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Army Aviation Equipment Useful Life Cost Benefit Analysis

22 November 2013

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Abstract

Army Aviation is considering pursuing the development of a future vertical lift (FVL) aircraft to replace its aging medium variant helicopters, which are the UH-60 Blackhawk and AH-64 Apache. The medium variant platforms comprise about 75% of the current Army fleet. Although its current fleet is over 30 years in age, to date, the Army is unsure whether the fleet should be replaced based upon cost, material condition, and technological capability. The critical issue is that the Army lacks objective research data to support the decision to either pursue a new aircraft or retain the current fleet. The intent of our research is to determine exactly how much any individual medium variant platform costs, per flight hour, and project its cost behavior over time. That information is then compared to a cost benefit analysis of a new build platform to help Army Aviation leadership with its FVL ambitions.

Keywords: Army Aviation, Cost Analysis, Future Vertical Lift, ALMIS, Maintenance

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First and foremost, our team thanks Army Aviation soldiers, aviators, and leaders for their sacrifice, dedication, and selfless service to our country. Their efforts established Army Aviation with unprecedented credibility with ground maneuver leaders the past 12 years of war. Army Aviation soldiers demonstrate the cunning resilience that makes our nation's military the best in the world.

We would like to thank the Program Office for Army Aviation for providing this research topic and all supporting data. Specifically, we would like to thank Mr. John Beck's G4 personnel for their outstanding support of this project. James Hale was key to our ability to execute this research project. Furthermore, we would like to thank CDR Aparicio, USCG, for helping our team obtain ALMIS data that support our recommendation of the Army incorporating a new enterprise-level system.

Finally, we want to thank Dr. Daniel Nussbaum and Dr. Jesse Cunha for their outstanding support as our project advisors. It was a true blessing to garner the advice from a renowned cost benefit analysis specialist and a Stanford economist. Their leadership and guidance truly ensured our team remained objective, focused, and accurate—thank you.

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About the Authors

MAJ Patrick "Josh" Baker graduated as a distinguished honor graduate from Auburn University in 1999 with a BS in aviation management. Following graduation, he attended flight school at Fort Rucker, AL, where he was rated as an AH-64D "Longbow" Apache pilot. His first assignment was as an attack platoon leader with C/2-101st Airborne Division. As a platoon leader, he deployed in support of the invasion of Iraq in 2003. Following OIF 1, he attended the Aviation Captain's Career Course at Fort Rucker, AL. Following this career course, he was assigned as the company commander of C/1-227th Attack Recon Battalion at Fort Hood, TX. He deployed to OIF 06-08, "The Surge," as the C company commander for the first six months of the deployment. He then took command of D/1-227th ARB, where he led the company for the remaining nine months of a 15-month deployment. Upon return from OIF 06-08 in 2008, he was assigned to the Army Acquisition Branch. MAJ Baker was assigned to PEO Aviation, where he performed duties as an APM for aviation communication systems, PM Apache, and finally as the aide/executive officer to the PEO from 2011–2012. MAJ Baker will work in the Office of Chief of Legislative Liaison in Washington, DC, as the coordinator for all Army aviation programs. He is married to the former Haley Pinson from Herndon, KY, and has two little girls, Taylor (3) and McKenzie (1). His awards and decorations include the Combat Action Badge, Army Parachutist Badge, Air Assault Badge, Senior Army Aviator Wings, two Bronze Stars, three Air Medals, one MSM, one Army Achievement medal, and a Presidential Valorous Unit Citation.

CPT Bryan Riddle graduated from The Citadel in 2004 with a BA in political science. After graduation, he attended flight school at Fort Rucker, AL. His first assignment was as a platoon leader in A Company, 2nd Battalion, 3rd Aviation Brigade, 3rd Infantry Division. After deploying with that unit to Iraq for 15 months and returning home, CPT Riddle attended the Military Intelligence Captain's Career Course at Fort Huachuca, AZ. After the career course, he deployed to Iraq again with Task Force ODIN as the company commander of Charlie Company. Upon redeploying with TF ODIN, CPT Riddle worked for the 21st CAV BDE until he was assigned to the Naval Postgraduate School. After graduation, he will attend CGSC at Fort Leavenworth, KS.

MAJ Jeremy Scott graduated from the U.S. Military Academy in West Point, NY, in 2003 with a degree in business management. After graduation he was commissioned as a second lieutenant in the Air Defense Artillery Corps, where he deployed to Iraq in support of Operation Iraqi Freedom as a platoon leader and battery executive officer. After his first tour to Iraq, MAJ Scott received a branch transfer to Aviation and qualified as both a CH-47 and C-12 pilot. His second tour to Iraq was in support of Task Force ODIN-Iraq as the A troop commander. He married his wife, Stephanie, in May 2004, and they have three children. After graduation in December 2013, he will be reporting as an assistant project manager to Redstone Arsenal, AL.

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List of Acronyms and Abbreviations

ACMS	Aviation Computerized Maintenance System
AH	Attack Helicopter
ALMIS	Aviation Logistics Management Information System
AMMIS	Asset Materiel Management Information System
APA	Aviation Procurement Army
ARSC	Aircraft Repair and Supply Center
BAA	Business Area Analysis
BPI	Business Process Improvement
BPR	Business Process Reengineering
CBA	Cost Benefit Analysis
CGDN	Coast Guard Data Network
CH	Cargo Helicopter
CBO	Congressional Budget Office
CONUS	Contiguous United States
DoD	Department of Defense
EIS	Executive Information System
ELAS	Electronic Logbook Automation System
FEDLOG	Federal Logistics Data
FVL	Future Vertical Lift
FVL–M	Future Vertical Lift Aircraft–Medium
FY	Fiscal Year
GUI	Graphical User Interface
IETM	Interactive Electronic Technical Manual
MAC	Man-Hour Allocation Chart
MC	Mission Capable
MOC	Maintenance Operational Check
MORPT	Monthly Operating Report
MTF	Maintenance Test Flight

OH	Observation Helicopter
O&M	Operations and Maintenance
OPFAC	Operational Facility
OPTEMPO	Operational Tempo
PEO Aviation	Program Executive Office for Army Aviation
RCM	Reliability Centered Maintenance
RDT&E	Research, Design, Test, and Evaluation
SDP	Software Development Plan
STAMIS	Standard Army Information System
TAV	Total Asset Visibility
UAS	Unmanned Aerial System
UFI	User-friendly Interface
UH	Utility Helicopter
ULLS–A	Unit-Level Logistics System–Aviation
USCG	U.S. Coast Guard
WW2	World War 2
WWW	World Wide Web

Executive Summary

As the federal budget tightens and the Department of Defense (DoD) evaluates all future programs for fiscal conservatism, the time is ever present for program executive offices throughout the Army, and her sister services, to properly plan, evaluate, and execute budgetary accountability. Army Aviation has set a tentative mark on the wall for the future of its rotary-wing aviation with the Future Vertical Lift (FVL) program. Looking to justify the program, the Program Executive Office for Army Aviation (PEO Aviation) must be able to explain the need for a new aircraft through various concessions. Our task was to analyze one of these concessions: Can individual airframe cost over time determine its age and, furthermore, be used to draw a fiscal line at which point a replacement airframe would be needed?

With the assistance of PEO Aviation, we analyzed the data from 60 randomly selected aircraft: 30 UH-60 Blackhawks and 30 AH-64 Apaches. Data used include maintenance records, man-hour costs, equipment costs, and man-hours required. What we discovered through our analysis and research is that the maintenance records did not provide sufficient data to accurately cost measure the aircraft's age in regard to maintenance costs. The records did not provide a historically accurate portrait; maintenance records did not indicate the corrective action taken, the amount of man-hours actually performed, or the parts required to mitigate the fault. Without this data or multiple assumptions, we were unable to develop a trend line indicating growth, decline, or stability in airframe cost over time.

Desiring to create a quality product for PEO Aviation to utilize in its analysis of the need for FVL, we contacted two of our sister services who maintain and operate variants of the UH-60 aircraft. The United States Coast Guard (USCG) utilizes an integrative system, the Aviation Logistics Management Information System (ALMIS), to integrate its maintenance, supply, and budget systems. As a small service, the USCG is accustomed to heavy budget scrutiny; therefore, it developed this system in order to justify all actions needed for its aviation fleet. The USCG obliged our research needs and provided us with the detailed information from its ALMIS database. Although told that ALMIS had the cost function built into the system, the ALMIS managers were unable to break out the individual cost for parts during our research. Regardless of our inability to procure the necessary data to complete the comparative analysis, the ALMIS system proves to be a step in the right direction for maintainers/leaders to assess readiness.

Our research does conclude that ALMIS is a quality system that should be examined to develop an Army enterprise maintenance program. A program like this will be costly to design and implement, but once maintainers are trained, the system

will provide quantitative feedback to users at all levels. Leadership will have higher visibility on the status of equipment, financial managers can better plan for future events, and PEOs can more effectively manage upgrades/replacements to keep the warfighter in the fight with the best weapons. Introducing a variant of ALMIS, improving upon the USCG database structure, and using lessons learned will inevitably increase awareness and efficiency throughout Army Aviation.

In conclusion, we were unable to answer the specific question we originally proposed. However, throughout the process, we did discover glaring issues, through our scope of investigation, that need to be addressed in order that future evaluations may be conducted and prove fruitful. We do propose that if detailed aircraft costing data is available through alternate sources, then further research should be conducted and updated to our current analysis in order to provide additional recommendations to PEO Aviation.

I. INTRODUCTION

A. ARMY AVIATION COST BENEFIT ANALYSIS OF THE AH-64 APACHE AND UH-60 BLACKHAWK

The United States Army has a rich aviation tradition. Manned flight by Army aviators spans nearly 100 years and covers every major conflict since the Civil War (Bradin, 1994, p. 49). Army Aviation was the birthplace for many revolutionary advances in flight, including the first use of fixed-wing aircraft in combat, numerous experimental projects, and the integration of rotary-wing aircraft into the span of combat operations.

Time and again, the U.S. Army has revolutionized combat operations through its employment of aviation assets. Regardless of the leaps in technology, the keystone to Army aviation's success is how it blends technology with highly trained personnel while conducting its mission. As imagined, the rigors of war leverage a heavy toll on man and equipment. Furthermore, advances in global technology also require the Army to upgrade its aircraft to meet emerging threats and capabilities.

Army aviation has reacted well to the aforementioned requirements throughout history—especially when considering its rotary-wing fleet. Supporting a modernization strategy for Army aviation is the focus of this research. In this chapter, we briefly discuss the modernization of the Army aviation fleet since World War 2 (WW2). Furthermore, the chapter provides insight on how the current fleet of AH-64 Apaches, UH-60 Blackhawks, OH-58 Kiowas, and CH-47 Chinooks have evolved to their current force structure and configurations. In this chapter, we then define the main goal of the research, which is to conduct a detailed cost benefit analysis (CBA) of the UH-60 and AH-64 to determine the cost behaviors associated with maintaining the fleet. That CBA is then used to determine if and when it is advisable to modernize the medium variant fleet of aircraft (UH-60 and AH-64).

B. ARMY AVIATION ROTARY-WING AIRCRAFT IN COMBAT

One of the key attributes of the U.S. Army's aviation program is its use of helicopters since WW2. Following that war, the Army Air Corps divested the majority of its fixed-wing assets to build the modern U.S. Air Force in accordance with the 1947 National Defense Authorization Act (Bradin, 1994, p. 61). Shortly thereafter, in 1952, the Army shifted its focus to retaining a robust rotary-wing fleet (Bradin, 1994, p. 78). The first combat rotary-wing mission conducted by the Army was during WW2 (Bradin, 1994, p. 59). During the Korean War, the Army integrated more helicopters into its combat operations. It was not until the Vietnam conflict that the Army truly revolutionized rotary-wing combat aviation tactics.

The Army's employment of the UH-1 Iroquois, AH-1 Cobra, and CH-47 Chinook revolutionized modern combat operations forever. The speed, maneuverability, and flexibility of the helicopter became the critical enabler for the Army during the conflict. Army aviators and maintainers developed new tactics for flying and sustaining the aircraft, many of which are still used today. The new technology of the time, resident in the CH-47, AH-1, and UH-1, proved instrumental in the success of the Army during the Vietnam conflict. The successes of the Army aviation enterprise in Vietnam securely locked its future as a must-have asset on the battlefield for all conflicts to follow. Pictures of the CH-47, AH-1, and UH-1 are provided in Figures 1–3.

Figure 1. CH-47 Chinook in Vietnam
(Leonard, 2006)

Figure 2. UH-1 "Huey" in Vietnam
(The Museum of Flight, n.d.)

Figure 3. AH-1 Cobra in Vietnam
("Vietnam War," 2008)

The post-Vietnam era for Army aviation resulted in significant leaps in rotary-wing technology. The lessons learned from the Vietnam conflict garnered significant political support and funding for various projects focused on modernizing the Army aviation fleet with platforms that could dominate Soviet technologies. The resulting fleet included the UH-60, AH-64, OH-58D, and CH-47D.

C. POST-VIETNAM AND ARMY AVIATION

The Vietnam conflict demonstrated the utility and necessity of helicopters on the modern battlefield. As such, and despite a post-war reduction in funding, the Army received appropriations to continue its development of rotary-wing assets (Bradin, 1994, p. 78). Lessons learned in Vietnam led to the development of the UH-1, OH-58, AH-1, and CH-47. The Vietnam conflict can be considered the birthplace of Army aviation tactics. The four aforementioned aircraft were the early manifestations of the current attack, utility, and cargo fleet.

The mid-1970s through early 1980s were the key developmental years for the modern Army aviation fleet (minus the CH-47). Cold War tensions and concerns over the growth of the Soviet war machine presented a clear and present need for advanced multiengine utility, observation, attack, and heavy-lift aircraft. The Army was focused on posturing for the emerging Soviet threat. The resultant fleet of modernized aircraft included the AH-64A, OH-58D, CH-47D, and UH-60 A/L. These aircraft included significant leaps in both performance and technological capability.

D. OPERATION DESERT STORM

The United States experienced its first major conflict against a Soviet-style standing army in Kuwait and Iraq in the early 1990s during Operation Desert Storm. This was the first true test of the modernized Army aviation fleet of AH-64s, UH-60s, CH-47s, and OH-58Ds. The aviation fleet was a critical enabler for all ground maneuver operations during the short conflict. As a matter of fact, the AH-64 fired the first ground shot of the war (Bradin, 1994, p. 182).

E. POST–DESERT STORM AND PRE-9/11

The tactical successes of the fleet during Operation Desert Storm secured aviation's position as a critical battlefield enabler. The years following the war remained focused on Cold War threats. Units conducted combined arms training exercises that deeply relied on Army aviation support. Additionally, the military experienced a significant reduction in force following Operation Desert Storm. It was around this time period that the Army divested its remaining legacy fleet of AH and UH-1 aircraft. The Army continued to upgrade/modernize the fleet of 60s, 64s, 58Ds, and 47s during the legacy divestiture. The upgrades included the transformation of the AH-64A to the AH-64D Longbow and the UH-60A/L and CH-47A/B/C/D to the CH-47F.

F. THE MODERN FLEET AND THE EFFECTS OF POST-9/11 OPERATIONS—AND THE WAY AHEAD

As the Department of Defense (DoD) enters the second decade of a protracted war effort, the toll on equipment and manning has proven arduous. Although the Global War on Terrorism has led to various leaps in military technological ability, the predominant portion of the equipment has been in the inventory in excess of 30 years. This is very much the case for the Army aviation fleet. The primary deployable fleet of aircraft includes the AH-64D Longbow, CH-47D/F Chinook, OH-58D Kiowa Warrior, and UH-60 Blackhawk helicopters. These airframes comprise the majority of the "fighting" fleet, but the Army also has myriad fixed-wing, unmanned aerial systems (UAS), and contiguous United States (CONUS)–only aircraft. Of the entire fleet, the only primary "new-build" aircraft are the unmanned aerial systems and CONUS LUH-72 Lakota.

Nearly all of the rotary-wing aircraft in the Army inventory are over a decade old. We theorize that the effects of the prolonged war have expedited the aging process of the respective airframes. For example, an AH-64D may have been built 12 years ago, but the aircraft "thinks" it is nearly 40 years of age, due to the stressors of the high operational tempo. Pre-September 11, 2001, Army aircraft flew approximately 140 hours per year. Since September 11, 2001, the aircraft have flown in excess of 90 hours a month (1080 hours a year) in combat under stresses not expected in a garrison environment (PEO Aviation, personal communication, October 28, 2013). Stressors include, but are not limited to, high-power settings due to extreme heat, occurrences of battle damage, and hard landings due to enemy-forced emergency procedures. Figure 4 highlights the number of combat flight hours accrued since the beginning of the Global War on Terrorism.

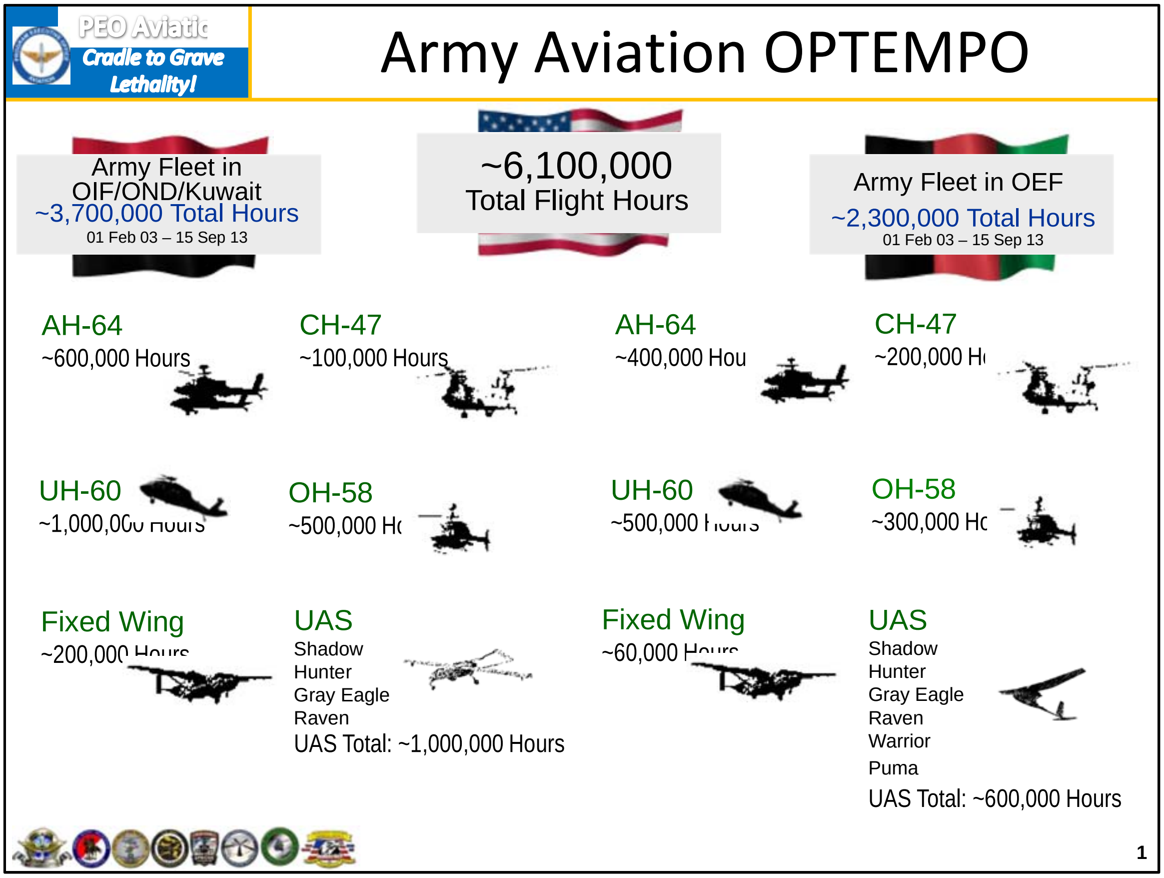

Figure 4. Army Aviation Operational Tempo for Operation Enduring Freedom and Operation Iraqi Freedom
(Program Office for Army Aviation [PEO Aviation], 2013)

In addition, many of the current Army Aviation fleet was designed over 30 years ago. Technological and production obsolescence plague the fleet as many of the prime manufacturers have discontinued the product lines of subcomponents designed for the current fleet. Each of these issues, coupled with the high demand for Army Aviation, has forced the acquisition community to essentially “Band-Aid” the fleet in order to keep aircraft supplied to the fight, and at a cost. Keeping the aircraft deployable requires continual deep-cycle scheduled maintenance as aircraft return from combat operations. Additionally, the aircraft are continually upgraded to rectify technological obsolescence. Figure 5 lays out the current life estimates of all of the Army Aviation aircraft. The figure captures Army Aviation’s modernization plan and how the Apache, Blackhawk, and Chinook have evolved from their base models to their current configurations.

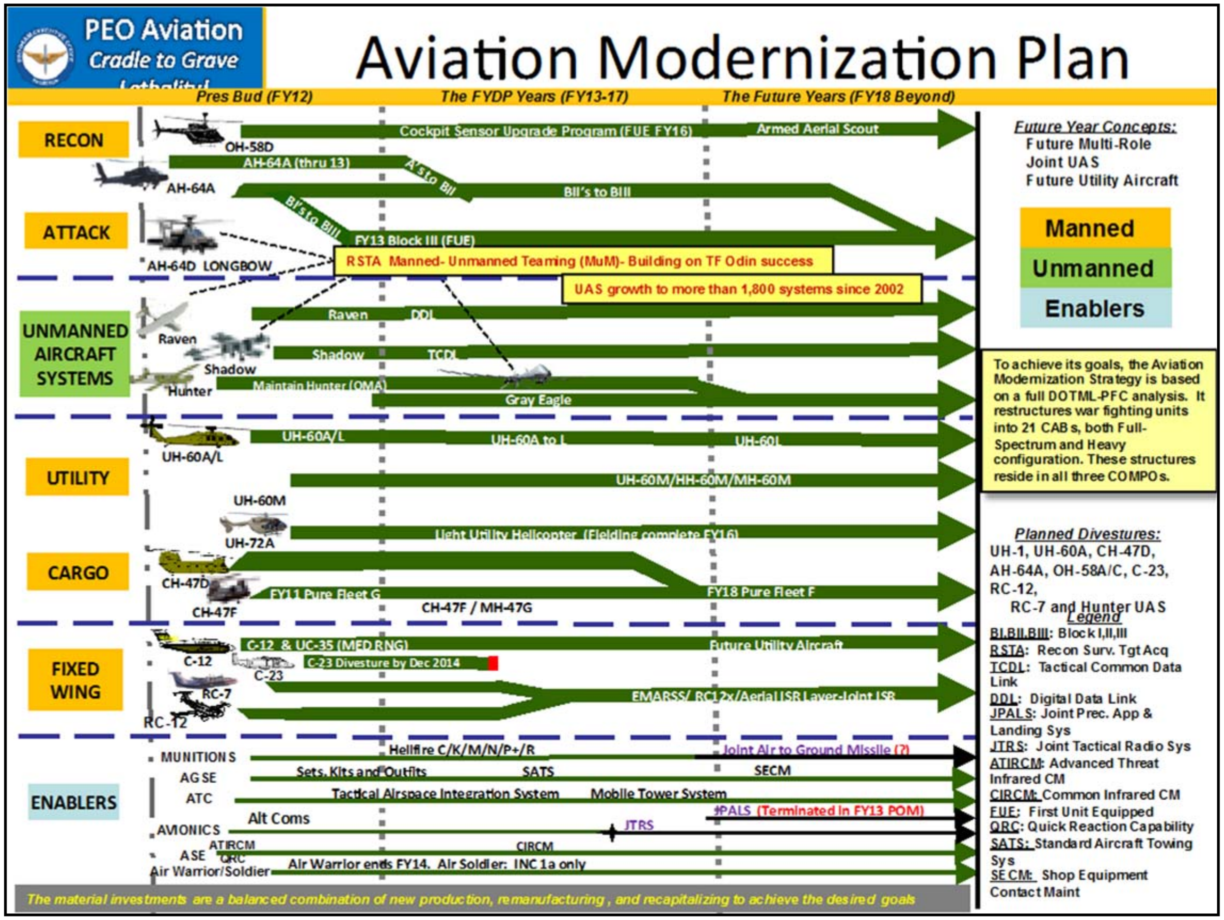

Figure 5. Army Aviation Modernization Plan
(PEO Aviation, 2013)

Currently, 70% of the Army Aviation Enterprise budget is allocated toward fleet sustainment, with the remaining 30% aimed at obsolescence upgrades and limited new aircraft purchases. The Army has primarily sustained and addressed only critical subcomponent obsolescence issues due to the rigorous combat demand for rotary-wing aircraft and budget constraints. If the Army does not address the current state of the fleet, there may very well be a significant sustainment cost in the future to retain the airworthiness of the elderly fleet. Moreover, national security could be a risk if the U.S. government does not look to invest in future Army Aviation capabilities.

Based upon initial maintenance assessments and the realities of the Army Aviation enterprise budget, we believe that these are the possible courses of action to address this issue:

- maintain the current fleet and address critical flight-safety obsolescence issues,
- invest in a new start future development platform, or
- maintain the current fleet—that is, the “do nothing” approach.

The costs and benefits for these three recommended courses of action are described as follows.

1. Maintain the Current Fleet and Address Critical Flight-Safety Obsolescence Issues

This course of action is in keeping with the current approved fiscal year (FY) 2012–2017 president’s budget for the Army Aviation Enterprise. This is the status quo course of action. The current budgeted amount for this course of action is $56.6 billion. The benefits of executing this course of action are that the funding is already approved, it meets the demands of the current war, it will not require an investment in the training or logistical system, and it is assumed to be more affordable than executing a new start program.

The risk of executing this plan is that it does not address the increasing obsolescence issues of the current fleet. As the technology on the aircraft ages, the prime contractors that originally developed the subcomponents are discontinuing the respective production lines due to non-profitability and the antiquation of production equipment. In addition, the reset and post-deployment deep-cycle maintenance do not rectify the sub-core airframe age. The maintenance actions simply clean and spot-repair the airframe substructure and replace subcomponent parts. As a result of these maintenance actions, the aircraft is essentially the same age it was when it entered maintenance.

2. Invest in a Future Vertical Lift Platform

This course of action is not funded in the FY2012–2017 president's budget. The course of action will require significant research, design, test, and evaluation (RDT&E) and Aviation Procurement Army (APA) investments to accomplish. Furthermore, if this program were executed in FY2013, the first unit equipped would not be expected until 2025. Choosing this course of action will rectify the majority of the current fleet's obsolescence issues and guarantee technological superiority for the nation. By developing a medium variant form factor to replace the UH and AH fleet, the Army will replace 75% of its current fleet. This course of action will also keep the American defense industry primed and "hot." The counterargument to this course of action is that it may be unaffordable within the current fiscal environment.

The total RDT&E investment for a new build is unknown at this time. The optimistic unit cost per airframe will be $30–$40 million. Furthermore, introducing a new platform will require a significant operations and maintenance (O&M) investment in both the training and logistical systems. Finally, selecting this course of action will require decommissioning the current fleet, which requires a redirecting of sustainment funding to the new build project. Deciding the optimal time for the funding shift could prove very risky and volatile, and could significantly impact national security.

3. Maintain the Current Fleet—That Is, Do Nothing

The Army does have the option to do nothing. This means that the Army will only just maintain the current fleet of aircraft and will not continue obsolescence upgrades. Of course, this option might create a significant risk to the Army's posture. Significant risk could be contributable to a lack of objective understanding of the physical condition and useful life remaining on the current fleet. This option is the cheapest of the three possibilities, but the Army would be forced to accept risk in both flight-safety factors and technological obsolescence. The lack of a future modernization strategy could jeopardize the Army's dominant position for future conflicts.

G. BUDGET REALITIES AND THE NEED FOR OBJECTIVE POSITIONING

The 2011 Budget Control Act (BCA) was set in motion in the spring of 2013. This BCA, better known as *sequestration*, presents an entirely new challenge to the DoD and Army Aviation (Congressional Budget Office [CBO], 2012). Sequestration sets mandatory spending reductions across the discretionary accounts throughout the executive branch of the U.S. government. These budget reductions could reduce the budget to as low as 40% of the Army aviation. This means that requests for investment funding (i.e., RDT&E) will be heavily scrutinized. Future discretionary budget reductions will lead to the urgent requirement for Army Aviation to be precisely certain of its position, regardless of which course of action is selected. The Congressional Budget Office (CBO) chart in Figure 6 shows the planned decline of U.S. discretionary spending in the absence of any laws to change sequestration.

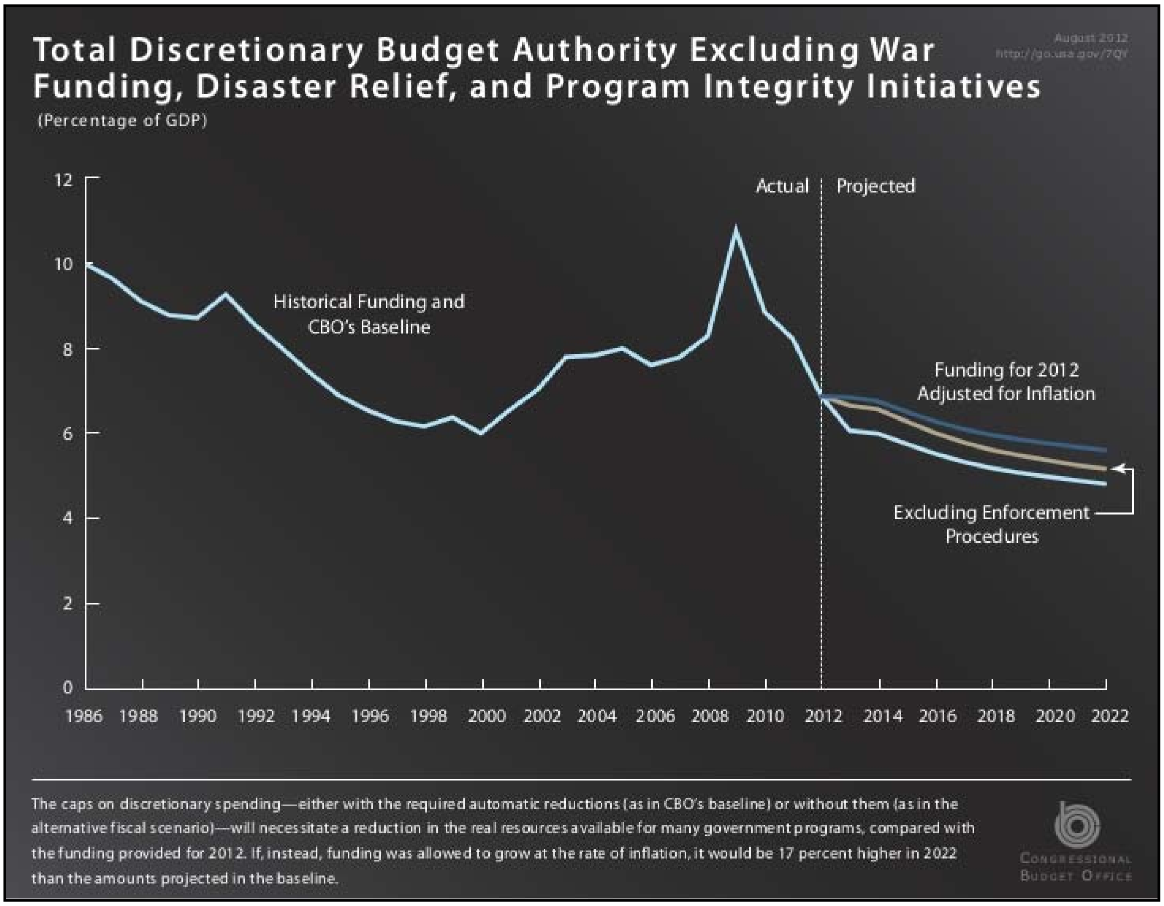

Figure 6. CBO Predicted Funding Trends
(CBO, 2012)

The PEO Aviation initiated a joint-level study effort to identify both the requirements associated with an FVL platform and the true condition of the current fleet. PEO Aviation also contributed to the development of a council of colonels to spearhead this effort. In 2012, the Aviation branch chief set 2020 as a target year for a possible fielding of a future vertical lift aircraft–medium (FVL–M). The aviation enterprise initially targeted the medium variant airframes due to their proliferation in the Army, Navy, and Coast Guard fleets. More specifically, the joint collaboration wants to analyze the UH-60 and AH-64 platforms.

PEO Aviation initiated various studies in order to develop an objective understanding of the status and potential of the current fleet. The research in this project is included in that plan. Harvesting accurate fleet data is critical to objectively identify the physical ability of the aircraft to last until 2020 or beyond. The PEO

Aviation study groups are leveraging numerous existing maintenance tracking systems that include the User-Level Logistics System—Aviation (ULLS-A), Electronic Logbook Automation System (ELAS), and the Standard Army Information System (STAMIS).

A large amount of data is available for the different studies, but no single source can provide precise costing data associated with any individual aircraft. Significant political support during the Global War on Terrorism for Army Aviation operations resulted in robust funding levels that allowed for funding aggregate upgrades and maintenance. The large funding levels were good in the sense that they allowed for the flexibility and reaction time needed to keep aircraft in the fight. Conversely, this funding did not force the Army to track "by the eaches" when it comes to how much an individual aircraft is costing the Army. The assumption is that "maintenance costs reflect age"; that is, the more an aircraft costs to maintain per flight hour, the more it is aging.

In order for the Army to pursue an FVL platform, it must know for sure that the current fleet of medium variant aircraft cannot last beyond 2020. This research is needed for helping the Army make an educated decision on what to do about Army Aviation. In short, this research is intended to supplement the overall study being conducted by PEO Aviation. The intent for this project is to approach the objective knowledge gap from a different perspective than the other research centers.

H. RESEARCH HYPOTHESIS

In this research, we hypothesize that an airframe's repair cost per flight hour is an indicator of age. The theory is that as an aircraft ages, its cost per flight hour to maintain will increase. We plot that cost behavior on a time line to determine the most cost-beneficial time for the Army to divest the legacy airframe and pursue an FVL-M platform.

The research focuses on both the UH-60 and AH-64D airframes in order to stay in line with the current Army Aviation enterprise intent. We attempt to identify the maintenance flight hour cost per individual airframe. We used a random sample of data from 30 UH-60 and AH-64D maintenance logbooks for the research in hopes of determining a standardized population behavior of the fleet through the central limit theorem. For pictures of the AH-64D Apache Longbow and UH-60 A/L/M Blackhawk, see Figures 7 and 8.

Figure 7. AH-64D Apache Longbow
(Boeing, n.d.)

Figure 8. UH-60 Blackhawk
(Sikorsky, n.d.)

Our intent is to dig beyond the Army's current aggregate costing and determine whether the individual aircraft O&M costs, annual or cumulative, can be used to determine the aircraft's age or remaining useful life span. In closing, we assumed that the cost behavior identified during this research could be leveraged by Army Aviation to determine whether current obsolescence upgrades and maintenance programs are keeping the ownership cost down or whether the aircraft are costing more over time.

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II. METHODOLOGY

A. INTRODUCTION

Our goal was to look at UH-60 Blackhawk and AH-64 Apache maintenance data in order to estimate the cost to maintain those aircraft as a function of aircraft age. We then planned to give those data to PEO Aviation in Huntsville, AL, so that its decision-makers could determine whether there was a need to replace those aircraft. In this chapter, we look at the data we received, the two different processes we used to analyze the data, and the issues we had in analyzing the data.

B. DATA RECEPTION AND PROCESS ONE

To start the flow of information, PEO Aviation sent us logbook data in Microsoft Excel format for 30 Apache and Blackhawk aircraft. The data included all maintenance actions that were recorded in the ULLS-A since the aircrafts' last upgrades. Each aircraft came with two documents: scheduled and unscheduled maintenance. The unscheduled data went back to the early 2000s, and the scheduled data went back to about 2006. This information combined to give us a history that was as complete as the Army could provide.

We started with the AH-64 logbooks and combined all of the entries from both documents for one aircraft. For our first attempt, Process One, we reviewed the data element by element to determine a cost for each maintenance action. To find each cost, we first checked the *Interactive Electronic Technical Manual* (IETM) to determine the number of soldiers that were needed to complete the task. We then used the Man-Hour Allocation Chart (MAC), which gave the number of hours that each action was expected to take. With that information, we had everything we needed for the personnel cost of the maintenance action. To find the parts costs, we used the Federal Logistics Data (FEDLOG) system. After we determined the personnel and parts costs, we added a standard cost if a maintenance test flight (MTF) was required and a standard cost if maintenance operational check (MOC) was required. The final equation we used was ((men used) × (man-hours used) × (36.72)) + (parts costs) + (MOC) + (MTF).

The goal with using this equation was to find the cost of each maintenance action over the life of the aircraft and then separate those actions into monthly totals. We then divided each month's totals by the number of flight hours that the aircraft flew that month and then plotted the data, giving a trend over time. We hoped this trend, when averaged with the trends from all of the other aircraft, would show a pattern of how aircraft age affects cost.

C. ISSUES WITH PROCESS ONE

When we starting sorting the data, we had high hopes of being able to get through all of the UH-60s and AH-64s in the time allotted. We quickly found that it took about an hour to get through about four maintenance actions. The time involved did not deter us at this point because we thought we would become faster at finding the costs as we gained experience using the IETM. The issue was that we could not find every single maintenance action that was written up in the IETM. On top of that, even if we could find the action in the IETM, the maintenance logs were not always clear about whether a part was replaced or repaired. The logs also did not give clear corrective actions for every write-up. Another major problem that we encountered with that data is that the older the data got, the less reliable they were. This problem arose because the system that is used to track the maintenance was phased in and not all of the aircraft had as much data to examine. These issues forced us to make many assumptions and speculations. When the assumptions started to outnumber our facts, we decided to build another process for analyzing the data.

D. PROCESS TWO

For our second attempt to analyze the data, Process Two, we attempted to categorize maintenance actions into three separate tiers to mitigate the fact that we could not determine all of the specific costs with Process One. To develop the tiers, we used a similar equation from Process One, minus MOC and MTF: ((men used) × (man-hours used) × (36.72)) + (parts costs). We then reviewed the logbooks and found maintenance actions that we could determine the costs for and added them to a list until we had enough actions to determine a trend in the data. We then separated the data by the costs we found. Tier One actions involved significant costs, Tier Two consisted of actions with less cost, and Tier Three included the least expensive actions. Then we averaged the costs for the maintenance actions to determine a tier cost. Tables 1 and 2 show the breakdown for Tiers One and Two, respectively, of the AH-64 Apache.

Table 1. Tier One

	men	man hours	parts		
replace main rotor blade	5	0.3	131273.00	131327.41	
APU replace	4	3	215047.00	215482.24	
engine replace	8	9.1	684192.00	686832.46	
night site replace	2	3.6	411091.00	411352.14	
30mm replace	4	8	90103.00	91263.64	
MPD replacement	2	5.6	108135.00	108541.22	274133.18

Table 2. Tier Two

Radar Altimeter	2	5.3	16930.00	17314.46	
Severance Device Replacement	3	5.4	2234.48	2822.05	
TDAC reinstallation	2	5.2	68320.00	68697.21	
Fuel Cell replace	4	23	15263.15	18599.99	
Main rotor head replace	5	29.8	39165.00	44569.23	
refrigerant tubing	2	2	461.16	606.24	
lateral transducer replacement	3	6	935.44	1588.30	22028.21

Tier Three costs were used for daily inspections and minor repairs. To determine the cost of this tier, we assigned two maintenance man-hours to represent a repair that is completed quickly and developed a cost of $73.44 per Tier Three action.

Once the tiers were built, we reviewed the list of maintenance actions and placed a 1, 2, 3, or N/A next to each one, with the following meanings:

- A “1” entered in the spreadsheet populated the Tier One cost of $274,133.18.
- A “2” entered in the spreadsheet populated the Tier Two cost of $22,028.21.
- A “3” entered in the spreadsheet populated the Tier Three cost of $73.44.
- An “N/A” entered in the spreadsheet did not populate a price and was used for double entries and entries that required no actions.

Our assumption in determining the costs for the three tiers was that the cost itself was less important than our using the numbers consistently to determine the data trends over time.

E. ISSUES WITH PROCESS TWO

Process Two presented its own challenges. The major issue that we had with analyzing the data with this method is that there were so many unknown variables in the data. As in Process One, we did not know whether parts had been replaced or repaired, but, more importantly, with many actions, we could not tell what, if anything, had been done to correct the maintenance write-up. Because parts had the greatest influence on the cost of each maintenance action, we did not think that our data were accurate enough to draw any conclusions.

F. THE NEXT STEP

Because we were unable to analyze the data that the Army tracks, we searched for another service that kept the data we thought important in determining the aircraft cost over time. Our search yielded one service that managed its maintenance with the level of detail that we required: the USCG. Our way ahead was to analyze the USCG's UH-60 data to determine if, in fact, we could find a trendline in the data. A positive trend would indicate that the Army must take steps to more tightly track its data so that it can show Congress when the fleet should be replaced.

III. UNITED STATES COAST GUARD AVIATION LOGISTICS MANAGEMENT INFORMATION SYSTEM

The USCG, a component of the Department of Homeland Security, serves to protect the nation's ports, waterways, coast, and international waters in support of national security (United States Coast Guard (USCG, 2013). A key component in accomplishing this large task is to use both naval and aviation assets. The USCG's inventory consists of 211 aircraft, with a mix of rotary-wing, fixed-wing, and UAS aircraft (USCG, 2013). With a tighter budget than its sister services—$9.79 billion, per the FY2014 president's budget—and a similar posture to be fiscally responsible, the USCG strives to utilize the most cost-effective maintenance, logistics, and procurement procedures (USCG, 2013). The USCG developed two systems, the Aviation Maintenance Management System (AMMIS) and the Aviation Computerized Maintenance System (ACMS), as mission-critical, evolving systems (Aircraft Repair and Supply Center, n.d.). The problem with having the two systems was the lack of integration, induced errors from inputting redundant data into two sources, and reduced efficiency at the user level (USCG, 2013). The systems made more work for the logisticians and maintainers, creating the need for the USCG to seek an alternative system for collecting, processing, and integrating the data from the two sources into one database. After conducting a business area analysis (BAA), the USCG selected the Aviation Logistics Management Information System (ALMIS) as a tracking system for equipment maintenance, cost, and scheduling.

ALMIS consolidates the tracking and information data from AMMIS and ACMS, providing real-time savings through improved logistics management (OAO Corporation, 1997, 1.2). Operating in 26 air stations throughout the U.S., the USCG needed a collective database in order to properly manage, procure, and maintain more than 200 aircraft across the nation (Deshpande, Iyer, & Cho, 2006). Parts for the entire aviation fleet are supported through one central warehouse, managing in excess of 60,000 part numbers with a total value of over $718 million (Deshpande et al., 2006). The USCG is a microcosm of the aviation support structure for the U.S. Army; what the USCG does differently is in the implementation of a comprehensive tracking system aimed at saving money.

A. AVIATION COMPUTERIZED MANAGEMENT SYSTEM

ALMIS was developed specifically to combine the products of two independent databases, ACMS and AMMIS. As independent systems, each database provides different products to the user as well as the manager. ACMS tracks all individual parts installed and maintenance flags, and it records the repairs via the serial numbers of all parts consumed (Deshpande et al., 2006). Utilized by all USCG air stations, this database also provides maintenance planning and execution, and configuration management of all individual aircraft. ACMS supports all day-to-day maintenance activities at the 26 USCG air stations (Department of Transportation [DoT] & USCG, 2001). ACMS's purpose of tracking the "maintenance, repairs, calibration, and transportation times of avionics equipment and aircraft components" (OAO Corporation, 1997, 3.3) supports the user's ability to query the database, through a user-friendly interface (UFI), in order to gain an operational manager's status of components and configuration schedules (OAO Corporation, 1997, 3.3). By utilizing the collection tools within the database, managers can access trend and statistical analyses, which in turn support the USCG's reliability centered maintenance (RCM) program (OAO Corporation, 1997, 3.3). What this database could not provide the user are the financial aspects of the maintenance, logistics, and procurement elements.

B. AVIATION MAINTENANCE MANAGEMENT INFORMATION SYSTEM

AMMIS is a stand-alone financial system operated at the USCG Aircraft Repair and Supply Center (ARSC). This centralized location and system breaks down the monetary allotments by cost center, unit, fund code, and finally the dollar amount. This data is then included in future USCG financial statements (Department of Homeland Security Office of Inspector General, 2009). The detailed database

> tracks every step of the process once the part comes off the aircraft. It tracks demand requisitions (orders) placed to the warehouse, the shipment of good parts to the air stations and maintenance facility, the receipt of failed parts (carcasses), their shipment to vendors or in-house repair, and their induction back into the system. (Deshpande et al., 2006)

Another by-product of AMMIS is its ability to provide total asset visibility (TAV), providing a visual of where all of the spare parts are located, either at the ARSC or the multiple air stations (DoT & USCG, 2001). Besides fiscal and supply management oversight, AMMIS also provides a method of tracking "aircraft flight and operations tracking, pilot and aircrew training and qualification training, and flight pay reporting" (DoT & USCG, p. 22). The AMMIS program is specifically designed to track calendar/scheduling-type movements and apply a cost figure to each entry. The following is an itemized list of the many activities that AMMIS provides the user:

- Flight Operations:
    - Operational Facility (OPFAC) Aircraft, including Receipt and Transfer Management,
    - OPFAC Personnel Management,

    - CG Aircraft Flight Record (4377) Data, and
    - Aircrew Training & Qualifications Management;
- Fiscal Accounting:
    - Ledger Accounts Management,
    - Personnel Services Management,
    - Industrial Services Management, and
    - Data Tables Maintenance;
- Supply:
    - Scheduled and Unscheduled Inventory,
    - Perform Inventory,
    - Inventory Management, and
    - Parts Shipment and Tracking, including 265 parts; and
- Procurement:
    - Maintenance Requirement Package Management,
    - Government Furnished Property Accounting,
    - Purchase Request Administration, and
    - Purchase Obligation Management. (OAO Corporation, 1997, 3.3)

Although AMMIS replaced obsolete software in late 1993, its own software needed refreshing and expandability after years of use (DoT & USCG, 2001). ALMIS was developed by the USCG to combine the ACMS and AMMIS databases. The first iteration of ALMIS was delivered in 2000 with the purpose of being expandable as well as upgradeable (DoT & USCG, 2001).

C. AVIATION LOGISTICS MANAGEMENT INFORMATION SYSTEMS: BACKGROUND, OBJECTIVES, AND GENERAL DESCRIPTION

In the late 1990s to 2000, the USCG employed OAO Corporation's Information Technology Division—East to perform a BAA and other related services to analyze its two current information systems: the ACMS and AMMIS. The BAA analyzed the need and applicability of ALMIS for the USCG's Aeronautical Engineering Division (OAO Corporation, 1997, 1.2). The USCG wanted a system that would not only be directed at saving money but would also combine the two current systems and be a user-friendly system supported and maintained by government and contractor personnel (OAO Corporation, 1997, 1.2). Availability via the World Wide Web (WWW) and graphical user interface (GUI) technologies was another requirement for expandability and accessibility as dictated by the USCG (OAO Corporation, 1997, 1.2).

The USCG further identified the five major business areas to be managed by a system such as ALMIS: aircraft maintenance (organizational and depot), flight operations, supply (organizational and depot), procurement management, and financial management. The oversight, management, and visibility of these five areas would need to be accomplished by performing, at a minimum, the following functions:

- Systems Analysis of Legacy Software Systems,
- Analysis of Hardware and Telecommunications Systems,
- BAA,
- Business Process Modeling,
- Logical and Physical Data Modeling,
- Business Process Reengineering/Business Process Improvement (BPR/BPI),
- Software Engineering,
- System Design, and
- Database Design. (OAO Corporation, 1997, 1.2)

With the decision to move forward with the ALMIS product, the BAA needed to identify hardware requirements, and operation support and training needs. The hardware package operates on the same DEC 2100/Sable host computer at the ARSC Management Information Systems Division for both systems, ACMS and AMMIS. USCG workstations provide access to users through the Coast Guard Data Network (CGDN). These hosts are interfaced via DEC 5000 office workstations that are connected to the development server and a separate DEC 3000 on the front end. All maintenance and support is provided at the government and contractor personnel level (OAO Corporation, 1997, 3.5.2.1). Structured training programs have been instituted for users based on their level of access and functional need. All database administrators receive more intensive training, to aid in the trouble-shooting and maintaining of the system, through a combination of classroom and on-the-job training (OAO Corporation, 1997, 3.7.5).

The analysis conducted through outside agencies as well as having a defined need enabled the USCG to develop a user-friendly database aimed at saving money through data collection, management, and analysis. The by-product of ALMIS provides the manager or requesting user with a compiled analysis of data in regard to cost, schedule, and performance. Additional benefits are present through ALMIS's upgradeability and flexibility. Management of inventory, flight hours, flight pay, and mission logs create a historical document for the unit as well as for the USCG's purview.

D. ALMIS DESCRIPTION: OBJECTIVES, FLEXIBILITY, AND ASSUMPTIONS

The objective of ALMIS is to be an integrated database able to support the following business practices: aircraft flight operations, aircraft maintenance and configuration, fiscal accounting, procurement management, aviation supply, and aviation headquarters (OAO Corporation, 1997, 5.1.2). In addition, the USCG desired to access the data via Internet technology, the WWW, and a GUI. Furthermore, the Executive Information System (EIS) would provide the user/manager with historical data enabling trend analysis (OAO Corporation, 1997, 5.2.1).

The USCG required that the production of ALMIS include flexibility and expandability as a mainstay. Designing the system in this fashion allows for updated and new hardware/software packages and a software development plan (SDP; OAO Corporation, 1997, 5.4.7.3). By developing the SDP in accordance with *Software Development and Documentation* (MIL-STD-498; DoD, 1994), the USCG is able to deploy a flexible and expandable database system to all of its air stations (OAO Corporation, 1997, 5.4.7.3).

As with any planning operation, a certain number of assumptions must be made in order to achieve a relative success for any objective. The USCG identified the following assumptions when creating ALMIS. The first assumption addressed the need for a contingency plan at the AR&SC as well as the USCG air stations in order to avoid/mitigate any major system degradation. Second, by creating an integrated system (ALMIS), the USCG would decrease the burden, as well as clerical errors, on the user by eliminating the input of redundant information. The third assumption was that all air stations would provide adequate training materials for all users and managers. The last major assumption addressed the proper documentation to facilitate maintenance of ALMIS after installation (OAO Corporation, 1997, 5.1.4). As the USCG identified objectives, flexibility, and assumptions, it was collectively more able to provide a narrower focus for the construction, development, and execution of the ALMIS program. These three areas of interest apply directly to the user interface and the USCG's ability to implement and maintain this database for years to come.

E. ALMIS: OPERATIONAL SCENARIOS AND IMPACTS

ALMIS supports all facets of USCG aviation logistics and operations. Managers can not only request ad hoc reports but also benefit from the multiple day-to-day operations performed by ALMIS. Analysis provided by ALMIS functions includes air station performance assessment reports, aircraft availability, aircraft/personnel transfer and receipt, flight data documentation, flight itineraries, flight crew assignments, and mission results. In addition, maintenance managers have the ability to request monthly operating reports (MORPTs) and view cannibalization rates and man-hours per flight hour for all major aircraft systems. Air stations utilize ALMIS to document the following daily tasks:

- scheduled and unscheduled maintenance actions;
- configuration management actions;
- aircraft enrollment activities;
- high-time component tracking;
- tracking maintenance activities;
- producing maintenance procedure cards;
- reliability, maintainability, and availability management;
- quality assurance management;
- time compliance technical orders;
- inventory management;
- parts issue;
- repairable parts management;
- aviation inventory management;
- stock-level adjustments; and
- parts shipping management. (OAO Corporation, 1997, 6)

Operationally, the use of ALMIS provides significant impacts to the organization's ability to view, manage, assess, and modify maintenance programs. Ridding the unit of redundant and sometimes flawed inputs will increase work efficiency as well as provide managers with accurate and easily assessed data. According to OAO Corporation (1997), "Local and enterprise-wide trend analysis of inventory levels, unscheduled maintenance and funds expenditure will provide managers the ability to better predict aircraft availability, and ultimately, lead to greater levels of mission support" (5.4.7.3). This system allows the USCG the ability to accurately manage, schedule, and execute a maintenance plan that will better address the need for oversight and fiscal responsibility.

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IV. CONCLUSION

The Army is in a precarious position when it comes to validating the requirement for an FVL aircraft. When considering the austere fiscal environment of the U.S. government, attaining approval and funding for a new acquisition category 1D (ACAT 1D) program will require significant substantiation. PEO Aviation is funding various research projects in hopes of supporting an FVL decision. Additionally, we acknowledge that numerous research approaches are available to help determine aircraft age. Our approach aimed at defining the true cost behaviors of the current Apache and Blackhawk aircraft. Our intent was to precisely identify the cost burden associated with individual aircraft, thus allowing the Army to see beyond its current process of simply funding aircraft sustainment on the aggregate. In short, our research hypothesis was to determine if individual airframe cost over time can determine age.

Based upon our research methodology, we believe that the Army currently lacks the ability to define with sufficient specificity the cost associated with any individual Apache or Blackhawk aircraft. Furthermore, the Army can identify individual aircraft cost behaviors, but doing so will more than likely require significant dedicated man power and time. The Army will need to alter its current system of funding aircraft operations and sustainment on the aggregate or large unit level and shift its enterprise tracking system to have the ability to monitor individual aircraft. Our conclusion is supported by aspects of the current Army maintenance system that include, but are not limited to, inconsistent data, a lack of detailed maintenance procedure information, and insufficient enterprise information tracking systems. We highlight the aforementioned aspects in following paragraphs but define the situation in the following analogy.

A. RESEARCH FINDINGS ANALOGY

Assume that the current fleet of Blackhawk aircraft is instead a service fleet of trucks utilized by a large, intrastate shipping company. The company's fleet of 300-plus vehicles (i.e., Blackhawks) is over 30 years in age. The company knows that the trucks break quite often and that repairs are sometimes expensive. However, the company does not track how often any of the individual vehicles break down or the repair cost associated with the failures—it just budgets for annual maintenance estimates for the entire fleet. Every year, it substantiates the next year's budget by taking the previous year's budget and adding a little more on top for inflation. So, even though the trucks keep breaking, the company simply pays for the repair and looks ahead, regardless of how many times any individual truck has issues.

All that the company cares about is keeping the fleet running in order to make deliveries and meet its corporate mission. The company could not tell exactly what the historical maintenance cost of any specific truck that is in its fleet. It never once thinks about whether keeping an old truck around is more expensive than buying a new one because it lacks the information tracking systems, and culture, to do so. Because the company cannot identify individual truck costs, it will never know whether 10% of its fleet is absorbing 90% of the annual maintenance budget. Based upon our research approach, what this fictitious truck company is doing is exactly what Army Aviation is doing with the current fleet of Apache and Blackhawk aircraft.

B. INCONSISTENT DATA

PEO Aviation provided us with the records of 30 random Apaches and 30 random Blackhawks. The only records available to us date back to when the respective aircraft were converted/upgraded from their original configuration to the current configuration (i.e., from when an Apache was upgraded from an “A” model to a “D” model). This means that the Army did not retain any aircraft maintenance information prior to that upgrade, which could potentially mean that up to 15 years of aircraft maintenance data are unavailable.

This is the first hindrance in determining the cost behavior of the aircraft because the documentation on the first half of an aircraft’s life no longer exists. Furthermore, the only detailed maintenance information on file spans an average of five to seven years per airframe. We lacked detailed information from that point back to when the aircraft was upgraded. The lack of historical maintenance data virtually eliminates the Army’s ability to define the precise cradle-to-present cost of any individual aircraft in the fleet. Table 3 displays the data provided for one aircraft. Notice how the data begin, following the conversion in 2002. Table 4 shows detailed maintenance data for the same airframe beginning in 2005.

Table 3. Scheduled Maintenance for Aircraft 105276
(Apache, n.d.)

AH64D	04/23/2003	1	SOF MSG. AH-64-03-04 INITIAL AND RECURRING INSP OF T/R BLADES ENTRY ENTERED ON 2408-13-1 AT 1940.9ACFT HRS (JC3023)	FT. HOOD TX. 76544	21ST CAV BDE/ DYNCORP
AH64D	04/15/2003	1	ACE/CPCE PERFORMED AT 1941 ACFT HRS. BY TEAM MEM- BER TT AMCOM PROJECT OLR KILLEEN TX. WAYNE A. DORRIS. (WD0176)	FORT HOOD TX. 76543	DYNCORP PROJECT OLR
AH64D	03/21/2003	1	AIRCRAFT TRANSFERED FROM BOEING MESA TO 21ST CAV BDE ON 21 MAR 03 @ 1933.3 ACFT HRS. (FB1420)	FORT HOOD TX. 76544	21ST CAV BDE/ DYNCORP
AH64D	03/05/2003	1	AH-64-03-ASAM-03 COMPLIED WITH ON 02 MAR 2003 (FB1420)	FT. HOOD,TX	DYNOCORP
AH64D	02/25/2003	1	AH-64-03-03 INSP OF AH-64D CYCLIC STICKS (JS3660)	MESA, AZ 85215	BOEING CO.
AH64D	02/25/2003	2	AH-64-03-ASAM-04 INSP OF WING MOUNTING NUTS/BOLTS C/W. HARDWARE REPLACEMENT REQUIRED NLT 1 FEB 06 (JS3660)	MESA, AZ 85215	BOEING CO.
AH64D	02/25/2003	3	AH-64-03-ASAM-05 INSP OF PYLON ATTACHMENT BOLTS (JS3660)	MESA, AZ 85215	BOEING CO.
AH64D	02/05/2003	1	LATE ENTRY-ACFT REST. TO HELLFIRE MISSILE OPERATION I/A/W AH-64--02-02 (CE9334)	FT BRAGG NC	1/229TH AVN REGT
AH64D	12/09/2002	1	AH-64-03-ASAM-02 COMPLIED WITH ON 09 DEC 2002 (FB1420)	FT. HOOD, TX	DYNCORP
AH64D	11/29/2002	1	SOF AH-64-03-01 COMPLIED WITH ON 27 NOV 2002 (FB1420)	FT HOOD, TX.	DYNCORP
AH64D	11/22/2002	1	AH-64-03-ASAM-01 COMPLIED WITH ON 20 NOV 2002 (FB1420)	FT. HOOD, TX	DYNCORP
AH64D	11/05/2002	1	THIS AIRCRAFT ORIGINALLY MANUFACTURED AS AH-64A, PV585, S/N 88-00255. REMANUFACTURED AS AH-64D, PVD276, S/N 0105276 MANUFACTURER: THE BOEING COMPANY UNDER CONTRACT: DAAH23-00-C-0001 ALL APPLICABLE SOF'S, TO INCLUDE ASAM'S, COMPLIED WITH AS OF DD250 DATE:16JAN03 HRS AT REMAN:1909.1 TOTAL HRS:1918.2 (HH9999)	MESA,AZ	THE BOEING COMPANY
AH64D	11/05/2002	2	ALL PHASE 1 THROUGH 4 REQUIREMENTS WERE COMPLETED DURING REMANUFACTURE TO AH64D. NEXT PHASE DUE IS #1 AT 2159.1 ACFT HRS. (HH9999)	MESA,AZ	THE BOEING COMPANY
AH64D	11/05/2002	3	TM1-1520-238, P/N 7-311112017-(#) SEVERANCE LOT NUMBERS AND INSTALLATION DATES: (5)OAC97B005-134 DATE:31OCT02 (7)ETI92D004-047 (9)MSV96G001-003 22OCT02 (11)MSV96F001-002 (33)UDC002C001-002 01OCT02 (35)(2EA)OAC96C007-030 (47,49)ETI94C001-007 (51)(3EA)OAC99H003-029 (HH9999)	MESA,AZ	THE BOEING COMPANY
AH64D	11/05/2002	4	TM1-1520-238, P/N 7-311112017-(#) SEVERANCE LOT NUMBERS AND INSTALLATION DATES: FWD FIRE BOTTLE S/N 041006-6556 #1,2:ESD93D008-002; #3:ESD9C008-001 25SEP02 AFT FIRE BOTTLE S/N 14310A1 #1,2,3:ESD93C008-001 (HH9999)	MESA,AZ	THE BOEING COMPANY
AH64D	02/15/2002	1	SOF AH-64-03-02 COPLIED WITH ON 11 FEB 2002. (FB1420)	FT HOOD, TX	DYNCORP

Table 4. Unscheduled Maintenance for Aircraft 105276
(Apache, n.d.)

08/08/2006	A	02	ACFT RESTRICTED TO BE OPERATED I/A/W THE LIMITATIONS AND RESTRICTIONS PRESCRIBED BY THE ENCLOSED AWRS:2003D-A24 REV1 14 NOV 03 (AMATS),2004D-A16 17 MAY 04 (ALQ-144C),2004D-A24 10 JUN 04 (COMBAT MANEUVERING FLIGHT),2004D-A39 REV1 15 DEC 05 (STROBES),2004D-A51 REV1 04 AUG 05 (IZLID),2005D-A13 REV1 28 JUL 05 (MTF CALCULATOR),2005D-A26 29 JUL 05 (VMEPS),2005D-A39 19 SEPT 05 (CEP),2005D-A44 REV1 18 NOV 05 (EDM),2006D-A19 17 APR 06 (MPSU) (DD9002)	+	Yes
08/08/2006	A	02	AIRCRAFT RESTRICTED TO BE OPERATED I/A/W THE LIMITATIONS AND RESTRICTIONS ENCLOSED IN THE INTERIM STATEMENT OF AIRWORTHINESS QUALIFICATION, DATED 17 MAY 1999 INCLUDING REVISIONS # 1 THROUGH 13 (DD9002)	+	Yes
08/08/2006	A	00	PLTS LONG RVDT WIRE HARNESS NOT INSTALLED IN CLAMP TIED HARNESS WITH STRING TO BE CLAMPED AS SOON AS FWD FUEL CELL RMVD (DD9002)	/	Yes
12/27/2005	A	02	ALQ-144 NOT INSTALLED ACFT REST FROM HOSTILE ENVIRONMENT (SL5082)	+	Yes
03/17/2005	E	19A	VCR WILL NOT RECORD SECURE COMMUNICATION DUE TO -9 LOT # CIU INSTALLED (MH9429)	/	Yes

As seen in the preceding figures, with this particular aircraft, there are three years of missing unscheduled maintenance data when compared to the beginning of the scheduled maintenance data. Scheduled maintenance data starts in 2002 while unscheduled maintenance data starts in 2005—giving us a three-year gap in the data. This example is representative of the entire sample of 30 Apache logbooks we received. Some aircraft have larger gaps in data. Overall, it is difficult to ascertain the overall cost of maintaining/operating an aircraft if the historical records no longer exist or are missing critical data. For instance, our research team spent in excess of 40 man-hours attempting to determine the cost associated with just one aircraft when using the data provided.

C. LACK OF DETAILED MAINTENANCE PROCEDURE DATA

When conducting detailed analysis on the information that was provided, we quickly determined that there were many gaps and inconsistencies in the logbook entries. The largest issue was the lack of details on what corrective maintenance action the maintainer conducted to repair each fault. The repair action is critical to determining the entire cost of a maintenance action. Was the part replaced? Did the repair inspection find no faults? Such questions cannot be determined due to the lack of accurate historical data in the maintenance logs.

Due to the lack of corrective action information, we were forced to assume that most actions required a complete part replacement. Although we only looked, in detail, at Apache and Blackhawk data, we assume that this issue could be indicative of the entire Army Aviation fleet. Table 5 is an example of how the lack of repair action information can mislead the cost associated with a maintenance action.

Table 5. Example Entry for Aircraft 105276
(Apache, n.d.)

02/20/2007	A	05	CRACK FOUND ON #3 MAIN ROTOR BLADE. CRACK LOCATED 2 INCHES LEFT OF TIP CAP.	X	Yes

The entry identifies the crack in the main rotor blade, but the lack of repair action information could result in gross miscalculation of the repair cost. For instance, was the blade completely replaced or were the unit’s internal shop assets able to repair the blade through other measures? This could be interpreted as a $300,000 replacement or a simple one-man-hour quick fix.

D. INSUFFICIENT ENTERPRISE MAINTENANCE INFORMATION TRACKING SYSTEMS

Army Aviation does an exceptional job at providing soldiers in the fight with fantastic maintenance tracking and documentation systems. Tactical units can track daily maintenance actions in real time, which is a cornerstone to the success of Army Aviation in combat during the Global War on Terror. Soldiers in the fight have mastered the ability to quickly detect faults and repair them. Unfortunately, the information in the systems being used by soldiers (i.e., ULLS-A) is nebulous and subject to unit norms. Simply put, different units accomplish and enter maintenance activities differently, thus causing gross inconsistencies within the fleet.

Soldiers are laser-focused on completing maintenance tasks and will do so much more quickly than estimated by man-hour allocation charts; yet, they will enter varying completion times for the same task. Furthermore, corrective action information is not tied with actual parts usages and the cost associated thereof. Inaccurate man-hour and parts allocation tracking is a catalyst for the lack of detailed, all-encompassing maintenance data needed to determine the cost behaviors of aircraft. Our research required the utilization of numerous information systems to try and coagulate the total flight-hour cost associated with one aircraft.

We did gain exposure to the USCG's ALMIS system, which possesses much of the functionality required for a successful aviation enterprise tracking system. The ALMIS system provides robust data but lacks an enterprise way of incorporating parts costs to specific aircraft. Individual aircraft parts usage is tracked by a separate system but not integrated with the ALMIS system. ALMIS is well suited as an enterprise tracking system that, we believe, is on the cusp of being able to identify exact aircraft costing behaviors over time. ALMIS's tie-in with USCG automated maintenance systems makes it a very reliable resource to determine maintenance trends over time for specific aircraft.

E. CLOSING

We were unable to provide an answer to our research hypothesis, but we did objectively identify a key issue that will possibly hinder Army Aviation's efforts to pursue an FVL program. Our research identified the notion that the Army cannot determine the cost associated with any individual aircraft and whether that aircraft is costing more to maintain over time. Because the current Army data cannot reveal that critical information, it is nearly impossible to determine the point in time when a new aircraft should be pursued. With that said, our findings are relegated to the information provided by the Army's leading source and subject-matter experts: PEO Aviation. If detailed individual aircraft costing data become available, then this research should be updated in hopes of answering our original thesis.

F. RECOMMENDATIONS

Based on our conclusions, we recommend that the Army adopt an enterprise system that allows it to better track the costs of maintenance at the individual aircraft level. The USCG has developed ALMIS, which the Army can use as a template, but there are certain capabilities that we think are key to being able to meet the objective laid out in this project. The capabilities that we see as key to success, in addition to the ones already provided by existing software, are to easily trace faults to corrective actions, accurately track man-hours for corrective actions, and tie the supply system to particular aircraft to better track costs.

One of the major challenges that we had during our research was being able to take a fault that was identified in the records we were provided and trace that fault to the corrective action that was completed to fix the fault. As discussed previously, any number of different corrective actions can be taken to fix a cracked rotor blade write-up, to include no action at all. With the current system and the data that we were able to retrieve, there was no way of correlating each individual fault with the maintenance action used to correct that fault. Without this information, there is no way of determining how much was spent to fix the faulty item(s). This lack of information can amount to difference of tens of thousands of dollars in cost estimation differences for individual faults, and without this information, there is no way to determine how much we are spending on an aircraft.

The next key capability is that the system needs to be able to accurately track the man-hours spent on corrective actions. The problem with this information is that it is subjective and easily skewed by inaccurate entries because the maintainer will be required to enter the number of hours spent on each action. The USCG system successfully uses this indicator in tracking the number of man-hours spent on aircraft maintenance and is able to show trends in man-hours over time with this data.

The final—and, in our opinion, the most important—key to accurately tracking maintenance costs on individual aircraft is to be able to tie the supply system to the maintenance tracking system so that the Army can easily determine what parts were used in the repair of an aircraft. Based on the data that we collected, the most important determinant in costs was the parts used for the maintenance actions. We believe that an enterprise solution is necessary to successfully tie these two very different tracking systems together. There are many other benefits to this type of system that should also be considered, but they are not as directly relevant to our MBA project.

While we understand that there are high costs associated with such a vastly different system like the one we are recommending, we think that the benefits of such a system greatly outweigh those costs. The Army is in a period of drawdown and will start having to fight for dollars again. An enterprise system that helps show actual costs and trends of programs is one that helps the Army to support its request to purchase future combat systems.

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