED

The experiment conducted for thesis provided results from which data could be used for future modifications. The conclusion resulted from conducting the experiment as much as from the data themselves. Some modifications have already been incorporated into the VEHELO system.

1. Poor Communications

Problem - Audio communication with the PUI proved to be slightly artificial which resulted in a form of negative training. Because of the aural variations within the test space in which the mock cockpit was set-up the PUI had to assume many the IP communications. There was also some level of interference with ambient noise within the local area.

Solution - In an attempt to simulate a more immersive environment in which to instruct the PUI, an upgraded audio capability was added. A voice operated transmit (VOX) and Intercommunications capability was incorporated into the VEHELO system. This was accomplished through the use of a set of 'Dave Clark single sided headset for the IP/Proctor. It also allows the PUI to utilize his actual flight rated helmet (minus the snap-on visor). The IP and PUI are connected through a commercial general aviation ICS. The model incorporated is a PC-400 battery operated ICS communication box. The PC-400 was modified with a 'pig-tail' audio cable to be able to plug into the flight rated helmet worn by the PUI.

2. Headgear Replacement

Problem - The headgear to support the V8 HMD was effective but unrealistic for the PUI to wear while training in the VEHELO. 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 modified by reinstalling the head tracker unit more forward on the visor. The associated cabling was also rerouted and condensed to be more 'user friendly'. The HMD also had snap-on straps (i.e. the same as those on the visor) to allow it to mount in the same position as the visor would on the flight helmet. An added benefit of this modification is that the HMD mounted in this fashion replicates the NVGs used by today's helicopter pilots. The weight and distribution of the HMD mounted in this fashion appear to replicate the ANVIS-7 and ANVIS-9 NVGs now in use with the USMC and USN.

3. Smart Remote Replacement

Upon completion of this experiment, the Smart Remote unit was replaced with newly available software. The new software completely replaces the remote control unit. This allows the Ultimatte 400 Mixer to be controlled via keyboard entry and a Microsoft Windows environment on the Stealth laptop console. It also allows a savings on seven inches high shelf location in the mobile equipment box.

B. RECOMMENDED IMPROVEMENTS AND RESEARCH

1. LED Litering

Advances in the Chromakey technology has advanced greatly since the creation of the early version of the VEHELO. The most troublesome and cumbersome part of the

system involve the fluorescent light fixtures. They are cumbersome to move and require a great amount of fine adjustments for the system to work effectively.

A solution to the lighting is to use an LED light ring from Reflecmedia referred to by it's commercial product name 'Litrering'. This product uses the Chromatte technology. Chromatte technology is a different means of keying from chromakey now being used. The technology utilizes a special reflective fabric and a circle of LEDs configured in a light ring which is placed around the camera lens. This combination is able to generate the chrominance required.



Figure 35. Reflecmedia's LED Litrering

The LEDs shine their light onto the Chromatte material which is made up of millions of small hemispherical aluminum coated glass beads. The net optical result is that the light shined onto the Chromatte material is only reflected back at its source (with the camera lens in the center). All required light is provided by the LED Litrering and thus it can be used in most lighting conditions.

A VEHELO system configured with the Litering and Chromatte material would permit additional training while using the system. The newly configured system would permit critical simulated darkened cockpit and NVG flights. It would also provide a savings in set-up/experiment time, lighting and ease of use.

Initial testing without test subjects proved extremely successful. Green LEDs provide more light than the optional blue and should be used for development in the next version of the VEHELO system. The commercial version of the light ring only comes in three sizes, the smallest of which is still too large to effectively mount around the system's Head Mounted Display (HMD) mounted camera. The light ring could be slightly modified to more closely fit around the current camera lens used on top of the HMD.

2. Modified Equipment Case(s)

The mobility of the VEHELO is much more effective than that of the earlier version tested by Lennerton. As convenient as the 'box on rollers' is, it can be improved upon. The easier the system is to transport, set-up and operate the more useful it will be for the intended users.

The software modification described above allows for a savings of seven inch tall shelf location and approximately 1.55 cubic feet inside the mobile equipment box. All this would allow the system to be mounted in two half size equipment cases. These cases would be man portable and would allow much more portability of the system. In this configuration transportation would not be a major concern as it is with the current configuration.

3. Equipment Selection/Modification

Some trouble concerning equipment fuses were experienced during the experiment and subsequent testing. All equipment unit used are commercial off the shelf units. This maintains a low overall price but does not address the support and time lines unique to NPS.

Suggested solution would be to have external, easily accessible fuses as criteria in the selection of future equipment. Also current units could be modified to accept an externally mounted replaceable fuse.

All this is an attempt to save time, money, and research availability from a possible work stoppage for something as simple as a blown fuse.

4. Equipment Transportability

To ease the logistical burden of transporting the VEHELO system, some minor modification should be completed prior to its next evaluation. Some of these are:

- Cut the PVC vertical screen poles in half and install an oversized sleeve to act as a cup to hold the upper piece when installed for use.
- Modify the Instrument Monitor stand to be a foldable, easily transportable unit.
- Create a longer ICS cord for audio connection between the Proctor/IP via ICS box to the PUI's flight helmet.

5. 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 Littering will permit all of these training scenarios.
- Attempt an experiment inside the actual aircraft in the following fashion:
 - o Obtain authorization to use an aircraft inside the hanger deck. HMMT-164 has already been briefed and approved this experiment when NPS is ready.
 - o Drape loose material over the windscreen and secure with removable nonmetallic fasteners (FOD Hazard).
 - o Power the system from the hanger deck outlet.
 - o Construct extended cables for the Instrument monitor and headgear to reach the equipment cart.
 - o Install hook and loop fasteners to accommodate the instrument panel being installed in front of the left seat in the aircraft.

- o All equipment and ICS cables will be routed from the PUI, through the crew entry tunnel and onto the hanger deck to connect to the equipment case.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSIONS

The VEHELO proved itself to be an immersive and highly familiar environment in which a pilot could learn initial piloting skills as well as to conduct proficiency training. The current configuration has addressed many of the issues that arose from earlier testing of the initial version system. The lack of first person fidelity of the earlier system was addressed in the current VEHELO system. The mock cockpit was configured for the Type/Model/Series (T/M/S) of the aircraft used for testing thus providing a much more familiar physical environment for the PUI.

Observations made during the experiment and interpretation of the data collected suggests that the latest VEHELO was successful at accomplishing the primary goal of this thesis. The system proved that it can be used in the capacity as a trainer for initial navigational training. It was effective at quantifying the advantages of a student learning the skill of terrain appreciation on the ground. The student then brought that new skill and an increased level of Situational Awareness (SA) into aircraft. Later research could suggest monetary or time savings in the training commands as well as in the fleet squadrons.

It also showed how it can be used to instruct Crew Resource Management training. This skill is required for all flight and not just in the navigational environment. It is also a skill that does not get taught or practiced in other simulated flights in the training commands.

The comments by the Instructor Pilot (IP) proved to be as valuable as any of the data received. It was his opinion

that the system made a noticeable difference in the performance of the two test groups of novice pilots.

In summation, this research proves that the value of an embedded trainer beyond that which was tested earlier. It shows a direction that future research with the system can take and suggests that there may be even more uses of the system than those already addressed in this and earlier work. An easily deployable and easy to use system will benefit the training of helicopter pilots at many different levels of pilot training. Whether the system is used to instruct novice pilots, rehearse a planned route of flight or raise a pilot's levels of proficiency, chromakey technology and an embedded trainer are tangible solution and merit further research.

LIST OF REFERENCES

- Chief of Naval Operations (1992). NWP 55-9-ASH, Vol. I (Rev. F) FMFM 5-35 Assault Support Helicopter Tactical Manual. Washington, DC: Government Printing Office.
- Chief of Naval Operations (1995). NWP 55-9-CH46, Vol. I A1 -H46AE-TAC-000. CH-46E Helicopter Tactical Manual. Washington, DC: Government Printing Office.
- Marine Corps Order P3500.50 Ch 1 (2004). Aviation Training and Readiness Manual (T&R) CH-46E. PCN 10203353500. Washington, DC: Government Printing Office.
- Commanding Officer HMMT 164 (2004). CH-46E Standardization Manual. Marine Air Group 39, Camp Pendleton CA.
- Funk, Kenneth & Colvin, Kurt (2000). Cockpit Task Management. [WWW Document]. URL <http://flightdeck.ie.orst.edu/CTM/> June 2004
- O'Conner, Paul. University of Aberdeen, Industrial Psychology Research Group (2001). An Interactive Virtual Environment for Training Map-Reading Skills in Helicopter Pilots. URL <http://www.sardawg.org/alpdownloads/aavpa%20crm%20survey.pdf> . June 2004
- Padfield, G.D. & White, M.D. (1997). Measuring Simulation Fidelity through an Adaptive Pilot Model. [WWW Document]. URL <http://pcwww.liv.ac.uk/eweb/fst/publications.htm>. June 2004
- Micheletti, J. D. & Wurpts M. J. (2000). Applying Chroma-Keying Techniques in a Virtual Environment. Southwest Research Institute, P.O. Drawer 28510, San Antonio, TX. [WWW Document]. URL http://www.tss.swri.edu/pub/pdf/2000AEROSENSE_HMD.pdf June 2004
- Barham, P., Plamondon, B., Dumanoir, P., & Pat Garitty (2001). VICTER: An Embedded Virtual Simulation System for Land Warrior (LW).

- Dismukes, K., Young, G., Captain Sumwalt, R. (1998). Cockpit Interruptions and Distractions. ASRS Directive. [WWW Document]. URL <http://asrs.arc.nasa.gov/directline issues/> June 2004
- Mole-Richardson Co. Inc. (2001). [WWW Document]. URL <http://www.studiodepot.com/store>. June 2004
- Pelco (1999). [WWW Document]. URL <ftp://www.pelco.com/ProductSpecs/2752.PDF>. June 2004
- Sullivan, J. A. (1998). Helicopter Terrain Navigation Training Using a Wide Field of View Desktop Virtual Environment. Unpublished Master's Thesis, Naval Postgraduate School, Monterey, CA.
- Lennerton, Mark (2004). Exploring a Chromakeyed Augmented Environment for Viability as an Embedded Training System for Military Helicopters. Unpublished Master's Thesis, Naval Postgraduate School, Monterey, CA.
- Ultimate Corp. (2000). Ultimatte-400 Deluxe Operating Manual. Chatsworth, CA.
- ReflectMedia, (2003). [WWW Document], URL <http://www.planetdv.net/frameset.asp?show=content&cat=16> June 2004
- Flight Link Inc. (2001). [WWW Document]. URL <http://www.flightlink.com/hardware/rotorwing/index.html>. June 2004
- Flo Co, Inc. (2001). [WWW Document]. URL <http://www.flo-co.com>. June 2004
- InterSense Inc. (1999). IS-600 Series Precision Motion Tracker User Manual. Burlington, MA.
- InterSense Inc. (2001). [WWW Document]. URL <http://isense.com/products/prec/is600/is600plus.pdf>. June 2004

Matsushita Electric Corporation of America (2002). [WWW Document]. URL http://www.panasonic.com/medical_industrial/gpus532.asp. June 2004

Virtual Research. (2000). [WWW Document]. URL <http://www.virtualresearch.com/index.html>. June 2004

THIS PAGE INTENTIONALLY LEFT BLANK

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

<u>STAGE</u>	<u>NO. EVENTS</u> <u>ACFT/SIM</u>	<u>NO. HOURS</u> <u>ACFT/SIM</u>	<u>CRP</u> <u>ACFT/SIM</u>
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	REPLY 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.

Ordinance. None.

External Syllabus Support. None.

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.

Ordinance. None.

External Syllabus Support. None.

THIS PAGE INTENTIONALLY LEFT BLANK

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	818525008E1107 2
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	Virtual Reasearch, USA	V8	N/A
10	HMD Control Box			V8EBY26 and USN 62271A2703

1 1	Head Tracker	Intersense	InertisCube ²	100-1MU00-0210 SC2-0210282-D
1 2	Instrument Panel Monitor	NEC	MultiSync	1880SX
1 3	Signal Converter	Leitch	ADC-6801 Mix Box Multi	0126364
1 4	Signal Converter	Leitch	SDC-100	N/A (Qty 2)
1 5	Equipment Case	Thermodyne	Quadraflex TM	One Case consisting of: ▪ Center Case w/internal racks ▪ 12107L Cover - Qty2 ▪ 12108R Cover - Qty 2
1 6	Rack-Mounted UPS	TrippLite	SMART450RT	9142ALCSM
1 7	Transient Surge Protector	Leviton		5500-190
1 8	Network Hub	Netgear	FS-105	N/A

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

APPENDIX C. HARDWARE SPECIFICATIONS

A. VRS V8 HEAD MOUNTED DISPLAY

- From Virtual Research Systems.

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

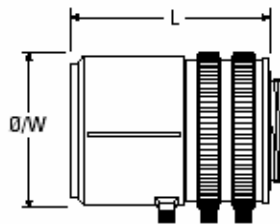
- 3-CCD High Performance Micro Head Color Camera with DSP from Panasonic.

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) super 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), 1/100, 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					
▪ Camera Head (Excluding Mounting Adapter)	<table><tr><td><u>Ht</u> 1 11/16 in (44mm)</td><td><u>Width</u> 1 5/16 in (34 mm)</td><td><u>Depth</u> 2.0 in (52 mm)</td><td><u>Weight</u> 0.24 lbs (110 g)</td></tr></table>	<u>Ht</u> 1 11/16 in (44mm)	<u>Width</u> 1 5/16 in (34 mm)	<u>Depth</u> 2.0 in (52 mm)	<u>Weight</u> 0.24 lbs (110 g)
<u>Ht</u> 1 11/16 in (44mm)	<u>Width</u> 1 5/16 in (34 mm)	<u>Depth</u> 2.0 in (52 mm)	<u>Weight</u> 0.24 lbs (110 g)		
▪ CCU (Excluding rubber foot & conn.)	<table><tr><td><u>Ht</u> 1 11/16 in (44mm)</td><td><u>Width</u> 8 1/8 in (206.5 mm)</td><td><u>Depth</u> 9.50 in (250 mm)</td><td><u>Weight</u> 3.74 lbs (1.7 kg)</td></tr></table>	<u>Ht</u> 1 11/16 in (44mm)	<u>Width</u> 8 1/8 in (206.5 mm)	<u>Depth</u> 9.50 in (250 mm)	<u>Weight</u> 3.74 lbs (1.7 kg)
<u>Ht</u> 1 11/16 in (44mm)	<u>Width</u> 8 1/8 in (206.5 mm)	<u>Depth</u> 9.50 in (250 mm)	<u>Weight</u> 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
<u>Operation</u>	-
▪ 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	<table><tr><td><u>Ht</u></td><td><u>Width</u></td><td><u>Depth</u></td><td><u>Weight</u></td></tr><tr><td>1.2 in</td><td>1.06 in</td><td>1.34 in</td><td>0.98 lbs</td></tr></table>	<u>Ht</u>	<u>Width</u>	<u>Depth</u>	<u>Weight</u>	1.2 in	1.06 in	1.34 in	0.98 lbs
<u>Ht</u>	<u>Width</u>	<u>Depth</u>	<u>Weight</u>						
1.2 in	1.06 in	1.34 in	0.98 lbs						

E. EXTRON VSC 200D VIDEO SCAN CONVERTER

- From Extron Electronics (VGA to D1)

<u>Video Input</u>	
• 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
<u>Video Processing</u>	
• 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
<u>Video Output</u>	
• 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
<u>Impedance</u>	- 75 ohms
<u>Sync</u>	
• Input Type	- Auto detect RGBHV, RGBS, and RGsB
• Output Type	- RGBHV, RGBS, and RGsB (all RGB formats are switch 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. LEITCH ADC-6801 SIGNAL CONVERTER

- From Leitch (RGB to D1).

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	- $\pm 10\%$
• Time Adjustment Range	- $\pm 1.8\mu\text{s}$
• Return Loss	- $>40\text{dB}$ to 5.5 MHz
Filtering As Per CCIR 601 Specifications	
• Frequency Response	- Y channel $\pm 0.1\text{ dB}$ to 5.5 MHz - Cr, Cb Channels $\pm 0.2\text{ dB}$ to 2.75 MHz
• Signal to Noise Ratio on all Channels	- $>64\text{ dB RMS}$, relative to 0.714 V, 10 kHz to 5.5 MHz
• Interchannel Crosstalk	- $<-50\text{dB}$
• 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	- $3.6\mu\text{s}$

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	- <u>4:2:2</u>
• FG and BG Out	- <u>4:2:2</u>
• 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	<table><tr><td><u>Ht</u> 0.98 in (2.5 cm)</td><td><u>Width</u> 2.95 in (7.5 cm)</td><td><u>Depth</u> 4.7 in (12.0)</td><td><u>Weight</u> lbs</td></tr></table>	<u>Ht</u> 0.98 in (2.5 cm)	<u>Width</u> 2.95 in (7.5 cm)	<u>Depth</u> 4.7 in (12.0)	<u>Weight</u> lbs
<u>Ht</u> 0.98 in (2.5 cm)	<u>Width</u> 2.95 in (7.5 cm)	<u>Depth</u> 4.7 in (12.0)	<u>Weight</u> 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	<u>Ht</u> 7.0 in	<u>Width</u> 17.0 in	<u>Depth</u> 1.75in	<u>Weight</u> 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	<table><tr><td><u>Ht</u> 7 in</td><td><u>Width</u> 19 in</td><td><u>Depth</u> 18 in</td><td><u>Weight</u> 35 lbs</td></tr></table>	<u>Ht</u> 7 in	<u>Width</u> 19 in	<u>Depth</u> 18 in	<u>Weight</u> 35 lbs
<u>Ht</u> 7 in	<u>Width</u> 19 in	<u>Depth</u> 18 in	<u>Weight</u> 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/m ² 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 1.75 in (482.6 mm)	Width 19 in (44.5 mm)	Depth 26.6 in (600 mm)	Weight 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	<u>Ht</u>	<u>Width</u>	<u>Depth</u>	<u>Weight</u>
	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	<u>Ht</u> 1.71 in (43.43mm)	<u>Width</u> 19.0 in (482.6mm)	<u>Depth</u> 4.55 in (115.57 mm)	<u>Weight</u> 15.5 lbs (7.0 kg)

0. THERMODYNE QUADRAFLEX™ 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	<u>Ht</u> in	<u>Width</u> in	<u>Depth</u> in	<u>Weight</u> <u>Empty</u> Lbs <u>Weight</u> <u>Operational</u> Lbs

P. NETGEAR HUB

Description	- Netgear FS105 - switch - 5 ports
Device Type	- Switch
Form Factor	- External
Compliant Standards	- IEEE 802.3U, IEEE 802.3i, IEEE 802.3x
Ports Qty	- 5 x Ethernet 10Base-T, Ethernet 100Base-TX
Data Transfer Rate	- 100 Mbps
Data Link Protocol	- Ethernet, Fast Ethernet
Communication Mode	- Half-duplex, full-duplex

Features	– Full duplex capability, uplink, MDI/MDI-X switch			
Dimensions	<u>Ht</u> in (2.7 cm)	<u>Width</u> In (15 cm)	<u>Depth</u> In (10.3 cm)	<u>Weight</u> 0.6 kg)

APPENDIX D. USER'S MANUAL

VIRTUAL ENVIRONMENT HELICOPTER SYSTEM **(VEHELO)**

SET-UP GUIDE AND PROCEDURES

I. SET-UP INSTRUCTIONS

1. Place the three collapsible Blue Screens to represent the 8 to 2 o'clock perspective of the PUI. Additionally place the 'loose' piece of matting in a position to represent the chin bubble view. Ensure all seams are covered and material is flat and taut.
2. Install a whiteboard or similar material in a position on the 'pilot's side' of the mock cockpit. This is to represent the area that could not be seen by the copilot during normal flight because of the pilot's body position.
3. Place the Flight Link Flight Controls and Seat in the center of the three collapsible screens.
4. Set-up the 'instrument console' CRT on its wooden base centered in front of the pilot's seat position.
5. Install the short (2 foot) fluorescent light fixture ahead of the CRT facing the front blue screen matting.
6. Position the two vertical light fixtures to attain the required amount of light reflected from the blue matting.
7. Ensure all components are connected IAW Figure 29 and Table 1.
8. Connect external power to the equipment box and power strips.

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 10. VEHELO Connections

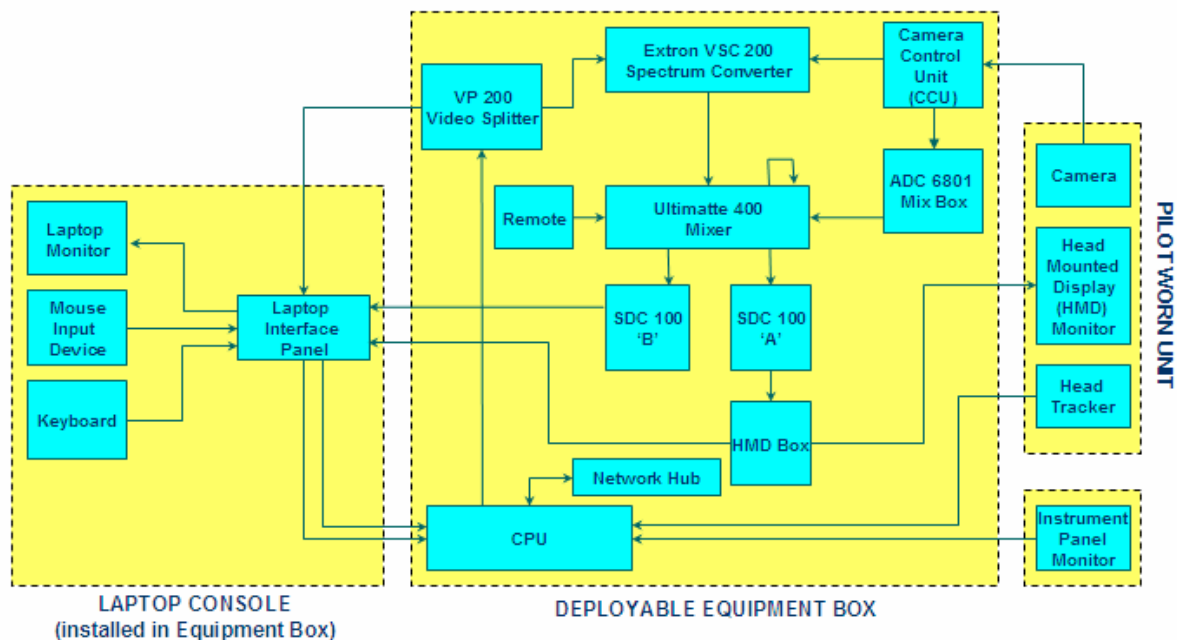


Figure 36. VEHELO Set-up Configuration

II. START-UP PROCEDURES

1. Turn the UPS on. Ensure it is operating on AC power and not battery power.
2. Turn on Ultimatte 400.
3. Turn on CPU after step #2.
4. After CPU boots, log on with -

Username: Seahawks
Password: Seahawks

5. Start the desired VEHELO program via shortcut on desktop.

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

6. 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.

NOTE: It might be necessary to move the cursor onto the bottom edge of the flight simulator window and tap SHIFT 'V' three times to get the proper display (flight sim view on laptop and instrument panel only on CRT in front of the pilot).

7. 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.

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 VEHELO. 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	Keystroke	Command
F1	30 ⁰ turn to the right		
F2	60 ⁰ turn to the right		
F3	90 ⁰ turn to the right		
F4	120 ⁰ turn to the right		
F5	150 ⁰ turn to the right		
F6	180 ⁰ turn to the left		
F7	150 ⁰ to the left		
F8	120 ⁰ to the left		
F9	90 ⁰ to the left	Advanced Commands	
F10	60 ⁰ to the left	w	toggle wire frame display
F11	30 ⁰ to the left	'	Frame Rate/Geometry Data
F12 or 'Q'	EXIT Program	l	toggle graphics state lighting (on/off)",
[or]	Decrease Airspeed by 5 kts.	m	cycle motion model type
- or +	Zoom 'in' or 'out'	p	toggle transparency (on/off)
f	Toggle fog (on/off)	s	cycle statistics
t	Toggle texture (on/off)	u	toggle backface display (on/off)
x	Pause program	b	toggle buffer mode (single/double)
SHIFT 'p'	VNE / Max Climb	j	toggle channel rendering (on/off)
SHIFT 'd'	Toggle Day/Night	k	toggle channel state (on/off)
⇐ ⇨	Once = ½ SRT Twice = SRT	P	print current eye point location
↑ ↓	Climb = 500 fpm(VSI) Nulls to zero	z	toggle Z-Buffer (on/off)
SHIFT 't'	Change direction of flight to 12 o'clock	'?'	toggle runtime key display in overlay (on/off)

* All turns are SRT or 90⁰ of turn in 30 seconds.

Table 11. VEHLO 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 VEHLO 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? _____

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

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.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Page 3 of 3

121

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX F. CH-46E NATOPS BRIEFING GUIDE

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

A. <u>Administrative Information</u> 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. <u>Mission Information</u> 1. Primary 2. Secondary/implied 3. Sequence of events. C. <u>Conduct of Flight</u> 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)	F. <u>Special Considerations</u> 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. <u>Crew Coordination</u> 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
--	---

(d) Alternates (e) Landing site lighting. 9. Fuel required (mission/minimum) 10. Fuel availability. D. <u>Flight Planning and Operational Data</u> 1. Navigational aids available and utilization 2. Load computation card 3. Mission essential equipment (a) Personal (b) Aircraft (c) Passengers. E. <u>Emergency Procedures</u> 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. <u>Training Information</u> 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

Please read first: 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)

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.

This image shows a single sheet of white paper with horizontal blue ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Page 3 of 3

127

THIS PAGE INTENTIONALLY LEFT BLANK

	Proposed route of flight to be flown in VEHELO and aircraft.
	Route of flight flown by student pilot in VEHELO.
	Route of flight actually flown by student pilot in aircraft.

Table 12. VEHELO Data Legend (Subject 1)

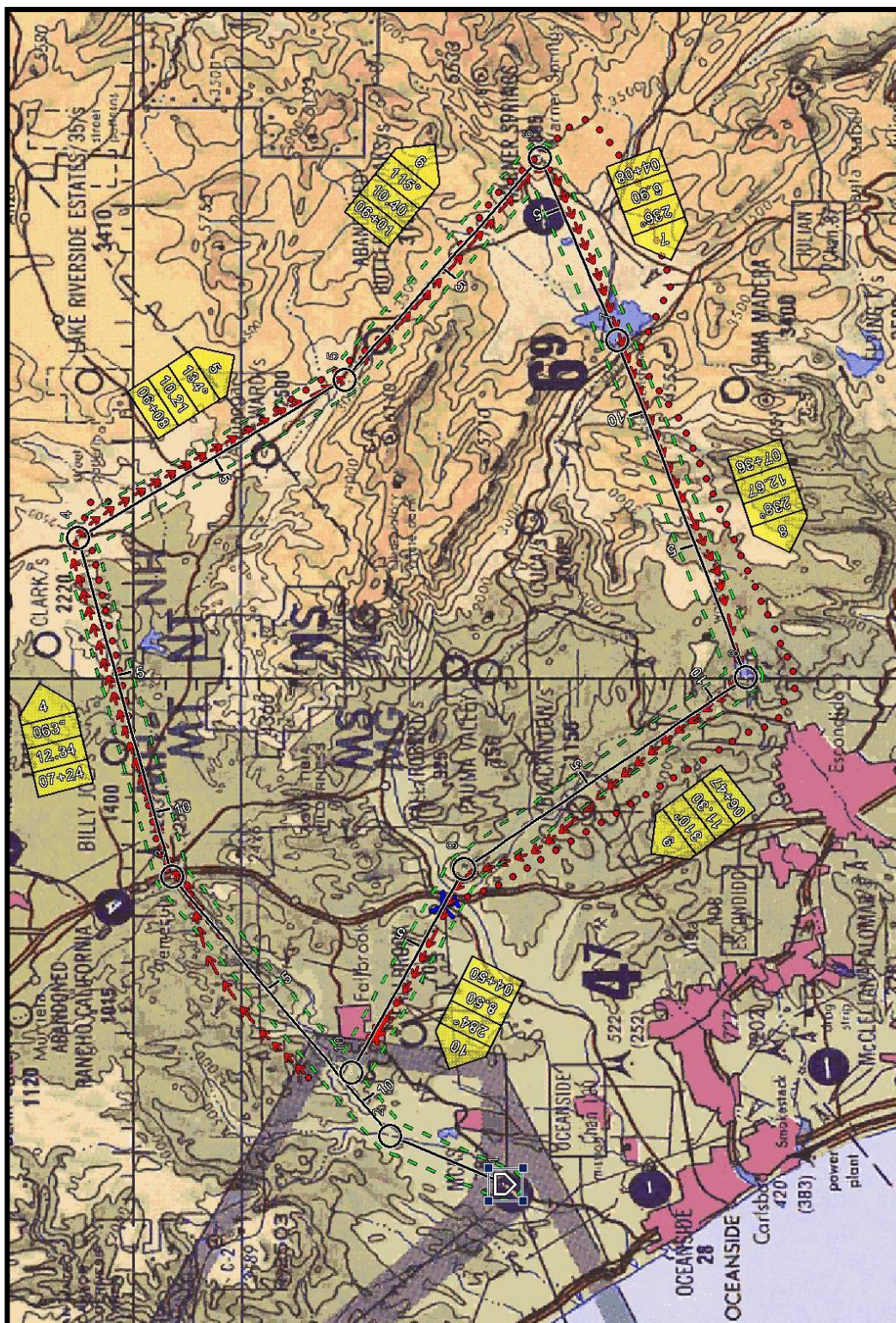


Figure 44. Subject 2 Results

	Proposed route of flight to be flown in VEHELO and aircraft.
	Route of flight flown by student pilot in VEHELO.
	Route of flight actually flown by student pilot in aircraft.

Table 13. VEHELO Data Legend (Subject 2)

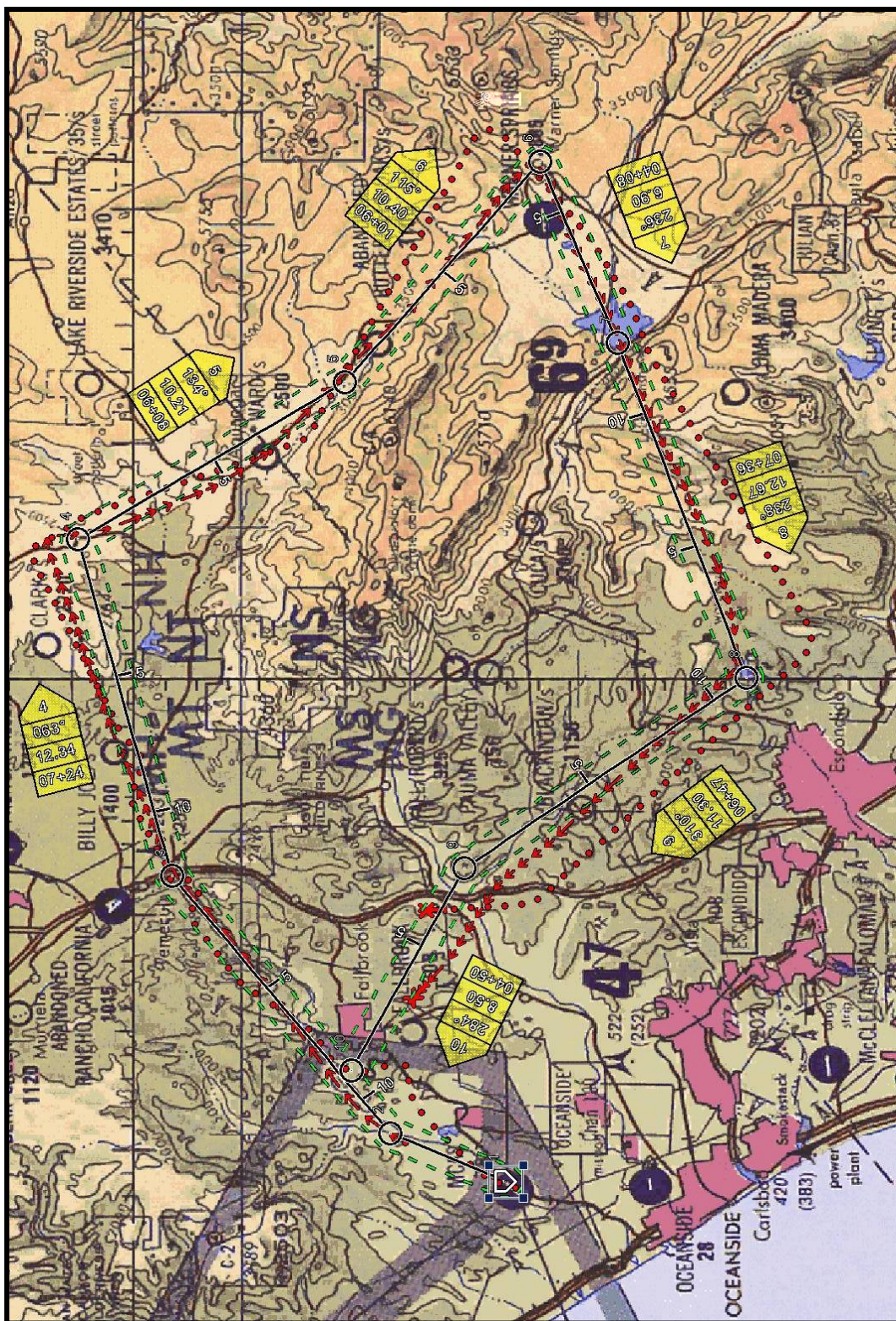
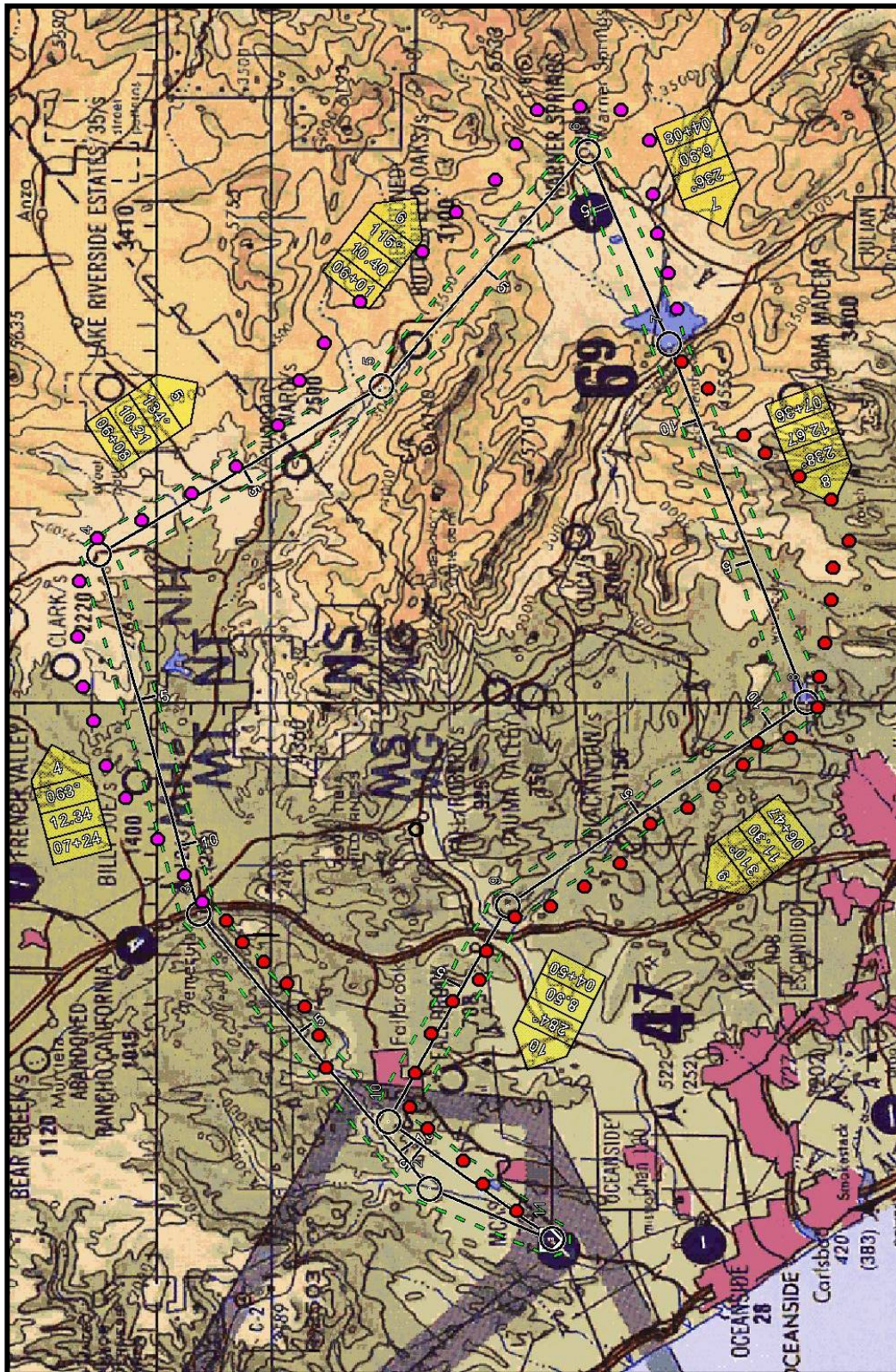


Figure 45. Subject 3 Results

	Proposed route of flight to be flown in VEHELO and aircraft.
	Route of flight flown by student pilot in VEHELO.
	Route of flight actually flown by student pilot in aircraft.

Table 14. VEHELO Data Legend (Subject 3)



	Proposed route of flight to be flown in VEHELO and aircraft.
	Route of flight flown by student pilot in aircraft w/out VEHELO experience. Data obtained from portable GPS unit.
	Route of flight flown by student pilot in aircraft w/out VEHELO experience. Data obtained from aircraft GPS system.

Table 15. Aircraft Flight Data Legend (Subject 4)

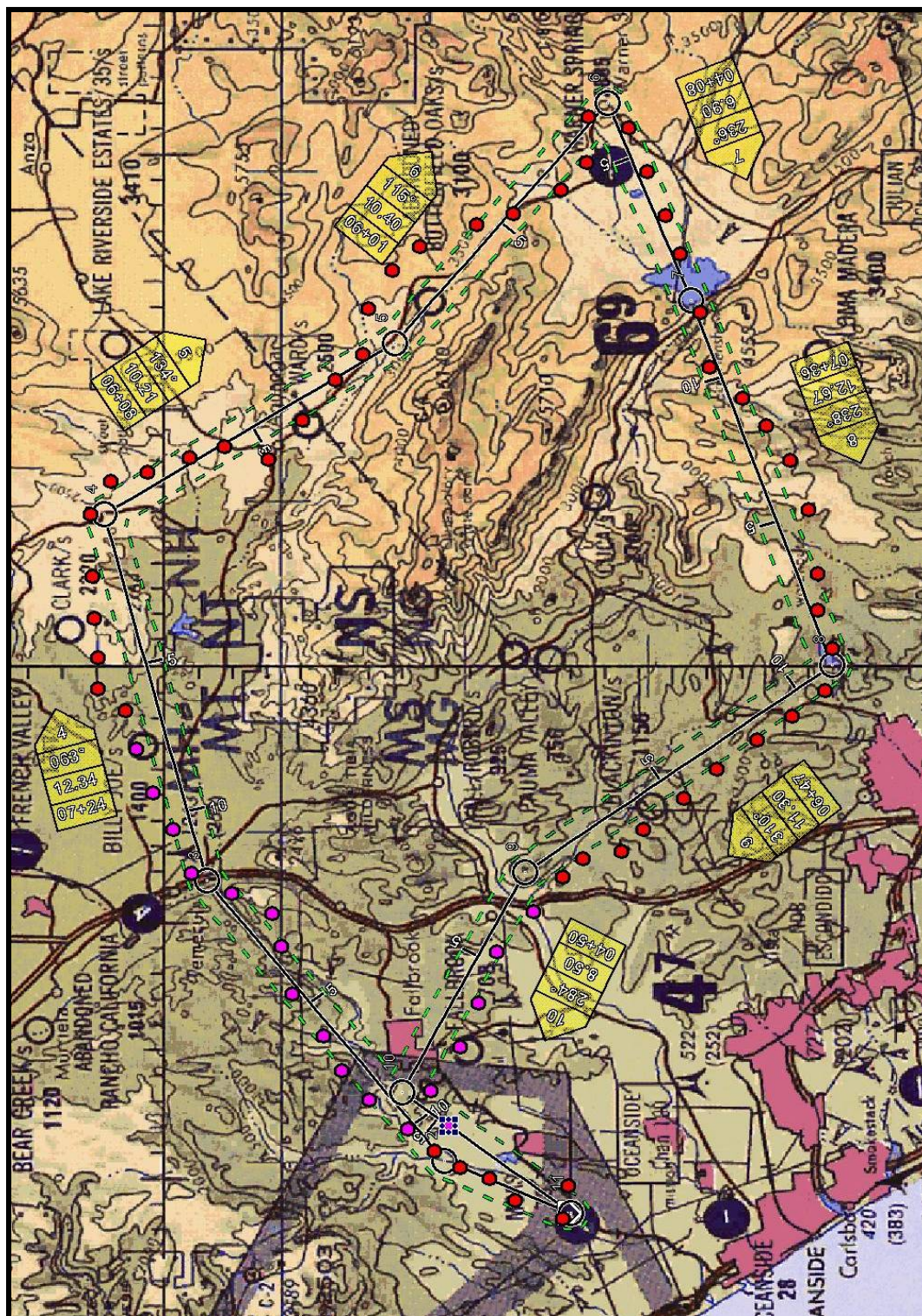


Figure 47. Subject 5 Results

	Proposed route of flight to be flown in VEHELO and aircraft.
	Route of flight flown by student pilot in aircraft w/out VEHELO experience. Data obtained from portable GPS unit.
	Route of flight flown by student pilot in aircraft w/out VEHELO experience. Data obtained from aircraft GPS system.

Table 16. Aircraft Flight Data Legend (Subject 5)

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
Ft. Belvoir, Virginia
2. Dudley Knox Library
Naval Postgraduate School
Monterey, California
3. Marine Corps Representative
Naval Postgraduate School
Monterey, California
4. Director, Training and Education, MCCDC, Code C46
Quantico, Virginia
5. Director, Marine Corps Research Center, MCCDC,
Code C40RC
Quantico, Virginia
6. Marine Corps Tactical Systems Support Activity
(Attn: Operations Officer)
Quantico, Virginia