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Optimizing the Use of the United States Army OH-58D Helicopter Simulator and Aircraft for Full-Authority Digital Electronic Control Manual Throttle Training

Conrad Rodgers
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Conrad Rodgers entitled "Optimizing the Use of the United States Army OH-58D Helicopter Simulator and Aircraft for Full-Authority Digital Electronic Control Manual Throttle Training." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

U. Peter Solies, Major Professor

We have read this thesis and recommend its acceptance:

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OPTIMIZING THE USE OF THE UNITED STATES ARMY OH-58D HELICOPTER SIMULATOR AND AIRCRAFT FOR FULL-AUTHORITY DIGITAL ELECTRONIC CONTROL MANUAL THROTTLE TRAINING

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Conrad Rodgers
December 2008

DEDICATION

The thesis is dedicated to my parents who have always inspired me to do well in everything. Also, I dedicate this thesis to my fellow OH-58D instructor pilots who spend countless hours teaching young men and women to be Army Aviators.

ACKNOWLEDGEMENTS

I wish to express great gratitude to the faculty and staff of the Aviation Systems Department. The knowledge and fortress of understanding I have gained here at UTSI will forever have an impact on my life. In particular, I would especially like to thank, Dr. Peter Solies for his instruction and guidance in this area of aviation study and Professor Rich Ranaudo. I wish to express my appreciation for the support of Professor Karen Wallen. I would like to thank the commander of the 110th Aviation Brigade, Colonel Dolan, and the commander of the 1st Battalion 14th Aviation Regiment LTC Lindsay for their support. Also, I would like to thank Kevin Hottell FS XXI Simulations Program Manger and Computer Sciences Corporation. CW4 Lusker, Brigade Standardization, was a great asset in this research, providing insight into the training program. I wish to thank all my fellow OH-58D aviators who took the time to participate in this research amidst all of their other commitments. Additionally, I would like to thank my family, friends and especially God for support during this research.

Disclaimer

ABSTRACT

Over the past decade the United States Army has used a Full-Authority Digital Electronic Control (FADEC) system to control fuel flow to the engine of the OH-58D helicopter. Currently, part of the training is primarily conducted for the scenario of a FADEC system failure in the aircraft. Because of the complexity of this task, a number of accidents have occurred resulting in minor to severe damage to the aircraft. The United States Army has recently fielded two OH-58D Operational Flight Training Simulators in an effort to increase training efficiency and effectiveness. It is anticipated that the simulators will provide a safer environment and an effected transfer of training to the aircraft.

Currently the OH-58D training unit has implemented the simulator into the manual throttle stage of training. This implementation has occurred through verification and validation of the Program of Instruction (POI) currently in use. An investigation into the transfer of training from the simulator to the aircraft was conducted to further optimize the distributions of training time in the simulator versus the aircraft. The primary source of data was collected from aircraft and simulator trials and flight hours to evaluate the transfer effectiveness ratio. The secondary source of data was collected through the use of pilot surveys and questionnaires.

The pilots reported a mean workload rating of 2.52 using the Bedford Workload Rating Scale in the aircraft after the simulator, which indicates a low workload. The Pilots reported mild to moderate simulator sickness symptoms after flying in the simulator. A total severity score of 20.06 was computed through the use of the Simulator Sickness Questionnaire. When compared to other helicopter simulators this score is fairly high. Overall there were low Pilot-Vehicle Interface problems in the simulator and aircraft. There was no decline in Situational Awareness from the simulator to the aircraft. The overall Transfer Effectiveness Ratios indicated a positive Transfer of Training. The current Program of Instruction and simulator hours are validated. The focus in the simulator should be placed on Method of Instructions step two “failure at a hover” and step four “running landing or approach to a hover.”

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ABBREVIATIONS AND SYMBOLS

ATM	Aircrew Training Manual
AUTO	Automatic
BWRS	Bedford Workload Rating Scale
CPG	Copilot/Gunner
ECU	Electronic Control Unit
ETL	Effective Translational lift
FADEC	Full Authority Digital Electronic Control
HMU	Hydromechanical Unit
IP	Instructor Pilot
MAN	Manual
MOI	Method of Instruction
NG	Gas Producer Speed
NP	Power Turbine Speed
NR	Rotor Speed
OFT	Operational Flight Trainer
OGE	Out of Ground Effect
POI	Program of Instruction
PVI	Pilot-Vehicle Interface
SART	Situational Awareness Rating Technique
SHP	Shaft Horsepower
SSQ	Simulator Sickness Questionnaire
TD	Training Day
TER	Transfer Effectiveness Ratio
TOT	Transfer of Training
TS	Total Severity
USAACE	United States Army Aviation Center of Excellence
α	Confidence level
P	P-Value

CHAPTER 1

INTRODUCTION

The OH-58D Kiowa Warrior is an armed version of the earlier OH-58D Kiowa Advanced Helicopter Improvement Program (AHIP) aircraft, which was modified from the OH-58A/C Kiowa. The OH-58D helicopter (Figure 1) is designed for use in close combat aerial reconnaissance, surveillance, and target acquisition. The helicopter is armed for self-defense and targets of opportunity. The weapons systems are integrated into the Control and Display Subsystem. The mast mounted sight allows the crew to perform a variety of missions while maintaining stand-off range from enemy observation. The crew can mask the aircraft behind terrain or an obstacle with only the sight exposed for observation.

Figure 1 OH-58D Kiowa Warrior

The sight laser range finder and designator designates targets for laser-seeking weapons and determines distance and direction from the helicopter to an intended target. Electronic systems provide communications, radar warning, accurate navigation data, and aircraft identification. The helicopter has requirements for a crew of two, consisting of a pilot and a copilot/gunner (CPG) seated side-by-side. The pilot is in the right seat of the crew station. The crew station is outfitted with dual controls and essential flight and mission instrumentation. The basic airframe consists of a fuselage and tailboom. In March 1997, a number of improvements were introduced into new production OH-58Ds. One of the most important improvements included an improved Allison 250-C30R/3 650 SHP engine equipped with an upgraded hot section to improve high-altitude and hot-day performance. The C30R/3 was fitted with a full authority digital electronic control (FADEC) system that replaced the pneumatic fuel control unit.

Full Authority Digital Electronic Control (FADEC) System

The FADEC system is a single channel electronic control fuel system with a hydromechanical backup (manual) mode. The FADEC provides rotor speed (NR) governing, engine torque limiting, temperature limiting, and automatic start sequencing. Power turbine speed (NP) and gas producer speed (NG) limiting capability are also available while in automatic mode. The system provides for precise governing and consistent engine acceleration and deceleration rates regardless of engine condition. The FADEC defaults to the Automatic mode on power-up after a successful built- in test (BIT). The FADEC hydromechanical backup system (manual mode) provides a get home capability in the event of a critical electronic control unit (ECU) failure (hard fault). A failure in the AUTO/MAN switch may not fail directly to the manual mode. This could cause the FADEC to fail in the fixed fuel flow position (the current fuel flow at the time of the failure). The hydromechanical unit (HMU) consists of a fuel metering unit and a fuel pump. The only FADEC automatic feature available in the manual mode is the NP overspeed protection. In this mode, the pilot's throttle input is tied hydromechanically to the fuel flow metering window in the HMU. The manual mode is engaged by pressing the FADEC AUTO/MAN switch, (Figure 2) located above the standby airspeed indicator on the instrument panel.

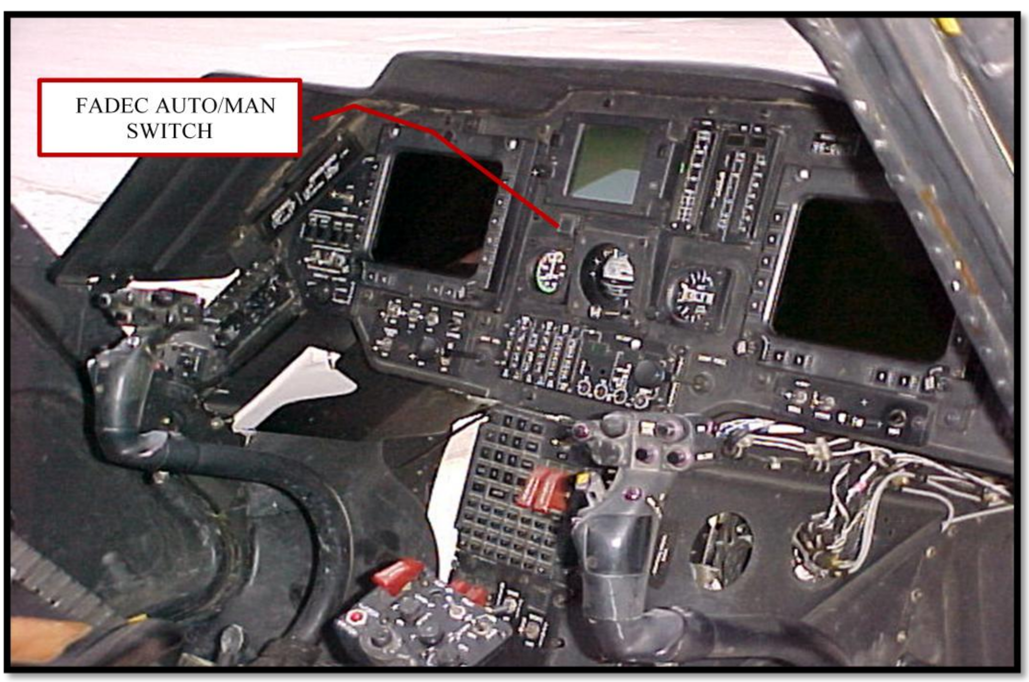


Figure 2 FADEC AUTO/MAN Switch

The illumination of the desired legend should be visually confirmed after switching modes. For example, the switch is in the AUTO mode when the word AUTO is illuminated in the color green (Figure 3).

Manual Throttle Operations

When FADEC fails to the manual mode, it requires immediate and accurate actions of the pilot. FADEC manual operation requires the pilot to manual control the NR and NP with the collective and throttle as necessary. The pilot must respond to the FADEC FAIL audio and FADEC FAIL message and/or FADEC manual message on the Multi Functional Display (MFD) (Figure 4). The FADEC could fail to the fixed fuel flow position (the current fuel flow at the time of the failure) which will not result in a FADEC manual message.

Figure 3 FADEC Switch in AUTO Mode

Figure 4 FADEC Messages of MFD

The pilot must immediately decide whether to raise or lower the collective based on NR and NP. The pilot is required to reduce the throttle to the 75% throttle position first by aligning the two white marks on the throttle (Figure 5) and then press the AUTO MAN switch. Regardless of what the AUTO MAN switch displays, the pilot must press it to ensure manual operation mode. After the helicopter is under control, a landing can be made to a suitable landing area. If the pilots exceed any limits, a landing must be made as soon as possible. The pilot must also take into consideration what limits are exceeded and the possible landing areas to avoid unnecessary damage to the aircraft or loss of life. The pilot must always continue to fly the aircraft at all times. Aircraft control is the number one consideration during an emergency.

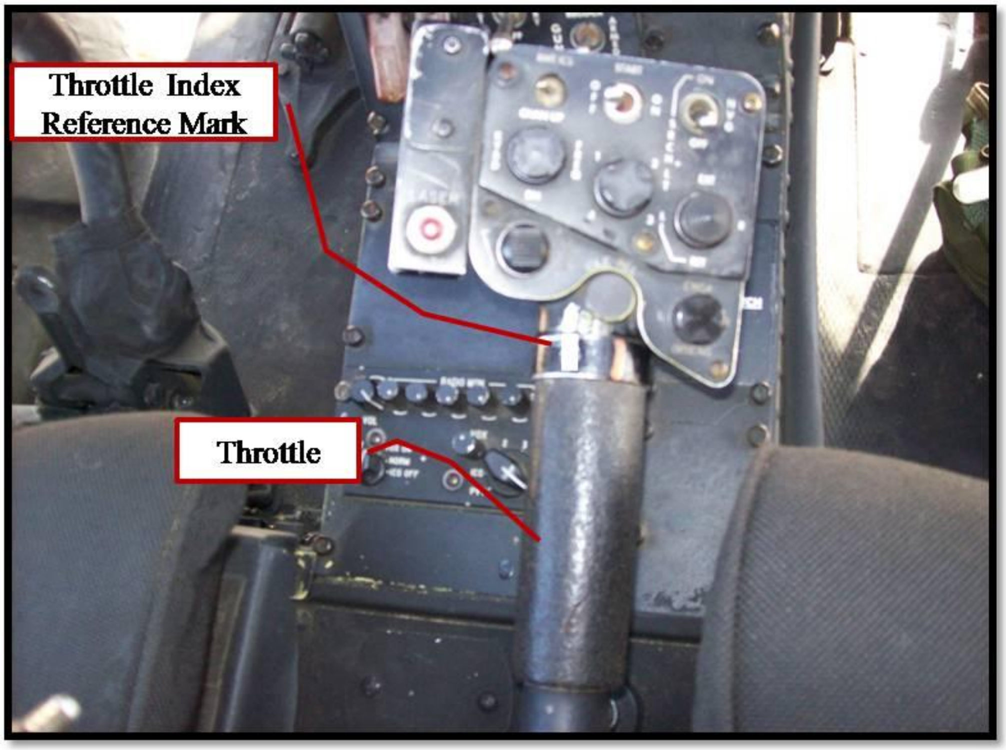


Figure 5 Manual Throttle 75% Throttle Reference Mark Alignment

Background

Currently, training is primary conducted for a FADEC system failure in the aircraft. The tasks, conditions, and standards for Perform Manual Throttle Operation (FADEC) are outlined in the Training Circular 1-248 Aircrew Training Manual (ATM) OH-58D Kiowa Warrior. A student pilot must demonstrate proficiency in this task to be considered qualified in the aircraft at the United States Army Aviation Center of Excellence (USAACE). Because of the complexity of this task, a number of accidents have occurred resulting in minor to severe damage to the aircraft. The United States Army has recently fielded two OH-58D Operational Flight Trainers (OFT) at USAACE in an effort to increase training efficiency and effectiveness for all ATM tasks. It is anticipated that the simulator will provide a safer environment and provide an effected transfer of training to the aircraft. Simulators are frequently integrated into training systems without evaluating their training effectiveness. Currently the OH-58D training unit has implemented the simulator into the manual throttle operation stage of training. This implementation has occurred through verification and validation of the Program of Instruction (POI) currently in use. The OH-58D training unit is making progress towards the optimal distribution of training time in the simulator versus the aircraft through the use of this process. Because of the complexity of manual throttle operations, an investigation into the transfer of training from the simulator to the aircraft was conducted.

Program of Instruction (POI)

The Current POI for the OH-58D (R) Warrior Transition Flight Training Guide (FTG) Flight School XII was implemented in May 2008. Stage two of the training (manual throttle operations) consist of seven training period and one evaluation period for a total of 9.6 hours. The OFT training periods consist of 1.5 hours each for a total of three hours. All stage two training is conducted from the right seat. Table 1 shows the flight hours for the current POI. The previous POI consisted of six training periods and one evaluation period for a total of 9.1 hours, with no OFT time. Table 2 shows the flight hours for the previous POI. Training is conducted in accordance with the manual throttle four-step Method of Instruction (MOI) in the OH-58D ATM (appendix A).

Table 1 Current POI for Manual Throttle Training

STAGE II- MANUAL THROTTLE OPERATIONS								
Flight Period	1	2	3	4	5	6	7	8
OH-58D(R)Time (hours)	0.5	1.2			1.2	1.3	1.3	1.1E
FLT SIM (OFT) Time (hours)			1.5	1.5				
Total Time (hours)	0.5	1.7	3.2	4.7	5.9	7.2	8.5	9.6

E - Evaluation

Table 2 Previous POI for Manual Throttle Training

STAGE II- MANUAL THROTTLE OPERATIONS							
Flight Period	1	2	3	4	5	6	7
OH-58D (R) Time (hours)	1.3	1.3	1.3	1.3	1.3	1.3	1.3E
Total Time (hours)	1.3	2.6	3.9	5.2	6.5	7.8	9.1

E - Evaluation

OH-58D Operational Flight Trainer

In February 2008 L-3 Link Simulation and Training delivered two OFTs to the U.S. Army Flight School XII Program. It was the first time that a Kiowa Warrior full motion high fidelity flight trainer was used. The cockpit operates with a six degree-of-freedom electric motion system (Figure 6). Vibration related to helicopter flight comes from a secondary motion system. The out-the-window view comes from imagery generated by a personal computer-based image generation system. The imagery comes through both wide field-of-view and chin window displays. The OH-58D electrical, engine, navigation, hydraulic, and communication systems are simulated by software. The hardware for the OH-58D is replicated by a physical- blade element model, sticks and grips, and electrically-driven servo flight controls.

Figure 6 Operational Flight Trainers

Pilot Workload Assessment

There are many of definitions for workload that researchers use today. The most common definition of pilot workload is “the integrated mental and physical effort required for satisfying the perceived demands of a specified flight task”. [1] The probability of pilot error increases when performing flight tasks if the workload is extreme. Assessing pilot workload is essential because task accomplishment is linked to the pilots’ physical and mental abilities. When a pilot receives a high workload while performing flight tasks, the tasks may be executed incorrectly or abandoned. The level of pilot workload must be evaluated to asses if the pilot is task overloaded.

Bedford Workload Rating Scale

The Bedford Workload Rating scale (BWRS) is based on a ten point rating scale with the concept of spare capacity and effort. The BWRS has been used extensively by the military, civil, and commercial aviation communities for pilot workload estimation. [2] Pilots rate the level of workload related to a task based on the amount of spare capacity that is felt to perform other tasks. Pilots are often required to perform several tasks at the same time, which makes spare workload capacity important. For example, pilots must maintain airspace surveillance, obstacle avoidance, and maintain rotor RPM within limits while performing manual throttle operations in the OH-58D Helicopter.

During the present test, the pilots completed the BWRS immediately after each flight in the aircraft and the OFT (appendix B). They used the BWRS to rate the level of workload for six ATM tasks and the four steps in the MOI that support FADEC manual throttle operations training. The ATM tasks selected are the only tasks that may be performed while conducting FADEC manual mode training or evaluation.

Simulator Sickness Assessment

Simulator sickness can be explained as a form of motions sickness that does not require real motion but does require a wide field of view visual display. When a physiological discomfort is felt in a flight profile in the simulator but not in the aircraft, it is simulator sickness. [3] Helicopter simulators are known to produce more sickness than fixed-wing simulators. This is a due to the fact that more visual flow is perceived from greater visual detail at lower altitude. [4] Some of the most common symptoms of simulator sickness are drowsiness, dizziness, and nausea. [3]. If pilots are distracted by discomfort during simulator sickness, it could influence levels of workload and situational awareness. One of the operational consequences of simulator sickness is pilot distraction. [5] Because the discomfort felt by pilots may lead to a distraction from task performance it is paramount to assess simulator sickness.

Simulator Sickness Questionnaire (SSQ)

The SSQ was developed and validated based upon 1,119 pairs of pre-exposure/post-exposure scores. This data was collected from 10 Navy flight simulators, fixed –wing and rotary-wing. The simulators selected were a mix of fixed-base models and 6-DOF motion models. The 16 symptoms [6] in the SSQ had four levels of severity (none, slight, moderate, severe). These symptoms are organized into three subscales: oculomotor (e.g., headache, eyestrain, difficulty focusing,), disorientation (e.g., dizziness, vertigo, blurred vision), and nausea (e.g., nausea, sweating, increased salivation, burping). All three subscale scores are combined to create a total severity (TS) score. The pilots were administered the SSQ (appendix C) to help assess whether they were being distracted by the discomfort.

Pilot-Vehicle Interface (PVI) Assessment

The pilots completed a PVI questionnaire (appendix D) after each flight in the OFT and aircraft. The intent was to identify any usability problems with components, systems, and subsystems of FADEC system. The PVI directly impacts pilot workload and situational awareness during a flight. It is important to assess PVI to identify any problem that should be resolved.

Pilot Situational Awareness (SA) Assessment

Formally situational awareness is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future."[7] Basically put, SA for the pilot is knowing what is going on around him and being able to predict future change and developments. Because SA directly affects pilots' performance it was important to assess. Usually a pilot's good decision making comes from an elevated level of SA.

Situational Awareness Rating Technique (SART)

The SART (appendix E) is one of the most carefully tested rating scales for estimating SA [8]. The SART is a subjective measure of SA that focuses on the pilot's knowledge in three areas: understanding, supply, and demand. SA depends on the pilot's understanding (U) (amount of knowledge received and understood), and the difference between the demand (D) (complexity of situation) and the pilot's supply (S) (ability to concentrate). If demand exceeds supply, there is a negative effect on understanding and a decline in SA. [9]

Transfer Effectiveness Ratios

The transfer of training (TOT) refers to the degree to which learning one task is made possible or hindered by the prior learning of another. Ground based flight trainer or flight simulator should be evaluated based on their training efficiency. [10] The TOT can be calculated using transfer effectiveness ratios (TER). TER can be expressed as the ratio of the trials or times saved in the helicopter to the trials or time spent in the simulator. In measuring transfer from the simulator to the helicopter, two groups of trainees are needed. The pace of learning for the helicopter only group is compared to the pace of learning for the pre-simulator training group. It was important to assess the TER because it provided a measure of the effectiveness of the simulator pre-training.

CHAPTER 2

METHOD

The primary source of data was collected from aircraft and simulator trials (number of task iterations) and flight hours to evaluate the transfer effectiveness ratio. The student pilot performance during the MOI four steps were considered "to standard" when the student received a grade of B for that step and did not receive a grade less than C for the next training cycle of that step. The secondary source of data was collected through the use of pilot surveys and questionnaires. The control group did not participate in the surveys and questionnaires. Data from the control group was collected from historical flight training records because this group graduated flight school through the use of the previous POI (no simulator). The training flight platoon and Instructor Pilots (IPs) used in the research were the same as for training the final class under the previous POI.

Research Conditions

The flight training started with a daily flight brief that included research procedures. The researcher was available for questions and assistance throughout the training. The IPs were asked to adhere to the training scenarios (appendix F) for each training day in the OFT. This allowed the conditions (winds, visibility, aircraft location, and cockpit setup) in the OFT to be the same for each student. In the OFT the IP position was behind the student pilots in the controller station. In the aircraft the IP position was in the left seat. The average wind speed for training in the aircraft was 5 knots and the average direction was 210 degrees.

Only one day of training was canceled due to weather because of the winds at 10 knots gusting to 20 knots with thunder storms. Flight line arrival time was 5:00 am for IPs and the researcher. The student arrival time was 5:30 am. This was due to the class being on a morning flight schedule.

Student Pilots

The pilots were from two groups, a control group and an experimental group. The control group was based on historical data from students' flight training records. The control group class was the final class to train under the previous POI (no OFT). The control group consisted of all males, which were eight Warrant Officers and two Lieutenants. In this group 70% had a college education. The average flight experience prior to manual throttle training was 107.0 hours. Table 3 lists demographic characteristics of the control group. The experimental group consisted of 10 males and one female which were eight Warrant Officers and three Lieutenants. In this group 91% had a college education. The average flight experience prior to manual throttle training was 100.7 hours. Table 4 lists demographic characteristics of the experimental group.

Data Collection

The pilots completed BWRS and PVI questionnaires immediately after each flight in the aircraft and OFT. The SSQ questionnaires were completed before and after each flight in the OFT. The SA questionnaires were completed after the last flight in the OFT and the last flight in the aircraft. Data for the TERs was collected after each flight in the aircraft and OFT from the IPs for the

Table 3 Control group demographics

Summary of demographics N= 10	Age Years	Flight hours prior to manual throttle training	Prior phases training grades
Mean	26.3	107	90.1
Median	27	107.2	90
Range	22 to 30	106 to 107.9	87 to 97

Table 4 Experimental group demographics

Summary of demographics N= 11	Age Years	Flight hours prior to manual throttle training	Prior phases training grades
Mean	28.1	100.7	89.1
Median	28	106	87
Range	23 to 39	48.3 to 107.3	70 to 90

experimental group (appendix G). The control group data for TERs was collected from students' flight records. A pre-test was conducted to refine the questionnaires and to ensure that they could be easily understood and completed by pilots. The research procedures were also part of the daily flight brief.

Data Analysis

Student pilot responses to the BWRS, SSQ, PVI and SART questionnaires were analyzed with percentages and means. Their responses to the BWRS and SART were further analyzed with the t-Test (Paired Two Sample for Means) to compare ratings between pilots when they flew the OFT versus when they flew the aircraft. SSQ scores were calculated using the scoring procedures from (Figure 7) [6]. To calculate the scale scores, each symptom variable 0 (none), 1 (slight), 2 (moderate), and 3 (severe) were summed down the column for a weighted total. The conversion formulas at the bottom were applied to the weighted totals for the Nausea (N), Oculomotor (O), and Disorientation (D) scores. The total severity (TS) was calculated by summing all the weighted totals and applying the conversion formula.

The overall SART score was calculated using the following method:

$$SA = U - (D - S) \qquad \text{(Equation 1)}$$

Where

SA = Situational Awareness

U = summed understanding

D = summed demand

S = summed supply

Computation of SSQ Scores

SSQ Symptom[a]	*Weight* *N*	*O*	*D*
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eyestrain		1	
Difficulty focusing		1	1
Increased salivation	1		
Sweating	1		
Nausea	1		1
Difficulty concentrating	1	1	
Fullness of head			1
Blurred vision		1	1
Dizzy (eyes open)			1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness	1		
Burping	1		
Total[b]	[1]	[2]	[3]

Score
N = [1] × 9.54
O = [2] × 7.58
D = [3] × 13.92
TS[c] = [1] + [2] + [3] × 3.74

[a]Scored 0, 1, 2, 3. [b]Sum obtained by adding symptom scores. Omitted scores are zero. [c]Total Score.

Figure 7 Scoring procedures for the SSQ

Source: Kennedy, R. S.; Lane, N. E.; Berbaum, K. S.; Lilienthal, M. G. "Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness." International Journal of Aviation Psychology 1993, *3*, 203-220

The TERs were calculated using the following method from Roscoe [11]:

$$\text{TER} = \frac{C_I - E_I}{E_{I(sim)}} \qquad \text{(Equation 2)}$$

Where

TER = Transfer Effectiveness Ratio

C_I = the number of control group (no simulator training group) training iterations or flight hours required to achieve standard performance in the aircraft

E_I = the number of experimental group (simulator pretraining group) training iterations or flight hours required to achieve standard performance in the aircraft

E_I (sim) = the number of experimental group training iterations or flight hours required to achieve standard performance in the simulator.

For Example, if it took the control group 4 training iterations to get step 1 tasks to standard performance in the aircraft, the experimental group 2 training iterations to get step 1 tasks to standard performance in the aircraft, and the experimental group 3 training iteration in the simulator to get step 1 tasks to standard performance, the TER would be 0.66. It would take the experimental group 2 iterations of step 1 to standard in the simulator to get a 1.00 TER.

$$TER = \frac{4-2}{3} = 0.66$$

The use of flight time in the TER formula was used in comparison to the number of training iteration because of the lack of iteration data from the control group. The interpretation of the iteration was conducted through regression and correlation. The first thing to accomplish was to determine if there was a relation between flight hours and number of iterations. If so, what was the strength of the relationship and what type existed? For example, step four flight hours to iteration had a strong positive relationship. The coefficient of determination (r^2) value was 0.792 (appendix H) which indicates 79.2% of the total variation is explained by the regression line using the independent variable (flight hours). By taking the square root of the r^2 value the correlation coefficient (r) is determined. For step four it is 0.889. The range of the correlation coefficient is from -1 to + 1. The value of r will be close to +1 for a strong positive relationship. The equation of the line was also used to calculate number of iterations. All of the MOI steps calculations from flight hours to iteration had an r value of .777 and above (appendix H).

The end of stage final grades were compared between both groups using the means and standard score. This score represents the number of standard deviations that a grade falls above or below the mean. The standard scores were calculated using the following method:

$$Z = \frac{x-\mu}{\sigma} \qquad \text{(Equation3)}$$

Where

Z = standard score

x = grade

μ = mean

σ = standard deviation

Limitations

The lack of available time and resources made it impracticable to conduct the research of both groups training at the same time under different POIs. The previous POI was no longer authorized to be trained. Most of the iteration for the control group was not logged in the training records. The iterations for the control group were interpolated based on current and historical data, somewhat limiting the usefulness of the comparison. The number of flight hours to standard was used for TERs as another means of comparison. Because of the shortage of IPs (four IPs for 11 students) all of student pilots were not able to fly every day. The eight day training period took 13 training days.

CHAPTER 3

RESULTS

Pilot Workload

The mean overall workload rating for all tasks performed in the OFT was 4.18 on a scale of 1 to 10 with 10 being the highest load. The mean workload rating for the same tasks in the aircraft after the OFT was 2.52 (appendix I). This difference between workload ratings given for the OFT and the aircraft was statistically significant (t-Test, $\alpha = .05$, $P = 2.05E\text{-}07$). If the P-value is less than or equal to the confidence level, the null hypothesis (the two sample means are equal) is rejected. The flight prior to OFT training had a mean workload of 2.86 with steps three and four of the MOI not being performed (Figure 8). The task with the lowest (2.12) workload in the flight prior to the OFT training was ATM task (1040) perform VMC takeoff. The task with the lowest workload (1.70) between the OFT and the aircraft was ATM task (1038) perform hovering flight. This ATM task was rated lowest in the aircraft while performing manual throttle operations. Two tasks received peak workload ratings of 10 in the OFT, indicating that workload had task abandonment. These tasks included step four of the MOI and the performance of a running landing. The same tasks received peak workload ratings of eight in the aircraft, indicating that workload was very high and not tolerable. The data from the workload assessment was ordinal (ranked). The data was not bimodal or skewed in the distribution. The median and the mean were assessed from the data with no significant difference.

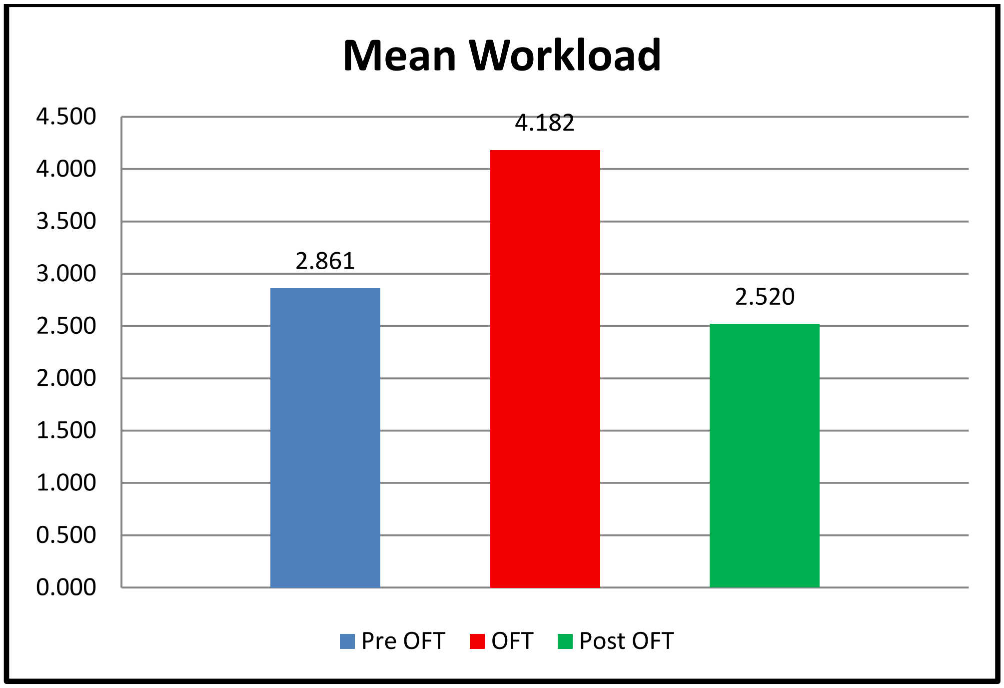


Figure 8 Combined mean workload for all tasks

Simulator Sickness

The student pilots reported a large number (75%) of simulator sickness symptoms during the OFT periods. Most of the symptoms involved vestibular disturbances such as dizziness and vertigo from the disorientation subscale (Table 5). The overall mean total severity score (post flight) for the pilots was 20.06 on a scale of 1 to 35(Table 6). The scoring procedures presumed that all personnel not in their usual fitness state are removed from a sample and only post-exposure data are scored.

OH-58D Operational Flight Trainer and Simulator Sickness Questionnaire ratings compared to other helicopters.

To assess whether the SSQ ratings provided by the pilots during the OH-58D OFT training periods were similar to or different from ratings obtained in other helicopter simulators, the mean total severity score for the OH-58D OFT was compared to the mean total severity scores for several other helicopter simulators: the AH-64A, S-3H, CH-46E, CH-53D, CH-53F, Sikorsky reconnaissance attack helicopter (RAH)-66 Engineering Development Simulator (EDS), RAH-66 Comanche portable cockpit (CPC), the UH-60M Battlefield Highly Immersive Virtual Environment (BHIVE) and Armed Reconnaissance Helicopter (ARH) Crewstation (Table 7). The higher scores are an indicator of more reporter discomfort than the lower scores in table 7. Based on the categorization of symptom scores from several thousand military pilots, the OH-58D OFT is considered a problem simulator (Table 8) [12].

Table 5 Mean subscale scores

Pilot	N	O	D
22			
21			
44	0	0	0
24	76.32	83.38	139.2
23	9.54	22.74	13.92
42	19.08	15.16	0
20	9.54	15.16	27.84
25			
41			
43	0	0	27.84
40	9.54	7.58	0
22	28.62	45.48	55.68
21	9.54	0	0
44	28.62	7.58	0
24	28.62	30.32	69.6
23	28.62	7.58	27.84
42	38.16	22.74	0
20	0	0	0
25	9.54	0	0
41	9.54	15.16	0
43	9.54	7.58	0
40			
Mean	18.52	16.50	21.29

(shaded) Precondition symptoms removed
N - Nausea
O - Oculomoto
D - Disorientation

Table 6 Two day mean Total Severity score

Pilot	TS July 1 08	TS July 2 08	Mean
22		44.88	44.88
21		14.96	14.96
44	0	3.74	1.87
24	108.46	48.62	78.54
23	18.7	22.44	20.57
42	14.96	26.18	20.57
20	18.7	0	9.35
25		3.74	3.74
41		11.22	11.22
43	7.48	7.48	7.48
40	7.48		7.48
		Mean 2 days	20.06

TS - Total Severity
(shaded) Precondition symptoms removed

Table 7 Comparison of OH-58D SSQ ratings

Comparison of OH-58D OFT SSQ ratings with other helicopter simulators.

Simulator	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)
AH-64A*	-------	-------	-------	25.81
ARH Crewstation *	-------	-------	-------	20.15
OH-58D OFT	18.52	16.50	21.29	20.06
SH-3H	14.70	20.00	12.40	18.80
RAH-66 EDS	11.84	14.98	4.54	13.25
CH-53F	7.50	10.50	7.40	10.00
RAH-66 CPC	3.29	12.94	7.89	9.80
UH-60M BHIVE (EUD)	13.88	6.89	0.00	8.50
CH-53D	7.20	7.20	4.00	7.50
CH-46E	5.40	7.80	4.50	7.00

*SSQ subscale data not available.

Table 8 SSQ Total score categorization

SSQ Total Score	Categorization
0	No symptoms
< 5	Negligible symptoms
5 – 10	Minimal symptoms
10 – 15	Significant symptoms
15 – 20	Symptoms are a concern
> 20	A problem simulator

Pilot-Vehicle Interface

The pilots completed a PVI survey after each flight. This survey allowed the pilots to assign ratings for each question and provide comments about why they rated the question a certain way. In this section of the report interest is placed on the most common issues that were addressed by the pilots. A complete set of PVI comments is included for review (appendix J). The pilots had the most problems with the throttle and throttle index reference mark in the OFT. There were no problems with the caution and warning input to the pilots. The most unused component was the fuel burn rate. There were no problems with the cyclic and collective in the aircraft. The pilots reported a small amount of problems with the collective in the OFT (Table 9). There was one report that an OFT would not come on motion. This problem was later resolved by maintenance after approximately 20 minutes.

Situational Awareness

An overall mean SART score of 21.27 on a scale of 1 to 35 was given by the pilots for the OH-58D OFT. This score points out that the pilots felt they had moderate levels of overall SA in the OFT. The overall mean SART score from the pilots in the aircraft was 23.73. This situational awareness (SA) rating of 23.73 indicates that the pilots felt they experienced moderate to high levels of SA in the aircraft. The difference between SA ratings for the OFT and aircraft was not statistically significant (t-Test, $\alpha = 0.05$, $P = 0.074$) and is

Table 9 OFT and aircraft PVI comparison

Aircraft Pilot-Vehicle Interface Problems (Percentages)			
Functional components / sub-components	Yes	No	Not Used
Multifunction Displays (MFD)	2.3	97.7	0.0
Fuel Burn Rate	0.0	90.9	9.1
Throttle Position Indicator	0.0	100.0	0.0
FADEC AUTO/MAN switch	2.3	97.7	0.0
FADEC FAIL Audio Tone	0.0	100.0	0.0
FADEC Manual Caution Message	0.0	100.0	0.0
FADEC FAIL Warning Message	0.0	100.0	0.0
NR (Rotor)	0.0	100.0	0.0
NP (Power Turbine)	0.0	95.5	4.5
TQR (Mast Torque)	4.5	95.5	0.0
Throttle	2.3	97.7	0.0
Throttle index reference mark	2.3	97.7	0.0
Collective	0.0	100.0	0.0
Cyclic	0.0	100.0	0.0
OFT Pilot-Vehicle Interface Problems (Percentages)			
Functional components / sub-components	Yes	No	Not Used
Multifunction Displays (MFD)	9.1	90.9	0.0
Fuel Burn Rate	4.5	68.2	27.3
Throttle Position Indicator	18.2	81.8	0.0
FADEC AUTO/MAN switch	0.0	100.0	0.0
FADEC FAIL Audio Tone	0.0	100.0	0.0
FADEC Manual Caution Message	0.0	100.0	0.0
FADEC FAIL Warning Message	0.0	100.0	0.0
NR (Rotor)	9.1	86.4	4.5
NP (Power Turbine)	9.1	81.8	9.1
TQR (Mast Torque)	9.1	81.8	9.1
Throttle	36.4	63.6	0.0
Throttle index reference mark	27.3	72.7	0.0
Collective	18.2	81.8	0.0
Cyclic	4.5	95.5	0.0

depicted in (figure 9). The mean subscale ratings for demand, supply and understanding increases slightly from the OFT to the aircraft (appendix K).

Transfer Effectiveness Ratios

The possible outcomes for each of the four methods of instruction steps were positive transfer of training, negative transfer of training, or no transfer of training. All four methods of instruction steps had some positive transfer of training with the use of flight hours or iterations (Table 10). The highest TER was in methods of instruction step four for both flight hours and iterations. The smallest TER was in methods of instruction step one for both flight hours and iterations. A TER greater than 0.6, is a good positive transfer of training, and a TER less than zero is a negative transfer of training.

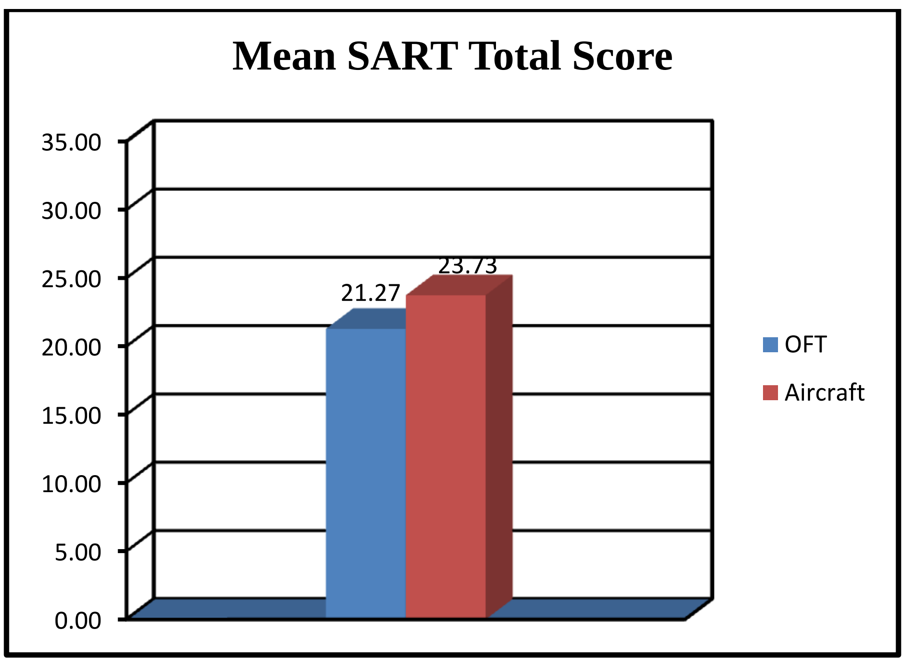


Figure 9 Comparison of mean SART scores

Table 10 TER form the OFT to the aircraft

Transfer Effectiveness Ratios for Transfer of Training				
	Step 1	Step 2	Step 3	Step 4
Flight Hours	0.50	1.03	0.59	0.86
Iterations	0.33	0.88	0.36	0.83
SD	0.12	0.11	0.16	0.02

SD -Standard deviation

The means for flight hour and iterations to standard performance were compared for statistical significance with both groups. This comparison was made with the t-Test (Two-Sample Assuming Unequal Variances) [13]. If the P-value is less than or equal to the confidence level, the null hypothesis (the two sample means are equal) is rejected. If the P-value is greater than the confidence level, the null hypothesis (the two sample means are equal) is accepted. The experimental group required fewer flight hours (2.35) than the control group (3.17) for MOI step one. The difference was not significant (t-Test α=.05, P= .09). The experimental group required fewer flight hours (1.75) than the control group (3.44) for MOI step two. The difference was significant (t-Test α=.05, P= 2.4E-4). The experimental group required fewer flight hours (1.75) than the control group (2.80) for MOI step three. The difference was not significant (t-Test α=.05, P= .06). The experimental group required fewer flight hours (2.35) than the control group (3.17) for MOI step four. The difference was significant (t-Test α=.05, P=

.01). The iterations have the same level of significance as the flight hours in all four steps of the MOI (Table 11).

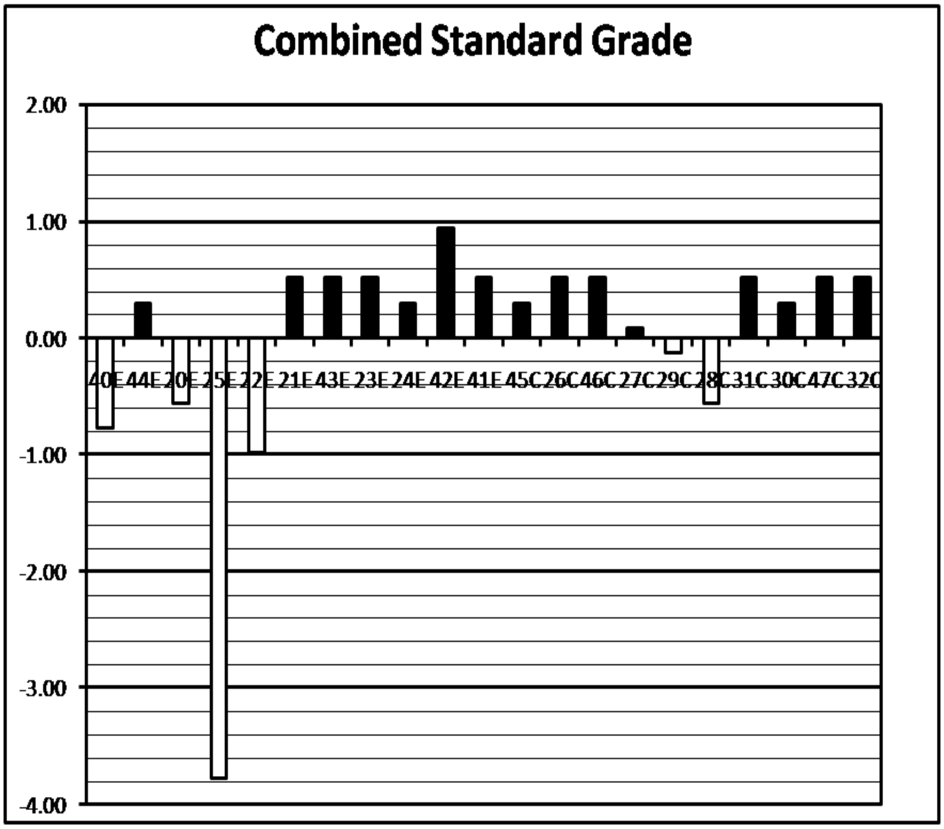
Flight Grades

The end of stage flight grades were compared using the standard score. All of the grades from both groups were combined for a mean of 87.62 and a standard deviation of 4.67. All of the grades are within one standard deviation of the mean besides one. This is due to the fact that one student from the experimental group scored an unsatisfactory on the final evaluation. When this occurs the highest grade that the student can achieve on reevaluation is 70. Although this grade could have been removed as an outlier, it was included to show the usefulness of the standard score. Only two of the control group students' grades fell below the mean (Figure 10).

Table 11 Mean flight hours and iterations to standard

Groups	Mean Iterations to Standard in the Aircraft							
	Step 1		Step 2		Step 3		Step 4	
	M	SD	M	SD	M	SD	M	SD
Experimental	2.18	0.98	3.18	1.66	3.18	2.32	5.64	2.77
Control	2.84	0.99	5.03	2.19	4.70	2.41	10.18	4.28
Groups	Mean Flight Hours to Standard in the Aircraft							
	Step 1		Step 2		Step 3		Step 4	
	M	SD	M	SD	M	SD	M	SD
Experimental	2.35	0.92	1.75	0.55	1.75	0.88	2.84	1.37
Control	3.17	1.14	3.44	0.96	2.80	1.38	4.94	1.97

SD -Standard deviation



C = control group
E = experimental group
= above the mean
= below the mean

Figure 10 Standardized flight grades

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Pilot Workload

The pilots reported a mean workload of 2.52 in the aircraft after the OFT, which indicates a low workload. This was a significant difference from the OFT (4.18) where there was insufficient spare capacity for other tasks. There were no ATM tasks that had a lower workload rating in the OFT than in the aircraft. The task with the highest workload rating (10) was MOI step 4. In the aircraft this task peaked to a workload rating of eight.

Simulator Sickness

The student Pilots reported mild to moderate simulator sickness symptoms after flying in the OFT. The total severity score was 20.06. When compared to other helicopter simulators this score is fairly high. The high score may be the cause for such an elevated workload score for the ATM task in FADEC training. Simulator sickness symptoms adversely affect pilot performance. The most common comment from pilots was the unusual high temperature in the front of the cockpit. When compared to a widely accepted categorization of symptom scores, the OH-58D OFT is considered a problem simulator. The combination of tasks being performed simulator characteristics could be the problem, not necessarily the simulator itself.

Pilot-Vehicle Interface

Overall there was a low level of PVI problems in the OFT and aircraft. The highest percentage of problems (36.4%) in the OFT was with the throttle. The most common comment from the pilots about the throttle was “throttle sticking”. The throttle index reference mark was not readable in both the OFT (27.3%) and the aircraft (2.3%). These two components are very important to the manual throttle task and should not have a usability problem. There were no problems with the caution and warning systems.

Situational Awareness

The difference between the SA rating in the aircraft (23.73) after the OFT (21.27) was not significant. In the subscale ratings no reported demand was greater than the supply, which had a positive effect on SA. The most important result was that there was no decline in SA from the OFT to the aircraft, instead a slight increase.

Transfer Effectiveness Ratios

The overall TERs indicated a positive TOT. According to the TER the most benefit of training in the OFT comes from MOI step four. The least benefit comes from MOI step one. The correlation of training iteration to flight hours was noteworthy. Despite the higher workload, the unusual large number of simulator sickness symptoms and PVI problems, there is good transfer of training. The simulator was an effective replacement of manual throttle flight training.

Flight Grades

The flight grade did not indicate a significant difference between the groups. All the combined grades remained within one standard deviation of the mean besides the one failed evaluation. The failed evaluation is not an indication that the experimental group did poorly. It represents only 10% of the class.

Recommendations

Based on the results and conclusions the following recommendations are made to optimize the simulator-aircraft training mix while enhancing both efficiency and effectiveness of the training program:

- Address and resolve the usability problems the student pilots reported with the throttle.

- The student should arrive for simulator training in good state of health and fitness.

- Having both students in the OFT for 3.0 hours should be readdressed. It is not recommended to schedule simulator sessions for greater than two hours for any reason.

- The focus in the OFT should be placed on MOI steps two and four. This would allow more useful breaks to reduce discomfort for the student and the IP.

- The overall positive transfer of training validates the use of the OFT. It does not, however give enough reason to justify for more time in the simulator.

Based on the findings of this study, the following future research studies are suggested:

- Further research should be conducted into simulator sickness in the OH-58D OFT. A Flight class should participate in the Simulator Sickness

Questionnaires for all phases of training in the simulator to get an extensive look at the symptoms.

- Transfer of Training research should be conducted for all ATM task that are trained in the OFT.

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APPENDICES

Appendix A.
FADEC Manual Throttle Operations Four-Step Method of Instruction (MOI)

FADEC Manual Throttle Four-Step MOI. This four step MOI is intended as a supplement to Task 1102 in TC 1-248. All four steps are designed around the building block technique of pilot training in accordance with the instructor pilots' handbook which gives the instructor pilot (IP) a more defined process for teaching this maneuver. **IPs should not allow pilots to progress from one step to the next unless they are proficient in the step that they are being trained.** This process also gives an IP the ability to revert to an earlier training step should a pilot experience an obstacle to learning.

STEP-1: BASIC. Begin on level ground at engine idle. The IP or pilot will switch the full authority digital electronic control (FADEC) to the manual (MAN) position. With the collective full down, the IP will direct the pilot on the controls (P*) to increase and decrease the throttle between idle and 100 percent rotor speed (Nr) to get the direction and "feel" of the throttle and how throttle movements affect NR. The IP will direct the P* to achieve/maintain 100 percent NR, then increase the collective while maintaining 100 percent NR until the aircraft is light on the skids and then decrease the collective to full down while maintaining 100 percent NR. Finally, the IP will direct the P* to perform a takeoff from the ground, maintain a hover, and practice left and right 360 degree turns. The IP will direct the P* to land the aircraft and return the collective to the full down position.

STEP-2: FADEC FAILS AT A HOVER. While in the automatic (AUTO) mode, the IP will direct the P* to observe the throttle while the P* makes a throttle reduction to the appropriate position using the index mark for reference. Once the P* can make a smooth, quick reduction to the correct position while looking at the throttle, the IP will direct the P* to practice the initial reduction without looking and then glance down to "fine tune." (This is how a pilot should react should a real failure occur.) Repeat until the reduction is smooth and controlled and can be made in approximately 2 seconds. The IP will place the FADEC switch from AUTO to MAN. The P* will react by making the necessary throttle and collective inputs to gain Nr control and maintain it within standards. After the P* has established positive control of NR, hovering turns and landing from a hover may be practiced to teach correlation of throttle and collective inputs to changing power requirements. The second variation is to announce to the P* that the FADEC has failed in the fixed flow mode. The P* will reduce the throttle to the appropriate position and then direct the IP to place the FADEC switch from the AUTO to the MAN position and make the necessary throttle and collective inputs to gain control of and establish the NR.

STEP-3: FADEC FAILS IN FLIGHT. Training in cruise flight is the next logical step. Begin at 80 knots, straight and level at an altitude that will allow sufficient time to recover should the need arise. The IP will switch FADEC to the MAN position. The pilot will react accordingly by making the necessary throttle and collective inputs to gain Nr control and maintain it within standards. Once the P* has gained manual throttle control and is straight and level, the IP will direct the pilot to decelerate to 40 knots and then accelerate back to 80 knots. This requires the pilot to correlate throttle and collective movements through power changes. Initially it may take several minutes and several miles to accomplish this procedure. While established at the minimum and maximum power settings of this maneuver, the pilot should observe the throttle index marks to stress the effect of power demands to appropriate throttle settings. Repeat until the P* can complete the entire step in approximately the time and distance equal to the standard downwind leg of a traffic pattern.

STEP-4: TAKING FADEC FAILURE TO THE GROUND (RUNNING LANDING/VMC APPROACH). This step is simply the culmination of training conducted so far. Step 4 should be conducted while flying a standard traffic pattern to a large clear area. At approximately the mid-downwind point, at 80 knots, straight and level, the IP will place the FADEC in the manual mode. The P* will react accordingly by making the necessary throttle and collective inputs to gain NR control and maintain NR within standards. The P* should maneuver the aircraft so that it is on final at approximately 40 to 45 knots, straight and level, in trim, and at the appropriate altitude before beginning the approach. The P* should know 3 foot and out-of-ground effect (OGE) hover power required in order to make comparisons with torque throughout the approach to help assist in anticipating power changes. The pilot should also be aware that the vertical speed indicator (VSI) is a good tool to indicate impending changes in altitude and/or approach angle. Once the approach angle has been intercepted and the approach has begun, the transition through ETL is the largest single power change the pilot will have to make prior to touchdown.

a. **Running landing.** Prior to arrival on final approach, the crew will establish operation in the FADEC MAN mode. On final approach, establish straight and level flight at 40 to 45 knots and determine an approach angle which allows safe obstacle clearance to arrive at the intended point of landing. Once the approach angle is intercepted, coordinate throttle and collective to maintain the approach angle and maintain operating limits. Maintain apparent ground speed and rate of closure to arrive at two feet above the intended touchdown area at approximately ETL. If all conditions are within parameters, reduce throttle to the engine idle position, (the throttle must be at the idle detent prior to touchdown or overspeed may occur), maintain heading with pedals, and apply collective to accomplish a smooth and controlled touchdown.

Source: Headquarters Department of the Army. TC 1-248: Aircrew Training Manual OH-58D Kiowa Warrior. Washington, DC: Government Printing Office, April 2007

Appendix B. Bedford Workload Rating Scale

1. PIN __ __ __ __ __ 2. Date (DD/MMM/YY): __ __ / __ __ __ / **0 8**

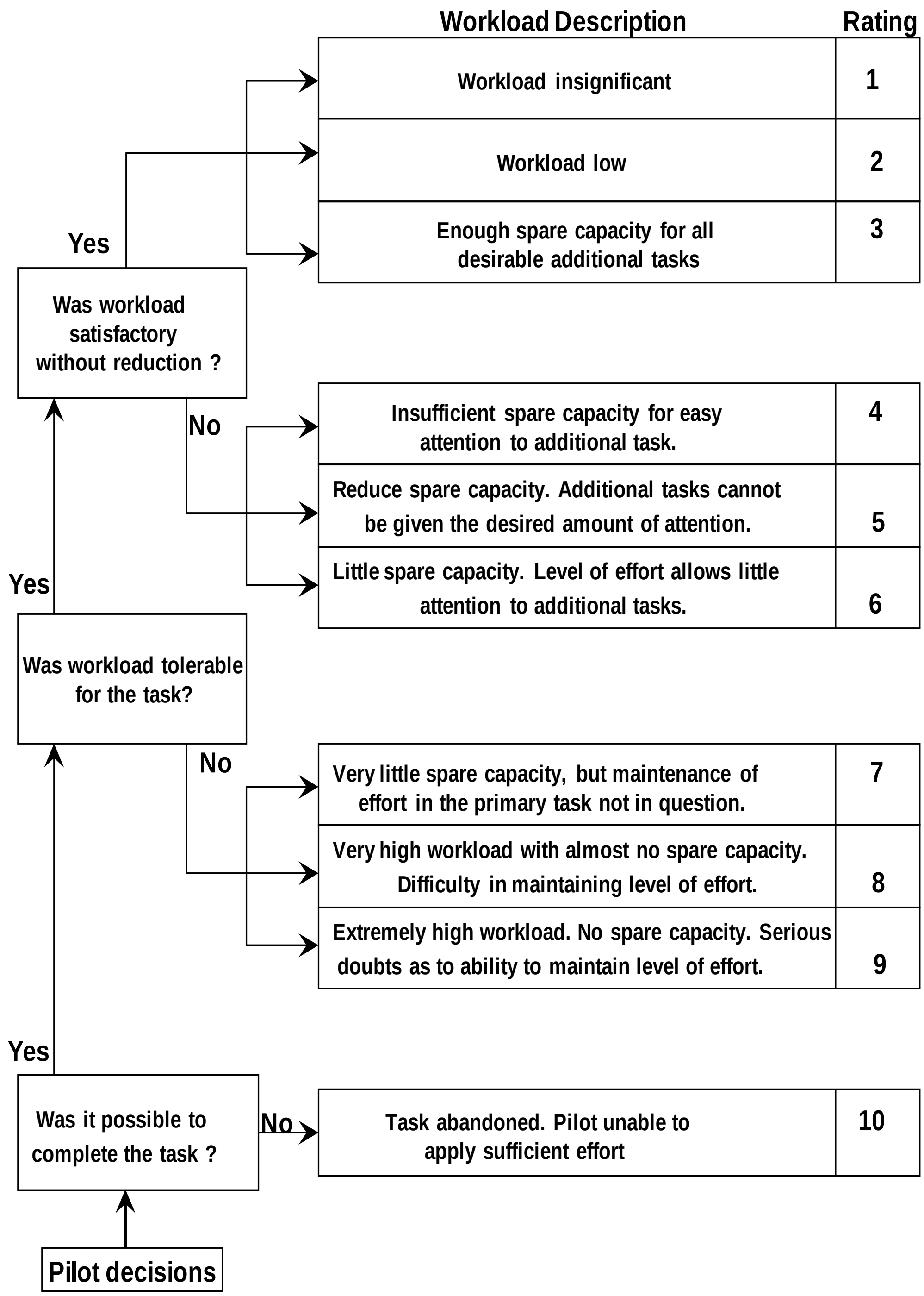
3. Right Seat _______ Left Seat _______ (Check one)

Workload

4. Rate the workload for the Flight Tasks you performed. The maneuvers listed below may be performed while conducting FADEC manual mode training/evaluations. Use the scale provided on the next page of this questionnaire. If you did not perform a task during the flight that you just completed, place an X in the non-applicable (N/A) column.

Task No.	ATM Task Title	OH-58D Aircraft Workload	OH-58D Simulator Workload	N/A
1038	Perform Hovering Flight			
1040	Perform VMC Takeoff			
1052	Perform VMC Flight Maneuvers			
1066	Perform a Running Landing			
1058	Perform a VMC Approach			
1102	Perform Manual Throttle Operation (FADEC)			
	Manual Throttle Operations Four-Step MOI (STEP 1)			
	Manual Throttle Operations Four-Step MOI (STEP 2)			
	Manual Throttle Operations Four-Step MOI (STEP 3)			
	Manual Throttle Operations Four-Step MOI (STEP 4)			

Additional comments: ____



Source: Roscoe, A. H.; Ellis, G. A. A Subjective Rating Scale For Assessing Pilot Workload in Flight: A Decade Of Practical Use. Royal Aerospace Establishment, Bedford, UK, 1990.

Appendix C. Simulator Sickness Questionnaire

1. PIN #: __ __ __ __ __ 2. Date (DD/MMM/YY): __ __ - __ __ __ - **08**

3. Seat you will fly from: Right Seat _______ Left Seat _______ (Check one)

4. Please indicate the severity of symptoms that apply to you right now by circling the appropriate word.

Symptom	0	1	2	3
General discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe
Eyestrain	None	Slight	Moderate	Severe
Difficulty focusing	None	Slight	Moderate	Severe
Increased salivation	None	Slight	Moderate	Severe
Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty concentrating	None	Slight	Moderate	Severe
Fullness of head	None	Slight	Moderate	Severe
Blurred vision	None	Slight	Moderate	Severe
Dizzy (eyes open)	None	Slight	Moderate	Severe
Dizzy (eyes closed	None	Slight	Moderate	Severe
Vertigo*	None	Slight	Moderate	Severe
Stomach awareness**	None	Slight	Moderate	Severe
Burping	None	Slight	Moderate	Severe

* Vertigo is a loss of orientation with respect to vertical upright.

** Stomach awareness is a feeling of discomfort just short of nausea.

5. Are you in your usual state of health and fitness? **YES** **NO**

6. Have you been ill in the past week? **YES** **NO**

a. If yes, are you fully recovered? **YES** **NO** **N/A**

Simulator Sickness Post Questionnaire

1. PIN #: __ __ __ __ __ 2. Date (DD/MMM/YY): __ __ - __ __ __ - **08**

3. Seat you will fly from: Right Seat _______ Left Seat _______ (Check one)

4. Please indicate the severity of symptoms that apply to you right now by circling the appropriate word.

Symptom	0	1	2	3
General discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe
Eyestrain	None	Slight	Moderate	Severe
Difficulty focusing	None	Slight	Moderate	Severe
Increased salivation	None	Slight	Moderate	Severe
Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty concentrating	None	Slight	Moderate	Severe
Fullness of head	None	Slight	Moderate	Severe
Blurred vision	None	Slight	Moderate	Severe
Dizzy (eyes open)	None	Slight	Moderate	Severe
Dizzy (eyes closed	None	Slight	Moderate	Severe
Vertigo*	None	Slight	Moderate	Severe
Stomach awareness**	None	Slight	Moderate	Severe
Burping	None	Slight	Moderate	Severe

* Vertigo is a loss of orientation with respect to vertical upright.
** Stomach awareness is a feeling of discomfort just short of nausea.

Additional comments: ____

____

____

____

____

Source: Kennedy, R. S.; Lane, N. E.; Berbaum, K. S.; Lilienthal, M. G. "Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness." International Journal of Aviation Psychology 1993, *3*, 203-220

Appendix D. Pilot-Vehicle Interface Questionnaire

1. PIN __ __ __ __ __ 2. Date (DD/MM/YY): __ __ / __ __ / **08**

3. Right Seat _______ Left Seat _______ (Check one)

The purpose of this questionnaire is to identify any problems that you experienced when using the various aircraft components to perform FADEC manual throttle operations. Your responses should be based only on the problems that you experienced during the flight that you just completed. The following table lists the functional components (and some sub-components) of the OH-58D helicopter and the caution, warning, advisory system. For each functional component (and sub-component), indicate whether or not you experience a problem using the component in a quick and efficient manner during the flight you just completed. Check "Yes" if you experience one or more problems. Check "No" if you did not experience any problems. Check "Not Used" if you did not use the functional component during the flight you just completed.

Multifunction Displays (MFD) Yes ______ No ______ Not Used ________
Fuel Burn Rate Yes ______ No ______ Not Used ________
Throttle Position Indicator Yes ______ No ______ Not Used ________

FADEC AUTO/MAN switch Yes ______ No ______ Not Used ________
FADEC FAIL Audio Tone Yes ______ No ______ Not Used ________
FADEC Manual Caution Message Yes ______ No ______ Not Used ________
FADEC FAIL Warning Message Yes ______ No ______ Not Used ________

Vertical Scales
NR (Rotor) Yes ______ No ______ Not Used _______
NP (Power Turbine) Yes ______ No ______ Not Used _______
TQR (Mast Torque) Yes ______ No ______ Not Used _______

Throttle Yes ______ No ______ Not Used _______
Throttle index reference mark Yes ______ No ______ Not Used _______

Collective Yes ______ No ______ Not Used _______
Cyclic Yes ______ No ______ Not Used ________

Additional comments:____

____

____

Source: Author

Appendix E. Situational Awareness Rating Technique

Pin # __ __ __ __ __ Date (DD/MM/YY): __ __/__ __/ **08**

Right Seat _______ Left Seat _______ (Check one)

Situation Awareness

Situation Awareness is defined as "timely knowledge of what is happening as you perform your tasks during the flight."

Assuming you had just performed task 1102 Perform Manual Throttle Operation (FADEC) in an OH-58D, rate the level of each component of situation awareness that you had. Circle the appropriate number for each component of situation awareness (e.g., complexity of situation).

DEMAND

Instability of situation: Low 1------2------3------4------5------6------7 High

Variability of situation: Low 1------2------3------4------5------6------7 High

Complexity of situation: Low 1------2------3------4------5------6------7 High

SUPPLY

Arousal: Low 1------2------3------4------5------6------7 High

Spare mental capacity: Low 1------2------3------4------5------6------7 High

Concentration: Low 1------2------3------4------5------6------7 High

Division of attention: Low 1------2------3------4------5------6------7 High

UNDERSTANDING

Information quantity: Low 1------2------3------4------5------6------7 High

Information quality: Low 1------2------3------4------5------6------7 High

Familiarity: Low 1------2------3------4------5------6------7 High

Additional comments: ____

____

____

____

____

Situation Awareness Rating Technique (SART)	
DEMAND	
Instability of Situation	Likeliness of situation to change suddenly
Variability of Situation	Number of variables which require your attention
Complexity of Situatio	Degree of complication (number of closely connected parts) of the situation
SUPPLY	
Arousal	Degree to which you are ready for activity; ability to anticipate and keep up the flow of events
Spare Mental Capacity	Amount of mental ability available to apply to new tasks
Concentration	Degree to which your thoughts are brought to bear on the situation; degree to which you focused on important elements and events
Division of Attention	Ability to divide your attention amoung several key issues during the mission; ability to concern yourself with many aspects of current and future events simultaneously
UNDERSTANDING	
Information Quantity	Amount of knowledge received and understood
Information Quality	Degree of goodness or value of knowledge communicated
Familiarity	Degree of acquaintance with the situation

Source: Taylor, R. M. "Situational awareness rating technique (SART): The development of a tool for aircrew systems design." Situational Awareness in Aerospace Operations (AGARD-CP-478), (3/1 - 3/17). Neuilly Sur Seine, France: NATO – AGARD, 1989

Appendix F. OH-58D OFT Simulator Scenario

OH58D(R) FSXXI SIMULATION
OFT Scenario
TD 132

01 Nov 2007

Scenario- Aircraft is located at HATCH, Lane 2, hdg 360 deg, with engine at idle. Start training at Engine run-up from the checklist.

Cockpit Setup- Ensure all cockpit switches are set as if the aircraft is at flight idle on the ground prior to loading IC # 3.

IOS Setup- Insert IC #3 TD 132

Load SAF- TD 132

Training Objectives-

	Task #	Task Name
R/SEAT	1102	Manual Throttle Operations (FADEC) Steps 1-4
	1102.03	Perform Acceleration / Deceleration
	1074	SEF at Cruise w/Power Recovery
	1052	VMC Flight Maneuvers
	1070	Respond to Emergencies
	1032	Radio Communication
	1046	Electronically Aided Navigation
	1024	Before start thru leaving helicopter checks
	1048	Fuel Management Procedures

Training Objective Statement: Focus of training is FADEC Steps 1-4. Coordinates for Accel/decel should be used as appropriate for task 1102.03. FADEC degrades also trained.

ATIS

Hanchey Army Heliport Information Charlie, ______ zulu, Weather.
Winds 170 @ 5 knots, Visibility better than 5000/5, Sky clear.
Temperature 20 deg C, dew point 15 deg C, Altimeter 29.92.
Landing and departing to the North. Advise on initial contact you have information Charlie.

OH58D(R) FSXXI SIMULATION
OFT Scenario
TD 133
01 Nov 2007

Scenario- Aircraft is located in at HATCH, **in flight, 700' AGL, 60 KIAS, hdg 360 deg, with engine at 100%.** Start training in flight.

Cockpit Setup- Ensure all cockpit switches are set as if the aircraft is at 100% in flight, prior to loading IC # 4.

IOS Setup- Insert IC #4 TD 133

Load SAF- TD 133

Training Objectives-

	Task #	Task Name
R/SEAT	1102	Manual Throttle Operations (FADEC) Steps 1-4
	1102.03	Perform Acceleration / Deceleration
	1074	SEF at Cruise w/Power Recovery
	1052	VMC Flight Maneuvers
	1070	Respond to Emergencies
	1032	Radio Communication
	1046	Electronically Aided Navigation
	1024	Before start thru leaving helicopter checks
	1048	Fuel Management Procedures

Training Objective Statement: Focus of training is FADEC Steps 1-4. Coordinates for Accel/decel should be used as appropriate for task 1102.03. FADEC degrades also trained. Allow student in Left seat to perform steps 2-4 (FAM) if time allows.

ATIS

Hanchey Army Heliport Information Delta, ______ zulu, Weather.
Winds 350 @ 5 knots, Visibility better than 5000/5, Sky clear.
Temperature 20 deg C, dew point 15 deg C, Altimeter 29.92.
Landing and departing to the North. Advise on initial contact you have information Delta.

D (Training Day)

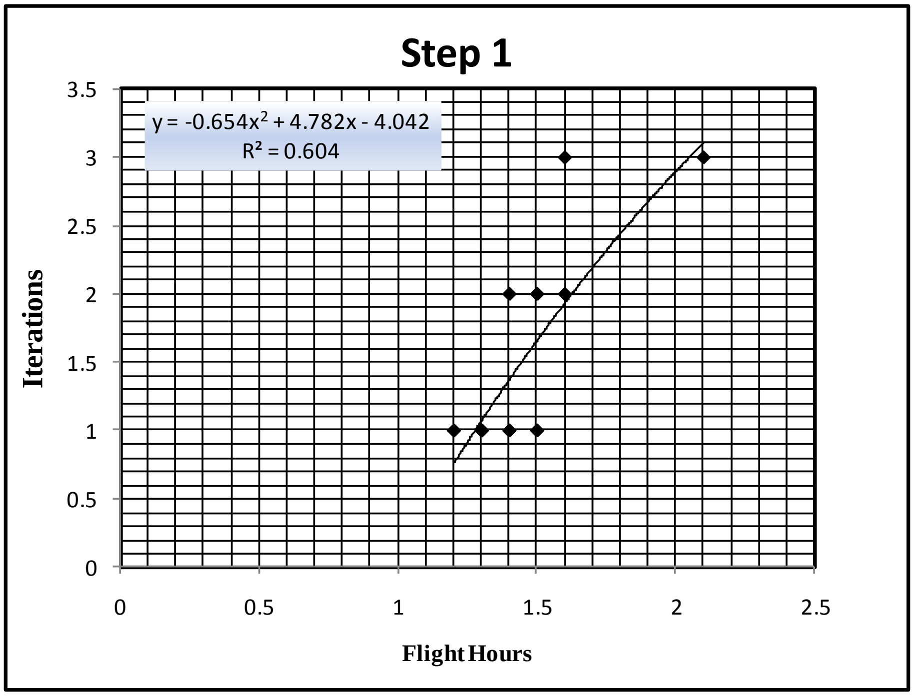
Source: OH58-D Flight School XXI, Computer Science Corporation Fort Rucker, Al. 36362

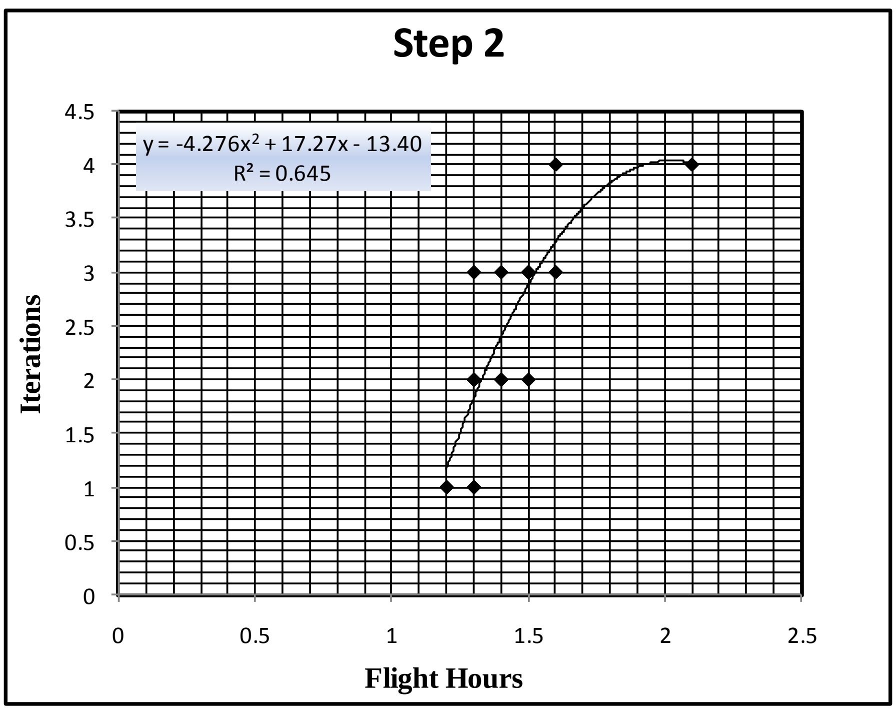
Appendix G. Iteration and Flight Hour Data Collection Sheet

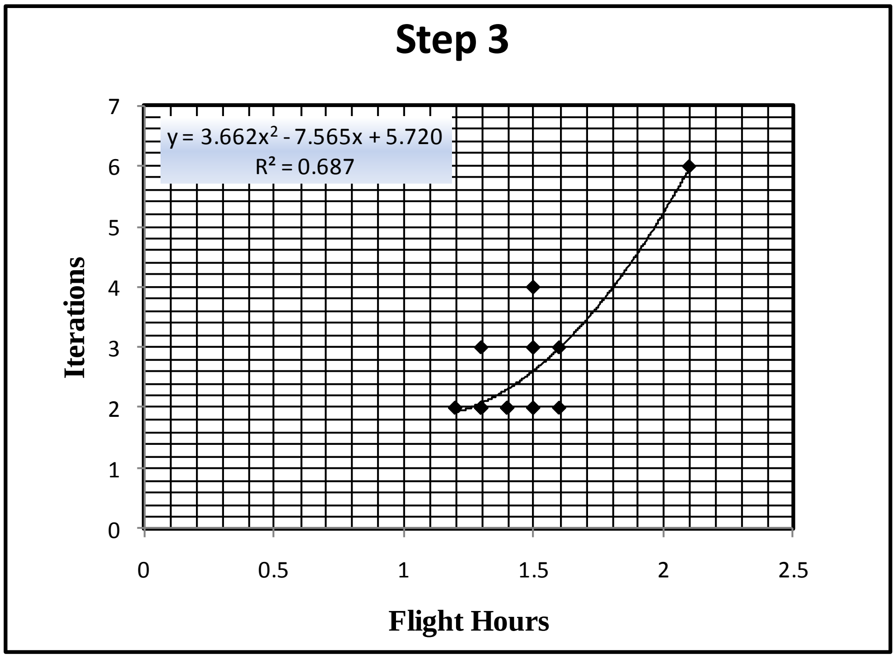
Date:		Aircraft / OFT		
PIN:	Step 1	Step 2	Step 3	Step 4
Hrs:	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD
Iterations:	/	/	/	/
	/	/	/	/
PIN:	Step 1	Step 2	Step 3	Step 4
Hrs:	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD
Iterations:	/	/	/	/
	/	/	/	/
PIN:	Step 1	Step 2	Step 3	Step 4
Hrs:	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD
Iterations:	/	/	/	/
	/	/	/	/
PIN:	Step 1	Step 2	Step 3	Step 4
Hrs:	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD
Iterations:	/	/	/	/
	/	/	/	/
PIN:	Step 1	Step 2	Step 3	Step 4
Hrs:	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD
Iterations:	/	/	/	/
	/	/	/	/
PIN:	Step 1	Step 2	Step 3	Step 4
Hrs:	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD
Iterations:	/	/	/	/
	/	/	/	/
PIN:	Step 1	Step 2	Step 3	Step 4
Hrs:	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD
Iterations:	/	/	/	/
	/	/	/	/
PIN:	Step 1	Step 2	Step 3	Step 4
Hrs:	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD	ITR / ITR STD
Iterations:	/	/	/	/
	/	/	/	/

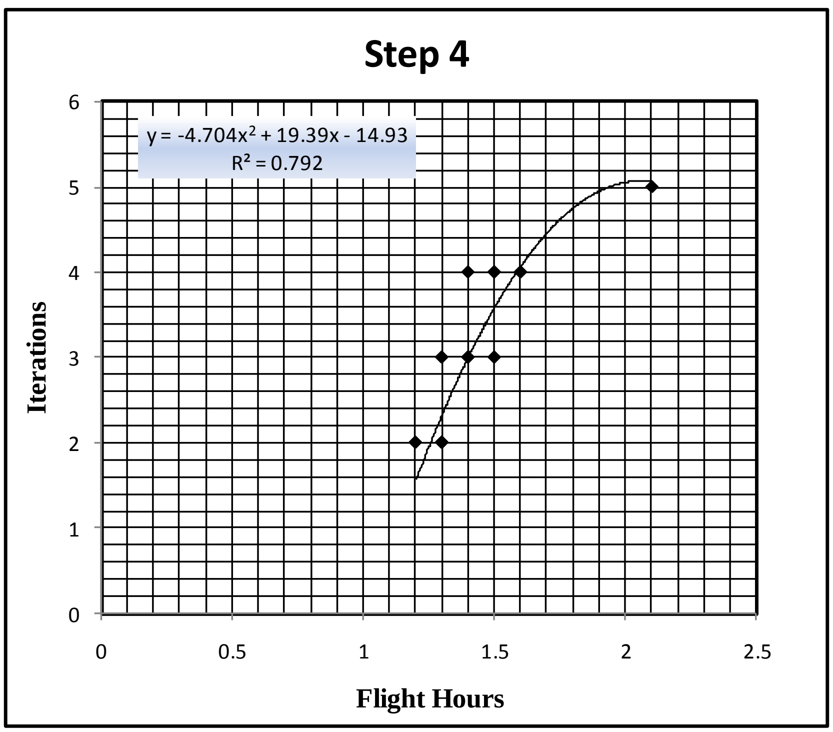
Source: Author

Appendix H. Iteration Correlation Charts









Source: Author

Appendix I. Mean Task Workload Rating

Mean Workload Ratings for ATM Tasks										
	ATM Task Numbers						Manual Throttle 4 step MOI			
	1038	1040	1052	1058	1066	1102	MOI step 1	MOI step 2	MOI step 3	MOI step 4
Combined workload rating before OFT for training flights										
Mean	2.909	2.125	2.875	2.429	3.000	3.250	3.000	3.300		
Combined workload rating for OFT for training flights										
Mean	3.900	2.810	3.048	3.941	4.111	4.905	4.150	4.850	4.636	5.474
Combined workload rating after OFT for training and evaluation flights										
Mean	1.705	1.707	1.841	1.881	2.500	3.227	2.651	2.707	3.186	3.795

Source: Author

Appendix J. Pilot PVI Comments

PVI Comments for the OH-58D Helicopter

Multifunction Displays (MFD)

- Pilot MFD scaled too big for screen

Throttle Position Indicator

- Throttle position indicator fluctuates 3-4%

FADEC AUTO/MAN switch

- AUTO/MAN switch did not return to AUTO position when selected

TQR (Mast Torque)

- Mast torque fluctuates 5-10% on final approach with collective power set
- Mast torque fluctuates up to 11% with power set

Throttle

- 2 Throttle stiff
- Throttle input excessive for rate of increase or decrease

Throttle index reference mark

- 2 Throttle index reference mark not readable

Collective

- Collective responds quicker in aircraft versus OFT

PVI Comments for the OH-58D OFT

Throttle Position Indicator

- Throttle position indicator changes 3-4 % with only slight adjustments with the throttle
- Throttle position indicator fluctuates 3-4 % with no throttle movement
- Throttle position indicator increases without moving throttle

Throttle

- Throttle retches at 65%-67% throttle position
- Throttle sticking
- Throttle not the same as yesterday in the same trainer

Throttle index reference mark

- 2 Throttle index reference mark not readable
- Throttle mark set to low for manual throttle training

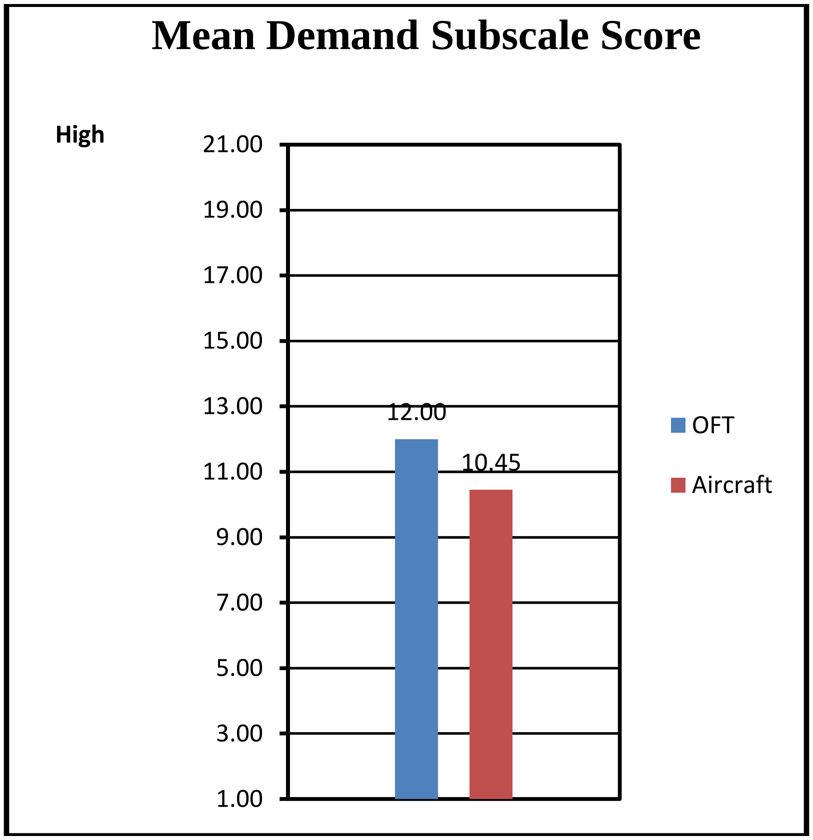
Collective

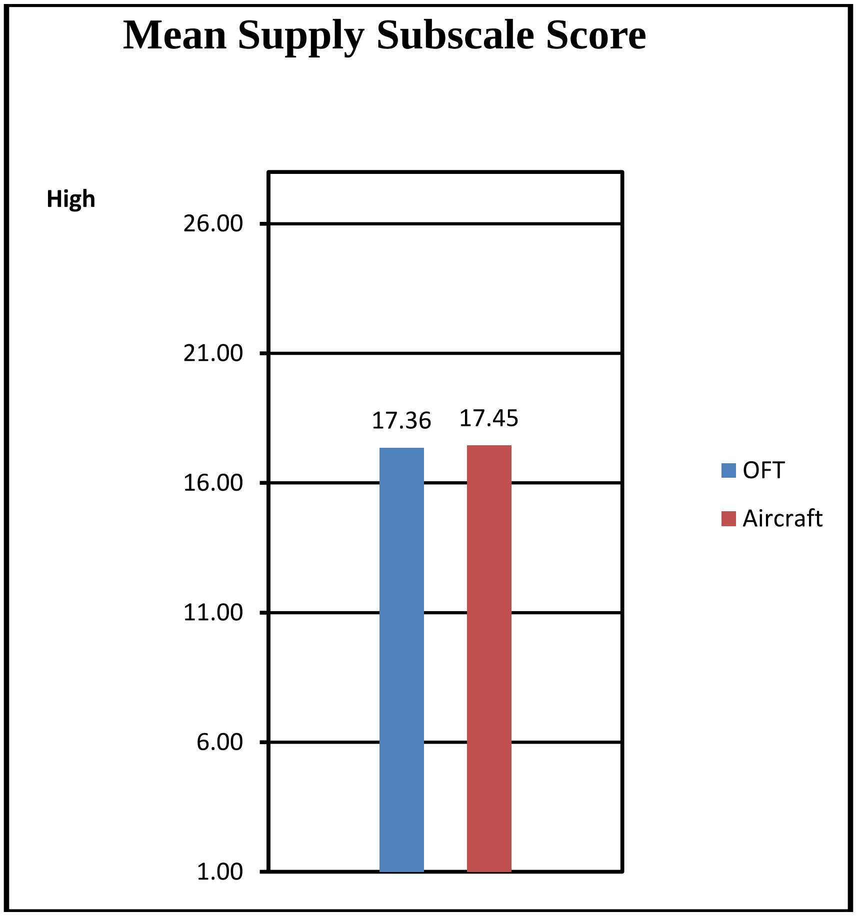
- 2 Collective stiff

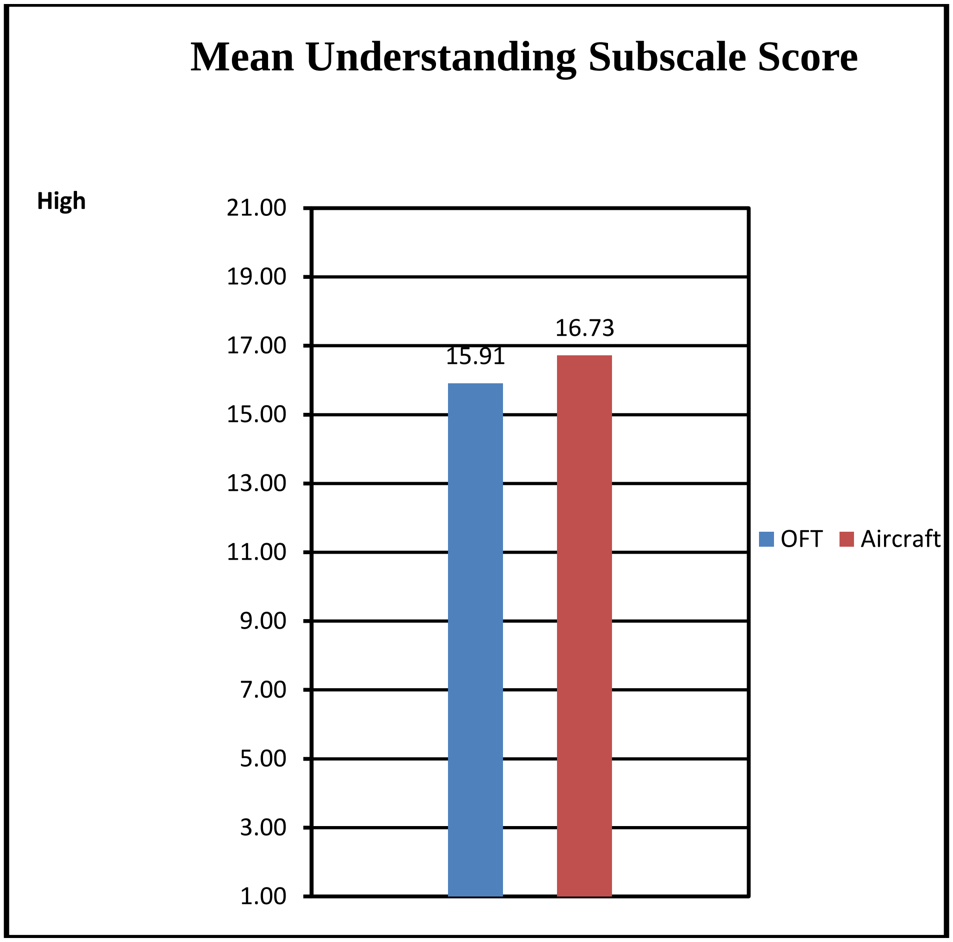
Screen for simulator on the right side (outside) did not function properly

Source: Author

Appendix K. Pilot SART Subscale Rating




Mean Supply Subscale Score
High
26.00
21.00
16.00
11.00
6.00
1.00
17.36
17.45
OFT
Aircraft



Source: Author

VITA

Conrad Rodgers was born in Miami, FL on June 28, 1966. He was raised in Mobile, AL and graduated from Williamson High School in 1985. After attending Bishop State Junior College, he enlisted in the U.S. Army as an Infantryman in 1986. In 1992 he attended Warrant Officer Candidate School and Army Flight School at Ft. Rucker, AL. Upon graduation from flight school, he was assigned as a UH-1helicopter pilot in the 101st Airborne Division at Ft. Campbell, KY. While serving at Ft. Campbell he piloted the OH-58A/C and OH-58D. In May of 2000 he received his BS in Aeronautical Science with a minor in Aviation Safety from Embry Riddle Aeronautical University. Throughout his other assignments at Ft. Hood, TX and Ft. Rucker, AL he served as a Standardization Instructor Pilot and Instrument Flight Examiner. He was deployed to Bosnia for seven months to conduct peace keeping duties and to South West Asia. While serving at Ft. Rucker with the 1st Battalion 14th Aviation Regiment he was an OH-58D flight platoon commander for Flight School XXI and the Instructor Pilot Course. In 2007 he was selected to attend advanced civil schooling. In 2008 he graduated from the University of Tennessee Space Institute with a Master's Degree in Aviation Systems and will be assigned to the US Army Aviation Technical Test Center after attending the United States Naval Test Pilot School.