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# Live Versus Virtual: Cost Benefit Analysis for Applying Simulation Towards Army Aviator Flight Minimums

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# LIVE VERSUS VIRTUAL:
# COST BENEFIT ANALYSIS FOR APPLYING SIMULATION TOWARDS ARMY AVIATOR FLIGHT MINIMUMS

by

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## ABSTRACT

The Longbow Crew Trainer (LCT) is a cost effective, safe alternative to live training in the AH-64D/E Apache helicopter. Current Army doctrine and regulations have provisions for the limited use of simulator in lieu of aircraft hours toward semiannual minimum flight hour requirements. With the defense budget in decline, the Army must find innovative, cost effective methods to conduct realistic, relevant training to sustain proficiency in their warfighting capabilities. The LCT fully replicates the cockpit environment through training scenarios for requisite crew tasks and missions in a realistic, modular, and transportable solution. An attack helicopter crew can safely train in customizable scenarios ranging from basic aviation tasks to crew-level missions and gunneries. The Army is currently aligning one LCT per attack battalion under the Aviation Restructure Initiative. There are 20 Armed Reconnaissance Battalions/Squadrons in the active component with approximately 35 aircrews per battalion. The premise of this study was to review cost benefits of training in a virtual environment over a live environment while exploring the effects on proficiency. The difference in cost per hour between an AH-64D and the LCT is approximately $3,998. Using this figure and the semiannual flight hour requirements from the current Aircrew Training Manual in a weighted average between Flight Activity Category (FAC) 1 and FAC 2 pilot's flight minimum requirements formed the basis for four models: Low, Status Quo (baseline), Moderate, and High Virtual Simulation Models. This study found that while the High Virtual Simulation Model resulted in the greatest cost savings, the current budget and previous literature does not require such drastic measures. The Low Virtual Simulation Model resulted in higher costs. Therefore, the Moderate Virtual Simulation Model, proved most relevant to budget analysts, aviation unit commanders, and pilots by decreasing annual costs by an estimated $76.2 million without degrading proficiency.

For Kaylin and Austin: Do not fear change. Shape it. Thank you for this opportunity to further my education. I hope to be an example for you to emulate and this time at UCF influences your decisions for where to continue your higher educations. Go Knights! Lastly, this thesis is for all fallen angels lost in training and combat.

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**TABLE OF CONTENTS**

# LIST OF FIGURES

## LIST OF TABLES

## LIST OF ACRONYMS/ABBREVIATIONS

| | |
|---|---|
| AH | Attack Helicopter |
| ARB | Attack Reconnaissance Battalion |
| ARI | Aviation Restructure Initiative |
| ARNG | Army National Guard |
| ATM | Aircrew Training Manual |
| ATP | Aircrew Training Program |
| AVCATT | Aviation Combined Arms Tactical Trainer |
| Bde | Brigade |
| Bn | Battalion |
| BCA | Budget Control Act |
| BCT | Brigade Combat Team |
| CAB | Combat Aviation Brigade |
| Cdr | Commander |
| CH-47 | Cargo Helicopter (Chinook) |
| CPG | Copilot-Gunner |
| CMS | Combat Mission Simulator |
| CTER | Cumulative Transfer Effectiveness Ratio |
| DA | Department of the Army |
| DES | Directorate of Evaluations and Standardization |
| DoD | Department of Defense |
| FAC | Flight Activity Category |
| FHP | Flying Hour Program |
| FLIR | Forward Looking Infrared |
| FORSCOM | Forces Command |
| FY | Fiscal Year |
| HDU | Helmet Display Unit |
| HQDA | Headquarters, Department of the Army |
| IE | Instrument Flight Examiner |
| IERW | Initial Entry Rotary Wing |
| ITER | Incremental Transfer Effective Ratio |
| IMC | Instrument Meteorological Conditions |
| I/O | Instructor/Operator |
| IP | Instructor Pilot |
| LCT | Longbow Crew Trainer |
| LCCS | Life Cycle Contract Support |

| | |
|---|---|
| LPT | Longbow Procedural Trainer |
| ME | Maintenance Test Pilot Evaluator |
| MP | Maintenance Test Pilot |
| MTPC | Maintenance Test Pilot Course |
| MTOE | Modified Table of Organizational Equipment |
| MTSTT | Modernized TADS Selectable Task Trainer |
| NVG | Night Vision Goggles |
| OCO | Overseas Contingency Operations |
| OFP | Operational Flight Trainer |
| O&M | Operation and Maintenance |
| OPTEMPO | Operational Tempo |
| PEO-STRI | Program Executive Office for Simulation, Training, & Instrumentation |
| PC | Pilot-in-Command |
| PI | Pilot |
| PM | Program Manager |
| POI | Program of Instruction |
| RL | Readiness Level |
| SFTS | Synthetic Flight Training System |
| SP | Standardization Instructor Pilot |
| TADS | Target Acquisition/Designation System |
| TER | Transfer Effective Ratio |
| TOT | Transfer of Training |
| UH-60 | Utility Helicopter (Blackhawk) |
| UT | Unit Trainer |
| XP | Experimental Test Pilot |

# CHAPTER ONE: INTRODUCTION

## Chapter One Summary

As the introductory chapter, this section presents the motivation for analysis with a description of the United States Army Aviation structure, aviator categories, a description of the AH-64D/E with associated simulation devices, and flight hour requirements. Additionally, this chapter reviews recent defense budget constraints; concluding with a description of the gap.

## Motivation for Analysis

With military downsizing and budget constraints a constant reality or looming threat, this analysis provides budget analyst and commanders the flexibility and monetary information to make an educated decision when faced with a decreased flight hour budget. Flying is an inherently dangerous and complex profession. Since July of 2000, there have been 38 aircraft destroyed and 25 aviators killed in non-combat related aircraft accidents (Allen, 2015). Conversely, zero aviators were killed in the simulator in the same time.

This study does not consider the cost of an aircraft loss or crew but will address an increase or decrease in exposure to risk of loss within the analysis. A recent article in the Stars and Stripes argues that budget cuts negatively affect the training and maintenance across the military's rotary-wing fleet. Since January 2015 through January 2016, there has been 42 deaths and 14 helicopters destroyed across all services, a significant increase from prior years (Copp, 2016).

The motivation for this analysis is to identify simulation based alternatives with an emphasis on minimizing cost and mitigating risk while, at a minimum, maintaining training proficiency and combat readiness for Army aircrews.

## Army Aviation Structure

Just five years ago, the Army was expanding to 13 active component (AC) Combat Aviation Brigades (CAB). After extensive reorganization due to downsizing and maximization of combat modularity and effectiveness, the Army currently operates with eleven Combat Aviation Brigades (CAB). Within each CAB, subordinate battalions own the aircraft. The subordinate units are the Armed Reconnaissance Battalion (ARB) (24 x AH-64), Armed Reconnaissance Squadron (ARS) (24 x AH-64 or 30 x OH-58 and 12 x Shadow UAS), Assault Helicopter Battalions (AHB) (30 x UH-60), General Support Aviation Battalion (GSAB) (12 x CH-47, 8 x UH-60, 15 x MEDEVAC UH-60), and one Aviation Support Battalion which owns zero aircraft. Under previous force structure, the brigades were classified as light, medium, or heavy. This designation referenced deployability, mission sets, and influenced which and how many aircraft were in the brigade. While the designation still exists on FMSWeb, as of fiscal year (FY) 15/16 authorization documents, all CABs have the same structure except two. 82d CAB is the only unit with one squadron of OH-58s and 2d Infantry Division CAB only has one ARB on the Korean Peninsula (Force Management Support Agency, 2015). This study only focuses on the AH-64D/E within the ARB and ARS. As part of the Aviation Restructure Initiative (ARI), the Army will retire all OH-58D helicopters. To fill the tactical reconnaissance and security requirement, one ARB per CAB will reorganize as an ARS. The ARS retains the 24

Apaches, but adds 12 shadows and associated personnel and equipment to their organic structure. By 2019, each of the 10 divisions in the Army will have one ARB and one ARS within their respective CAB (Tan, 2015). Research of organizational structure change and the application of UAS for potential cost and risk mitigation are beyond the research scope for this paper, but is a topic of great discussion and concern. Table 1 reflects FMSWeb data reflecting FY15 and 16 authorization documents for the total number of AH-64D/E aircraft authorized across the 11 AC CABs within 20 battalions/squadrons.

Table 1: Total Number of Active Component AH-64 Apache Helicopters

| Nomenclature | Number of ARB/ARS | Number Auth |
|---|---|---|
| HELICOPTER ADVANCE ATTACK AH-64E: | 5 Bn | 120 |
| HELICOPTER: ATTACK AH-64D | 15 Bn | 360 |
| Total | 20 Bn | 480 |

## **Army Rotary-Wing Aviators**

In the United States Army's Aviation branch, both commissioned and warrant officers branch fly. All Army aviators receive their training at Fort Rucker, Alabama. Upon graduation from flight school, aviators leave qualified in one of the Army's advanced helicopters and usually stay in that aircraft their entire career. The basic level of piloting in the Army is under the status of "pilot" or PI. No matter the level of expertise or rank, all newly assigned pilots to a unit arrive with the designation of pilot (PI) at readiness level 3 (RL 3). Pilots increase their readiness status through a process called readiness level (RL) progression. Depending on the aviator's prior service and performance at a former duty location and records evaluation, the commander decides whether an aviator progresses higher than pilot status during their RL progression. Once the pilot proves to an instructor pilot, through a series of check rides, that they can complete tasks to standard and possess a knowledge of the local area policies and procedures, they advance to a fully qualified status of RL 1. Additionally, commanders select pilots who are ready to go the next level at any point in their tenure depending on the aviator's performance.

Beyond the pilot level, aviators progress to various forms of pilot-in-command or PC. While each unit has different requirements for making pilots-in-command, a foundation of sound judgment, maturity, pilotage expertise, a mastery of tactics, and local operating policies and procedures round out the requirements. All flights in an Army helicopter require a PC in one of the pilot stations (Department of the Army, 2014). While a flight might have two aviators who are designated PC, only one aviator logs PC time and is the pilot responsible for the flight. In order to become an instructor pilot or any of the other designations outlined in Table 2, an aviator must first achieve the status of pilot-in-command followed by specialized training.

Table 2: United States Army Aviator Designation

| **Designation** | **Secondary Designation** |
|---|---|
| Pilot (PI) | |
| Pilot-in-Command (PC) | Unit Trainer (UT) |
| | Instructor Pilot (IP) |
| | Instrument Examiner (IE) |
| | Standardization Instructor Pilot (SP) |
| | Maintenance Test Pilot (MP) |
| | Maintenance Test Pilot Examiner (ME) |
| | Experimental Text Pilot (XP) |

The unit's personnel authorization does not list or mandate an aviator's designation. While there are slots designated for positions such as instructor and maintenance test pilots, personnel filling a position for an Armament Officer might not be a pilot-in-command, whereas, the aviator filling the Pilot slot, might carry the designation of PC through authorization of the commander. An ARB/ARS manages the flight training for all aviators in the three flight companies and a headquarters and headquarters company, which contains all staff officers to include the battalion/squadron commander, a maintenance company, a support company, and a portion or all of the staff aviators at the brigade level. Generally, an ARB/ARS has approximately 70 aviators to manage, with about half of those designated as PI. Each position has a flight activity category (FAC). The commander designates and aviator's FAC level in relation to their assignment or position. An aviator in one of the three flight companies with direct access to aircraft holds a FAC 1 designation, while a FAC 2 supported aviator at the brigade level has neither direct access to aircraft nor holds a position where flying is a primary duty. Aviators at the battalion or brigade staff level are generally designated FAC 2. FAC 3 aviators are usually at the division or higher or in a unit that has access to a simulator but not aircraft. The FAC 3 aviator has no live flight requirements. This designation is rarely used and not considered for purposes of this study. The FAC determines how many hours the aviator must fly in both the aircraft and Longbow Crew Trainer (LCT) semiannually. Based on manning and force structure, but variable at the commander's discretion, FAC 1 aviators generally outnumber FAC 2 aviators at a 3:1 ratio.

## AH-64D/E Longbow Apache and Simulation Devices

This section describes the capabilities, history, and associated simulation devices for the AH-64D/E helicopter. Currently, the Apache uses a mix of four simulation devices: The LCT, The Aviation Combined Arms Tactical Trainer (AVCATT), Modernized TADS Selectable

Task Trainer (MTSTT), and Longbow Procedural Trainer (LPT). The LCT is the only compatible Synthetic Flight Training System (SFTS). The AVCATT is a collective trainer, the MTSTT is a procedural trainer, and the LPT is a personal computer based emulator. This section concludes with an in depth description of the LCT.

### AH-64D/E Apache Longbow/Guardian

The AH-64 Apache helicopter is the United States Army's primary attack and reconnaissance aerial platform. A proven combat multiplier with more than 3.9 million hours flown in training and combat for the United States and 11 other countries (The Boeing Company, n.d.). The Apache is a twin-engine, four-bladed, tandem-piloted helicopter. While both pilots have full access to aircraft controls, the pilot in the back seat is generally responsible for flying the aircraft, whereas, the co-pilot/gunner (CPG) can spend the majority of the flight managing other aircraft or identifying and engaging targets using the Target Acquisition Designation System (TADS). The helmet in the AH-64 is linked to the aircraft's sights, sensors, and weapon systems. Additionally, each pilot has access to full flight symbology with a forward-looking infrared systems (FLIR) overlay displayed through a helmet display unit (HDU) over the right eye. Armament includes a combination of 30mm canon ammunition, various 2.75" rockets, and laser or radar guided Hellfire missiles (Gower Jr., Lilienthal, Kennedy, Fowlkes, & Baltzley, 1987). The Apache was instrumental in the first Gulf War and essential in support of ground forces throughout the War on Terror.

Figure 1:  AH-64 Apache Longbow Helicopter (Boeing, n.d.)

The AH-64 Apache developed by Hughes in the late 1970s and delivered in the 1980s by McDonnell Douglas as the AH-64A Apache, is currently in its third generation under the Boeing Company as the AH-64E Apache Guardian.  Between the Apache and the Guardian was the AH-64D Apache Longbow, which added a fire-control radar and digitized avionics, displays, and communication.  Over the lifecycle of the Longbow, there were multiple firmware upgrades, enhancements to survivability, deployability, and ease of maintenance.  Additionally, the Longbow went through three major upgrades called “Blocks.”  Fifteen battalions in the current force pool still own and operate Block II AH-64D Longbows.  In 2012, The Block III AH-64D Longbow was renamed the AH-64E Guardian and with enhanced engines, avionics, networked communications and fuselage, the Guardian is the future for the Army’s Apache platform (The Boeing Company, n.d.).

To discuss the airframe and pilots, one would be remised to fail to mention crew chiefs and maintenance.  The crew chiefs do not fly in an Apache as they do in a Blackhawk or Chinook helicopter.  Apache maintenance is on a phased-maintenance methodology.  All aircraft receive a daily service inspection prior to the first flight of the day.  There are service checks and inspections based on hours, dates, and durations.  Meaning some inspections occur when an aircraft flies for 10 hours, others every ten days, and for some, one year from when a part was last serviced.  Scheduled maintenance occurs at the 50 hour, 125 hour, 250 hour, and a major phase overhaul at 500 hours.  Unscheduled maintenance keeps crew chiefs engaged and trained between scheduled maintenance.  While crew chiefs conduct some services based on date, a lull in flights equates to a degradation to the tempo and training iterations for the crew chiefs.

Flight simulations have always been integral to Apache aircrew training, both at the schoolhouse and at the unit for sustainment training.  The AH-64A Apache's compatible SFTS was a full-motion, non-deployable CMS with six degrees of freedom.  Looking for a more transportable and deployable option, the Army dropped the full motion capability for seat plates in the LCT for the AH-64D Longbow.  The LCT is the primary flight simulator for all Apache variants in the Army's current inventory.  Additionally, units can arrange the Aviation Combined Arms Tactical Trainer in an AH-64D/E configuration for collective task training.  The AH-64E Longbow Modernized TADS Selectable Task Trainer (MTSTT) is a procedural trainer for increasing a CPG's reaction time and efficiency in gunnery tasks.  Table 3 outlines the associated compatible SFTS for the AH-64 Longbow and Guardian aircraft (Department of the Army, 2014).  This study focuses primarily on the LCT as the only SFTS with the fidelity to train tasks at the individual and crew level.  The primary purpose of the Aviation Combined Arms Tactical Trainer's is to train collective tasks and compromises control touch and avionic fidelity to meet cost and requirements, thus disqualifying the device as a direct substitution for maintaining or acquiring individual and crew proficiency.

Table 3: AH-64D/E Compatible Synthetic Flight Training System (SFTS)

| Designation | Compatible Aircraft |
|---|---|
| AH-64D Longbow Crew Trainer 2B64D | AH–64D |
| AH-64E Longbow Crew Trainer 2B64E | AH–64E, AH-64D BLK II |
| AH-64E Longbow Modernized TADS Selectable Task Trainer (MTSTT) | AH–64E |
| Aviation Combined Arms Tactical Trainer | None |

**AH-64 Longbow and Longbow Crew Trainer (LCT)**

The LCT trains aviators at the individual and crew level in all tasks to include standard flight maneuvers, instrument flight, gunnery skills, and mission specific tasks and conditions. In addition to the aircrew, an instructor/operator (I/O) facilitates the scenario, injects emergencies or weather conditions, monitors performance, and controls other friendly and enemy vehicles. One LCT system consists of a device trailer and a service trailer with a self-contained power multi-fuel generator and environmental control unit. The unit is transportable and deployable. Inside the device trailer, the two pilot stations face away from each other on opposite sides with the I/O station in the middle. The pilot and copilot/gunner stations are exact replicas of the respective stations from the aircraft. The I/O has access to both pilot's video, audio, instrumentation, and multiple screens and controls to facilitate and monitor training. Aircrews can fly and train on a number of mission sets from a customizable database to include overwater training, requisite gunnery tables, mission rehearsals, and combat scenarios. The I/O controls weather conditions and induces emergency procedures in which the aircraft and instrumentation reflect conditions relative to the emergency. The I/O can also pause the system mid-scenario or review the flight afterwards for evaluation purposes.

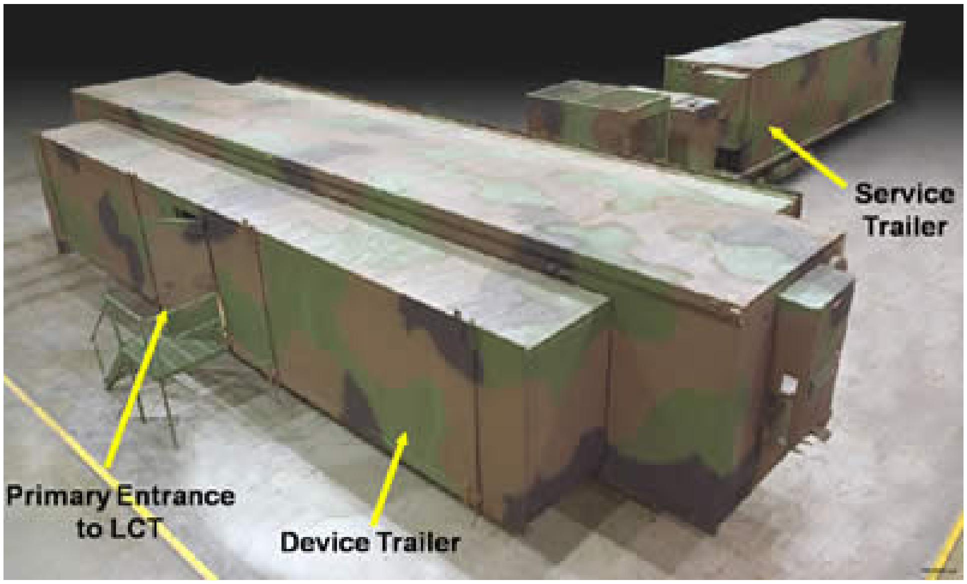


Figure 2: LCT (Training Support Center, Fort Carson, Colorado, 2012)

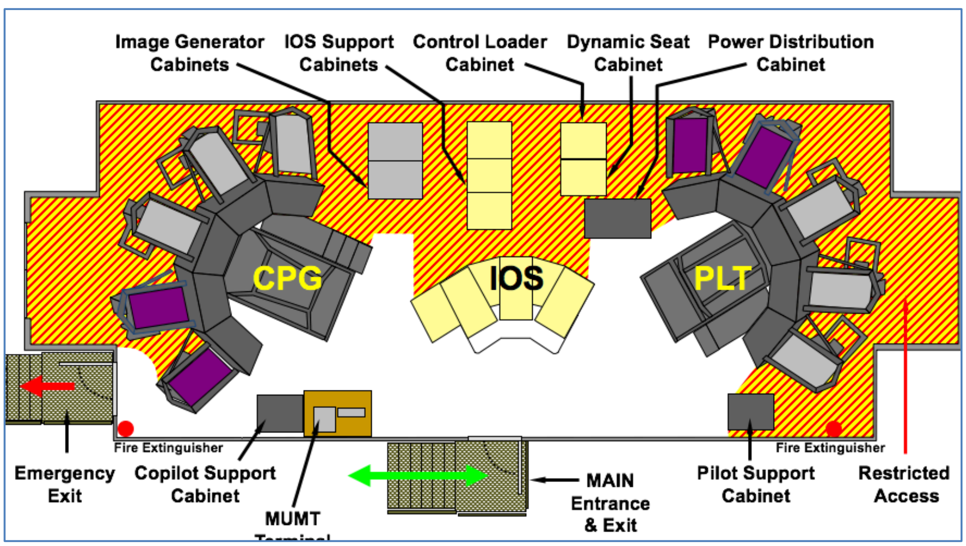


Figure 3: LCT Generation 4 Device Layout (Mings, 2016)

Pilots wear the same helmets and aviation life support equipment they normally fly with.in the actual aircraft. The only difference is that the helmet does not bore sight, or align, with the aircraft using the helmet's integrated infrared harness as it would in the aircraft. Instead, the LCT uses a proprietary wired sensor that clips into the top of the helmet. As depicted in Figure 4, aircraft controls, seats, avionics, and displays are all direct replicas or even the same parts from the aircraft.  Five high-resolution displays, wrap around each station for a field of view of approximately 140 degrees.  The LCT uses dynamic motion cueing seating to provide pilots proprioceptive feedback to provide a deeper level of immersion and reduce simulation sickness.  Pilots communicate between each other, and via the I/O, other aircraft, air traffic controllers, or ground forces using the the same suite of radios and digital means as found in the actual aircraft (Department of the Army, 2010).  The LCT has no provisions for NVG training or capability to link multiple devices for collective training.

Figure 4:  LCT CPG/Gunner Station (Boeing, n.d.)

As of August 2015, there are twelve LCTs in the active component, nine reserve component systems, and six systems at Fort Rucker, AL.  This distribution equates to one system for each geographical area to support up to two ARBs.  As the Army National Guard transfers Apaches to the active component, LCT systems transfer as well.  By September of 2019, each ARB will own a respective LCT.  When computing throughput and availability, this study assumes each active component ARB has an LCT, as this is the Army's tentative end state.

## LCT Benefits

Some of the benefits of applying LCT flight hours in lieu of live hours to meet semiannual flight hour minimum requirements include:

1. LCT flight mitigates the risk to aircrews to almost zero.
2. The cost of an LCT flight hour is $3,998 cheaper than a live hour.
3. Unlimited ammunition and fuel.
4. Accurate emergency procedure training.
5. Customizable database for terrain, scenario, and threat systems.
6. Ability to pause, reset, review, and provide real-time feedback to the crew.
7. Poor weather conditions affect live flights and have a minimal affect on the availability of the LCT.
8. LCT contracted availability rates of 90% (Mings, 2016). Aircraft maintenance rates vary between units and rarely reach the 90% level.

## LCT Limitations

Some of the limitations of applying LCT flight hours in lieu of live hours to meet semiannual flight hour minimum requirements and limitations of this study include:

1. The LCT does not have the means to train NVGs.
2. The LCT is a crew trainer and is not collective trainer. The LCT does not replicate multi-ship flight, air-ground integration, or joint attacks at a level appropriate to gain or maintain proficiency.
3. Loss of confidence in the aircraft due to a lack of iterations and familiarity.

4. Crew chiefs and other maintainers do not receive the number of maintenance tasks requisite to maintain proficiency due to the reduction of hours and subsequent service requirements on the aircraft.
5. Lack of presence and emersion. The crew will never feel the risk associated with flying an actual aircraft in the LCT.

## Flight Hour Training Requirements

Each aircraft has an Aircrew Training Manual (ATM), which defines flight and LCT minimum semiannual flight requirements. An aviator can fly more than the minimum but the hours listed in the ATM are the absolute minimums. AH-64D/E aviators can be both dual-seat or single-seat designated and fall into one of three flight activity categories (FAC). The seat designation has no effect on the total number of hours an aviator must fly in a semiannual period. It only reallocates how many of those hours must be flown in each seat. For example, a dual-seat designated FAC 1 aviator must fly a minimum of 15 hours in each crew station out of the 70 hours required, whereas a single-seat designated FAC 1 aviator must fly 63 hours in the designated crew station (Department of the Army, 2013). An aviator's FAC level affects semiannual minimums in both the aircraft and simulator. Table 4 details the AH-64D/E minimum semiannual flight and simulation hour requirements per the AH-64D/E ATM (Department of the Army, 2013).

Table 4: AH-64D/E Semiannual Minimum Training Requirements in Hours per System

| FAC | Aircraft Flight Time Minimum Semiannual Requirement (when maximum allowable simulation hours are substituted) | Simulator Minimum Semiannual Requirement (maximum allowable hours transferable to aircraft flight time requirements) |
|---|---|---|
| 1 | 70 (58) | 15 (12) |
| 2 | 50 (38) | 9 (12) |
| 3 | 0 | 24 |

Of note, the following is already written in the current ATM, "Trainers and evaluators may credit instructor/operator (I/O) hours toward their semiannual simulation device flying hour requirements. All aviators may apply a maximum of 12 simulation hours flown in a semiannual period toward that period's semiannual flying hour requirements" (Department of the Army, 2013). As Table 4 illustrates, a FAC 1 aviator may apply 12 of the 15 simulator hours towards the aircraft semiannual requirement for a revised requirement of 58 live hours. Whereas, a FAC 2 aviator can fly up to three additional simulation hours to apply the full 12 simulator hours towards live hours for 38 live hours. Interestingly, there is no difference in the standard for successful execution of a task for a FAC 1 aviator or a FAC 2 aviator. A loose interpretation of this lack of a difference means a FAC 2 aviator who flies a minimum of 50 hours or 38 hours semiannually with full simulation applied has the same expectation or standards to accomplish tasks as that of a FAC 1 aviator who flies 70 hours or 58 hours semiannually with full simulation applied. Since FAC 1 aviators typically outnumber FAC 2 aviators at a 3:1 ratio and for the purpose of this study, the resulting weighted minimum semiannual requirement is 65 aircraft hours and 13.5 simulator hours.

## Budget

After the attacks on September 11, 2001, the Department of Defense budget skyrocketed to support The Global War on Terrorism.  Overseas contingency operations (OCO) funding supplements the base budget to support deployment related operations and sustainment.  As shown in Table 5, the peak of the base budget was in 2012 at $530.4 billion with OCO funding peaking in 2011 at $158.8 billion.  Because of the 2011 Budget Control Act (BCA), failure of the Joint Committee on Deficit Reduction, and sequestration, the 2013 budget was cut by $30 billion and continued at the reduced levels through 2015.  For the first time since 2012, the FY 2016 base budget request is back to pre-sequestration levels.  However, the Department of Defense's objective is to reduce spending by $487 billion through 2023, so additional cuts are forthcoming.  Additionally, OCO funding is one-third of what it was in 2009 (Under Secretary of Defense (Comptroller), 2015).

Table 5:  Department of Defense Topline Budget

| **($ in billions)** | **FY 2009** | **FY 2010** | **FY 2011** | **FY 2012** | **FY 2013** | **FY 2014** | **FY 2015** | **FY 2016** |
|---|---|---|---|---|---|---|---|---|
| Base | 513.2 | 527.9 | 528.2 | 530.4 | 495.5 | 496.3 | 496.1 | 534.3 |
| OCO | 145.7 | 162.4 | 158.8 | 115.1 | 82 | 84.9 | 64.2 | 50.9 |
| Other | 7.4 | 0.7 | | | 0.1 | 0.2 | 0.1 | |
| **Total** | **666.3** | **691** | **687** | **645.5** | **577.6** | **581.4** | **560.4** | **585.2** |

Manpower is the most expensive item in the Army's budget.  As such, the Department of the Army continues downsizing of the active component force to 475k in FY 2016 and an eventual 450k by FY 2018.  For the first time since sequestration, the active component will not require OCO funding.  Additionally, the Army continues the ARI by retiring the OH-58D while increasing emergency response to the National Guard by transferring Apaches for Blackhawks between the active and reserve component. If sequestration continues and manning drops below the 420k level, the Army will struggle to sustain one prolonged multi-phased contingency operation. Table 6 denotes the Department of the Army's budget in relation to the DOD budget from Table 5 (Army Financial Management, 2015).

Table 6: Department of the Army Budget

| ($ in billions) | FY 2009 | FY 2010 | FY 2011 | FY 2012 | FY 2013 | FY 2014 | FY 2015 | FY 2016 |
|---|---|---|---|---|---|---|---|---|
| Base | 143 | 144 | 140 | 138 | 127 | 126 | 121 | 127 |
| OCO | 92 | 99 | 100 | 67 | 50 | 36 | 28 | 21 |
| **Total** | **235** | **243** | **240** | **205** | **177** | **162** | **149** | **148** |

## Description of the Gap

Under sequestration, the services were forced to make cuts and sacrifices in order to meet budgetary requirements. The Army, in particular, faces difficult decisions in force structure, modernization, and operation and maintenance (O&M) elements, to include decreased funding for Army ground and aviation readiness (Funding, 2014). At the division and below level, units are asked to get creative with shortages in operational tempo (OPTEMPO) funding, specifically in fuel, maintenance, and repair parts. The 2012 Army Training Strategy, FY 14 U.S. Army's Forces Command (FORSCOM), and FY 14 1st Armor Division's Annual Training Guidance all reference optimizing simulation to offset reductions to operational funding (McCaffrey, 2012) (U.S. Army Forces Command, 2013) (1st Armor Division, 2013). Additionally, FORSCOM's FY 14 initial flight hour funding to 1st Armor Division's Combat Aviation Brigade was at a 10.6 hour OPTEMPO instead of the average 11.6 from previous years (U.S. Army Forces Command, G-3 Aviation, 2013). Mathematically, 11.6 hours multiplied by six months equates to the FAC 1 minimum flight requirements of 70 hours. Even a shortage of just one hour in OPTEMPO funding results in a necessity to apply simulator hours to achieve semiannual flight hour minimum requirements.

# CHAPTER TWO: LITERATURE REVIEW

## Chapter Two Summary

This chapter covers literature relating to the benefits and effectiveness of simulation for training and explores the appropriate balance of live and virtual training.

## Simulation Training Benefits and Effectiveness

There are a number of articles and studies written outlining the benefits and disadvantages of simulation. Orlansky et al. (1994) summarizes these advantages and disadvantages as they relate to flight simulation training.

Advantages (Orlansky, Dahlman, Hammon, Metzko, & Taylor, 1994)

- Trains tasks in the same manner as the live equivalent.
- Cost savings in procurement, usage, and sustainment compared to the live equivalent.
- Mitigates risk while reducing maintenance costs of live equipment.
- Decreases pollution and environmental impact compared to live equivalent.
- Better facilitates instruction and feedback.
- Cost savings in fuel, ammunition, and support.
- Less risk and costs from damages to equipment by novices unfamiliar with the system or procedures.

- Allows for training untenable or too high risk in live equivalent.
- Replicates a threat environment for force on force rehearsals, scenarios, and engagements.

Disadvantages (Orlansky, et al., 1994):

- Reducing OPTEMPO using simulation could decrease training readiness and confidence in the actual aircraft.
- Inaccuracies in aerodynamics, engagements, motion, control inputs, or procedures can lead to negative habit transfer or misleading expectations in live training or combat.
- Simulators require funding to procure, field, update, and sustain.
- Motion/simulator sickness

In a 2002 article, E Salas and C.S. Burke state training is effective when (Salas & Burke, 2002):

- The simulation is a tool for teaching and training.
- The simulation is scenario based using cognitive task analysis to train tasks deliberately.
- The simulation is a tool for assessing individuals and teams.
- An instructor directs training through task-focused or scenario-based training.
- The simulation fidelity is not too much or too little for the training objectives.
- Subject matter experts collaborate with system designers and trainers.

## The Balance of Live and Virtual Training

The purpose of this study is to understand the cost or impact to increasing or decreasing the amount of simulation to live training and the related effect on proficiency. To understand the total cost, one must understand the impact to an aviator's proficiency when shifting the balance between the two training environments.

The preponderance of research in the field of simulation training occurred from 1975-1999. Since then, the focus has been on finding the minimum level of fidelity at the lowest cost to provide the greatest cost savings. Most of the research between 1975 and 1999 attests that simulation is an effective tool for cost savings, risk reduction, and is an appropriate supplement to live training. Very little research sets an upper limit for when simulation impedes performance or is not worth the output for time, labor, or costs. Additionally, many of the studies only evaluate initial training, which is far different from sustainment training. This section of the literature review cites sources that define training transfer, reference similar research articles with experiments or models that attempt to determine the proper mix of live and virtual training in relation to an aviator's efficacy, and summarize when simulator use is appropriate.

## Transfer of Training (TOT)

TOT is the true measure of a simulation device's value on an aviator's proficiency as defined by Muchinsky (2006) as, "the extent to which trainees effectively apply the knowledge, skills, and attitudes gained in a training context back to the job" (p. 205). Another definition, more specific to flight simulation states:

> A flight simulator is effective if the skills that a pilot learns in the simulator can be performed in the aircraft, that is, if the skills transfer from the simulator to the aircraft. The effectiveness of training in a flight simulator is a function of the amount of skill that transfers. Its cost-effectiveness in a pilot-training program depends on the amount of skill that transfer to the aircraft as well as the ratio of simulator to aircraft operating costs. (Taylor, Lintern, & Koonce, 1993)

## TOT Case Studies

Two case studies that epitomize the value of simulation in reference to TOT, proficiency, and costs savings are the integration of simulation within the MH-53J Pave Low and AH-64A Apache qualification courses.

The 1986 MH-53H qualification course was almost exclusively in the aircraft. Due to decreasing budgets in the early nineties, compounded with the cost of integrating and training the MH-53J update, the decision was made to incorporate as many simulator and procedural trainer hours as possible. By 1993, the course was almost half-live and half-simulation. This resulted in hourly cost savings of approximately $2k (Selix, 1993). The real proof of concept was in a subsequent study by Rakip, Kelly, Appler & Riley (1993) where Pave Low crewmembers and commanders evaluated crews. The sample of crews was broken into two groups: those trained in the simulation era and those who were not. The survey was perception and opinion based and not centered on any performance measure of proficiency. Those trained in the simulator era rated higher in all aspects except NVG and aircraft control. Those trained in the simulator group were mission ready in 2-3 months versus the non-simulation era group who took almost a year to reach the same standard.  In this case study, the method in which the simulator was integrated into the training program not only replaced aircraft hours at a cost benefit, but also proved advantageous to the aviator's aptitude (pp. 432-438).

In a similar scenario, the traditional AH-64A qualification course program of instruction (POI) consisted of 45 hours in the aircraft and 28 hours in the simulator.  In an effort to save money, select students performed tasks in the simulator until achieving task standards.  They then demonstrated their proficiency in an aircraft where evaluators measured the requisite total aircraft flight time to conduct the task to standard.  When compared to students conducting the traditional POI, the sample population skill was on par with their counterpart but with lower live aircraft requirements.  Therefore, the course was restructured to 25 hours in the aircraft and 56 hours in the simulator for an estimated cost savings of $70k (Wightman & Wright, R.H., in preparation).

Simulator integration in POIs across the military are now common practice and occur at the initial, intermediate, and graduate level.  Two examples of this practice are the AH-64D Instructor Pilot Course POI and the AH-64E Transition Course POI.  The Instructor Pilot Couse consists of a total of 82.9 hours with 58.9 hours in the aircraft, 21 hours in the LCT, and three hours of non-flight time on the LPT/Emulator (United States Army Aviation Center of Excellence, 2011).  The AH-64E Transition Course entails a much heavier simulator load with 10.8 hours in the LCT and 4.4 of instructor led LPT hours versus only 8.5 hours in the actual aircraft (Project Manager, Apache Attack Helicopter, 2014)

## Tools

Two tools that attempt to quantify the most efficient balance of live and virtual training are the FAPV Training Tool and the Transfer Effectiveness Ratio Tool (TER).

The letters in FAPV stand for familiarize, acquire skill, practice skill, and validate skill, which refer to the steps in the learning process for each of the trained tasks. Used mostly in an instructional system design manner, the FAPV tool is a Microsoft Excel based program in which factors such as tasks, training times, student loads, training devices, student/instructor ratios required on the different devices, and readiness rates are entered into a database. Using Advanced Learning Environments, the FAPV tool determines whether live, virtual, or constructive methods are most appropriate for the task and factors the inputs to provide the most cost effective solution in relation to time, cost, and availability (Frank, Helms, & Voor, 2000).

The second example, applied by Stewart and Nullmeyer (1999), use Transfer, Cumulative Transfer, and Incremental Transfer Effective Ratio (TER, CTER, and ITER) analysis to determine the optimal mix of live and virtual training. TER is the ratio of training in the simulator to the savings in the aircraft. CTER is the combined effects of simulator iterations. Essentially, it is a linear graph of a set of TERs. The CTER curve provides visual information on the rate of diminishing returns through increasing simulator iterations. Finally, ITER answers whether it is worthwhile to conduct one more iteration of the task or where the point of diminishing returns exists (pp. 9-11). A number of variables affect the CTER. One of which is a well-developed training plan. A sufficient training plan will bring the CTER closer to 1.0 (Diehl & Ryan, 1977). The Stewart and Nullmeyer (1999) study on the optimization of simulation for initial entry rotary wing training through experiments using TER, CTER, and ITER resulted in approximately 2.75 simulator iterations equated to one saved live hour (p. 30).  Essentially all research using this approach results in an eventual diminished returns with an increase in simulation to replace live iterations.

## Maximum Simulation

Looking at simulation purely from a cost savings perspective, 100% simulation training is the safest and most cost effective solution, but at what point does simulation result in negative transfer or become too time and resource intensive to achieve the same or better results in the aircraft?  Can virtual training replace all live training or is there associated risk associated with proficiency due to simulation limitations in fidelity or training quality?  Army doctrine, guidance, and regulation send conflicting or ambiguous messages regarding live and virtual training intent.  Most of the research and experimentation supports simulation as a supplement to live training, but fails to address how it affects an aviator's proficiency over time and at various stages in their career.

The Army Training Strategy states that leaders should increase virtual, constructive, and gaming capabilities when there is a decrease in live training resources (McCaffrey, 2012).  The Army Strategy is not prescriptive in how commanders should partition the training environments, nor does it define a maximum allocation.  The training circular for developing aircrew-training programs, TC 3-04.11, clearly says, "Virtual and constructive simulation training cannot replace live training.  However, they can supplement, enhance, and complement live training to sustain unit proficiency" (Department of the Army, 2009).  Finally, the ATM specifically sets the ratio of live to virtual semiannual minimum flight requirements to 70 live and 15 virtual for FAC 1 aviators and 50 live and 9 virtual for FAC 2 aviators or an approximate 8:2 ratio or 7.6:2.4 ratio with simulation applied to minimum flight requirements for a FAC 2 aviator. Commanders can only substitute 12 live hours with LCT hours semiannually (Department of the Army, 2013). The statements presented in Army doctrine and guidance proves the Army accepts simulation as a supplement to live training but not an absolute or even majority replacement.

A large number of studies exist where researchers examine a simulation's effect on performance. In most cases, there is a significant increase in performance, but in a few others, the results show an insignificant difference between live and simulated performance, lack of evidence to establish a maximum simulation threshold, or even a degradation in performance due to a simulation's shortcomings.

In a 2012 non-experimental study contemplating an increase in simulation for the Initial Entry Rotary Wing (IERW) phase of Flight School XXI, the research found an increase in simulation results in the potential for substantial cost savings. However, there was inconclusive evidence to support a full conversion to simulation would produce students at the same proficiency level or better. In fact, the study cited several sources where senior Army leadership perceives that a 100% simulation conversion presents too much risk to a student's common core (Blow, 2012). The recommendations for future research section lists a need for "empirical data regarding the quality of aviator produced after completing various levels of simulator and real aircraft training" (p. 44).

The Goetz, Harrison, Robertson (2012) study is a great example of simulation providing an insignificant difference to an aviator's proficiency. In this study, a sample of twelve participants trained three hours in a Frasca 141 flight-training device before flying an aircraft.

Upon completion of the simulator portion, examiners tracked total flight hours and days to the participant's first solo in a Cesna 172 aircraft. The experimental group required a mean time of 17.4 hours and 77.3 days where the historic group flew a solo flight at a mean time of 17.4 hours and 86.1 days. From a statistical reference, this difference is insignificant.

In contrast, an experiment performed by the Directorate of Simulation sampled CH-47 aviators in the graduate level Maintenance Test Pilot Course (MTPC) and another entering the second phase of initial training. The entire MTPC was in a virtual environment minus the evaluation check ride. The initial training sample trained in 75% simulation. Subjects from both experiments successfully passed evaluations to standard even with a reduction in live aircraft hours. However, due to fidelity issues and other glitches experienced in the simulator, instructors had to retrain participants in fine motor and proprioceptive intensive tasks such as slope landings and ground taxiing (U.S. Army Directorate of Simulation, 2011).

## <u>**Summary of Literature Review**</u>

The literature review illustrates the benefits and limitations of simulation-based training, defines methods to maximize simulator effectiveness, and addresses the balance of live and virtual training regarding TOT and proficiency. Most of the literature concerning TOT advocates that simulation training increase proficiency while reducing costs, but very little literature defines an optimized level of simulation before risking a degradation to proficiency or negative transfer. The Army doctrine and leadership offers commanders nonspecific guidance regarding the amount of simulation application, but maintains a stance that too much simulation poses an unacceptable risk to proficiency. The literature reviews in several studies note a lack of research and empirical evidence regarding a maximum point of simulation training as it relates to proficiency for live training replacement. Models and tools exist for calculating the balance of simulation but require very specific inputs and the majority focuses on instructional design, just as most studies concentrate on initial training and not mid-career sustainment training in operational units.

## Research Gap

The majority of research relating to simulation based training focuses on initial training, individual aviators, and accepts that simulation reduces costs by replacing live training iterations while maintaining, or in some cases, improving proficiency. There is limited research on the cost savings and proficiency effects simulation application has on mid-career aviators, realistic crew sample selections, and the point of diminishing returns as they relate to the balance and optimization of live and virtual training. This paper focuses solely on aviators at operational units in realistic crew configurations. The models in this study apply simulation shifts to general pilots (PIs) who generally struggle to meet minimum semiannual flight requirements and units have the highest potential and lowest risk for applying virtual flight hours to semiannual requirements. There is insufficient evidence to take anything other than a conservative approach to the live/virtual ratio reflected in the various models.

# CHAPTER THREE: METHODOLOGY

## **Chapter Three Summary**

This chapter defines the problem and outlines the assumptions, scope, and methodology for analyzing potential cost savings associated with replacing live flight hours with virtual hours. This chapter concludes with defining four models with varying live to virtual ratios.

## **Define the Problem**

The problem is to understand the financial and training significance of balancing live and virtual aviation training given current or future budget constraints for the purpose of cost avoidance or savings and aviator proficiency.

## Assumptions

The following lists assumptions made for the purposes of this analysis and in many ways represent a perfect world scenario where all pilots are RL1; all units have an operational LCT, etc.

- Personnel and equipment strength levels match Modified Table of Organizational Equipment (MTOE) authorization requirements.
- No units are deployed.
- All Pilots (PI) are Readiness Level 1.

- 75% of pilots are FAC 1, 25% FAC 2 for a weighted average baseline semiannual flight requirement of 65 hours and LCT requirement of 13.5 hours.
- The designation of 50% of authorized pilots is PC, UT, IP, IE, SP, MP, ME, or XP. The other 50% are PI.
- The Army continues with the Aviation Restructure Initiative by transferring LCTs and Apaches from the National Guard to the AC. This assumption is highly political and subject to change. For the purpose of this study, all LCTs and Apaches from the National Guard transfer to the AC.
- Each ARB manages and has regular access to one LCT
- Crew requirements:
  - A crew in a live aircraft is one pilot with the designation (UT, PC, IP, IE, SP, MP, ME, or XP) and the other pilot is a PI.
  - A crew in a virtual aircraft meet the crew requirements listed above (1 x PC with 1 x PI) with a qualified I/O. Even though a crew in the LCT can consist of 2 x PI, it does not affect the outcome in this study since the PCs also have simulator minimums and for every 2 x PI crew, there would have to be a 2 x PC crew to maximize efficiency in the simulator; but the outcome is the same since the PC:PI ratio is 1:1.
  - In a perfect scenario, crews remain constant with a PC and PI in every live and LCT period. In this perfect setting, aviators meet all simulation requirements for minimums, gunnery, and evaluations with zero overage.

## Scope of Analysis

The scope of the analysis outlined in this study is as follows:

- United States Army active component attack aviation units.
- Authorizations and structure based on FY15 or FY16 FMS-Web data.
- Aircraft and SFTS:
    - AH-64D/E Block II and LCT (AH-64E Longbow Crew Trainer 2B64E)
- Analysis only applies to Pilots (PI) based on MTOE authorized strength. Analysis does not apply to pilots with the following designations: PC, UT, IP, IE, SP, MP, ME, or XP.
- This analysis does not include FAC 3 aviators since the population is small and insignificant to the outcome of this study.
- Computations are annual figures based on semiannual requirements.

## Models

Using fixed variables for the costs of live and simulator flight hours and numbers of crews and battalions, the four models have varying ratios for live to virtual flight hour requirements and/or applying a portion of the simulator hours to satisfy the live flight hour requirements. The Low Virtual Simulation Model includes the least amount of simulation flown and applied to live hours and the highest number of live flight hours. Whereas the High Virtual Simulation Model employs a combination of the highest amount of simulation flown and applied to flight hour requirements compared to live flight hours. The Status Quo Virtual

Simulation Model is the baseline model and consistent with Army doctrine and practices out in the field. Finally, the Moderate Virtual Simulation Model is a hybrid of the Status Quo and High Virtual Simulation Models and maximizes simulation applied per current doctrine.

Through a compensatory method, each of the models apply the fixed variables for the cost of a live flight hour, the cost of a simulator flight hour, the number of crews, the number of battalions, and varying factors for live and simulator flight hours per crew and the number of simulation hours applied to live minimums. The limited scope of the analysis is purposeful to represent savings solely at an hour flown level. Any other factor, such as destroyed aircraft, loss of life, injury, or ammunition costs, benefit to the side of using more simulation. Essentially, the cost savings outlined in Chapter 4 represent minimum savings potential.

## Variables and Equations

- Fixed Variables
    - Cost of live flight hour: cL
    - Cost of simulation flight hour: cS
    - Number of crews: nC
    - Number of units (battalions): nU
- Variables
    - Live flight hours/crew: hL
    - Simulator hours/crew: hS
    - Simulation hours applied to minimums: hA

- Equations

Table 7: Equations

| Description | Formula |
|---|---|
| Total Live/Crew | (hL * cL) |
| Total Simulation/Crew | (hS * cS) |
| Total Simulation applied to min/Crew | -(hA * cS) |
| **Grand Total/Crew** | **(hL * cL) + (hS * cS) - (hA * cS)** |
| Total Live/ARB | (hL * cL) * nC |
| Total Simulation/ARB | (hS * cS) * nC |
| Total Simulation applied to min/ARB | -(hA * cS) * nC |
| **Grand Total/ARB** | **((hL * cL) * nC) + ((hS * cS) * nC) - ((hA *cS) * nC)** |
| Total Live Army Wide | ((hL * cL) * nC) * nU |
| Total Simulation Army Wide | ((hS * cS) * nC) * nU |
| Total Simulation applied to min Army Wide | (-(hA * cS) * nC) * nU |
| **Grand Total Army Wide** | **(((hL * cL) * nC) + ((hS * cS) * nC) + ((hA * cS) * nC))) * nU** |

## Low Virtual Simulation Model

In the Low Virtual Simulation Model, all pilots (PI) increase live flight hour requirements a maximum of five hours, decrease simulator requirements a maximum of five hours, and apply zero simulator hours in lieu of live hours semiannually. This model supports the argument for more live training and less simulation.

## Status Quo (Baseline) Virtual Simulation Model

In the Status Quo Virtual Simulation Model, all pilots (PI) meet semiannual requirements using live flight hours as well as the required simulator hours based on FAC level requirements. This model supports how units generally execute flight hour requirements.

## Moderate Virtual Simulation Model

In the Moderate Virtual Simulation Model, all pilots (PI) apply 12 hours of simulated flight hours to their semiannual flight requirements while simultaneously meeting the required simulator hours based on FAC level requirements. This model supports options for commanders per the ATM.

## High Virtual Simulation Model

In the High Virtual Simulation Model, all pilots (PI) decrease live flight hour requirements a maximum of five hours, increase simulator requirements a maximum of five hours, and apply a maximum of 17 simulator hours in lieu of live hours semiannually. This model supports the argument for more simulation and less live training from a cost perspective.

## Model Summary

Table 8 and Figure 5 present differences between the four models. The Low and Status Quo Virtual Simulation Models result in 157 total hours flown while the Moderate and High Virtual Simulation Models result in 133 total hours flown after applying simulation hours in lieu of live hours. The Commander maintains the authorization of applying simulation time to live requirements, and if not approved, the aviator must offset the simulation applied to live with actual flight in the aircraft. All figures are based off of the weighted average for FAC 1 and FAC 2 aviators. The simulation applied to live and simulation hours in addition to simulation applied represents the total simulator minimums required annually. For example, The Moderate Virtual Simulation Model requires 27 simulation hours flown annually.

Table 8: Model Comparison for Total Hours Flown Annually per Crew

| Model | Live Hours | Sim Applied to Live | Simulation Hours in Addition to Sim Applied | Total Hours |
|---|---|---|---|---|
| Low | 140 | 0 | 17 | 157 |
| Status-Quo | 130 | 0 | 27 | 157 |
| Moderate | 106 | 24 | 3 | 133 |
| High | 96 | 34 | 3 | 133 |

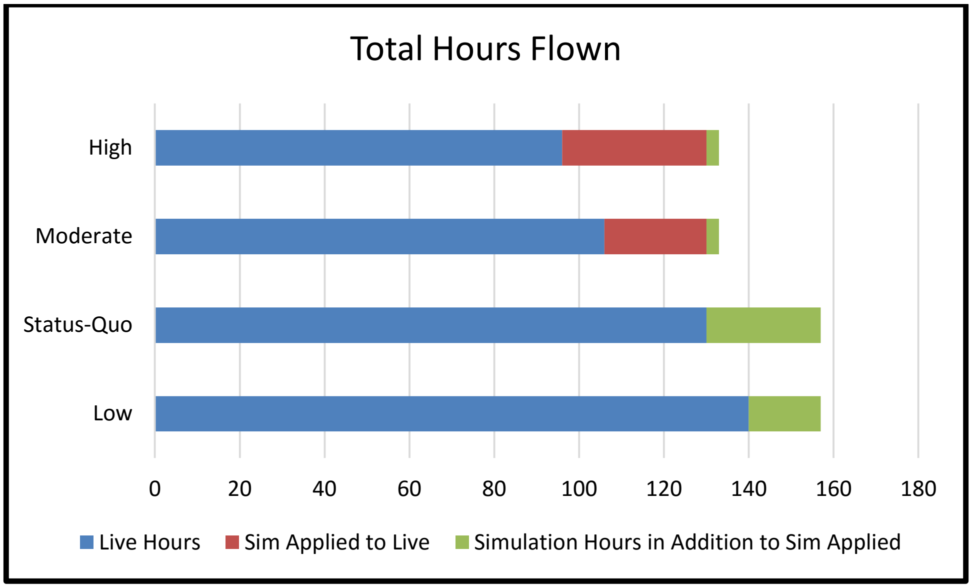


Figure 5: Model Comparison for Total Hours Flown Annually per Crew (Graph)

# CHAPTER FOUR:  DATA AND ANALYSIS

## Chapter Four Summary

This chapter applies figures to the methodology from Chapter 3 and how that applies to either a fixed or variable factor.  Data found in this chapter includes the total number of aviators and crews, LCT throughput, cost factors for live and virtual flight hours.  This chapter concludes with cost analysis for each of the four models and sensitivity analysis for fuel and training.

## Data

This section outlines and explains key figures for conducting the cost analysis such as the total number of aviators/crews, how much throughput an LCT can manage, and the cost factors for an hour of live and virtual aviation training in the AH-64D/E and LCT, respectively.

### Number of Aviators

As of November of 2015, there are 20 Attack Reconnaissance Battalions in the Active Component (Force Management Support Agency, 2015).  Each battalion supports 70 aviators (35 crews, under perfect crew assignment and balance of PCs and PIs).  This equates to approximately 1400 aviators across the active component assigned to a Combat Aviation Brigade.  For the purpose of this study half of those 1400 are Pilots (PIs) and the other half are Pilots-in-Command (PC) or equivalent.

## LCT Throughput

An LCT operates with contract support for maintenance and operation. Contracts include an I/O for limited hours. Units have the flexibility to surge during gunnery and other simulation intensive periods for short durations. A standard garrison week is 40 hours or eight hours a day, five days a week. Units can surge to 50 hours a week for six weeks per contract year. The standard garrison throughput for a single LCT system is 2140 hours (Mings, 2016).

Per Figure 6, none of the models approach the threshold. Should each ARB/ARS not have their own LCT system and is sharing it with the other ARB/ARS in the brigade or a National Guard Unit, then the High Simulation Model could easily surpass the threshold.

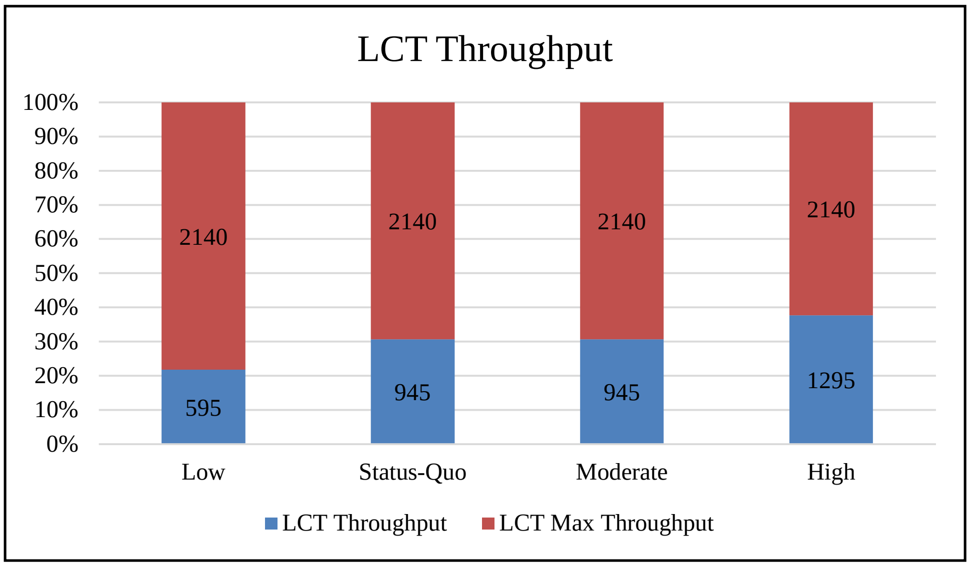


Figure 6: LCT Throughput

## Cost Factors

Given the Apache does not have contractor logistic support, meaning crew chiefs within the organization perform maintenance and service tasks, the cost factor for one hour in an AH-64D/E Apache helicopter includes cost projections for petroleum, oil, and lubricants (POL), consumable repair parts, and depot level repairable parts (Department of the Army, 2014). Additional costs not factored into this cost factor or within the scope of this study are associated ammunition, destroyed aircraft, accidental damages, or crew losses. These excluded costs would only bolster the cost avoidance benefits for simulation usage as ammunition is unlimited and there is zero risk for destroyed aircraft, accidental damages, or crew losses in the virtual environment(Department of the Army, 2014). The cost factor of $4,267 is in accordance with Table 23 in Appendix A: III Corps FY16 Flying Hour Program Cost Factors.

Three sources provide data to formulate a per hour cost factor for the LCT. There are fixed costs for Life Cycle Contractor Support (LCCS) which include on-site technicians, general material, and the delta for repair costs above $20k. Over and Above cost factors, again at the LCCS level, include government directed system relocation impact costs, non-fair wear and tear, and extended training outside of contracted hours. Finally, garrison cost factors include contracted I/Os, water, fuel, and electricity, facility costs for improvements and maintenance, and the security and safety support. Table 9 breaks down the cost estimates for an hour of LCT simulated flight time. The total cost factor is $268.99 per hour (Mings, 2016).

Table 9: LCT Hourly Cost Factors

| Item | Cost |
|---|---|
| LCCS per LCT Hour | $ 162.72 |
| I/O per LCT Hour | $ 57.28 |
| Facilities per LCT Hour | $ 49.00 |
| **Total LCT Hour** | **$ 268.99** |

Table 10 denotes the FY2016 cost factors for the AH-64D/E and the LCT of $4,267 and $269 per hour, respectfully. The delta between an hour of LCT and and hour in an Apache is $3,998.

Table 10: Cost Factors

| Flight Mode | Cost per Hour |
|---|---|
| Live | $4,267 |
| Virtual (LCT) | $269 |
| Difference | $3,998 |

## Cost Analysis

This section combines the factors listed above with the methodology outlined in Chapter 3 to determine the cost analysis for each of the four models. The cost analysis includes costs at the crew, battalion, and Army level for live, simulation, and total cost. All models use the fixed variables as noted in Table 11.

Table 11: Fixed Variables

| Fixed Variables | Factor |
|---|---|
| Cost of live Flight Hour (cL) | $ 4,267.00 |
| Cost of Simulation Flight Hour (cS) | $ 269.00 |
| Number of Crews (nC) | 35 |
| Number of Battalions (nU) | 20 |

## Low Virtual Simulation Model

In the Low Virtual Simulation Model, Table 12, 35 crews fly 140 hours in the aircraft, 17 hours in the simulator, and apply zero simulation hours to live flight hours based on the weighted annual requirements for the FAC 1 to FAC 2 ratio and flight hour requirements from current Army doctrine. To compute the total cost for the Low Virtual Simulation Model, add the total live hours per crew to the total simulation hours per crew and multiply the number of crews by the number of battalions/squadrons in the Army. Crews fly a total of 157 hours annually. More specifically, the crew flies a total of 140 hours in the aircraft instead of the 130 hours in the Status Quo Virtual Simulation Model. This increases the crew's exposure time to risks inherent to flying a live helicopter by 10 hours or 7.8 percent annually. The total cost in this model is $421,367,100 and the total LCT throughput is 595 hours.

Table 12: Low Virtual Simulation Analysis

| Variable | Factor | LCT Throughput |
|---|---|---|
| Live Flight Hours/Crew (hL) | 140 | 595 |
| Simulation Hours/Crew (hS) | 17 | |
| Simulation Hours Applied to min (hA) | 0 | |
| | | |
| **Description** | **Formula** | **Total** |
| Total Live/Crew | (hL * cL) | $ 597,380.00 |
| Total Simulation/Crew | (hS * cS) | $ 4,573.00 |
| Total Simulation applied to min/Crew | -(hA * cS) | $ - |
| **Grand Total/Crew** | **(hL * cL) + (hS * cS) - (hA * cS)** | **$ 601,953.00** |
| Total Live/ARB | (hL * cL) * nC | $ 20,908,300.00 |
| Total Simulation/ARB | (hS * cS) * nC | $ 160,055.00 |
| Total Simulation applied to min/ARB | -(hA * cS) * nC | $ - |
| **Grand Total/ARB** | **((hL * cL) * nC) + ((hS * cS) * nC) - ((hA *cS) * nC)** | **$ 21,068,355.00** |
| Total Live Army Wide | ((hL * cL) * nC) * nU | $ 418,166,000.00 |
| Total Simulation Army Wide | ((hS * cS) * nC) * nU | $ 3,201,100.00 |
| Total Simulation applied to min Army Wide | (-(hA * cS) * nC) * nU | $ - |
| **Grand Total Army Wide** | **(((hL * cL) * nC) + ((hS * cS) * nC) + ((hA * cS) * nC))) * nU** | **$ 421,367,100.00** |

## Status Quo Virtual Simulation Model (Baseline)

In the Status Quo (Baseline) Virtual Simulation Model, Table 13, 35 crews fly 130 hours in the aircraft, 27 hours in the simulator, and apply zero simulation hours to live hours based on the weighted annual requirements for the FAC 1 to FAC 2 ratio and flight hour requirements from current Army doctrine. The analysis for this model is fairly simple: add the total live per crew to the total simulation per crew, multiply the number of crews by the number of battalions/squadrons in the Army. Crews fly a total of 157 hours annually. The total cost in this model is $393,381,100 and the total LCT throughput is 945 hours.

Table 13: Status Quo Virtual Simulation Analysis

| Variable | Factor | LCT Throughput |
|---|---|---|
| Live Flight Hours/Crew (hL) | 130 | 945 |
| Simulation Hours/Crew (hS) | 27 | |
| Simulation Hours Applied to min (hA) | 0 | |
| | | |
| **Description** | **Formula** | **Total** |
| Total Live/Crew | (hL * cL) | $ 554,710.00 |
| Total Simulation/Crew | (hS * cS) | $ 7,263.00 |
| Total Simulation applied to min/Crew | -(hA * cS) | $ - |
| **Grand Total/Crew** | **(hL * cL) + (hS * cS) - (hA * cS)** | **$ 561,973.00** |
| Total Live/ARB | (hL * cL) * nC | $ 19,414,850.00 |
| Total Simulation/ARB | (hS * cS) * nC | $ 254,205.00 |
| Total Simulation applied to min/ARB | -(hA * cS) * nC | $ - |
| **Grand Total/ARB** | **((hL * cL) * nC) + ((hS * cS) * nC) - ((hA *cS) * nC)** | **$ 19,669,055.00** |
| Total Live Army Wide | ((hL * cL) * nC) * nU | $ 388,297,000.00 |
| Total Simulation Army Wide | ((hS * cS) * nC) * nU | $ 5,084,100.00 |
| Total Simulation applied to min Army Wide | (-(hA * cS) * nC) * nU | $ - |
| **Grand Total Army Wide** | **(((hL * cL) * nC) + ((hS * cS) * nC) + ((hA * cS) * nC))) * nU** | **$ 393,381,100.00** |

## Moderate Virtual Simulation Model

In the Moderate Virtual Simulation Model, Table 14, 35 crews fly 106 hours in the aircraft, 27 hours in the simulator, and apply 24 simulation hours to live based on the weighted annual requirements for the FAC 1 to FAC 2 ratio and flight hour requirements from current Army doctrine. The 24 simulation hours reflect the 12 hours of simulation a commander can authorize an aviator to use toward flight minimums semiannually as written in current version of the Attack Helicopter Aircrew Training Manual (Department of the Army, 2013). The weighted average of 13.5 semiannually result in a total of 27 simulator hours annually, three simulator hours over the 24 hours used toward flight hour requirements. To compute the total cost, add the total live per crew to the total simulation per crew, subtract the simulation hours applied to minimums, and multiply the number of crews by the number of battalions/squadrons in the Army. Crews fly a total of 133 hours annually. More specifically, the crew flies a total of 106 hours in the aircraft instead of the 130 hours in the Status Quo Virtual Simulation Model. This reduces the exposure time of the crews to risks inherent to flying a live helicopter by 24 hours or 18.5 percent. The total cost in this model is $317,176,300 and the total LCT throughput is 945 hours.

Table 14: Moderate Virtual Simulation Analysis

| Variable | Factor | LCT Throughput |
|---|---|---|
| Live Flight Hours/Crew (hL) | 106 | 945 |
| Simulation Hours/Crew (hS) | 27 | |
| Simulation Hours Applied to min (hA) | 24 | |
| | | |
| **Description** | **Formula** | **Total** |
| Total Live/Crew | (hL * cL) | $ 452,302.00 |
| Total Simulation/Crew | (hS * cS) | $ 7,263.00 |
| Total Simulation applied to min/Crew | -(hA * cS) | $ (6,456.00) |
| **Grand Total/Crew** | **(hL * cL) + (hS * cS) - (hA * cS)** | **$ 453,109.00** |
| Total Live/ARB | (hL * cL) * nC | $ 15,830,570.00 |
| Total Simulation/ARB | (hS * cS) * nC | $ 254,205.00 |
| Total Simulation applied to min/ARB | -(hA * cS) * nC | $ (225,960.00) |
| **Grand Total/ARB** | **((hL * cL) * nC) + ((hS * cS) * nC) - ((hA *cS) * nC)** | **$ 15,858,815.00** |
| Total Live Army Wide | ((hL * cL) * nC) * nU | $ 316,611,400.00 |
| Total Simulation Army Wide | ((hS * cS) * nC) * nU | $ 5,084,100.00 |
| Total Simulation applied to min Army Wide | (-(hA * cS) * nC) * nU | $ (4,519,200.00) |
| **Grand Total Army Wide** | **(((hL * cL) * nC) + ((hS * cS) * nC) + ((hA * cS) * nC))) * nU** | **$ 317,176,300.00** |

## High Virtual Simulation Model

In the High Virtual Simulation Model, Table 15, 35 crews fly 96 hours in the aircraft, 37 hours in the simulator, and apply 34 simulation hours to live based on the weighted annual requirements for the FAC 1 to FAC 2 ratio and flight hour requirements from current Army doctrine. The 34 simulation hours reflect the 12 hours of simulation a commander can authorize an aviator to use toward flight minimums semiannually as written in current version of the Attack Helicopter Aircrew Training Manual plus an additional ten hours to compensate for the reduction in live flight hours. (Department of the Army, 2013). The weighted average of 13.5 hours plus an additional five hours semiannually result in a total of 37 simulator hours annually, 3 simulator hours more than the 34 hours used toward flight hour requirements. To compute the total cost, add the total live per crew to the total simulation per crew, subtract the simulation hours applied to minimums, and multiply the number of crews by the number of battalions/squadrons in the Army. Crews fly a combined total of 133 hours annually. More specifically, the crew flies a total of 96 hours in the aircraft instead of the 130 hours in the Status Quo Virtual Simulation Model. This reduces the exposure time of the crews to risks inherent to flying a live helicopter by 34 hours or 26 percent. The total cost in this model is $287,286,300 and the total LCT throughput is 1295 hours.

Table 15: High Virtual Simulation Analysis

| Variable | Factor | LCT Throughput |
|---|---|---|
| Live Flight Hours/Crew (hL) | 96 | 1295 |
| Simulation Hours/Crew (hS) | 37 | |
| Simulation Hours Applied to min (hA) | 34 | |
| | | |
| **Description** | **Formula** | **Total** |
| Total Live/Crew | (hL * cL) | $ 409,632.00 |
| Total Simulation/Crew | (hS * cS) | $ 9,953.00 |
| Total Simulation applied to min/Crew | -(hA * cS) | $ (9,146.00) |
| **Grand Total/Crew** | **(hL * cL) + (hS * cS) - (hA * cS)** | **$ 410,439.00** |
| Total Live/ARB | (hL * cL) * nC | $ 14,337,120.00 |
| Total Simulation/ARB | (hS * cS) * nC | $ 348,355.00 |
| Total Simulation applied to min/ARB | -(hA * cS) * nC | $ (320,110.00) |
| **Grand Total/ARB** | **((hL * cL) * nC) + ((hS * cS) * nC) - ((hA *cS) * nC)** | **$ 14,365,365.00** |
| Total Live Army Wide | ((hL * cL) * nC) * nU | $ 286,742,400.00 |
| Total Simulation Army Wide | ((hS * cS) * nC) * nU | $ 6,967,100.00 |
| Total Simulation applied to min Army Wide | (-(hA * cS) * nC) * nU | $ (6,402,200.00) |
| **Grand Total Army Wide** | **(((hL * cL) * nC) + ((hS * cS) * nC) + ((hA * cS) * nC))) * nU** | **$ 287,307,300.00** |

## Sensitivity Analysis

Sensitivity analysis denotes the influence cost variables have on the different models. This sensitivity analysis includes changes in operating costs and operational tempo (OPTEMPO) using the examples of POL costs and training requirements in the form of hourly requirements.

The price of governmental POL is locked and contracted years in advance, therefore this analysis does not reflect a rapid change, but a change over a significant period of time. The percentage of POL costs is approximately 11.4% of the total cost per live hour and 5% of the total cost per LCT hour.

To reflect the impact a fluctuation in POL costs and training requirements have on the cost analysis, this analysis considers shifts of plus or minus 25% in POL and 20% in training. This section includes an exemplary analysis for the Moderate Virtual Simulation Model and concludes with an Army level comparison of the four models. Annex B: Sensitivity Analysis Data includes the complete data at the crew, battalion, and Army level in Tables 24 and 25.

### Moderate Virtual Simulation Model POL Sensitivity Analysis

Applying a 25% variation to the POL costs for both the aircraft and LCT in the Moderate Virtual Simulation Model illustrates the impact a change to a single variable such as POL has on the overall cost factor. Multiplying plus or minus 25% of 11.4% for a live hour and 5% for a virtual hour for POL costs to the baseline costs per hour results in a decrease of $364.83 and increase of $608.05 per aircraft hour and a decrease of $10.09 and increase of $16.81 per LCT hour. At the Army level, a decrease in POL costs results in a $27 million delta and an increase of $45.2 million annually (Table 16 and Figure 7). As POL prices increase, more simulation results in more significant costs savings potential.

Table 16: POL Analysis Moderate Virtual Simulation Model Data

| Fixed Variables | Factor w/ 25% POL Cost Decrease | Baseline Cost Factor | Factor w/ 25% POL Cost Increase |
|---|---|---|---|
| Cost of live Flight Hour (cL) | $ 3,902.17 | $ 4,267.00 | $ 4,875.05 |
| Cost of Simulation Flight Hour (cS) | $ 258.91 | $ 269.00 | $ 285.81 |
| Number of Crews (nC) | 35 | | |
| Number of Battalions (nU) | 20 | | **POL Cost Percentage** |
| | | Aircraft | 11.4% |
| **Moderate Virtual Simulation Model** | | LCT | 5% |
| **Variable** | **Factor** | | |
| Live Flight Hours/Crew (hL) | 106 | | |
| Simulation Hours/Crew (hS) | 27 | | |
| Simulation Hours Applied to min (hA) | 24 | | |
| **Description** | **25% POL Cost Decrease** | **Baseline Cost** | **25% POL Cost Increase** |
| **Grand Total/Crew** | **$ 414,406.92** | **$ 453,109.00** | **$ 517,612.47** |
| **Grand Total/ARB** | **$ 14,504,242.08** | **$ 15,858,815.00** | **$ 18,116,436.54** |
| **Grand Total Army Wide** | **$ 290,084,841.55** | **$ 317,176,300.00** | **$ 362,328,730.75** |

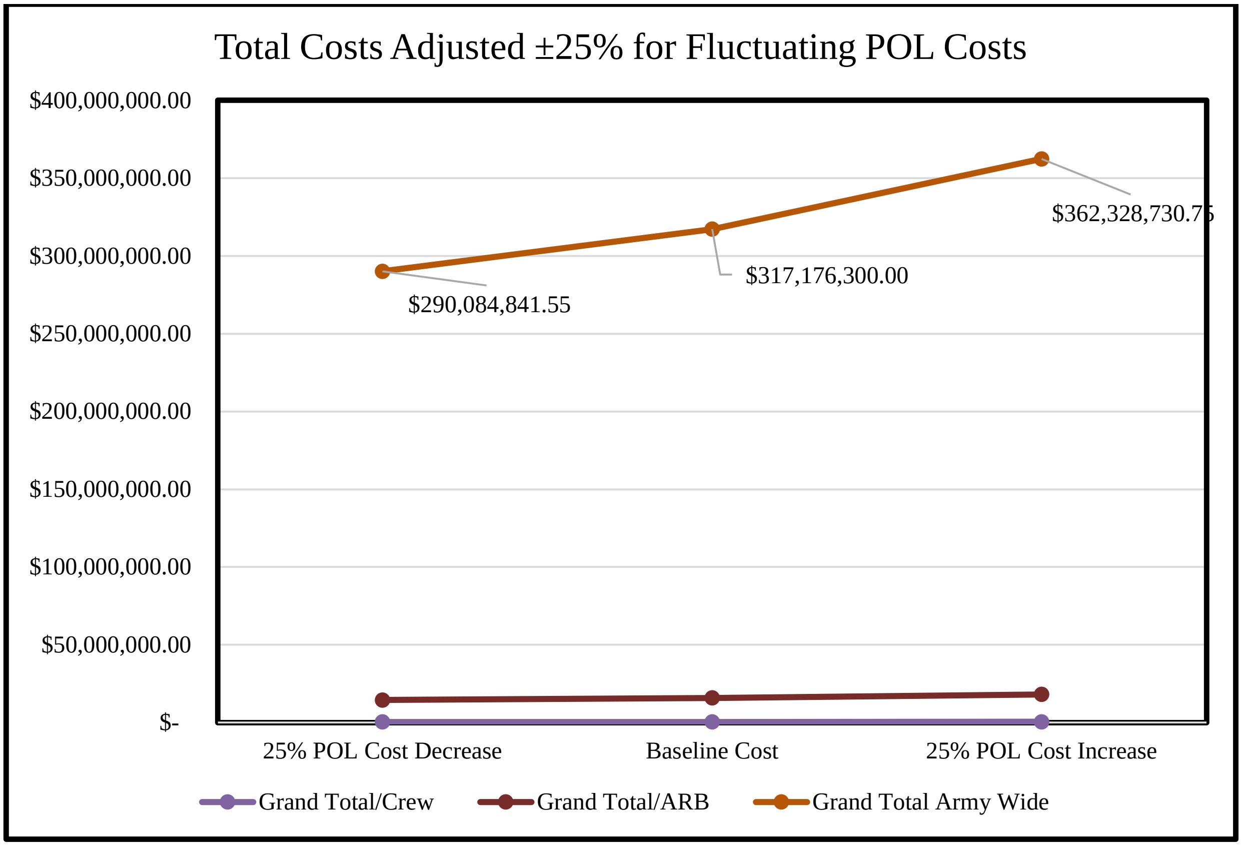


Figure 7: POL Analysis Moderate Virtual Simulation Model Graph

**Model Comparison for POL Sensitivity Analysis**

In the model comparison for fuel costs, all models reflect an approximate 25% percentage delta between the decreased factor and the increased factor. The largest percentage delta from baseline is when POL costs increase resulting in an approximate increase of 14%. A decrease of the same magnitude results in a percentage delta from baseline of approximately 8.5% for all models. When POL costs increase, the Low Virtual Simulation Model shows the greatest delta with approximately $59.8 million, while the High Virtual Simulation Model shows the lowest delta with approximately $40.9 million. Conversely, when the cost of POL decreases, the delta, while not nearly as significant as an increase in POL costs, is at a maximum delta of approximately $35.9 million in the Low Virtual Simulation Model and minimum delta of only $24.5 million for the High Virtual Simulation Model. This is due to the amount of live flight hours which carry the largest POL costs, and when modified, result in the greatest change, exponentially (Table 17 and Figure 8).

Table 17: Fuel Analysis Model Comparison Data

| Model | 25% POL Cost Decrease | Baseline Cost | 25% POL Cost Increase | Decrease Delta | Increase Delta |
|---|---|---|---|---|---|
| Low | $ 385,493,865.75 | $ 421,367,100.00 | $ 481,155,823.75 | $ 35,873,234.25 | $ 59,788,723.75 |
| Status Quo | $ 359,991,052.75 | $ 393,381,100.00 | $ 449,031,178.75 | $ 33,390,047.25 | $ 55,650,078.75 |
| Moderate | $ 290,084,841.55 | $ 317,176,300.00 | $ 362,328,730.75 | $ 27,091,458.45 | $ 45,152,430.75 |
| High | $ 262,769,641.05 | $ 287,307,300.00 | $ 328,203,398.25 | $ 24,537,658.95 | $ 40,896,098.25 |

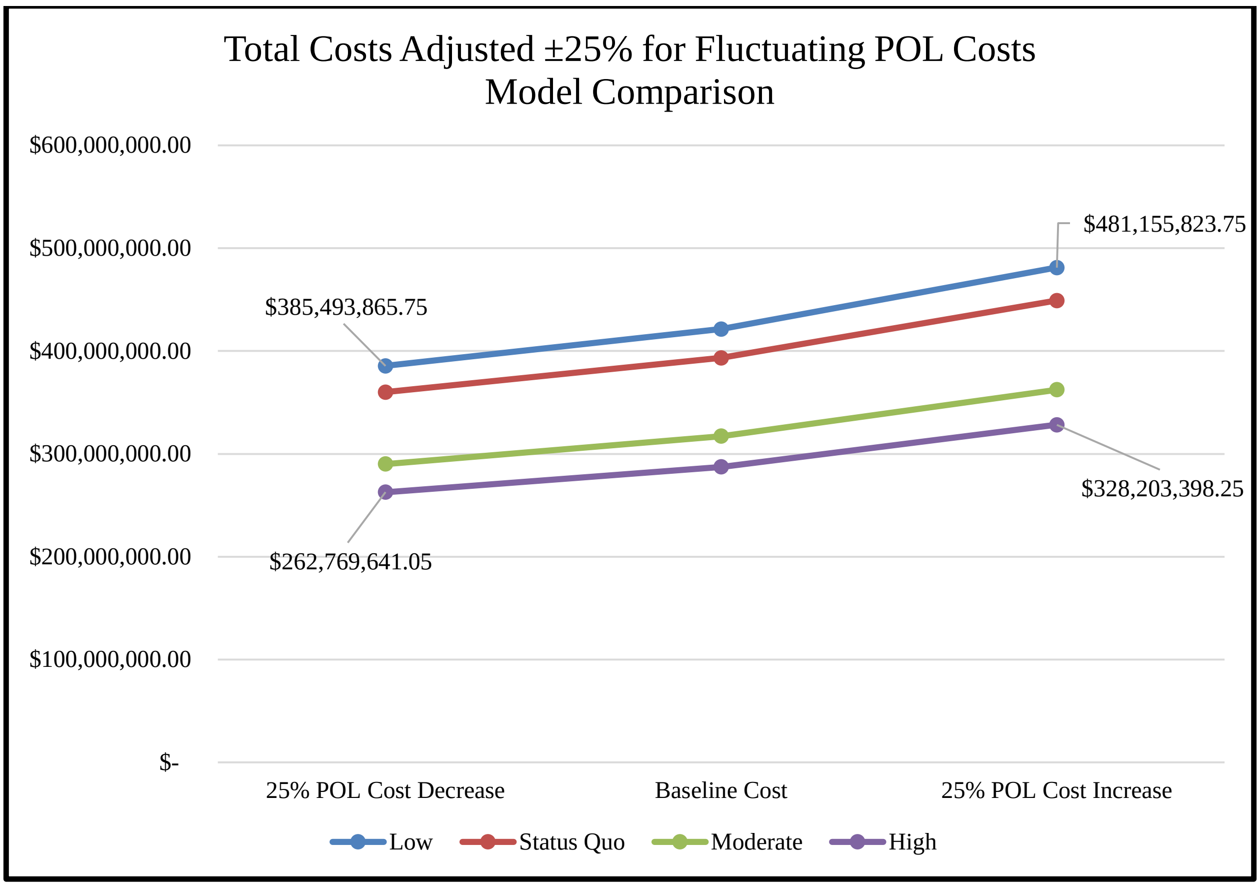


Figure 8: POL Analysis Model Comparison Graph

## Moderate Virtual Simulation Model Training Sensitivity Analysis

Applying a 20% variation to training costs for both the aircraft and LCT in the Moderate Virtual Simulation Model illustrates the impact a change to a single variable such as training requirements has on the overall cost factor. Multiplying plus or minus 20% to the baseline number of training hours results in a delta of 21.2 aircraft hours annually, 5.4 LCT hours, and 4.8 hours applied to live flight minimum annual requirements. At the Army level, the cost delta is approximately $63.4 million annually (Table 18 and Figure 9).

Table 18: Training Analysis Moderate Virtual Simulation Model

| Fixed Variables | Factor | | |
|---|---|---|---|
| Cost of live Flight Hour (cL) | $ 4,267.00 | | |
| Cost of Simulation Flight Hour (cS) | $ 269.00 | | |
| Number of Crews (nC) | 35 | | |
| Number of Battalions (nU) | 20 | | |
| **Moderate Virtual Simulation Model** | | | |
| **Variable** | **25% Training Reduction** | **Baseline Training** | **25% Training Increase** |
| Live Flight Hours/Crew (hL) | 84.8 | 106 | 127.2 |
| Simulation Hours/Crew (hS) | 21.6 | 27 | 32.4 |
| Simulation Hours Applied to min (hA) | 19.2 | 24 | 28.8 |
| | | | |
| **Description** | **25% Training Cost Decrease** | **Baseline Cost** | **25% Training Cost Increase** |
| **Grand Total/Crew** | **$ 362,487.20** | **$ 453,109.00** | **$ 543,730.80** |
| **Grand Total/ARB** | **$ 12,687,052.00** | **$ 15,858,815.00** | **$ 19,030,578.00** |
| **Grand Total Army Wide** | **$ 253,741,040.00** | **$ 317,176,300.00** | **$ 380,611,560.00** |

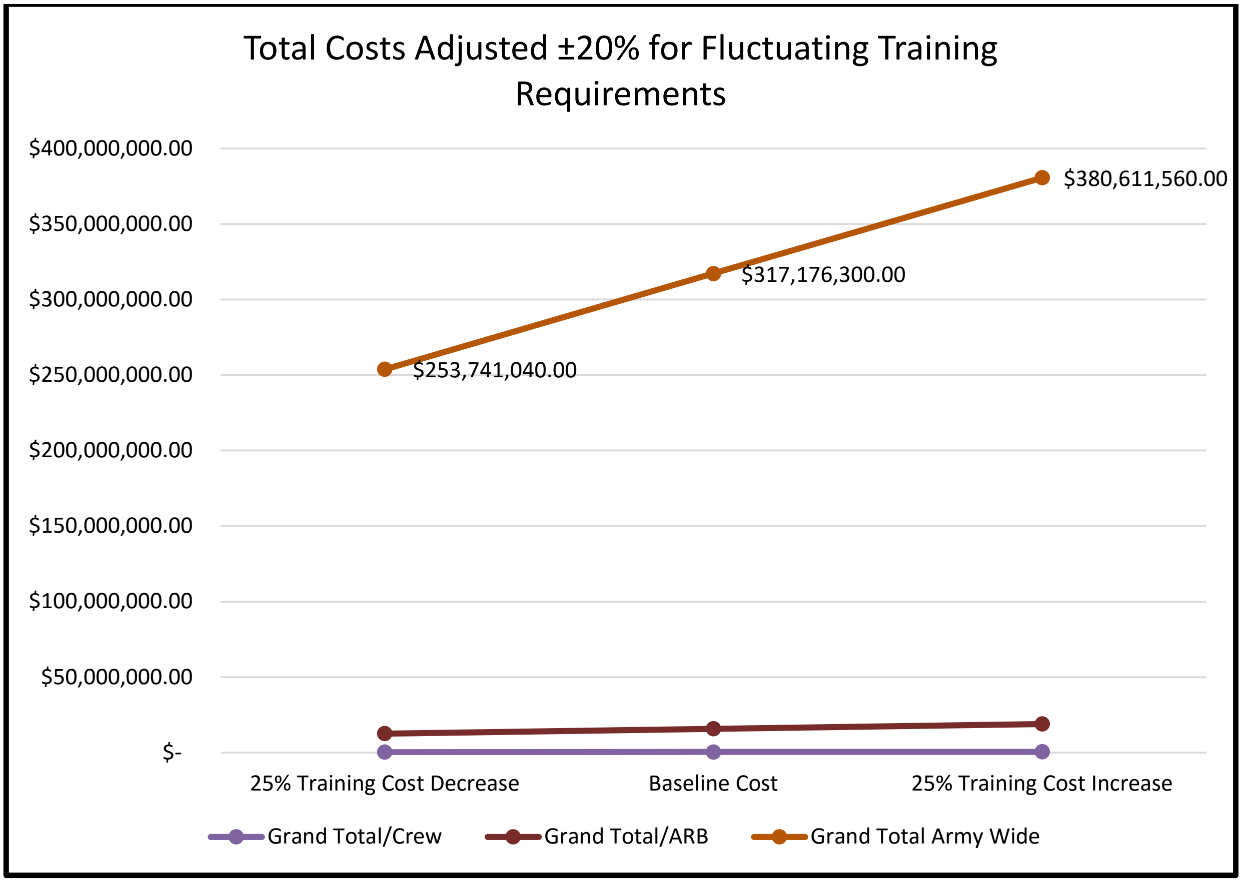


Figure 9: Training Analysis Moderate Virtual Simulation Model (Graph)

**Model Comparison for Training Sensitivity Analysis**

In the model comparison for training costs, the Low Virtual Simulation Model shows the greatest delta with approximately $84.3 million while the High Virtual Simulation Model shows the smallest delta with approximately $57.5 million. This is due to the amount of live flight hours which carry the largest operational costs, and when modified, result in the greatest change (Table 19 and Figure 10.

Table 19: Training Analysis Model Comparison Data

| Model | 20% Training Cost Decrease | Baseline Cost | 20% Training Cost Increase | Delta |
|---|---|---|---|---|
| Low | $ 337,093,680.00 | $ 421,367,100.00 | $ 505,640,520.00 | $ 84,273,420.00 |
| Status Quo | $ 314,704,880.00 | $ 393,381,100.00 | $ 472,057,320.00 | $ 78,676,220.00 |
| Moderate | $ 253,741,040.00 | $ 317,176,300.00 | $ 380,611,560.00 | $ 63,435,260.00 |
| High | $ 229,845,840.00 | $ 287,307,300.00 | $ 344,768,760.00 | $ 57,461,460.00 |

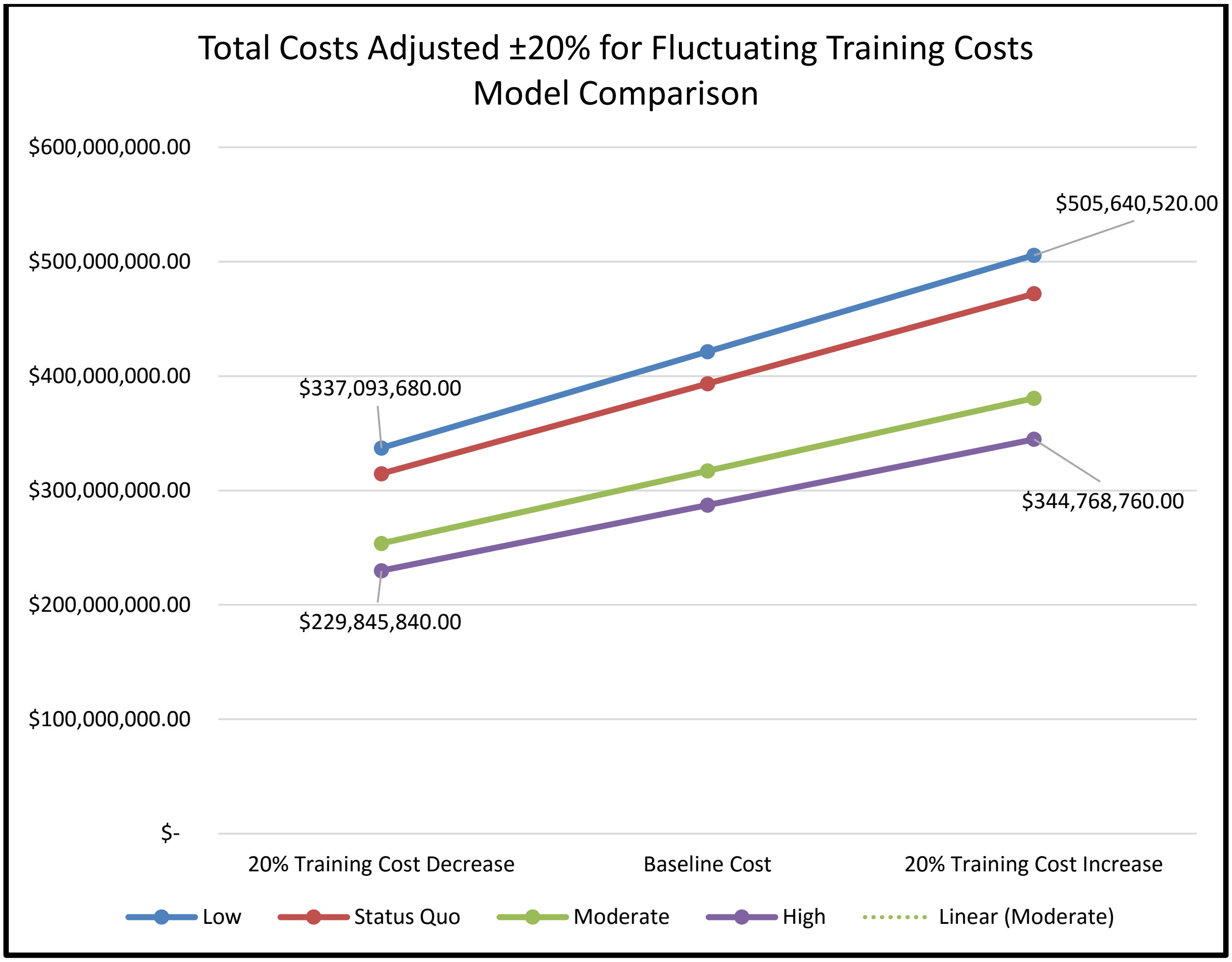


Figure 10: Fuel Analysis Model Comparison (Graph)

# CHAPTER FIVE: DISCUSSION AND RECOMMENDATIONS

## Chapter Five Summary

Chapter 5 serves as the conclusion chapter with an overall discussion of the topics, data, analysis through discussion, conclusion, current recommendation, and recommendations for further research.

## Discussion

In this study, we examined the cost benefits of replacing live flight hours with virtual live hours while addressing concern for the aviator's proficiency. The study focused on the AH-64 platform, LCT, active component aviation structure, and aviator designation to apply the methodology to a realistic sample. In this study, that sample was the general pilot or PI who, in a garrison training environment, generally fly the minimum flight requirements.

The LCT is a viable simulation solution and, as such, the only approved synthetic flight simulation system for the Apache. When training programs integrate the LCT with the conditions outlined by the Salas and Burke study, the LCT is a relevant and effective supplement to a comprehensive training plan. The LCT affords aircrews the ability to accomplish dangerous or, otherwise unauthorized tasks, such as auto-rotations terminating to the ground and hovering auto-rotations. Additionally, simulated emergency procedure training in the LCT provides the crew with realistic conditions, indications, and feedback without exposing the crew to unnecessary risk. The LCT is an excellent instrument meteorological condition (IMC) and gunnery/weapons trainer. Unlike a flight in an aircraft, the LCT is unaffected by poor weather and other uncontrollable factors. Lastly, I/Os can pause, reset, and evaluate training in real-time. On the other hand, the LCT does not have the means to train night vision goggles or multi-ship flight or collective training without the use of I/O controlled avatars.

Over the past few years, units were forced to make difficult decisions regarding FHP management due to declining budgets and sequestration. For those who have only experienced the post-9/11 military, budget management and fiscal stewardship are unfamiliar territory. With OCO funding and budgets supporting the war fight, units operated with what felt like an unlimited budget. When sequestration became a reality, units were required to operate at a significant detriment. While the Army was dealing with sizing and troop level restructuring, units at the lowest level, were deciding which repair parts to purchase, how to meet annual training requirements with scarce resources (e.g. fuel, ammunition, and parts), and relevant to this study, who gets to fly and how do they meet minimum flight requirements. The budget is back on the rise, but the threat of additional cuts looms. The Army cannot afford to risk proficiency while reducing costs, thus reducing the training budget. Supplementing live hours with simulation is a cost effective methodology but, at an unclear point, could potentially affect the aviator's skill in the actual aircraft. Budget analysts and commanders need to understand the effects increasing simulator usage has on costs and aviator proficiency before haphazardly responding to budget cuts. This study provided four options at different flight hour and price points while remaining conservative to sustain aviator proficiency. From a safety perspective, a reduction in exposure to the live environment mitigates risk to the aircrew but if there is a loss in proficiency due to flying too much simulation, the risk increases despite a reduction in live flight hours.

Tables 20 through 22 consolidate the data analysis from Chapter 4 and compare the potential cost savings from baseline for each model at the crew, battalion/squadron, and Army level. Ultimately, the High Virtual Simulation Model provides the most potential for cost savings of $106,073,800 for each crew annually, but at the expense of live hours. The Low Virtual Simulation Model comes at a cost increase of $27,986,000 for each crew annually due an increase in flight hours compared to simulation hours and has very little potential of implementation due to the higher costs and the trend of using increased simulation. The High and Low Virtual Simulation Models require changes to current doctrine, specifically with the amount of LCT hours a commander can authorize an aviator to apply to their semiannual flight minimum requirements. The Status Quo and Moderate Simulation Virtual Models do not require changes to doctrine. LCT throughput is never an issue with any of the models, assuming each battalion owns an LCT or even through proper management when sharing one system.

The final point of discussion is that of the proper amount of simulation without detriment in proficiency to the crew. In this study, transfer has a direct relationship to proficiency. While the LCT is a suitable training supplement, it is just that, a supplement for training. The LCT could never completely replicate the immersion or risk of consequence the crew experiences in the actual aircraft. Crew chiefs need hours flown on the aircraft, so they can train their respective maintenance tasks. Additionally, due to limitations of the LCT, live air to ground integration training as well as joint attacks with aircrews from the other services are only practicable and most realistic in live conditions. Finally, the current budget affords aircrews to maintain flight minimums with very little modification. Current Army doctrine and guidance accepts some simulation supplementation for live training and that apportionment is specifically defined in the ATM as reflected in the Status Quo and Moderate Virtual Simulation Models.

Table 20: Cost Summary (Crew)

| Model | Total Cost | Difference from Baseline | Percentage Delta from Baseline |
|---|---|---|---|
| Low Simulation | $ 601,953 | $ 39,980 | 7.11 |
| Status Quo | $ 561,973 | $ - | 0.00 |
| Moderate Simulation | $ 453,109 | $ (108,864) | -19.37 |
| High Simulation | $ 410,439 | $ (151,534) | -26.96 |

Table 21: Cost Summary (Battalion/Squadron)

| Model | Total Cost | Difference from Baseline | Percentage Delta from Baseline | LCT Throughput |
|---|---|---|---|---|
| Low Simulation | $ 21,068,355 | $ 1,399,300 | 7.11 | 595 |
| Status Quo | $ 19,669,055 | $ - | 0.00 | 945 |
| Moderate Simulation | $ 15,858,815 | $ (3,810,240) | -19.37 | 945 |
| High Simulation | $ 14,365,365 | $ (5,303,690) | -26.96 | 1295 |

Table 22: Cost Summary (Army Wide)

| Model | Total Cost | Difference from Baseline |
|---|---|---|
| Low Simulation | $ 421,367,100 | $ 27,986,000 |
| Status Quo | $ 393,381,100 | $ - |
| Moderate Simulation | $ 317,176,300 | $ (76,204,800) |
| High Simulation | $ 287,307,300 | $ (106,073,800) |

## Study Benefits

Some of the benefits of this study include:

1. Viable options for budget analyst and commanders to better implement alternative flying hour program methodologies in fluctuating budgets.
2. Realistic crew applicability.
3. Serves as a prelude to additional analysis and research for other aviation platforms and cost savings.

## Study Limitations

Some of the limitations of this study include:

1. Limited compensatory analysis which only applies the cost of an aircraft hour versus an LCT hour. This study excludes the associated costs for loss of aircraft, loss of crew, or other overhead costs not applicable to the operations costs of an aircraft hour.
2. No sampling or experimentations on aircrews to test the validity of the models in regard to transfer and proficiency.
3. An estimation of crew mix versus a true comprehensive sampling of the Army Aviation force structure accounting for personnel shortages, turnover, and unit training readiness.

This study does not adequately address the follow aspects but could benefit from additional research:

1. To what effect do different simulation motion replication formats have on transfer of training (e.g. motion plates, 6 DOF)? The LCT has motion plates in the seats as well as other systems to heighten immersion such as vibration and aural effects, but the instrument panel is fixed. There is potential that a 6 degree of freedom simulator could better replicate the proprioceptive sensation fine motor tasks such as ground taxiing and slope landings require as well as provide feedback for environmental factors such as crosswinds and turbulence.
2. Many of the commercial fixed-wing airlines conduct some portion of simulation training in a 6 DOF simulator as specified by the FAA AC120-40b (1991). What

risk level does the FAA determine proficiency requiring 6 DOF simulation and are these risk levels transferable for military rotary-wing training? For the LCT motion platforms versus 6 DOF platforms, for corresponding flight tasks, what is the difference in acceptable risk levels?

3. The LCT does not currently offer night vision goggle capability and hence does not directly train pilots for operation with night vision goggles. The Apache's primary night vision sensor is the forward looking infrared, but as proven in training and combat, crews must train on both the FLIR and NVG systems in case of damage or failure of the FLIR system. Night flights are the most dangerous and demanding flight modes.
4. This research assumed LCT throughput was always available and did not address in terms of cost savings either excess or shortfall in availability of the LCT for training. An additional variable for sensitivity analysis is LCT throughput as there appears to be excess LCT availability. The LCT funding accounts for almost 50% more hours than that needed to meet aviator minimum simulation requirements for one battalion. Future analysis of requirements, LCT utilization, and maintenance rates could bring contract costs down to even lower levels.
5. For the range (Low to High) of simulation hour substitution for live hours used in the sensitivity analysis, no loss of training proficiency is assumed. To assume continued linearity of equal tradeoff of simulation hours for live hours beyond the low to high range discussed in this thesis is risky. As seen in repeated studies, a rapid non-linear increase in pilot proficiency may be observed with initial simulator training until the pilot reaches a level of proficiency. Similar to an S-

curve, once the proficiency asymptote is reached, there are likely diminishing returns with additional simulation. Conversely replacing live flight time with simulation time may experience a reverse S curve non-linear loss of proficiency. At some unknown point substitution of live flight hours with simulation hours may result in decreasing proficiency and even negative training as seen in the CH-47 study with asymmetric outcomes such as deadly accidents. This study intentionally limits the range of sensitivity analysis for substituting live flight hours with simulation hours to the fore mentioned low and high range to avoid non-linear loss of pilot proficiency with possible asymmetric outcomes. This research targets the plateau in the middle of the curve to avoid the inevitable drop in proficiency.

## Conclusions

Although the application of LCT flight hours in lieu of actual flight time to make semiannual flight hour minimums is not preferred and often rejected at the unit level, this study proved the cost savings and risk mitigation with marginal risk to proficiency makes the application of virtual flight hours to semiannual flight minimums a viable option and at times a necessary alternative. While the effects on proficiency are only theoretical within this study, additional research and experimentation would narrow the parameters in finding a suitable balance between live and virtual requirements.

## Current Recommendations

Given the 2016 budget increase, combined with the Army's current flying hour budget, there are no reasons to take any drastic measures or impose mandates to commanders regarding the use of virtual in lieu of live training. Commanders should continue to promote the use of the LCT while resourcing training with the proper emphasis to ensure quality training in the simulator as well as manage flight hours to achieve both live and virtual flight hour minimums efficiently and effectively. Additionally, live training should place emphasis on refining control touch, maintaining confidence in the aircraft through pre-flight checks and flight profiles, and performing tasks not effectively replicated in the LCT. Those tasks include, but are not limited to, taxiing and airfield operations with other aircraft on the airfield, multi-helicopter operations, and joint and combined training.

Since the proficiency research is inconclusive and would only be clarified with more specific research and experimentation, the current recommendation is to maintain a flight hour program in line with current Army doctrine. Both the Status Quo and Moderate Virtual Simulation Models meet that recommendation. The Moderate Virtual Simulation Model produces in the greatest savings from both a monetary and risk perspective. Applying twelve hours to a PIs semiannual minimum flight requirements is already written in regulation and therefore, accepted by Army leadership. The negative stigma of applying simulation to flight minimums is an antiquated approach to managing an FHP. The High Virtual Simulation Model is feasible but at this point unnecessary and too aggressive in relation to risk to proficiency to enact.

## Recommendations for Further Analysis

Applying similar analysis with the Army's other advanced helicopters is the natural progression for this research topic. Additionally, the impact on proficiency from shifts in the balance of live and virtual flight simulation has on the individual crew and aviator remains unclear. One method of resolving this research gap is through experimental testing of aviator proficiency with a combination of forward, backwards, or quasi-experimental studies on samples of aviators at various levels in their respective careers (Hancock, Vincenzi, Wise, & Mouloua, 2008) or applying the tools presented in Chapter 2. Finally, collecting long term data on the proficiency levels of the aviators with reduced live hours and increased simulation hours in factors such as evaluation success rates, flight hours to pilot-in-command status, accident or incident rates and cause, and graduation/grades in graduate aviator courses such as instructor pilot and maintenance test pilot courses, is essential to understanding the impact decreased live and increased virtual hours has on an aviator's proficiency.

# APPENDIX A:
# III CORPS FLYING HOUR PROGRAM COST FACTORS

Table 23: III Corps FY16 FHP Cost Factors

| MODEL | COST FACTOR |
| --- | --- |
| AH-64A | $ 8,834 |
| AH-64D | $ 4,267 |
| AH-64E | $ 4,267 |
| C-12 | $ 370 |
| CH-47D | $ 6,287 |
| CH-47F | $ 6,224 |
| HH-60 | $ 2,775 |
| LUH-72A | $ 270 |
| OH-58C | $ 515 |
| OH-58D | $ 1,582 |
| UH-60A | $ 3,791 |
| UH-60L | $ 2,382 |
| UH-60M | $ 2,775 |

## APPENDIX B:
## SENSITIVITY ANALYSIS DATA

Table 24: POL Sensitivity Analysis Data

| Fixed Variables | Factor w/ 25% POL Cost Decrease | Baseline Cost Factor | Factor w/ 25% POL Cost Increase |
|---|---|---|---|
| Cost of live Flight Hour (cL) | $ 3,902.17 | $ 4,267.00 | $ 4,875.05 |
| Cost of Simulation Flight Hour (cS) | $ 258.91 | $ 269.00 | $ 285.81 |
| Number of Crews (nC) | 35 | | |
| Number of Battalions (nU) | 20 | | |

| | POL Cost Percentage |
|---|---|
| Aircraft | 11.4% |
| LCT | 5% |

**Low Virtual Simulation Model**

| Variable | Factor |
|---|---|
| Live Flight Hours/Crew (hL) | 140 |
| Simulation Hours/Crew (hS) | 17 |
| Simulation Hours Applied to min (hA) | 0 |

| Description | 25% POL Cost Decrease | Baseline Cost | 25% POL Cost Increase |
|---|---|---|---|
| Total Live/Crew | $ 546,304.01 | $ 597,380.00 | $ 682,506.65 |
| Total Simulation/Crew | $ 4,401.51 | $ 4,573.00 | $ 4,858.81 |
| Total Simulation applied to min/Crew | $ - | $ - | $ - |
| **Grand Total/Crew** | **$ 550,705.52** | **$ 601,953.00** | **$ 687,365.46** |
| Total Live/ARB | $ 19,120,640.35 | $ 20,908,300.00 | $ 23,887,732.75 |
| Total Simulation/ARB | $ 154,052.94 | $ 160,055.00 | $ 170,058.44 |
| Total Simulation applied to min/ARB | $ - | $ - | $ - |
| **Grand Total/ARB** | **$ 19,274,693.29** | **$ 21,068,355.00** | **$ 24,057,791.19** |
| Total Live Army Wide | $ 382,412,807.00 | $ 418,166,000.00 | $ 477,754,655.00 |
| Total Simulation Army Wide | $ 3,081,058.75 | $ 3,201,100.00 | $ 3,401,168.75 |
| Total Simulation applied to min Army Wide | $ - | $ - | $ - |
| **Low** | **$ 385,493,865.75** | **$ 421,367,100.00** | **$ 481,155,823.75** |

**Status Quo Virtual Simulation Model**

| Variable | Factor |
|---|---|
| Live Flight Hours/Crew (hL) | 130 |
| Simulation Hours/Crew (hS) | 27 |
| Simulation Hours Applied to min (hA) | 0 |

| Description | 25% POL Cost Decrease | Baseline Cost | 25% POL Cost Increase |
|---|---|---|---|
| Total Live/Crew | $ 507,282.30 | $ 554,710.00 | $ 633,756.18 |
| Total Simulation/Crew | $ 6,990.64 | $ 7,263.00 | $ 7,716.94 |
| Total Simulation applied to min/Crew | $ - | $ - | $ - |
| **Grand Total/Crew** | **$ 514,272.93** | **$ 561,973.00** | **$ 641,473.11** |
| Total Live/ARB | $ 17,754,880.33 | $ 19,414,850.00 | $ 22,181,466.13 |
| Total Simulation/ARB | $ 244,672.31 | $ 254,205.00 | $ 270,092.81 |
| Total Simulation applied to min/ARB | $ - | $ - | $ - |
| **Grand Total/ARB** | **$ 17,999,552.64** | **$ 19,669,055.00** | **$ 22,451,558.94** |
| Total Live Army Wide | $ 355,097,606.50 | $ 388,297,000.00 | $ 443,629,322.50 |
| Total Simulation Army Wide | $ 4,893,446.25 | $ 5,084,100.00 | $ 5,401,856.25 |
| Total Simulation applied to min Army Wide | $ - | $ - | $ - |
| **Status Quo** | **$ 359,991,052.75** | **$ 393,381,100.00** | **$ 449,031,178.75** |

| Moderate Virtual Simulation Model | |
|---|---|
| **Variable** | **Factor** |
| Live Flight Hours/Crew (hL) | 106 |
| Simulation Hours/Crew (hS) | 27 |
| Simulation Hours Applied to min (hA) | 24 |

| Description | 25% POL Cost Decrease | Baseline Cost | 25% POL Cost Increase |
|---|---|---|---|
| Total Live/Crew | $ 413,630.18 | $ 452,302.00 | $ 516,755.04 |
| Total Simulation/Crew | $ 6,990.64 | $ 7,263.00 | $ 7,716.94 |
| Total Simulation applied to min/Crew | $ (6,213.90) | $ (6,456.00) | $ (6,859.50) |
| **Grand Total/Crew** | **$ 414,406.92** | **$ 453,109.00** | **$ 517,612.47** |
| Total Live/ARB | $ 14,477,056.27 | $ 15,830,570.00 | $ 18,086,426.23 |
| Total Simulation/ARB | $ 244,672.31 | $ 254,205.00 | $ 270,092.81 |
| Total Simulation applied to min/ARB | $ (217,486.50) | $ (225,960.00) | $ (240,082.50) |
| **Grand Total/ARB** | **$ 14,504,242.08** | **$ 15,858,815.00** | **$ 18,116,436.54** |
| Total Live Army Wide | $ 289,541,125.30 | $ 316,611,400.00 | $ 361,728,524.50 |
| Total Simulation Army Wide | $ 4,893,446.25 | $ 5,084,100.00 | $ 5,401,856.25 |
| Total Simulation applied to min Army Wide | $ (4,349,730.00) | $ (4,519,200.00) | $ (4,801,650.00) |
| **Moderate** | **$ 290,084,841.55** | **$ 317,176,300.00** | **$ 362,328,730.75** |

| High Virtual Simulation Model | |
|---|---|
| **Variable** | **Factor** |
| Live Flight Hours/Crew (hL) | 96 |
| Simulation Hours/Crew (hS) | 37 |
| Simulation Hours Applied to min (hA) | 34 |

| Description | 25% POL Cost Decrease | Baseline Cost | 25% POL Cost Increase |
|---|---|---|---|
| Total Live/Crew | $ 374,608.46 | $ 409,632.00 | $ 468,004.56 |
| Total Simulation/Crew | $ 9,579.76 | $ 9,953.00 | $ 10,575.06 |
| Total Simulation applied to min/Crew | $ (8,803.03) | $ (9,146.00) | $ (9,717.63) |
| **Grand Total/Crew** | **$ 375,385.20** | **$ 410,439.00** | **$ 468,862.00** |
| Total Live/ARB | $ 13,111,296.24 | $ 14,337,120.00 | $ 16,380,159.60 |
| Total Simulation/ARB | $ 335,291.69 | $ 348,355.00 | $ 370,127.19 |
| Total Simulation applied to min/ARB | $ (308,105.88) | $ (320,110.00) | $ (340,116.88) |
| **Grand Total/ARB** | **$ 13,138,482.05** | **$ 14,365,365.00** | **$ 16,410,169.91** |
| Total Live Army Wide | $ 262,225,924.80 | $ 286,742,400.00 | $ 327,603,192.00 |
| Total Simulation Army Wide | $ 6,705,833.75 | $ 6,967,100.00 | $ 7,402,543.75 |
| Total Simulation applied to min Army Wide | $ (6,162,117.50) | $ (6,402,200.00) | $ (6,802,337.50) |
| **High** | **$ 262,769,641.05** | **$ 287,307,300.00** | **$ 328,203,398.25** |

Table 25: Training Sensitivity Analysis Data

| Fixed Variables | Factor | | |
|---|---|---|---|
| Cost of live Flight Hour (cL) | $ 4,267.00 | | |
| Cost of Simulation Flight Hour (cS) | $ 269.00 | | |
| Number of Crews (nC) | 35 | | |
| Number of Battalions (nU) | 20 | | |
| | | | |
| **Low Virtual Simulation Model** | | | |
| **Variable** | **20% Training Reduction** | **Baseline Training** | **20% Training Increase** |
| Live Flight Hours/Crew (hL) | 112 | 140 | 168 |
| Simulation Hours/Crew (hS) | 13.6 | 17 | 20.4 |
| Simulation Hours Applied to min (hA) | 0 | 0 | 0 |
| | | | |
| **Description** | **20% Training Cost Decrease** | **Baseline Cost** | **20% Training Cost Increase** |
| Total Live/Crew | $ 477,904.00 | $ 597,380.00 | $ 716,856.00 |
| Total Simulation/Crew | $ 3,658.40 | $ 4,573.00 | $ 5,487.60 |
| Total Simulation applied to min/Crew | $ - | $ - | $ - |
| Grand Total/Crew | $ 481,562.40 | $ 601,953.00 | $ 722,343.60 |
| Total Live/ARB | $ 16,726,640.00 | $ 20,908,300.00 | $ 25,089,960.00 |
| Total Simulation/ARB | $ 128,044.00 | $ 160,055.00 | $ 192,066.00 |
| Total Simulation applied to min/ARB | $ - | $ - | $ - |
| Grand Total/ARB | $ 16,854,684.00 | $ 21,068,355.00 | $ 25,282,026.00 |
| Total Live Army Wide | $ 334,532,800.00 | $ 418,166,000.00 | $ 501,799,200.00 |
| Total Simulation Army Wide | $ 2,560,880.00 | $ 3,201,100.00 | $ 3,841,320.00 |
| Total Simulation applied to min Army Wide | $ - | $ - | $ - |
| Low | $ 337,093,680.00 | $ 421,367,100.00 | $ 505,640,520.00 |
| | | | |
| **Status Quo Simulation Model** | | | |
| **Variable** | **20% Training Reduction** | **Baseline Training** | **20% Training Increase** |
| Live Flight Hours/Crew (hL) | 104 | 130 | 156 |
| Simulation Hours/Crew (hS) | 21.6 | 27 | 32.4 |
| Simulation Hours Applied to min (hA) | 0 | 0 | 0 |
| | | | |
| **Description** | **20% Training Cost Decrease** | **Baseline Cost** | **20% Training Cost Increase** |
| Total Live/Crew | $ 443,768.00 | $ 554,710.00 | $ 665,652.00 |
| Total Simulation/Crew | $ 5,810.40 | $ 7,263.00 | $ 8,715.60 |
| Total Simulation applied to min/Crew | $ - | $ - | $ - |
| Grand Total/Crew | $ 449,578.40 | $ 561,973.00 | $ 674,367.60 |
| Total Live/ARB | $ 15,531,880.00 | $ 19,414,850.00 | $ 23,297,820.00 |
| Total Simulation/ARB | $ 203,364.00 | $ 254,205.00 | $ 305,046.00 |
| Total Simulation applied to min/ARB | $ - | $ - | $ - |
| Grand Total/ARB | $ 15,735,244.00 | $ 19,669,055.00 | $ 23,602,866.00 |
| Total Live Army Wide | $ 310,637,600.00 | $ 388,297,000.00 | $ 465,956,400.00 |
| Total Simulation Army Wide | $ 4,067,280.00 | $ 5,084,100.00 | $ 6,100,920.00 |
| Total Simulation applied to min Army Wide | $ - | $ - | $ - |
| Status Quo | $ 314,704,880.00 | $ 393,381,100.00 | $ 472,057,320.00 |

| Moderate Virtual Simulation Model | | | |
|---|---|---|---|
| Variable | 20% Training Reduction | Baseline Training | 20% Training Increase |
| Live Flight Hours/Crew (hL) | 84.8 | 106 | 127.2 |
| Simulation Hours/Crew (hS) | 21.6 | 27 | 32.4 |
| Simulation Hours Applied to min (hA) | 19.2 | 24 | 28.8 |
| | | | |
| Description | 20% Training Cost Decrease | Baseline Cost | 20% Training Cost Increase |
| Total Live/Crew | $ 361,841.60 | $ 452,302.00 | $ 542,762.40 |
| Total Simulation/Crew | $ 5,810.40 | $ 7,263.00 | $ 8,715.60 |
| Total Simulation applied to min/Crew | $ (5,164.80) | $ (6,456.00) | $ (7,747.20) |
| **Grand Total/Crew** | **$ 362,487.20** | **$ 453,109.00** | **$ 543,730.80** |
| Total Live/ARB | $ 12,664,456.00 | $ 15,830,570.00 | $ 18,996,684.00 |
| Total Simulation/ARB | $ 203,364.00 | $ 254,205.00 | $ 305,046.00 |
| Total Simulation applied to min/ARB | $ (180,768.00) | $ (225,960.00) | $ (271,152.00) |
| **Grand Total/ARB** | **$ 12,687,052.00** | **$ 15,858,815.00** | **$ 19,030,578.00** |
| Total Live Army Wide | $ 253,289,120.00 | $ 316,611,400.00 | $ 379,933,680.00 |
| Total Simulation Army Wide | $ 4,067,280.00 | $ 5,084,100.00 | $ 6,100,920.00 |
| Total Simulation applied to min Army Wide | $ (3,615,360.00) | $ (4,519,200.00) | $ (5,423,040.00) |
| **Moderate** | **$ 253,741,040.00** | **$ 317,176,300.00** | **$ 380,611,560.00** |

| High Virtual Simulation Model | | | |
|---|---|---|---|
| Variable | 20% Training Reduction | Baseline Training | 20% Training Increase |
| Live Flight Hours/Crew (hL) | 76.8 | 96 | 115.2 |
| Simulation Hours/Crew (hS) | 29.6 | 37 | 44.4 |
| Simulation Hours Applied to min (hA) | 27.2 | 34 | 40.8 |
| | | | |
| Description | 20% Training Cost Decrease | Baseline Cost | 20% Training Cost Increase |
| Total Live/Crew | $ 327,705.60 | $ 409,632.00 | $ 491,558.40 |
| Total Simulation/Crew | $ 7,962.40 | $ 9,953.00 | $ 11,943.60 |
| Total Simulation applied to min/Crew | $ (7,316.80) | $ (9,146.00) | $ (10,975.20) |
| **Grand Total/Crew** | **$ 328,351.20** | **$ 410,439.00** | **$ 492,526.80** |
| Total Live/ARB | $ 11,469,696.00 | $ 14,337,120.00 | $ 17,204,544.00 |
| Total Simulation/ARB | $ 278,684.00 | $ 348,355.00 | $ 418,026.00 |
| Total Simulation applied to min/ARB | $ (256,088.00) | $ (320,110.00) | $ (384,132.00) |
| **Grand Total/ARB** | **$ 11,492,292.00** | **$ 14,365,365.00** | **$ 17,238,438.00** |
| Total Live Army Wide | $ 229,393,920.00 | $ 286,742,400.00 | $ 344,090,880.00 |
| Total Simulation Army Wide | $ 5,573,680.00 | $ 6,967,100.00 | $ 8,360,520.00 |
| Total Simulation applied to min Army Wide | $ (5,121,760.00) | $ (6,402,200.00) | $ (7,682,640.00) |
| **High** | **$ 229,845,840.00** | **$ 287,307,300.00** | **$ 344,768,760.00** |

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