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ANALYSIS AND FORECASTING OF AIR FORCE OPERATING AND

SUPPORT COST FOR ROTARY AIRCRAFT

THESIS

Matthew E. Laubacher, First Lieutenant, USAF

AFIT/GCA/ENV/04M-05

DEPARTMENT OF THE AIR FORCE
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AFIT/GCA/ENV/04M-05

ANALYSIS AND FORECASTING OF AIR FORCE OPERATING AND SUPPORT COST FOR ROTARY AIRCRAFT

THESIS

Presented to the Faculty

Department of Systems Engineering and Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Cost Analysis

Matthew E. Laubacher, AAS, BBA

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March 2004

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AFIT/GCA/ENV/04M-05

ANALYSIS AND FORECASTING OF AIR FORCE OPERATING AND SUPPORT COST FOR ROTARY AIRCRAFT

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AFIT/GCA/ENV/04M-05

Abstract

This research explores forecasting techniques to estimate the Cost per Flying Hour for Air Force Helicopters. Specifically, this research evaluates three separate forecasting techniques to predict the CPFH for better estimating and budgeting by the USAF. It starts by empirically analyzing the Operating and Support cost by CAIG categories for each helicopter. For forecasting purposes the actual CPFH figures were compiled from FY96 to FY03 for a total of eight MAJCOMs flying the MH-53J/M, the HH-60G, or the UH-1N helicopters. The research explores the use of a 3-year moving average, the single exponential smoothing method, and the Holt's linear method. These forecasting techniques were used to forecast for FY02 in evaluating the best methodology to forecast the CPFH for FY04. By comparing both the budgeted and forecasted figures for FY00 to FY02 to the actual CPFH figures in the same years, the forecasting methods were able to more accurately predict the actual CPFH for all of the MAJCOMs that achieved a budget variance of less than 20 percent. It was discovered that the Holt's linear method was the best forecasting method for 75 percent of the time series analyzed since they contained positive trends. Finally, these techniques were employed to provide the best possible forecast of the CPFH for FY04.

Acknowledgements

I would like to thank Maj Michael Greiner, my thesis advisor, for all the direction, guidance, and time that he gave during this research. His experience in the thesis process was an invaluable asset that diffused several potential stressful situations. I would also like to thank my committee members, Lt Col Marvin Arostegui, and Ms Krystyna Kolesar. They both have given generously of their time, and their insight and guidance has also helped shape the direction and content of this research.

I would also like to thank my thesis team members, Capt Christopher Wilkes and Lt Clay Hawkins, for making this team situation not only work, but making it excel. I am also grateful to the many professionals who have given their assistance to include Capt Christopher Purvis, Ms. Annette Beard, Mr. Dave Flamand, Mr. Ray Scheuring, Mr. Thom Brown, Mr. Ron Vorhis, Dr. Freda Stroher, and Ms. Donna Ericson.

I thank God, the Air Force, and my family for giving me the opportunity to be an AFIT student. I especially thank my wife for her patience, understanding, and for providing an environment that has allowed me to achieve academic success.

Matthew E. Laubacher

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ANALYSIS AND FORECASTING OF AIR FORCE OPERATING AND SUPPORT COST FOR ROTARY AIRCRAFT

I. Introduction

Background

The cost of operations and support (O&S) activities has become increasingly important in recent years due to shrinking budgets, aging aircraft, and the cost of maintaining newer, more technologically advanced weapon systems. O&S costs include "All personnel, equipment, supplies, software, services, including contract support, associated with operating, modifying, maintaining, supplying, training, and supporting a defense acquisition program in the DoD inventory" (1:49). O&S costs are one of the four main cost categories that constitute the life cycle cost of a weapon system. The other three cost categories are Research and Development (R&D), Investment, and Disposal. O&S costs constitute the majority of the total life cycle cost for aircraft, see Figure 1 below.

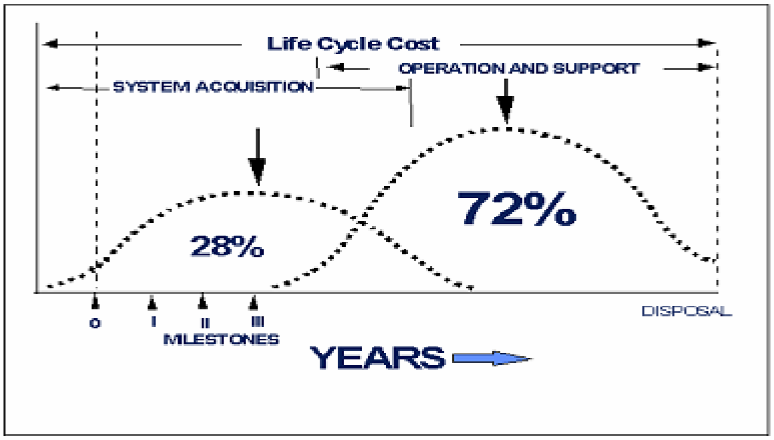

Figure 1. Nominal Cost Distribution

Controlling life cycle costs for weapon systems is a major issue for the Department of Defense (DoD). The military must do more with less. O&S costs are rising and have become a very large portion of the Air Force's budget. Increases to O&S costs limit budget requests for new weapons systems development, modernization, and infrastructure. O&S costs consist primarily of operations and maintenance (O&M) and military personnel (MILPERS) appropriations. In an August 2001 report, the Congressional Budget Office (CBO) reported that approximately 37 percent of the DoD's budget goes to support the O&M costs for military weapon systems (2:1). The costs will continue to rise as weapon systems become older and more antiquated.

Managers and cost analysts must pay increased attention to the trends in cost management. A view involving the total life-cycle cost must be adopted; an incomplete perspective that only includes the costs of development and production is no longer acceptable. More accurate estimating will lead to better budgeting, reduction in total ownership costs, and improved fiscal responsibility. As today's aircraft age the cost of maintaining the equipment will increase to unprecedented levels. This research will examine O&S costs for Air Force rotary aircraft in an effort to develop forecasts for future cost per flying hour (CPFH). The research conducted and model developed will prove valuable in the overall aim to reduce the Air Force's total ownership costs of current and future rotary aircraft weapon systems.

Problem

A discrepancy has arisen in the past several years between submissions the services have provided in the Program Objective Memorandum (POM) during the out-years and the actual expenditures reported for CPFH programs. The Office of the Secretary of Defense/Cost Analysis Improvement Group (OSD/CAIG) requests the development of a measurement tool to analyze the validity of the services' submissions effectively. Forecasting models for CPFH are necessary for all aircraft within each service. The aim of this research will be to develop a model that accurately forecasts future CPFH for Air Force rotary aircraft. The ultimate goal will be to give the OSD/CAIG a useful tool with which to compare the services projections against independent analyses in expectations of forecasting and possibly controlling future O&S costs.

Research Questions/Objectives

The following research questions and objectives are addressed in the body of the thesis:

1. Primary:
    - To provide OSD/CAIG with a useful tool to forecast CPFH for Air Force rotary aircraft.
2. Secondary:
    - For the weapons systems being studied, what are the forecasted CPFH for fiscal year 2004?
    - How do the forecasted figures of FY00-FY02 compare to the POM submissions in the same years?
    - To what extent did the POM submissions deviate from actual CPFH figures in FY00-FY02?

- What are the major O&S cost drivers, by MAJCOM, for each weapons system?

Summary of Current Knowledge

The services believe that the increase in total O&M costs is mainly attributable to the escalating costs for aging equipment (2:1). O&S costs consist of O&M plus the cost of military personnel. Therefore, escalating O&M costs would directly increase O&S funding levels. The aforementioned study conducted by the Congressional Budget Office indicates that increased O&M spending is not a direct result of aging equipment. O&M spending includes diverse cost categories such as costs for health care, environmental programs, real property maintenance, and base operating support. Although the report does not support the contention that the increase in O&M costs is due to aging equipment, evidence exists that aircraft become more costly to maintain as the aircraft age. For example, Navy aircraft spending could escalate by $40 million to $130 million per year in a yearly O&M budget of $23 billion (2:2). Because O&M costs constitute a large portion of O&S costs, O&S CPFH will more than likely accelerate in the future.

The CBO study suggests average aircraft age has increased slightly over the past two decades. Cumulative O&M spending per hour has increased but not significantly so. The study differs from the services' perspective in that the services suggest that O&M costs for aging equipment are spiraling out of control. According to the CBO, only 20 percent of O&M spending is directly dependent on equipment. The report states, "CBO's findings are in conflict with the services' statements that spending on O&M for equipment is growing rapidly. Those statements are sometimes based on selective data"

(2:9). The study indicates that aircraft, including rotary, are the only weapon systems that have increased in average age; however, none of the weapon systems have experienced notable O&M cost growth over the past couple of decades (2:8).

The CBO report surmises that costs for operating equipment may indeed increase as the weapon systems age but that cost may be paid for with other appropriations not including O&M funding. The sources that fund O&S costs include the following: operation and maintenance, military personnel, procurement, military construction, stock funds, and other appropriations (1:49). The rising costs could be attributed to higher personnel costs due to increased maintenance for modifications to equipment paid for with procurement funds (2:20). Thus, even though the CBO does not agree that weapon systems O&M costs are rising mainly due to aging equipment, the services' contention that O&S costs are rapidly increasing for aging equipment remains valid because O&S costs are funded by other appropriations besides O&M money.

More research needs to be conducted for cross-service studies to address cost growth and the relationship between cost growth and age. This thesis will address the O&S CPFH for rotary aircraft within the Air Force. Trends over time will provide answers to whether or not CPFH has increased substantially by aircraft type and as a whole. Trends will be forecasted to provide the OSD/CAIG with a yardstick to measure against Air Force rotary aircraft CPFH budget submissions for the POM out-years.

Scope and Limitations

This research will develop a forecasting model useful in predicting trends in CPFH for AF rotary aircraft. At the same time this research is being conducted similar research efforts will be conducted for the Army and Navy. Hawkins examines the O&S CPFH for Army rotary aircraft. Wilkes investigates O&S CPFH for Navy rotary aircraft. The results from all three theses will provide the OSD/CAIG with an effective tool to measure against the services' POM submissions and the results will give the CAIG a better understanding of the services' rotary aircraft CPFH.

Standards

In developing an accurate projection of future events, models must be constructed that utilize certain relationships inherent within a system. In the case of forecasting, historical data can be analyzed and relationships between time series data can be used to develop models that suggest increasing or decreasing trends. Certain standards will be utilized to obtain the best forecasting or predictive model. Chapter three will address these standards such as mean error, variances, and other useful statistical performance measures.

Approach/Methodology

Each service tracks O&S costs for rotary aircraft. The Navy was the first service to implement a database responsible for presenting all O&S cost information for weapon systems. The Navy database is called the Visibility and Management of Operating and Support Costs (VAMOSC). The Army and Air Force created similar systems of their own for reporting O&S cost information. The Army's version of the VAMOSC is the Operating and Support Management Information System (OSMIS). The Air Force named their system the Air Force Total Ownership Costs (AFTOC) database. The

AFTOC system will be used extensively to extract O&S cost information for Air Force rotary aircraft.

The AFTOC database will be used to sort O&S cost information by rotary aircraft model and MAJCOM for each year. The first step is to analyze the data to determine how the costs are broken out according to the cost element structure (CES) of O&S costs described in the O&S Cost Estimating Guide. The results will indicate any trends in recent years. Additionally, the data will identify any components that may significantly increase as a percentage of the overall cost. Any change in the CES cost composition will be addressed to decide if the change is model specific or if the trend subsists in all models of rotary aircraft.

The next step involves collecting the cost per flying hour (CPFH) for each of the rotary aircraft types for each year. The Government Accounting and Finance System (GFAS) contains all rotary aircraft information during the years 1996-2002. This data will then be compared to the POM submissions in the same year to show any variances that exists between the actual CPFH and the budgeted CPFH.

Next the actual CPFH data from the previous step will be employed in developing a predictive model for forecasting CPFH for rotary aircraft. The model will capture any trends within the cost data. The model will help defend the CAIG's position if a future disconnect arises between the services' submissions and OSD/CAIG's in-house estimates.

After developing a robust model useful for providing future CPFH forecasts, the forecasted CPFH will be compared to the actual CPFH to show any variances present. These variances will be compared to the budget variances. The CAIG can compare its estimates to the model to decide if any revisions are needed in the current CAIG forecasting process. The final step of the research will be using the model developed for each MAJCOM to forecast the CPFH for FY04.

Organization

This thesis is divided into five chapters. Chapter one provides background information on the importance of accurate O&S cost estimation. A brief description of the problem and research questions/objectives is given. Then the scope, limitations, and methodology portions are introduced. Chapter two presents more detailed background information on O&S costs and CPFH. Past research is analyzed to provide the reader with a historic look at the research that has been previously completed. Chapter three describes the methods used to answer the research questions presented. The findings and results of this research are given in chapter four. Chapter five provides a summary and conclusion based upon the analyses performed; and finally, recommendations for future research are offered.

II. Literature Review

Chapter Overview

This literature review provides a background into estimating Operating and Support (O&S) costs and the Cost Per Flying Hour (CPFH) program. It explains the regulations that dictate O&S costs estimating, describes the CPFH program, describes the mission and current Air Force inventory of the helicopters being studied for this research, and finally, covers past research in this area. This literature review explains what is required by law and by the regulations governing O&S costs and the CPFH program, and also explains the origin and requirements of the Visibility and Management of Operating and Support Costs (VAMOSC) database used in this research to forecast future years CPFH for the specific weapons systems being studied.

Introduction

The life-cycle cost for a Major Defense Acquisition Program (MDAP) encompasses the combined costs for a weapon system from the Mission Need Statement (MNS) through disposal and deactivation. In recent years, decision makers within DoD in recent years have increasingly emphasized projecting realistic O&S costs. This initiative to estimate costs realistically results from escalating outflows for aging systems and the need for newer, more technologically sound weapons in an unprecedented era of rapid deployment and global terrorism. The ability to plan for precise life-cycle costs has become more crucial because of increased scrutiny involving oversight of funds and competition for scarce resources. O&S costs represent the largest portion of the total life-cycle cost. Figure 2 illustrates a typical breakout of the life-cycle costs for a typical weapon system.

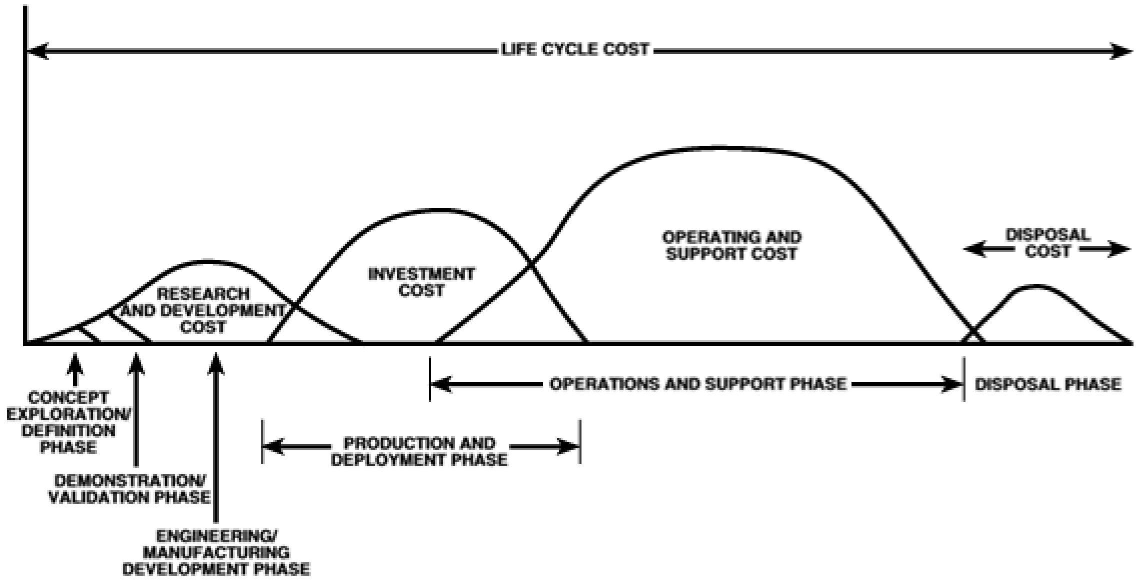

Figure 2. Program Life Cycle (Illustrative)[1]

The Department of Defense (DoD) will spend billions of dollars on force modernization in the post September 11 timeframe. Although the Bush administration has increased the defense budget, the military still faces an uphill battle to produce cutting edge technology. Military men and women must remain vigilant in all areas of defense budgeting. The cost analyst can make significant contributions by accurately forecasting O&S costs. The overall defense budget has shrunk since the Cold War and consequently, the military must do more with less. Table 1 shows the DoD Budget Authority by Appropriation figures for the total budget and the O&M portion of the budget.

[1] Figure 2-1 is taken from the OSD CAIG *Operating And Support Cost-Estimating Guide* (Ref 6). The figure is used for illustrative purposes only. Actual program results may vary.

Table 1. Department of Defense- Budget Authority by Appropriation Table[2]

Fiscal Year	Current $ (Billions)	Constant FY03 $ (Billions)	O&M Current $ (Billions)	O&M Constant $ (Billions)	% of O&M Growth (FY03 Constant $)	O&M % of DoD Budget
1985	286.802	461.666	77.803	126.827	-	27.47%
1990	292.999	405.421	88.309	123.188	-	30.39%
1998	258.583	294.567	97.215	110.484	2.5	37.51%
1999	278.595	309.988	104.992	116.663	5.6	37.63%
2000	290.534	315.183	108.776	118.479	1.6	37.59%
2001	309.948	326.385	115.758	121.259	2.3	37.15%
2002	329.878	337.195	127.668	130.241	7.4	38.62%
2003	378.624	378.624	150.444	150.444	15.5	39.73%

In 1985, the DoD budget totaled approximately $462 billion (FY03 constant dollars). The 1985 total exceeds FY03 by almost $84 billion. The overall budget has decreased in terms of FY03 constant dollars from 1985 to 2003, but the amount of O&M funding has increased during this period. O&S costs consist mainly of O&M and military personnel (MILPERS) appropriations. The percentage of O&M funding out of the total budget increased from 27.5% in 1985 to nearly 40% in 2003. The percent of real cost growth in O&M funding increased 15.5% from 2002 to 2003. Thus, O&M has become a substantial part of the defense budget. Therefore, accurate predictions for O&M cost estimates, including O&M estimates for Cost Per Flying Hour (CPFH) is imperative. Figure 3 depicts the budget trends graphically. The DoD total budget exhibits an upward trend but increases at a slower pace during the 1980s. O&M costs show a steady increase in the overall trend.

[2]Actual results taken from the Appendix A budget tables from Donald H. Rumsfeld's Annual Report to the President and the Congress (Ref 11).

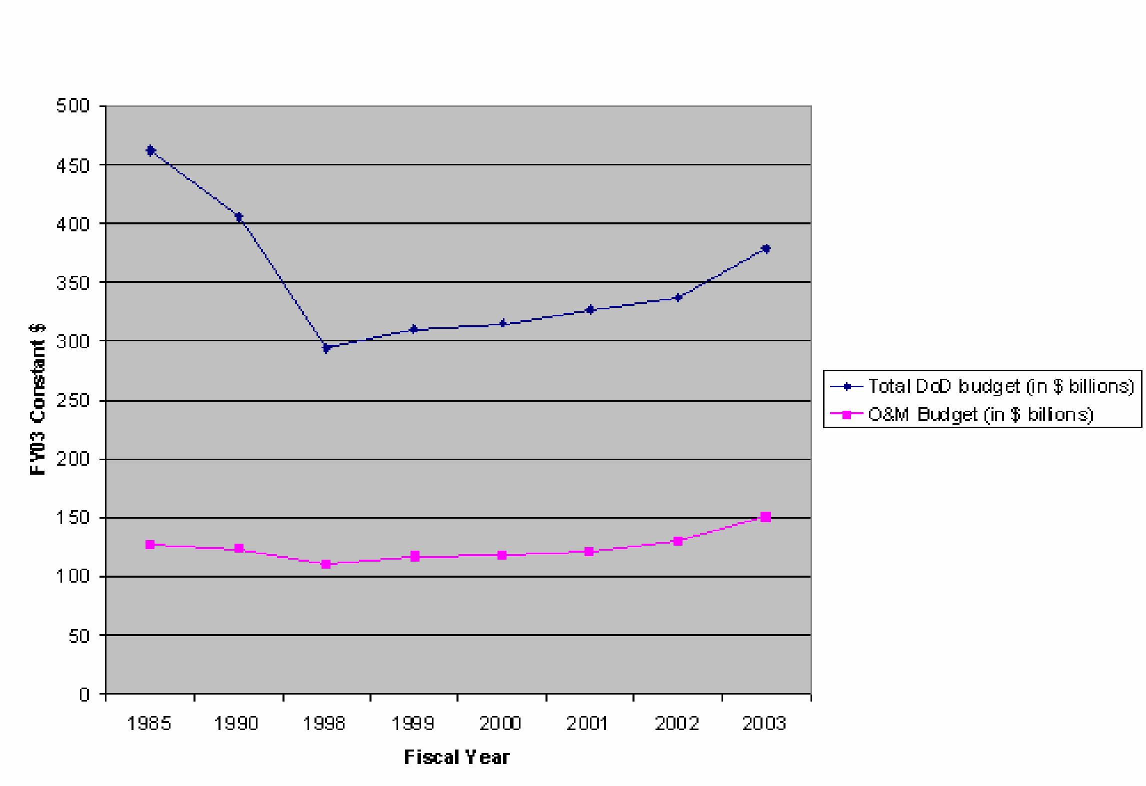

Figure 3. DoD Annual Budget and O&M Funding

When looking at the initial cost of procuring a weapon system, the acquisition professional must not focus solely on the cost to produce the weapon system, but instead must look at the entire spectrum of costs. The sustainment portion of the life-cycle cost constitutes the major apportionment of funding. This thesis concentrates specifically on examining the CPFH distribution of O&S costs for Air Force rotary aircraft. The rotary wing aircraft within the Air Force arsenal are:

- HH-60G Pave Hawk
- MH-53J/M Pave Low III/IV
- UH-1N Helicopter

Forecasting tools will be applied to predict O&S CPFH for Air Force rotary wing aircraft. The projections will serve the cost estimating community at the OSD/CAIG level with more defined CPFH data. The OSD/CAIG analysts will then possess the tools to identify any discrepancies with future estimates provided in the program objective memorandum (POM) estimates submitted by the services.

History of O&S Initiative

The DoD realizes the significant impact of O&S costs on its budget. The first efforts to track and control these costs began with the Visibility and Management of Operating and Support Costs (VAMOSC II) project in 1975 (3:1). This initiative was prompted by the Management By Objective (MBO) 9, with the stated goal of reducing operating and support (O&S) costs within the DoD (3:1). MBO 9-2, a subset of MBO 9, pointed out that historically, DoD components did not include O&S costs as a major factor in the acquisition of a new weapon system (3:1). The costs of maintaining current weapon systems should be identified and analyzed in order to estimate costs of new systems under consideration. The purpose of MBO 9-2 was to define the total costs associated with the acquisition and fielding of a weapon system within the different branches of the armed services (3:1). The objective divided the total Life Cycle Cost (LCC) of a system into two main categories: acquisition costs and ownership costs (3:2). The ownership costs, known collectively as O&S costs, were the area for concern and what most interested the DoD. Figure 4 shows the total ownership cost composition for aircraft.

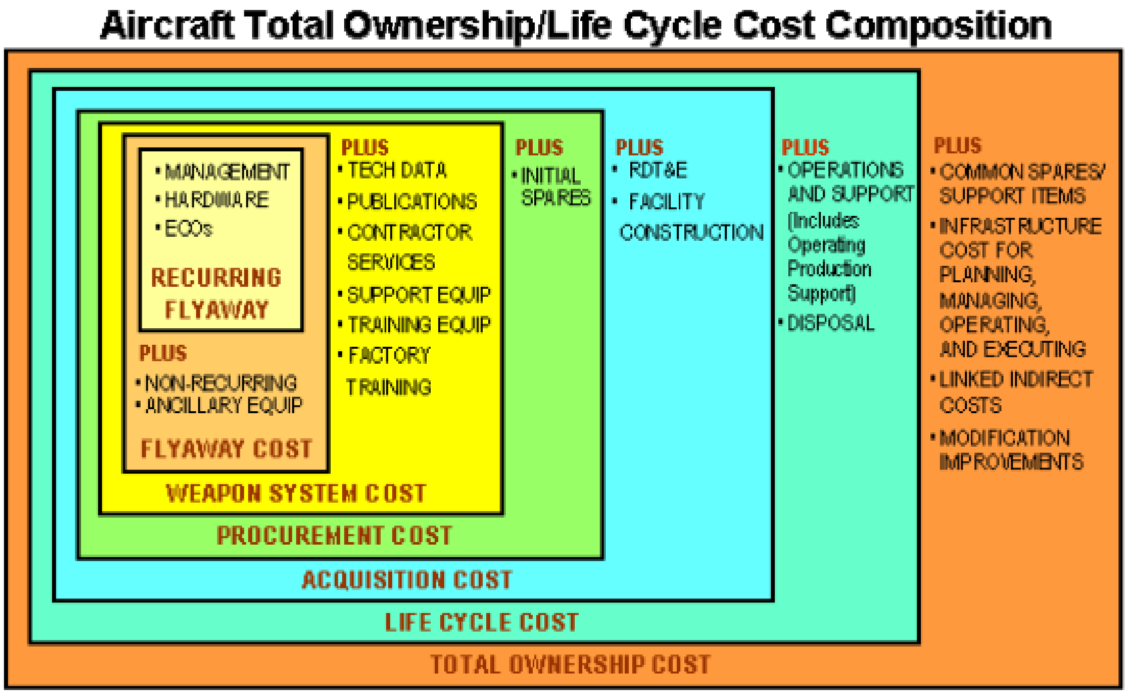

Figure 4. Aircraft Total Ownership/Life Cycle Cost Composition (20)

Since the establishment of MBO 9-2, "DoD policy requires the explicit consideration of O&S costs from the beginning of the acquisition process throughout the operational life of a program" (4:53). The OSD VAMOSC program was created to fill the need for O&S tracking within DoD. The Air Force responded to the initiative first with the development of the Air Force Total Ownership Cost (AFTOC) database. The Army followed with the Operating and Support Management Information System (OSMIS). The OSMIS is a central database that gathers information from Army weapon and materiel systems in order to track total O&S costs for every weapon system included in the Army's inventory.

The Office of the Secretary of Defense/Cost Analysis Improvement Group (OSD/CAIG) is responsible for executive oversight of each service's O&S database according to DoD regulation 5000.4-M. The regulation requires each DoD component to establish and maintain a database consisting of historical O&S data for all weapon systems in its inventory (4:53). "VAMOSC data shall be used as a basis for decisions concerning affordability, budget development, support concepts cost tradeoffs, modifications, and retention of current systems" (4:53). The OSD/CAIG promotes standardization of data collection by DoD components and provides a means for exchange of ideas between the different components in order to improve the use of the VAMOSC data (4:55). The CAIG also provides guidance on improving analytical methods for using O&S data.

Major O&S Guidance

This section explains the legal requirements of O&S estimating and reporting, as well as the requirements of O&S estimating provided in DoD directives and guidance. It also provides the background of the current DoD and Air Force O&S reporting program. This section summarizes these regulations; it is not intended as a substitute.

Title 10.

United States Code Title 10 Section 2434 states:

> The Secretary of Defense may not approve the system development and demonstration, or the production and deployment, of a major defense acquisition program (MDAP) unless an independent estimate of the full life-cycle cost of the program and a manpower estimate for the program have been considered by the Secretary (5:Sec. 2434).

The Secretary of Defense shall prescribe regulations governing the content and submission of these required estimates (5:Sec. 2434). The regulations shall require that the independent estimate of the full life-cycle cost of a program include all costs of development, procurement, military construction, and operations and support without regard to funding source or management control (5:Sec. 2434). The regulation shall also require that the manpower estimate include an estimate of the total number of personnel required to operate, maintain, and support the program upon full operational deployment; and to train personnel to carry out these activities (5:Sec. 2434).

DoD 5000.4-M – O&S Costs.

> DoD Instruction 5000.2 and DoD 5000.2-M require that both a program office estimate (POE) and a DoD Component cost analysis (CCA) estimate be prepared in support of acquisition milestone reviews. As a part of this requirement, DoD 5000.2-M specifies that the DoD Component sponsoring an acquisition program establish, as a basis for cost-estimating, a description of the salient features of the program and of the system being acquired. This information is present in a Cost Analysis Requirements Description (CARD) (4:8).

The following sections of the CARD impact O&S costs:

- System Reliability
- System Maintainability
- Hardware Support Concept
- Software Support Concept
- Supply
- Training
- System Manpower Requirements
- Operation Support Facilities

One of the seven cost terms standardized by DoD 5000.4-M is O&S costs.

> O&S costs include all personnel, equipment, supplies, software, services, including contract support, associated with operating, modifying, maintaining, supplying, training, and supporting a defense acquisition program in the DoD inventory. This includes costs directly and indirectly attributable to the specific defense program; ie., costs that would not occur if the program did not exist (4:48).

The DoD 5000.4-M lists these O&S categories:

- Mission Personnel
- Unit Level Consumption
- Intermediate Maintenance
- Deport Maintenance
- Contractor Support
- Sustaining Support
- Indirect Support (4:48-49)

These O&S categories are currently (2003) in review and will be brought up to date with the new structure described in the Operating and Support Cost Estimating Guide from the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) dated July 31, 2003.

Operating and Support Cost Estimating Guide.

The O&S Cost Estimating Guide provides a cost structure to be established as a guide to assist DoD costs analysts develop and present the results of operating and support cost analyses (6:1). The OSD CAIG O&S cost structure categorizes and defines cost elements that cover the full range of O&S cost that should occur in any defense system (6:1). The O&S cost element structure is divided into six major categories:

- Unit Personnel
- Unit Operations
- Maintenance
- Sustaining Support

- Continuing System Improvements
- Indirect Support (6:2)

The Unit Personnel element includes the costs of all operator, maintenance, and support personnel at operating units (6:2). Unit Personnel include active and reserve military, government civilian, and contractor personnel costs (6:2). Unit Personnel Costs are intended to include direct costs (i.e., costs of individuals assigned at installations that own the system and that can be clearly associated with the system performing its intended defense mission (6:3)).

Unit Operations includes the unit-level consumption of operation materials such as fuel, POL, electricity, expendable stores, training munitions and other operating materials (6:5). Also included are any unit-funded support activities; training devices or simulator operations that uniquely support an operational unit; temporary additional duty/temporary duty (TAD/TDY) associated with the unit's normal concept of operations; and other unit funded services (6:5). Unit-funded service contracts for administrative equipment as well as unit-funded equipment and software leases are included in this portion of the estimate (6:5).

Maintenance includes the costs of labor above the organizational level and materials at all levels of maintenance in support of the primary system, simulators, training devices, and associated support equipment (6:7). All maintenance costs provided through a system support contract will be separately identified within the appropriate cost element (6:7).

Sustaining support includes support services provided by centrally managed support activities not funded by the units that own the operating systems (6:10). It is intended that costs included in this category represent costs that can be directly tied to a specific system and exclude costs that must be arbitrarily allocated (6:10).

Continuing System Improvements includes the costs of hardware and software updates that occur after deployment of a system that improve a system's safety, reliability, maintainability, or performance characteristics to enable the system to meet its basic operational requirements through out its life (6:12). These costs include government and contract labor, materials, and overhead costs (6:12). Costs are required to be separated into government and contactor costs within each cost element (6:12).

The Continuing System Improvements portion of an O&S estimate does not include all changes to a system developed subsequent to the initial delivered configuration (6:12). System improvements identified as part of a pre-planned product improvement program that are included in the acquisition cost estimate are not included in this portion of an O&S cost estimate (6:12). Improvements designed to be incorporated in production lots (eg., design series, block changes) and improvements that would qualify as distinct Major Defense Acquisition Programs (MDAP) are not typically included in this portion of the O&S cost estimate (6:12-13).

Indirect Support costs are those installation and personnel support costs that cannot be directly related to the units and personnel that operate and support the system being analyzed (6:13). The three levels of Indirect Support include Installation Support, Personnel Support, and General Training and Education (6:14-15).

DoD 5000.4-M – Establishment of Visibility and Management of Support Costs and Air Force Total Ownership Costs.

Chapter 4 of the DoD 5000.4-M lays the foundation for the Visibility And Management of Operating and Support Costs (VAMOSC) Program. The purpose of the VAMOSC program is to achieve visibility of O&S costs; the DoD components are required to establish a historical data collection system and maintain a record of O&S data that facilitate the development of a well-defined, standard presentation of O&S costs by MDAP (4:53).

The objectives of the VAMOSC system are to provide visibility of O&S costs for use in cost analysis of MDAPs and force structure alternatives in support of the Planning, Programming, and Budgeting System (PPBS) process and satisfy the Congressional requirement that DoD track and report O&S costs for major acquisition programs (4:53). VAMOSC is also to provide visibility of critical maintenance and support costs at the subsystem level in sufficient detail to promote cost-conscious design and configuration management of new and fielded defense programs (4:54). VAMOSC is to provide visibility of O&S costs so they may be managed to reduce and control program life-cycle costs (4:54). Finally, VAMOSC is to improve the validity and credibility of O&S cost estimates by establishing a widely accepted database, thereby reducing the cost and time for collecting these defense program O&S costs for specific application (4:54).

The OSD/CAIG is charged with executive oversight of VAMOSC (4:55). In this capacity the OSD/CAIG shall promote standardization of O&S cost data collection by the DoD Components, provide a forum for the exchange of ideas among the DoD

Components, and promote the effective use of VAMOSC data in predicting future costs (4:55).

In April of 1998 the Air Force replaced its VAMOSC system with the Air Force Total Ownership Cost (AFTOC) data system (7:19). This new and improved system is also under the oversight of the CAIG and subject to the same objectives as described above and in DoD 5000.4-M. The AFTOC database will be used for the analysis of the CPFH of the HH-60G Pave Hawk, the MH-53J/M Pave Low III/IV, and the UH-1N Helicopter.

HH-60G Pave Hawk

Figure 5. HH-60Gs Over Naval Air Station Fallon, Nevada (21)

There are currently 105 HH-60G Pave Hawk Helicopters in the Air Force inventory; its primary operational mission is Combat Search and Rescue (CSAR) (8:98). The Pave Hawk is the most rapidly deployable, long range, combat capable rescue helicopter in the Air Force inventory (8:98). The Pave Hawk conducts day and night marginal weather alert response missions to recover downed aircrew or other isolated personnel in hostile or permissive environments (8:98). It also performs disaster relief, NEO, counter-drug, civil SAR, and Space Shuttle support (8:98).

MH-53J/M Pave Low III/IV

Figure 6. MH-53J Deploying Flares (21)

There are currently 35 MH-53J/M Pave Low III/IV Helicopters in the Air Force inventory (8:105). Its primary mission is low-level, long-range, undetected penetration into denied areas, day or night, in adverse weather, for infiltration, exfilitration, and resupply of special operations forces (8:105). Missions are almost always conducted under the cover of darkness, and are frequently conducted under adverse weather conditions requiring extended flight operations at an altitude as low as 50 feet using Night Vision Goggles or Instrument Meteorological Conditions as low as 100 feet above ground level (8:105). Missions involve deep penetrations of hostile areas, at extreme ranges, without escort (8:105).

UH-1N Helicopter

Figure 7. UH-1N over Yokota Air Base, Japan (21)

There are currently 63 UH-1N Helicopters in the Air Force inventory (8:119). This aircraft provides Special Air Mission support for the National Capital Region, and VIP airlift (8:119). It also provides airlift of emergency security and disaster response forces (8:119). It provides nuclear weapons security and surveillance, as well as search and rescue, and missile launch security (8:119).

Background of the Cost Per Flying Hour Program

The Cost per Flying Hour program is a subset of the O&S portion of a budget submission. The Air Force program consists of four model-driven factors: (1) consumable supplies (both General Support and System Support Divisions); (2) Depot-level reparables (DLRs); and (3) aviation fuel (AVFUEL) (9:4).

(1) Consumable supplies include aircraft parts and supplies that are not repaired and are discarded after use (9:4-5).

(2) Depot-level reparables are aircraft parts that are removed by maintenance personnel and sent to a depot for repairs (9:5).

(3) AVFUEL is fuel used during flight (9:5).

The cost associated with the Air Force flying hour program is calculated by using a metric known as Cost Per Flying Hour (CPFH) (9:4). "Flying hours are the basic element for measuring aircraft usage to train aircrews for wartime taskings" (9:4). Each year in the November/December timeframe, the major commands (MAJCOMs) must submit recommended CPFH rates for each weapon system that will be included in the Cost per Flying Hour Program (9:6). A separate factor for consumables, DLRs, and AVFUEL will be included in the submission (9:6).

The CPFH development begins by creating a baseline rate using the most recent year-end totals for obligations and flying hours (9:6). "Year-end obligations corrected for one-time obligations divided by hours flown develop the baseline CPFH" (9:6). The next step involves adjusting the four approved factors due to economic conditions, such as inflation/deflation (9:6). Major commands also review the factors and adjust them to account for anything that will affect the cost per flying hour, such as forecasted changes in policy, special programs starting, or changes in the level of maintenance (10:8-9).

At the same time, the Air Force Working Capital Fund (AFWCF) updates the budget and rates for all the AFWCF products, which includes DLRs and consumables, a major part of the CPFH expense (9:7). The four CPFH factors are adjusted according to price changes forecast by managers of the AFWCF (10:10).

Finally, the factors are used to fund flying hour programs in Air Force's Program Objective Memorandum (POM), the Budget Estimate Submission (BES), and the President's Budget (PB), as well as the Financial Plan's initial distribution to the MAJCOMs (9:7).

"The Air Force Working Capital Fund was created in 1996 by the Under Secretary of Defense (Comptroller) as a reorganization of the Defense Business Operations Fund" (10:10). The AFWCF is a revolving fund that sells items necessary to support troops, weapon systems, aircraft, communications systems, and other military equipment (10:10). DoD Financial Management Regulation 7000.14R requires that the prices established by the AFWCF at the beginning remain stable for the remainder of the fiscal year (10:10). This stability allows analysts to use the cost factors previously calculated to budget more accurately for the flying hour program. For fiscal years 1996 and 1997, the AFWCF was unable to establish accurate price lists for the repairable parts and consumable items that it supplied to Air Force flying units. After budgets were submitted and approved, prices for repairable parts and consumables were raised to the point that the MAJCOMs feared they would not have enough money to complete their flying hour programs (10:12). This price increase forced the Air Force to request supplemental funding to correct the projected shortfall (10:12). The AFWCF price instability has been known for some time and efforts to correct it are currently in progress (10:14).

Past Research

Trends in Weapon System Operating and Support Costs.

This 1997 study focuses on the weapons systems and mission areas that are responsible for force structure-related O&S cost increases. Two portions of this study that are of particular interest to this research are the Department and Mission Category Analyses, and the Weapons System Case Studies. The Department and Mission Category Analyses compares O&S costs for FY 1975, 1985, and 1995 for the DoD as a whole, the services, and for selected major mission categories, and analyze the results with respect to changes in equipment levels, activity rates, capability, age, and asset value (12:I-3). The Weapons System Case Studies compare O&S costs for the same years at system-class level in selected mission categories as case studies (12:I-3). The Future Years Defense Program (FYDP) database was used as the primary source of O&S cost data for the Department and Mission Category Analyses; and for the Weapons System Case Studies the O&S cost data was drawn from each services VAMOSC database (12:I-4,7).

This study first looks at the O&S growth for the department and services during the FY 1975 to FY 1995 period. When the data is normalized to FY 1975, the O&S cost of the DoD grew four percent, Navy grew two percent, Army declined six percent, and the Air Force declined thirteen percent (12:I-8). These figures are a combination of substantial reductions in military personnel costs and substantial increases in O&M costs

(12:I-8). For the same period, DoD O&M costs grew by 36 percent, the Army by 31 percent, the Navy by 23 percent, and the Air Force by 11 percent (12:I-8).

After a brief methodology explaining the charts to be used, the study focuses its attention on the different services starting with the Department of the Army. The review of this study will focus on the Department of the Army since the analysis of the Army included helicopters and the areas covering the Navy and the Air Force excluded helicopters from the analysis of O&S costs.

The Army experienced a six percent decrease in O&S costs between FY 1975 and FY 1995; at the same time, O&M costs rose by twenty-four percent (12:II-1). In the Mission Category review of the Army the study included Attack Helicopters, Observation Helicopters, and Utility Helicopters.

Attack Helicopters.

For Attack Helicopters Table 2 and Figure 8 show that between FY 1975 and FY 1995:

- The total number of aircraft increased 82 percent while flying hours increased by 78 percent,
- There was a 157 percent increase in total O&M,
- Asset value increased by 285 percent and mission capability increased by 339 percent (12:II-8).

Table 2. Attack Helicopter Data

Data Element		FY75	FY85	FY95
Aircraft		766	1,140	1,393
O&M ($M)		205	326	527
Hours		133,046	201,898	236,370
Asset Value ($M)		2,920	4,599	11,248
TASCFORM		1,538	2,655	6,754
Average Age		5	11.5	13.5
Flying Hours Per Aircraft		174	177	170
O&M Per Aircraft ($K)		268	286	378
O&M Per Flight Hour ($)		1,544	1,613	2,228
O&M Per $10K Asset Value ($)		703	708	468
O&M Per Capabiity Unit ($K)		134	123	78
Equipment Data	AH-1E		97	23
	AH-1F	352	501	490
	AH-1G	31	11	3
	AH-1P	2	95	10
	AH-1S	381	389	121
	AH-64A		47	746

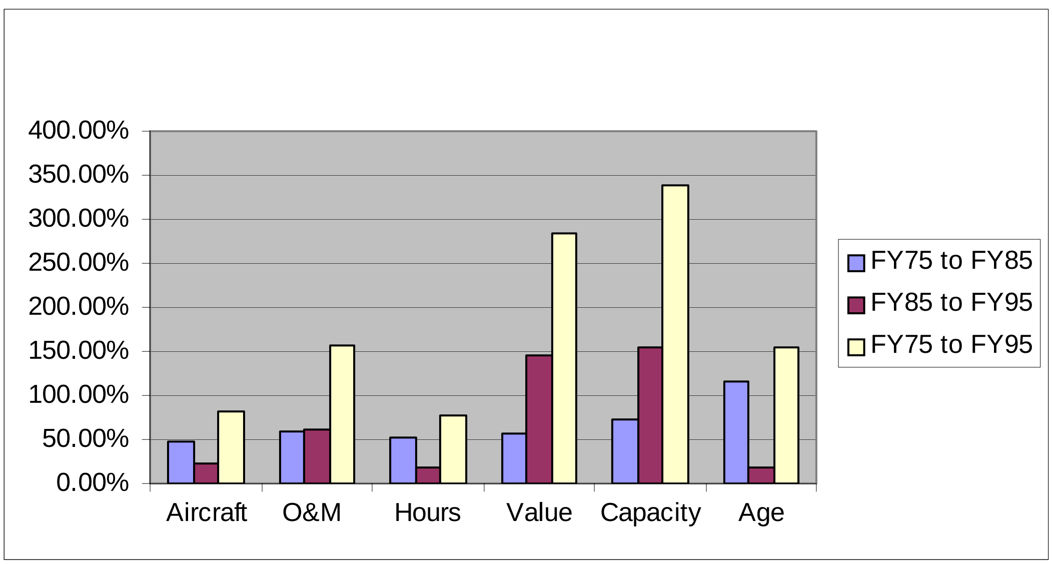

Figure 8. Attack Helicopters

The per unit section of Table 2 and Figure 9 show that between FY 1975 and FY 1995 O&M cost:

- Per aircraft increased by 41 percent,

- Per flying hour increased by 44 percent,
- Per $100K of Asset Value dropped by 33 percent, and
- Per unit of capability dropped by 41 percent (12:II-8).

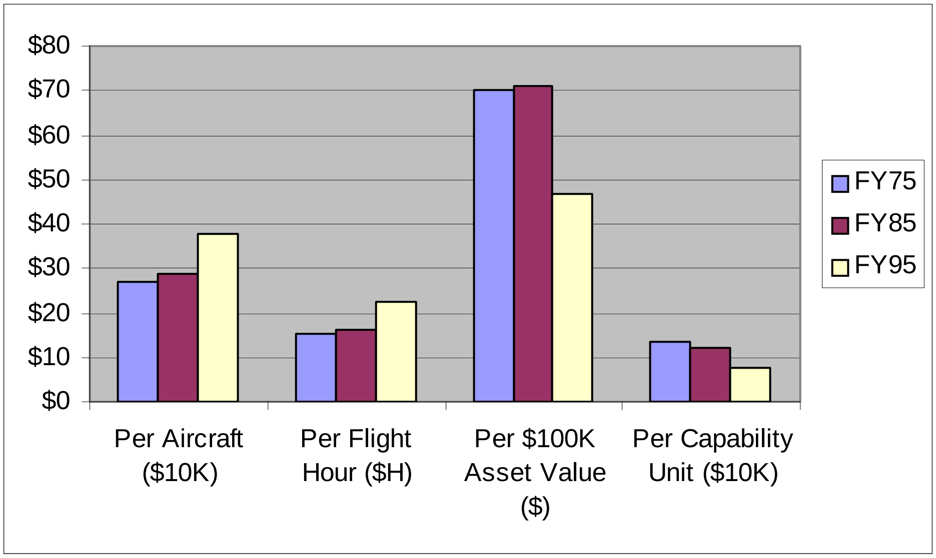

Figure 9. Attack Helicopter O&S Cost Ratio Changes

During the FY 1975 to FY 1995 period there was a marked increased modernization of attack helicopters (12:II-10). Table 3 focuses on attack helicopter inventories for the time period of this study. The Army phased out over 300 older AH-1s during the period and introduced over 700 new AH-64s (12:II-10). This modernization has had a substantial effect on operating costs, Table 3 also shows the annual operating cost figures for attack helicopters and indicates that the AH-64s are nearly twice as expensive as the AH-1s (12:II-10).

Table 3. Attack Helicopter Modernization & Annual O&M Costs

Aircraft Type	FY75	FY95	Change
AH-1S	381.00	121.00	-260.00
AH-1G	31.00	3.00	-28.00
AH-1E		23	23.00
AH-1P	2.00	10.00	8.00
AH-1F	352.00	490.00	138.00
AH-64A		746	746.00

Aircraft Type	O&M ($M)
AH-1S	0.31
AH-64	0.57

The Army's experience in this mission area is typical of one in which substantial modernization has taken place during the 20-year period:

- O&M cost per flight hour is up,
- O&M cost per unit of asset value is down,
- O&M cost per unit of capability is down, and
- O&M cost per aircraft has been managed down somewhat by reducing flying hours (12:II-11).

The flying hour reduction per aircraft is small:

- In FY 1975, 133,046 flying hours were allocated among 766 aircraft to produce an average of 174 flying hours per aircraft per year (12:II-11).
- In FY 1995, 236,370 flying hours were allocated among 1393 aircraft to produce an average of 170 flying hours per aircraft, a decrease of approximately 2 percent (12:II-11).

Altogether, changes in the number and mix of aircraft between FY 1975 and FY 1995 and the differences in their operating costs substantially account for the $322 million increase in O&M cost in Table 2 (12:II-11).

Observation Helicopters.

For Observation Helicopters Table 4 and Figure 10 show that between FY 1975 and FY 1995:

- The total number of aircraft decreased 35 percent,
- There is a 30-percent decrease in total O&M, and
- Asset value decreased by 27 percent (12:II-11).

Table 4. Observation Helicopter Data

Data Element		**FY75**	**FY85**	**FY95**
Aircraft		2,470	2,324	1,606
O&M ($M)		120	113	83
Hours		481,650	453,180	313,170
Asset Value ($M)		313	297	228
TASCFORM			Not Available	
Average Age		4	14	19.3
Flying Hours Per Aircraft		195	195	195
O&M Per Aircraft ($K)		49	49	51
O&M Per Flight Hour ($)		250	250	264
O&M Per $10K Asset Value ($)		3,842	3,816	3,629
Equipment Data	OH-58A	1,479	1,368	782
	OH-58C	594	582	443
	OH-58D	5	7	327
	OH-6A	392	367	54

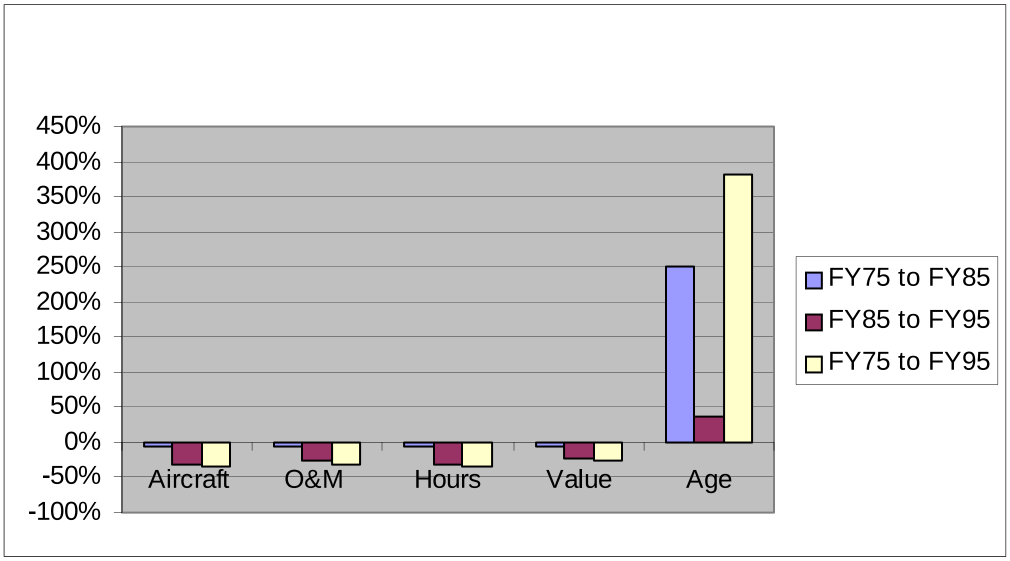

Figure 10. Observation Helicopters Total Resource and Performance Changes

The per unit section of Table 4 and Figure 11 show that between FY 1975 and FY 1995, the O&M cost:

- Per aircraft increased by 4 percent,
- Per flying hour increased by 6 percent, and
- Per $100K of Asset Value dropped by 6 percent (12:II-12)

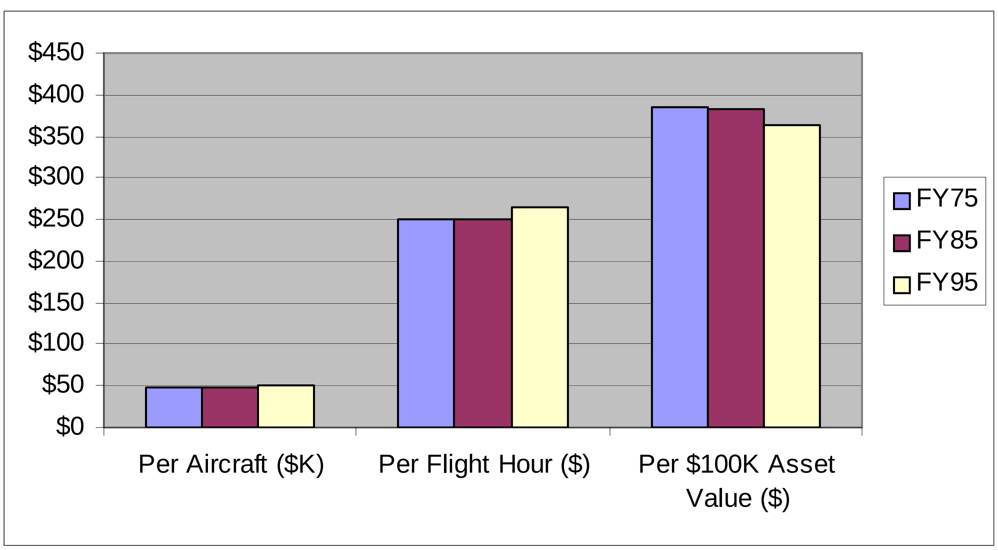

Figure 11. Observation Helicopter O&S Cost Ratio Changes

The Army bought new models of observation helicopters and reduced the size of its fleet during this period (12:II-13). Table 5 focused on observation helicopter inventories for the time period of this study. The Army phased out 338 older OH-6A and 848 OH-58A-C models during the period and introduced 322 new OH-58Ds. (12:II-13). This modernization has increased operating costs for observation helicopters, Table 5 also shows the annual operation cost figures for observation helicopters and indicates that the OH-58s are nearly twice as expensive as the OH-6s.

Table 5. Observation Helicopter Modernization & Annual O&M Costs

Aircraft Type	FY75	FY95	Change
OH-6A	392.00	54.00	-338.00
OH-58A	1479.00	782.00	-697.00
OH-58C	594	443	-151.00
OH-58D	5.00	327.00	322.00

Aircraft Type	O&M ($K)
OH-6	34.0
AH-64	67.0

The Army's experience in this mission area is one in which some modernization has taken place during the 20 year period (12:II-14). Also, a significant drawdown in the number of aircraft changed the model mix enough so that:

- O&M cost per flight hour is up, and
- O&M cost per unit of asset value is down (12:II-14).

The change in the number and mix of aircraft between FY 1975 and FY 1995 substantially accounts for the $37 Million decrease in O&M costs shown for observation helicopters in Table 4 (12:II-14).

Utility Helicopters.

For Utility Helicopters Table 6 and Figure 12 reveal several important changes between FY 1975 and FY 1995:

- The total number of aircraft decreased 25 percent,
- There is a 56 percent increase in total O & M, and
- Asset Value increased by 23 percent. (12:II-14).

Table 6. Utility Helicopter Data

Data Element		FY75	FY85	FY95
Aircraft		4,430	4,427	3,335
O&M ($M)		331	476	517
Hours		952,450	951,131	715,783
Asset Value ($M)		3,598	7,716	9,558
Ton-miles per hour		945,362	1,191,810	1,167,006
Average Age		6.6	13.8	18.6
Flying Hours Per Aircraft		215	215	215
O&S Per Aircraft ($K)		75	108	155
O&S Per Flight Hour ($)		348	500	722
O&S Per $10K Asset Value ($)		920	617	540
O&S Per Capabiity Unit ($)		350	399	443
Equipment Data	UH-1B	430	55	38
	UH-1H	3,322	3,066	1,688
	UH-1M	309	246	
	UH-1V	369	386	367
	UH-60A		674	926
	UH-60L			316

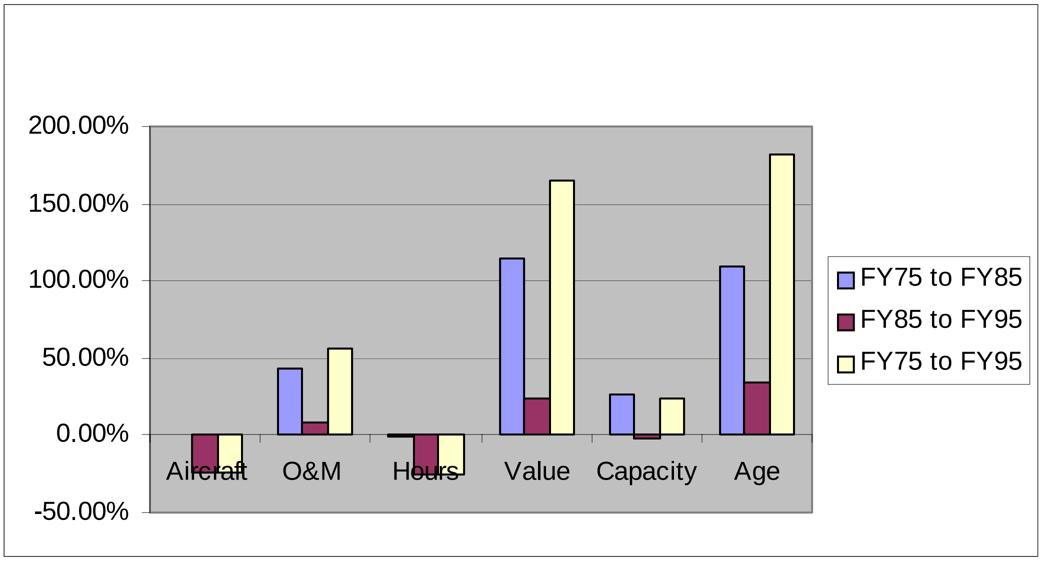

Figure 12. Utility Helicopter Total Resource and Performance Changes

Looking at the per unit section of Table 6 and Figure 13 we see that between FY 1975 and FY 1995 the O&M cost:

- Per flying hour increased by 207 percent,
- Per $100k of Asset Value dropped by 166 percent, and
- Per unit of capability increased by 27 percent (12:II-14).

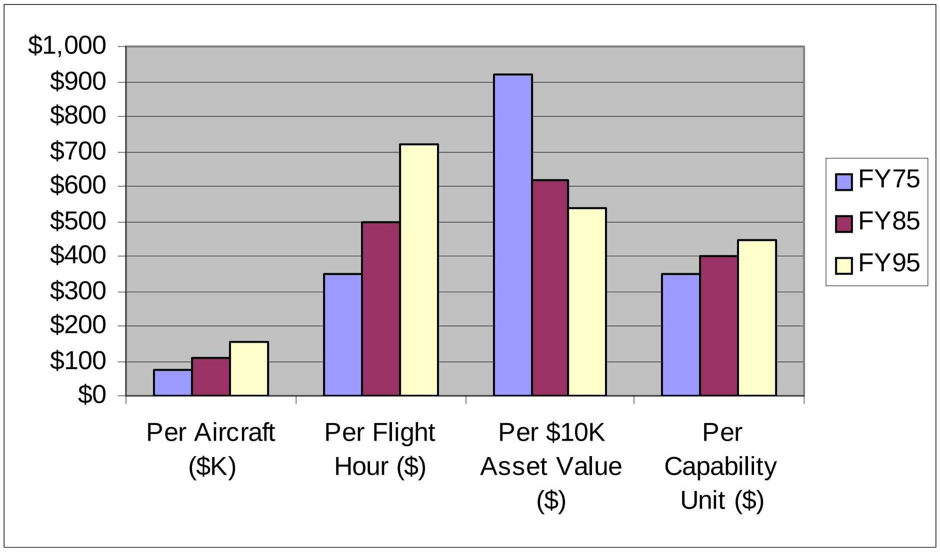

Figure 13. Utility Helicopter O&S Cost Ratio Changes

The Army modernized its utility helicopters during this period and reduced the size of its fleet (12:II-16). Table 7 focuses on Utility Helicopter inventories for the time period of this study. Lover 2,300 older UH-1 models were phased out during the period and over 1,200 new UH-60s were introduced (12:II-16). Table 7 also shows that this modernization has caused mission operating costs to increase, and also indicates that the UH-1s are much cheaper to operate than the UH-60s (12:II-16).

Table 7. Utility Helicopter Modernization & Annual O&M Costs

Aircraft Type	FY75	FY95	Change
UH-1B	430	38	-392
UH-1H	3,322	1,688	-1,634
UH-1M	309		-309
UH-1V	369	367	-2
UH-60A		926	926
UH-60L		316	316

Aircraft Type	O&M ($K)
UH-1H	54.0
UH-60A	194.0
UH-60L	305.0

The change in the mix of aircraft between FY 1975 and FY 1995 substantially accounts for the $186 million increase in O&M costs shown for Utility Helicopters in Table 6 (12:II-16). The Army's experience in this mission area is typical of one in which moderate modernization has taken place during the 20 year period:

- O&M cost per flight hour is up, and
- O&M cost per unit of Asset Value is down (12:II-17).

However, in the case of utility helicopters, O&M cost per unit of capability is up (12:II-17).

The study shifts its attention to case studies comparing O&S costs and characteristics of similar weapon systems. Two studies that are of particular interest are Attack Helicopters: AH-1s vs. AH-64A and Utility Helicopters: UH-1H vs. UH-60A.

Attack Helicopters: AH-1s vs. AH-64A.

Comparative O&S cost and helicopter characteristic data are summarized in Table 8 for the Cobra (AH-1) and the Apache (AH-64A) attack helicopters (12:II-19).

Table 8. O&S Costs and Characteristics for Attack Helicopters

Cost Element	**AH-1S**	**AH-64A**
Fuel	8,648	10,220
Ammunition	38,532	7,497
Consumables	11,262	60,494
Repairables (Net)	150,352	326,922
Intermediate Maintenance	28,253	22,782
Depot Maintenance (End Item)	14,756	1,769
Annual Direct O&S Cost	251,803	429,685
Flight Hours Per Year	130	130
Direct O&S Cost Per Flight Hour	1937	3305
Cost Ratio	1	1.71
Characteristics		
Max TOGW (lbs.)	10,000	14,694
Empty Weight (lbs.)	6,598	11,387
Max Speed (knots)	133	158
Operating radius (miles)	369	300
Endurance (hours)	2.6	1.83
Fuel Capacity (gallons)	262	370
Crew	2	2
Asset Value ($M)	3.7	12.81
Capability (TASCFORM score)	3.182	10.47
Weapon Control	AWG-10	AWG-9
Armament	20-mm cannon	30-mm chain gun
	8 TOW missiles	Hellfire missiles
	76 2.75-in. rockets	Hydra 70 rockets

Total O&S costs for the AH-64A are 71 percent higher than comparable costs for the AH-1S (12:II-20). Consumables and component repair (repairables) showed much larger than average increases while ammunition, intermediate maintenance, and depot end-item maintenance were less (12:II-20).

The AH-64A is larger, heavier, and faster than the AH-1S and has a more sophisticated armament and fire-control system (12:II-20). The asset value of the AH-64A is 246 percent higher than for the AH-1, and the TASCFORM score, a measure of weapon system capability, is 229 percent higher for the AH-64A (12:II-20). The AH-64's asset value and capability grew faster than its O&S cost, which results in a lower O&S cost per unit of asset value or capability than for the AH-1S.

Utility Helicopters: UH-1H vs. UH-60A.

Comparative O&S cost and helicopter characteristic data are summarized in Table 9 for the for the Huey (UH-1H) and Blackhawk (UH-60A) utility helicopters (12:II-20). The UH-60A is more than twice the empty weight of the UH-1H, and it has the capability to carry twice as much cargo (externally loaded) (12:II-20). The maximum speed is 145 knots compared to 107 for the UH-1H. The asset value of the UH-60A is 615 percent higher than for the UH-1H (12:II-20). The UH-60A is 172 percent higher in terms of ton-miles per hour, a measure of capability used for cargo carrying non-combat vehicles (12:II-20).

Table 9. O&S Costs and Characteristics for Utility Helicopters

Cost Element	UH-1H	UH-60A
Fuel	9,104	10,220
Ammunition	259	7,497
Consumables	4,843	60,494
Repairables (Net)	43,782	326,922
Intermediate Maintenance	32,599	22,782
Depot Maintenance (End Item)	8,674	1,769
Annual Direct O&S Cost	99,261	429,685
Flight Hours Per Year	150	130
O&S Cost Per Flight Hour	662	3305
Cost Ratio	1	2.77
Characteristics		
Max TOGW (lbs.)	9,500	14,694
Empty Weight (lbs.)	5,210	11,387
Max Speed (knots)	106.7	158
Combat radius (miles)	317	300
Fuel Capacity (gallons)	209	370
Payload	4,000 lbs external	8,000 lbs external
	or 10 passengers	11 combat troops
Crew	3	3
Asset Value ($M)	0.923	6.6
Capability (Ton-miles per hour)	213.4	580
Armament	3 x 7.62-mm MGs	2 x 7.62-mm MGs

O&S costs for the UH-60A are 177 percent higher, asset value is 615 percent higher, and capability is 172 percent higher than for the UH-1H. The UH-60's capability grew at about the same rate as its O&S cost, which resulted in a similar O&S cost per unit of capability compared to the UH-1H (12:II-21). The UH-60's asset value grew faster than its O&S cost, which results in a lower O&S cost per unit of asset value (12:II-21).

Both the Department of the Navy and the Department of the Air Force sections of this study looked at the Air to Ground Mission Categories for each service. However, neither of these sections or mission categories addressed O&S costs of Navy or Air Force helicopters. This further validates the need for research in these areas and lends credit to the methodology of this research which looks to compare like weapon systems across services.

Parametric Cost Modeling for Navy Aircraft.

Parametric models have been developed for numerous weapon systems to provide cost analysts with tools useful for predicting costs for analogous systems. In his thesis entitled, *A Parametric Cost Model for Estimating Operating and Support Costs of U.S. Navy Aircraft*, Mustafa Donmez develops multiple parametric models to determine yearly O&S costs for new naval aircraft acquisition programs. Physical parameters such as thrust and weight are used to establish any relationships between the dependent and independent variables. The VAMOSC system is used to extract all historical aircraft information. Cost information is analyzed from 1987 through 1998 and is reported in constant FY00 dollars.

Donmez focused on two main objectives throughout his research. The goals were to find the best fitting O&S model and to create a robust aircraft O&S cost estimating methodology for Navy cost analysts when limited information is available to complete the estimate (13:5). Three different parametric cost models were built in the analysis. Donmez used multivariate linear regression, a tree-based model, and single variable regression to construct the models (13:10). The weighted ordinary least squares method was used on the first two models because VAMOSC does not break out costs for individual aircraft and each command possesses different numbers of aircraft.

The cost data supplied by the Naval Center for Cost Analysis (NCCA) is broken out by different classes of aircraft. The four categories are as follows: Fighter/Attack (FA), Cargo/Utility (C/U), Rotary-Wings (HELO), and Other (OTH) (13:14). Multiple Type/Mission/Series aircraft were removed from the analysis due to small sample size. Natural Logarithms were use to transform the data for the purpose of normalization. After eliminating specific T/M/S from analysis and transforming the data, two assumptions were validated:

- The weighted average annual cost for any aircraft T/M/S is constant; it does not systematically increase or decrease annually (13:18).
- Annual O&S cost observations are random samples and drawn from a hypothetical population of aircraft (13:18).

In the multivariate model, the following independent variables were used to examine significant effects on O&S costs (13:34):

- **Commands**- Atlantic Fleet (LANFLT), Pacific Fleet (PACFLT), NET (Naval Education and Training), Naval Air Systems Command (NAVAIR), Naval Forces Europe (NAVEUR), Reserve Commands (RESERVE), and MISC (Miscellaneous)
- **Weight**- Continuous Variable (in lbs)
- **Length**- Continuous Variable (in ft)
- **Wing Span**- Continuous Variable (in ft)
- **Height**- Continuous Variable (in ft)
- **Thrust**- Continuous Variable (in st lb)
- **Type**- Categorical Variable (A/F, C/U, OTH, HELO)

- **Speed**- Continuous Variable (in mph)
- **Crew**- Categorical Variable (Number of Manpower on Board
- **Engines**- Categorical Variable (Number of Engines)

The results of the multivariate model show that wingspan and height have an effect on O&S cost growth and weight, engine number, and thrust do not affect O&S costs when other independent variables are present (13:40). Stepwise regression was used to determine the utility of the model. The multivariate model exhibits the best summary statistics out of the three models but it is the least useful model. There are too many independent variables in the equation to have any practical use for accurate prediction.

The second model constructed, the tree-based model, provides the best model for estimating O&S costs. The results prove more reliable than the other regression-type models. Tree models successively split data into homogeneous subsets (13:46). Tree-based models can be described as "a recursive procedure resulting in terminal nodes or "leaves" containing groups of cases with similar values in their independent variables, which reflect response probabilities" (13:46).

The tree-based model for this particular research splits the data into two subsets: Reserve and Non-Reserve data. Each T/M/S was further broken into the four aircraft categories mentioned previously. Weight, length, and thrust were used as predictor variables because of their alleged relationship with O&S cost. The original model resulted in a tree with 51 nodes and a standard error of 1.536 (13:48). The model was reduced to a 10-node tree with an increased standard error of only 0.115. The 10-node tree is more easily interpreted than the 51-node tree.

The last model analyzed used univariate regression as a predictor of O&S costs. Again, the same predictor parameters of weight, length, and thrust were used because of the perceived relationship with O&S costs. All of the predictive measures exhibit poor summary statistics when analyzed in a statistical software package. The parameter variables do show some predictive capabilities confirmed by the low F-statistic values (13:58-68).

The final conclusions of Donmez's research indicates more research needs to be completed to find better predictive models for estimating O&S costs. The univariate and multivariate models show that "O&S costs of future aircraft acquisitions are not well-modeled by the physical and performance parameters identified in this study" (13:69). The performance parameters do affect O&S costs but they are not successful in explaining costs. The regression models analyzed provide rough-order-of-magnitude (ROM) estimates for analysts that do not possess the time nor experience to complete a comprehensive analysis for future O&S costs for a weapon system. The tree-based model provided the most successful model in terms of overall use coupled with predictive capability.

Parametric Cost Modeling for Air Force Aircraft.

While studying at the Naval Post Graduate School, Wu Ming-Cheng completed a thesis that explored O&S parametric modeling for all Air Force aircraft from 1990 through 1998. Ming-Cheng developed his research from a prior RAND study that developed cost-estimating relationships (CERs) for Air Force aircraft from 1981 through 1986. Ming-Cheng reported that flyaway costs and flying hours were the major cost drivers during that period (14:2). Additionally, the Ming-Cheng thesis reported modest cost growth as the aircraft fleet aged.

Ming-Cheng tried to determine if the cost drivers for O&S costs observed during the years of the RAND study still applied to Air Force aircraft in recent years past. The ability to retrieve O&S aircraft cost data is easier now that the AFTOC system is fully operational. Ming-Cheng cited three subsystems broken down in the AFTOC system: Weapon System Support Cost (WSSC), Component Cost System (CSCS), and Source Data Preprocessor (SDP) (14:5-6). Ming-Cheng's thesis specifically focused on the WSSC subsystem of the AFTOC.

Ming-Cheng developed three models using regression analysis to obtain the best equation for successfully predicting O&S costs for aircraft models. Flying hours, flyaway costs, number of aircraft, and aircraft fleet ages were the independent variables in the analysis (14:37-40). Additionally, Ming-Cheng added dummy variables for type of aircraft. Aircraft types were broken down into three categories: fighter/attack, cargo/tanker, and other. The results of the regression analysis provides a similar conclusion to the previously mentioned RAND study that examined O&S cost drivers for Air Force aircraft. Average flying hours, number of aircraft, flyaway costs, and fleet age were all significant in predicting whether or not a certain type of aircraft will experience O&S cost growth. The flyaway cost variable is noted as possibly the most significant explanatory variable in predicting O&S cost growth (14:49).

O&S Cost Reduction – U.S. Navy.

O&S reduction initiatives have been at the forefront for all service branches. Significant cost savings were identified for the Navy in its replacement timing of its H-3 helicopter fleet with the CH-60. The Sikorsky H-3 helicopter has been in service for an average of 34 years (15:2). The Navy has 54 in its inventory and has projected the first replacement CH-60 to occur in the year 2008 (15:2-3). Even though the H-3 fleet recently underwent an overhaul process, maintaining these old aircraft will become increasingly expensive (15:2).

The H-3 performs the following missions for the Navy:

- Executive battle staff transportation- the movement of VIPs from ship to ship, ship to shore, shore to ship, or shore to shore.
- Search and rescue
- Passenger/Mail/Cargo Services and Air
- Torpedo/Drone recovery
- Special warfare support

The CH-60 will be able to meet all the above mission requirements along with additional capability. The addition of external fuel tanks will allow an endurance increase up to six hours (15:10). Air speed with the CH-60 will be faster, between 150 and 175 knots compared to 120 knots of the H-3. It will also have a more modern computerized hovering system, allowing it more stability when hovering (15:11). The CH-60 will also be able to carry up to 5,500 pounds of palletized cargo, as well as a 9,000 pound cargo hook compared to a 6,000 pound hook for the H-3 (15:13-15). Finally, the CH-60 will have self protection available, making it equipped to perform many of its duties in more hostile environments if necessary (15:16). "It will have ballistically tolerant fuel systems, flight controls and dynamic components. It will have infrared suppression, wire strike protection, and chaff and flare dispensers (15:15-16)."

In order to compare the benefits of replacing the H-3 with the CH-60, a comparison of historical costs was performed. From 1986 to 1996, the Navy operated seven models of the H-3 helicopter (15:21). One of the models, the SH-3H, was used for anti-submarine warfare and not combat support mission, so data for this version was not included in the calculation of O&S costs for the H-3 (15:21). The data for the total yearly O&S cost for the six models came from the Navy's VAMOSC system. The total annual O&S cost for the H-3 was found by adding the costs for each of the 10 years. The total O&S costs were approximately $1.1 billion (1997 constant dollars) (15:21-22). The total flying hours for each model by year was also available in the VAMOSC database, which totaled across the ten year period to 200,580 hours (15:27). The average O&S cost per flight hour was found by dividing the total annual cost by the total flying hours, which was $5,324 (1997 constant dollars) (15:28).

Now that an average cost per flight hour had been determined for the H-3, similar calculations had to be performed for the CH-60. At the time of the comparison, the CH-60 had not entered into Navy service, so historical O&S cost data was unavailable (15:29). The Navy VAMOSC system had data available on the HH-60 helicopter, which was the closest aircraft in mission and configuration to the CH-60 (15:29). The HH-60H Sea Hawk was determined to be the best surrogate for CH-60 O&S costs (15:31). Data was available for the Sea Hawk from 1990 to 1996 (15:32). The estimated cost per flight hour for the HH-60H was $3,347 (15:38).

The estimated savings in O&S costs per year were found by multiplying an average utilization rate of 342 hours per helicopter by the number of H-3s in the Navy's inventory by each of the determined cost per flying hour figures previously calculated (15:40-41). The total savings achieved by replacing the H-3 now as opposed to much later was $36.5 million annually (15:45).

The current plan involved replacing the H-3 starting in 2008 by procuring 6 the first year, followed by 18 each year until 42 CH-60s were available to replace 54 H-3s (15:42). The proposed plan involved accelerating the procurement by eight years and increasing the first purchases up to 36 aircraft (15:44). The total O&S savings for the period from 2000 to 2010 were found to be $292.1 million (15:45).

Since the planned replacement of the H-3 with the CH-60 was not a one-to-one replacement, base operating and support costs would also be much lower (15:46). These costs are incurred by the facility that supports the squadron that operates the aircraft and include such things as lodging, personnel support, and general support (15:46). Finally, "increasing the number of helicopters purchased per year would allow the manufacturer to take advantage of economies of scale and spread the fixed costs of the production of the aircraft over more units (15:47)." The procurement cost per unit would be lower, compensating the cost of replacing the helicopters sooner (15:47).

Assessing Competitive Strategies for the Joint Strike Fighter.

The management team of the Joint Strike Fighter (JSF) saw the importance of reduced O&S costs in the early concept and development stages of the program. The management team wanted to analyze the benefits to be realized in O&S cost savings by introducing contractor competition during the Engineering and Manufacturing

Development (EMD) and production phases. The idea is that such competition will lead to better design and production, which would also lead to better reliability during field operations. A frequently referenced example is the great engine war, which pitted General Electric's F-110 engine against Pratt & Whitney's F-100 engine to induce Pratt & Whitney to produce a more reliable version of the F-100 engine (16:65). DoD relied on the fact that this higher reliability will lead to a reduction in O&S costs. The JSF management team decided to examine the extent of possible competition-induced reductions in O&S costs to see if such reductions might be large enough to affect their estimate of the likelihood of breaking even by introducing a second-source producer (16:65).

The analysis of this O&S costs reduction effort followed a four-step approach:

1. Elements of O&S costs were identified that were likely to be affected by the contractor's actions during EMD and production in a typical military aircraft program. This was done by reviewing the categories by which O&S costs are typically reported and judging which of those would be likely to change as a result of changes in system reliability.

2. The magnitudes of those competition-sensitive O&S costs in the JSF were determined, as currently estimated its projected operational life. The JSF Program Office provided this data.

3. The sensitivity of those competition-sensitive O&S costs to changes in reliability were calculated. Those estimates, made by the Naval Air Systems Command (NAVAIR) using the JSF O&S cost estimation model, yielded a range of possible savings resulting from competition during production, expressed as a percentage change in certain JSF O&S costs.

4. The Savings were used to adjust previously reported break-even calculations to determine whether the projected O&S cost savings led to a significant change in the overall likelihood of breaking even (16:65-66).

In step 1, it was concluded that contractors have the highest level of potential influence over O&S costs in five areas: unit-level consumable supplies, depot-level repairables, airframe overhauls, engine overhauls, and support equipment repair (16:66). In step 2 engine overhauls was excluded because competition for engine EMD and production is already planned. Percentages of O&S costs were determined for consumables, Depot-level repairable, and overhauls. It was determined in steps 3 and 4 that competition-induced improvements in system reliability are likely to yield O&S dollar savings over the operational life of the JSF fleet, however, the reductions that would be realized would not be large enough to overcome the cost penalties of introducing competition (16:72).

Air Force Flying Hour Program – Historical Problems.

The Air Force has had problems accurately forecasting flying hour program estimates, mainly due to the confusion over how to define flying hour consumable supplies. "Up until FY92, when wing financial analysts used the term 'flying hour program', they were referring to consumable supplies used to maintain their wing's aircraft (17:1)." The term 'flying hour program' was redefined and included many more elements when funding for Depot Level Reparables (DLRs) and Aviation Petroleum, Oil, and Lubricants (AVPOL) was decentralized to the wing level (17:1).

For years, the financial community had worked diligently on the task of clearly defining and properly measuring the flying hour consumable supplies program (17:1). With the decentralization of DLRs and AVPOL, the work was left unfinished and a more clear-cut definition was not made available (17:1).

Since 1980, financial analysts had significant problems with the planning, programming, and budgeting for flying hour consumable supplies (17:2). Since there was no Air Force-wide definition of consumables, each major command (MAJCOM) distributed funding, tracked expenditures, and performed analysis based on its own definition (17:2). Another issue that arose involved the different philosophies among the MAJCOMs (17:2). "While one command might consider flying hour related costs to include any costs directly or indirectly related to maintaining the aircraft, another might use a stricter definition and only include costs directly related to maintaining the aircraft (17:2)."

With funding decentralization and growth of the flying hour program, wing and MAJCOM levels had a more critical task of justifying funding requirements and also spending reduction with funding already in place (17:2-3). The different consumable supply definitions used by the MAJCOMs and inconsistencies between, as well as within commands, on what is considered a flying hour expense made this task difficult for the wing and MAJCOMs (17:3).

At the time, consumable supplies shared the same accounting codes with non-flying mission items. A financial analyst had to manually separate the flying mission items from non-flying items, a very time-consuming task prone to error (17:8). If consumables had their own unique accounting code, retrieving the needed information specifically for flying-mission items would be much simpler and allow the analyst to construct a true picture of flying hour expenditures (17:8). Due to cost reduction efforts DoD wide, more accurate information is critical for leaders to make informed decisions (17:8).

A formal definition of what qualifies as flying hour consumables must be developed and distributed (17:9). "This definition should not be based on where an item is purchased, but what an item is and how it relates to the flying mission (17:9)." The definition should include a formalized list of criteria, with examples to aid personnel in determining whether an item should be classified as flying hour-related (17:9).

Cost Per Flying Hour Calculation.

In a thesis entitled *Flight Hour Costing at the Type Commander and Navy Staff Levels: An Analytical Assessment*, Edwards examines the Flying Hour Program (FHP) and assesses the models used at the operational level, the community sponsor level, and the budgeting level (18:6). The Navy FHP "is the primary vehicle through which the Service maintains a readily available force of combat and support aircraft, aircrews, and ground support personnel" (18:7). Edwards concentrates his research on the Pacific Fleet (COMNAVAIRPAC). One goal of the thesis was to "provide guidelines for budget control to more accurately predict variances as well as the average flight hour costs by aircraft type" (18:3-4). Edwards claims that FHP estimates are not correct during budget formulation because FHP funds are capped by Congress (18:2). The calculation for FHP funding is calculated by multiplying required flight hours to sustain a planned proficiency by the CPFH of each specific T/M/S of aircraft (18:1-2). The thesis explores alternate methods of predicting FHP costs in the search for a better way of estimating future costs.

Edwards asserts that inaccurate estimates for the FHP adversely affect mission readiness. This research provides Type Commanders and Naval Air Station comptrollers with the current factors that affect FHP calculations so that true FHP predictions reflect all of the crucial factors involved in forecasting FHP projections. Edwards describes the procedures involved in the budget submission process for the FHP. The calculation for the annual budgeted cost for active duty units is as follows:

- (Primary Authorized Aircraft per sqdn) x (Crew Seat Ratio) = Allowed Crews per Squadron (18:17).
- (Allowed Crews) x (Aircrew Manning Factors) = Budgeted Crews per Squadron (18:18).
- (Budgeted Crews) x (Req. Hrs/Crew/Month) x (12 mos.) = Annual Flying Hours Required per Sqdn (18:18).
- (Ann. Flying Hrs Req. per Sqdn) x (Number of Sqdns) = Total Annual Flying Hours Required (18:18).
- (Total Ann. Flying Hrs Req.) x (Primary Mission Readiness percentage) = Annual Budgeted Flying Hours (18:18).
- (Ann. Budgeted Flying Hours) x (CPFH) = Annual Budgeted Cost, Active Duty forces (converted to "then-year" dollars) (18:18).

Each individual unit submits requirements through the chain of command during the budget cycle. The units are compiled and later combined with the other services inputs. Reviews are conducted until OSD and the Office of Management and Budget (OMB) agree on the funding items. Eventually, the submission for the FHP becomes part of the Federal Budget submission to Congress.

Edwards describes the relationship between the players involved in submitting the flight hour costing information as well as the CPFH determination. The office of the Special Assistant for the Flying Hour Program (N889E) collects flight information compiled into a database dating back to 1982. The Type Commanders submit data in Flight Hour Cost Reports (FHCR) that separate the information into actual obligations taken from each T/M/S by total number and cost pool (18:42). The database is updated monthly. To make budgeted CPFH projections, the Navy Comptroller's Office calculates a three-year running average of the actuals presented by the Type Commanders on their FHCR's (18:42). After a three-year average is determined, the appropriate escalator factors for inflation are applied and a projection is forecasted. Any unforeseen event which may cause an extraordinary increase or decrease in actual funding is normalized to smooth the data for future forecasting.

One of the problems with CPFH determination deals with the consistency with matters of "conflicting data, computations, and priorities which should be addressed" (18:43). Organizations use different databases, formulas, and priorities when calculating CPFH numbers. Type Commanders must get their figures in line with the community sponsor or persuade the FHP office to change the way computations are made (18:45). Variances of ten arise between what is planned and what actually occurs. A negative CPFH variance is often viewed as damaging to the organization. At the unit level, the Type Commanders have developed factors influencing CPFH calculations. Some of the major factors include:

- **Unit Location**- "The operating environment of a squadron can have a significant effect on flying expenses" (18:46).

- **Operational Tempo (OPTEMPO)**- Funding is approved on a yearly basis. The operational tempo may vary extremely from year to year depending on the flow of operations (18:47).

- **Type of Flying**- "Whereas the Training and Readiness Matrices provide guidance as to the *number* of flight hours each event requires, it does not specify the intensity of the evolution" (18:48).

- **Non-PMA and Support Flights**- A portion of the missions flown do not count towards aircrew readiness. These miscellaneous flight hours must be flown by the units (18:48).

- **Aircraft Maintenance Costs and Human Error**- The cost of aircraft maintenance and repair is a core constituent in the CPFH equation. The collection and reporting of maintenance requests and data submissions is a tedious process. Human error is likely to occur at some point in the process (18:49-50).

Army Flying Hour Program Methodology – Historical Problems

The Army's flying hour program has been criticized in the past due to poor performance. From fiscal years 1984 to 1988, the Army underflew its flying hour program by 35.6 percent, compared to an overflight by the Navy of 2.3 percent and underflight by the Air Force of 3.7 percent (19:3). Even though the Army has an aircraft fleet larger than the Navy, and as large as the Air Force, it did not have the headquarters personnel in place to effectively manage its flying hour program (19:3). The Navy and Air Force had at least six individuals committed to the program, while the Army dedicated only one (19:4).

The Army improved its execution rate in its flying hour program from 87.4 percent in fiscal year 1986 to 98.2 percent in fiscal year 1988 (19:4). Despite this positive trend, then Executive Secretary to the Defense Resources Board (Programming Phase) David C. Chu directed the Army to submit a report to the Deputy Secretary of Defense no later than 1 May 1989, outlining plans for improving the management and oversight of the Aviation Flying Hour Program (19:4). There was still serious doubt in the DoD whether the Army's procedures were strong enough to effectively plan and execute the flying hour program (19:4).

The under execution of the flying hour program can be traced to the different methodologies used to predict flying hour requirements for the different commands. The methods used by unit, major command (MACOM), and Department of the Army levels were all different, leading to inaccurate and inflated requirements. The inflated requirements were difficult, sometimes impossible, for the Army units to attain. This inability lead to the program being underflown.

At the unit level, the methodology was people and event based (19:16). A unit commander considered the number of aircrew personnel and aircraft assigned, mission support requirements, hours necessary for maintenance, and the status of aviation and supported unit training (19:12). Training requirements were broken out to include: qualification training, refresher training, mission training and initial as well as refresher night vision goggle training (19:13). The hours required for each type of training were multiplied by the number of personnel to come up with a total hourly requirement. Simulator time was deducted from this total to come up with a net total hourly requirement for training (19:13). The second part of a unit's flying hour program included unique mission support and operational requirements, such as: combat and combat support; executive and staff transport; aerial photography and mapping; research, development, test, and evaluation; aeromedical evacuation; and special missions unique to location and operation (19:13-14). The commander also estimated how much training could be accomplished collectively, as well as the hours required for maintenance activities (19:14-15). A model detailing the flying hour requirements for each helicopter in a unit was completed and forwarded to the MACOM responsible for funding allocation of the flying hour program. It should be pointed out again that the unit level methodology was people and event based in order to properly compare it to the methodology of the Department of the Army, which will be explained later.

The MACOM aviation officer relies on military judgment, expertise, and historical data to identify any deviations from what would be considered normal for a particular unit (19:19). The MACOM simply totaled requirements for all subordinate units and forwarded the data for all aircraft systems to the Department of the Army Headquarters for funding (19:19-20).

The Department of the Army based predictions for the flying hour requirements on the assumption that for every airframe there is one and only one crew available to fly the aircraft (19:23). The Department of the Army level was airframe based while the subordinate units, or actual users of the flying hours, was based on crews available and annual personnel turnover rates (19:23). Typically, aviation units are undermanned, leading to an overstatement of requirements with the airframe based methodology (19:23).

As much as possible, Army headquarters rolled up all the MACOM requests for flying hour funding into the Army's POM. Since there were still concerns about the accuracy of the requests, the Army staff responsible for the flying hour program recomputed the data using an Air OPTEMPO rate (19:25). This rate was an indicator that expressed flying hour requirements, resourcing levels, and execution in terms of flight per-crew per-month for rotary wing aircraft (19:25). This rate was applied to the active component's six combat commands (19:25). For example, the Air OPTEMPO rate for fiscal year 89 was 15.0 hours (19:25). For a unit with 21 aircraft assigned, the number of hours required for the year would be found by multiplying 15 hours by 21 aircraft by 12 months to arrive an annual requirement (19:25). Since the airframe based methodology assumes one aircrew per airframe, this lead to a requirement overstatement (19:26). After applying this procedure across the entire service, Army headquarters was seeking more hours than the individual units could fly (19:26). This situation gave the impression that the Army was either very inefficient in executing its flying hour program or very inaccurate at predicting requirements (19:26).

Chapter Summary

In this chapter, we document the implications of O&S costs on the total life-cycle cost of weapon systems and how these costs are increasing from year to year. The O&S regulations and instructions provided by the DoD are explained to show what the services are required to estimate and track in order to reduce the O&S costs associated with major acquisition programs, as well as systems currently in inventory. Along with the establishment of the VAMOSC system for each service, these efforts were intended to allow more accurate estimates of O&S costs and better budgeting. From the perspective of the Air Force and Navy, the efforts to develop predictive models for O&S costs have had mixed results. Due to the size and complexity of O&S costs, it was determined that forecasting a small segment of these costs, the CPFH program, would be a better approach. Some of the historical problems with the CPFH calculations for all services were detailed in this chapter to show differences that lead to inaccurate estimates. From these studies, we will develop a simple forecasting model that can be used quickly and, most importantly, is easily explained.

III. Methodology

Chapter Overview

This chapter provides an in-depth view of the methodology that will be applied in conducting the research of O&S costs for Air Force rotary winged aircraft. This chapter starts with a brief description of the AFTOC database and how data was collected for the empirical portion of this research. Then the chapter focuses on the details of the empirical breakout of the current FY03 OSD/CAIG format for O&S data for each Air Force Major Command (MAJCOM) by helicopter type. The next step is to compare the actual expenditures for CPFH to the budget submissions of each MAJCOM for each helicopter being studied. Then the actual CPFH expenditures are analyzed, exploring different forecasting options to determine which option best fits each series of data. After the best forecasting option is selected, the forecasted figures will be analyzed by comparing them with the actual expenditures. The results of this comparison are then analyzed by comparing them to the results of the actual expenditures compared to the budget submissions. The final step in this methodology is to apply the chosen forecasting method in developing a forecast for FY04 for each helicopter by MAJCOM.

Database

As mentioned in Chapter I, the AFTOC database will be used to gather the necessary data for the empirical O&S cost breakout analysis. The database includes all major Air Force systems. AFTOC was developed to satisfy Congressional O&S reporting requirements and contains all unclassified operating and support costs associated with a weapons system. The data contained in the AFTOC database is a collection of data from various sources. It contains actual expenditures from the Command On-line Accounting & Reporting System (COARS), fuel information from the Fuels Automated Management System (FAMS), and military personnel costs from the Military Personnel Data System E300Z report. Flying hour data and aircraft inventory data is extracted from the Reliability and Maintainability Information System (REMIS).

The necessary data for the O&S cost analysis is accessed through the AFTOC's Aircraft menu. Upon selecting CAIG New from the list of options, the User is taken to a search page that allows one to tailor the information to specific needs. From here drop down menus allow for the selection of the fiscal year of the data requested and the type of helicopter. The Level 1 CAIG Data is then downloaded in the format shown in Table 10.

Table 10. Level 1 CAIG Data

CAIG	CAIG Description	ACC	AETC	AFRC	ANG	PACAF
1.0	Unit Personnel	$64,598,964	$2,396,036	$26,548,595	$21,983,029	$14,600,701
2.0	Unit Operations	$10,574,936	$531,910	$3,707,830	$3,677,501	$2,799,767
3.0	Maintenance	$35,343,112	$11,442,069	$15,818,893	$11,024,078	$7,541,889
4.0	Sustaining Support	$4,241,899	$5,757	$1,438,623	$1,462,154	$62,411
5.0	Continuing System Improvements	$968,379				
6.0	Indirect Support	$11,424,934	$495,952	$5,826,519	$4,045,191	$1,780,029
Ttl	Total Expenditures	$127,152,224	$14,871,724	$53,340,459	$42,191,953	$26,784,796

When this data is retrieved, the User is given the option to download the data in a spreadsheet format. After selecting this option, the Level 1 CAIG Data and the necessary Cost per Operating Hour Data, as shown in Table 11 below, are both available in this format.

Table 11. Level 1 CAIG Data, Cost per Operating Hour

CAIG	CAIG Description	ACC	AETC	AFRC	ANG	PACAF
1.0	Unit Personnel	$6,526	$586	$5,443	$5,290	$5,990
2.0	Unit Operations	$1,068	$130	$760	$885	$1,149
3.0	Maintenance	$3,570	$2,796	$3,243	$2,653	$3,094
4.0	Sustaining Support	$429	$1	$295	$352	$26
5.0	Continuing System Improvements	$98				
6.0	Indirect Support	$1,154	$121	$1,195	$973	$730
Ttl	Total Expenditures	$12,845	$3,635	$10,937	$10,153	$10,988

This data was extracted from AFTOC for FY96-FY02 for each of the three helicopters being studied in order to create charts showing the costs as a percentage of the six CAIG cost categories for each fiscal year.

Empirical O&S Breakout

The Level 1 CAIG Data is used for the empirical O&S breakout. Each helicopter is evaluated from FY96- FY02 for each MAJCOM. Line charts are created showing the percentage that each of the six CAIG O&S Cost categories contributes to the entire cost for each fiscal year. An example of the charts is shown in Figure 14, which shows the empirical O&S breakout for the HH-60G in ACC. The percentage that each of the six categories contributes to O&S costs provides a means to compare the costs from year to year without the outside influence of inflation, because increases due to inflation will apply to all of the categories. For each MAJCOM the percentage breakout for each fiscal year will be compared to one another to analyze any trends that might be present.

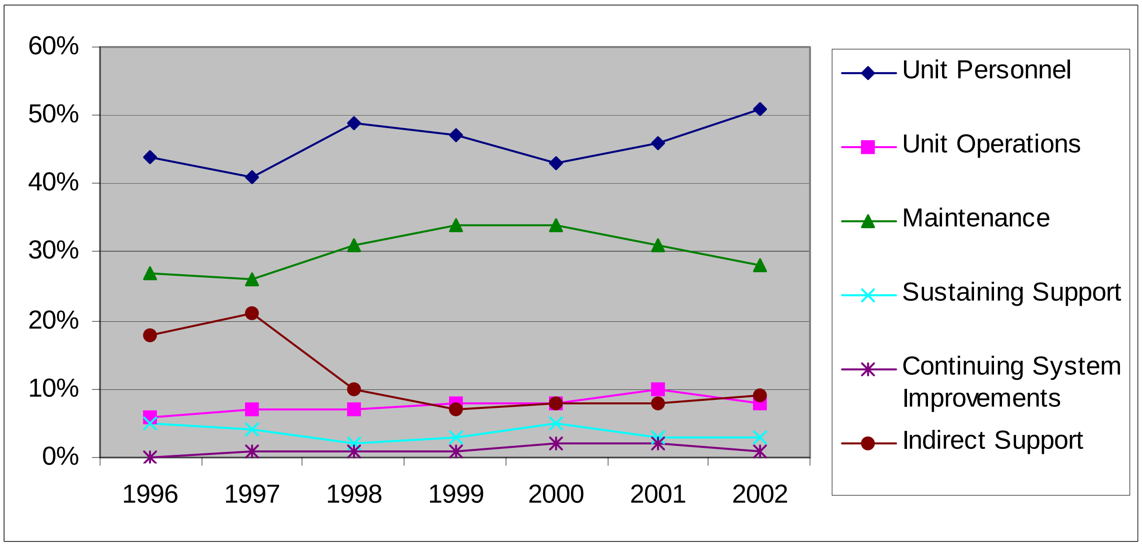

Figure 14. ACC HH-60G O&S COSTS

Actual Cost Per Flying Hour Versus Budget Submissions

The Air Force budgets the CPFH by MAJCOM. In this section the budget submissions of the CPFH of the helicopters for FY00-FY02 are evaluated for each MAJCOM by comparing them to the actual CPFH collected from the Government Accounting and Finance System (GAFS). A percent of error will be calculated for each comparison to be made by using the following formula:

$$\frac{\text{actual} - \text{budgeted}}{\text{actual}} \cdot 100 \qquad (1)$$

Using the percent of error will also place emphasis on the fact of being over or under the budgeted CPFH. This is important because it will show if a constant trend exists of either over or under budgeting by a MAJCOM. These errors will be summarized and then readdressed later when the forecasted CPFH is calculated and compared to the actual CPFH using the same formula.

Forecasting Options

For each MAJCOM being analyzed, three different forecasting techniques are used to evaluate the CPFH data extracted from GAFS. The three forecasting techniques being employed are a three-year moving average (MA3), the single exponential smoothing (SES) method, and the Holt's linear method. The MA3 uses the average of the past three observations to forecast for the current period. The number of data points in each average remains constant and includes the most recent observations (22:142). The formula for an MA3 is:

$$F_{t+1} = \frac{1}{3} \cdot \sum_{i=t-2}^{t} Y_i \qquad (2)$$

Where F_{t+1} is the current forecast, Y_i is the i^{th} observation, and t is the sequence order number of the observation before the current forecast. This method was selected for use in this research mainly for its simplicity, it is very easy to use and explain. The reason the order of the MA is three and not a higher order, such as five, which could possibly result in better forecasting, is due to the fact that the data series are so small and having a larger order would greatly restrict the number of figures forecasted. The main problem with this forecasting technique is that it does not handle trends very well and can take several periods before the forecast can catch up to a level shift in the data (22:146).

The SES method uses the following formula to forecast for the next period:

$$F_{t+1} = F_t + \alpha\left(Y_t - F_t\right) \qquad (3)$$

Where, F_t is the most recent forecast, $F_{t+1}$is the current forecast, Y_t is the most recent observation, and alpha is a weight value between 0 and 1. The new forecast is essentially the previous forecast plus an adjustment for the error of the previous forecast. The level of alpha dictates how much the previous forecast error is weighted, the weight of the previous error increases as alpha increases and becomes closer to 1. The Solver function within excel will be used to find the optimal value for alpha for each SES forecast. Initialization of all of the SES forecasts will be done by using the first observed value as the first forecast, so that $F_1 = Y_1$, and then proceeding from that point using the equation for SES. This forecasting technique was also selected for its simplicity of use and understanding. This method is good because as each new forecast uses the error of the previous forecast it ends up using a weighted scheme that uses decreasing weights as the observations get older (22:147). The downfall of this forecasting method is the same as the MA3 in that it doesn't handle trends very well and it will trail any trend in the actual data (22:148).

The Holt's linear method uses the following three formulas to forecast for the next period:

$$L_t = \alpha\ Y_t + \left(1 - \alpha\right)\left(L_{t-1} + b_{t-1}\right) \qquad (4)$$

$$b_t = \beta\left(L_t - L_{t-1}\right) + \left(1 - \beta\right)b_{t-1} \qquad (5)$$

$$F_{t+m} = L_t + b_t m \qquad (6)$$

Where L_t is an estimate of the level of the series at time t and b_t is an estimate of the slope of the series at time t, alpha and beta are smoothing constraints between 0 and 1, Y_t is the most recent observation, L_{t-1} is the last smoothed value, b_{t-1} is trend of the previous period, and m is the number of periods ahead to be forecasted (22:158). This method of forecasting was selected because unlike the previous two methods Holt's can handle trends within the data (22:158). This method is also useful because it can forecast more than one period ahead if needed. One of the cons of this method is that it can take the forecast a long time to overcome the influence of a shift in the opposite direction of the overall trend of the data (22:161). The main con of this method is the complexity involved in both using this method and explaining it to management that might not have a background in forecasting.

Four evaluation measures will be utilized for every forecast calculated. They are: The Mean Error (ME), the Mean Absolute Error (MAE), the Mean Percent Error (MPE), and the Mean Absolute Percent Error (MAPE). With all four of these evaluation measures it is favorable for the forecasting method to report the least amount of error possible. The ME is simply the average of all of the error terms and uses the following formula:

$$ME = \frac{1}{n} \cdot \sum_{t=1}^{n} e_t \qquad (7)$$

Where e_t is error (observation – forecast), and n are the number of observations.

However, the ME is likely to be small since positive and negative errors tend to offset one another (22:43). The MAE compensates for this bias by first taking the absolute value of each error term and then taking the average. The formula for MAE is:

$$\mathrm{MAE} = \frac{1}{n} \cdot \sum_{t=1}^{n} |e_t| \tag{8}$$

The MPE is calculated by finding the percent of error for each term and then taking the average of those terms. The formula for MPE is:

$$\mathrm{MPE} = \frac{1}{n} \cdot \sum_{t=1}^{n} PE_t \tag{9}$$

Where PE_t is the percentage error [(actual-forecast)/actual]*100.

As with the ME, the MPE allows terms to offset one another. The MAPE compensates for the bias of MPE by taking the absolute value of each percent of error and then taking the average. The formula for MAPE is:

$$\mathrm{MAPE} = \frac{1}{n} \cdot \sum_{t=1}^{n} |PE_t| \tag{10}$$

These four summary statistics measure the goodness of fit of the model to the historical data (22:45). All four statistics will be evaluated as a whole because all of these measures together can tell a more complete story of goodness of fit than any one of them individually.

Actual Cost Per Flying Hour Versus the Forecast

After the forecast has been evaluated and the method of forecasting has been chosen for each time series being studied, the forecasted CPFH for FY00-FY02 will be compared to the actual CPFH using the following percent of error formula:

$$\frac{\text{actual} - \text{forecasted}}{\text{actual}} \cdot 100 \qquad (11)$$

These percent of errors will then be compared to the percent of errors computed when evaluating the accuracy of the budgeted CPFH.

Forecasting For FY04

The final step of this research is to provide a forecast of the CPFH for FY04. This will be accomplished upon the availability of the FY03 CPFH data. The method chosen for each MAJCOM flying a particular helicopter in the Forecasting Options section is utilized to make the FY04 forecast. The FY03 data points are added to each applicable time series, the alpha and beta will be recalculated using solver if applicable and then the forecast for FY04 CPFH is calculated.

Chapter Summary

This chapter provided a roadmap for conducting the necessary research of this thesis. The methodology was provided in a logical order in which the research will be conducted. The figures provide insight into the AFTOC database and what to expect for the Empirical O&S Breakout section of Chapter IV. The formulas and their descriptions provide an in-depth look at the statistics being used to evaluate not only the forecast, but also the budget submissions of each MAJCOM. Following the steps laid out in this chapter will provide answers to the research questions/objectives listed in Chapter I.

IV. Results and Discussion

Chapter Overview

This chapter provides the results of the analysis performed for each helicopter being studied. The first helicopter examined was the MH-53J/M Pave Low III/IV. It was analyzed using the methodology laid out in Chapter III before moving on to the next helicopter. Then the chapter focuses on the UH-1N Helicopter, and ends with the last helicopter examined, the HH-60G Pave Hawk.

MH-53J/M Pave Low III/IV

Before reporting on the analysis for this helicopter it is important to reiterate the point that the MH-53 is handled differently by the financial community than the other helicopters studied in this research. The Air Force normally budgets and tracks CPFH by MAJCOM. Two MAJCOMs currently fly this helicopter, Air Force Special Operations Command (AFSOC) and Air Education and Training Command (AETC). However, the budgeting and subsequent CPFH reporting is completed by AFSOC and is not reported or tracked by separate MAJCOMs. This unique situation can be simplified by analyzing the O&S data in total, which will avoid problems that can arise in AFTOC by allocating certain expenses based on percentage of flying hours.

Empirical O&S Breakout

The percentage breakout of historical cost by CAIG category for the MH-53 is typical. Looking at the CAIG definitions of these categories one would expect the biggest portions of overall cost of a weapons system to come from Personnel, Maintenance, and Indirect Support. This is clearly the case with the MH-53 as can be seen in Figures 15 below.

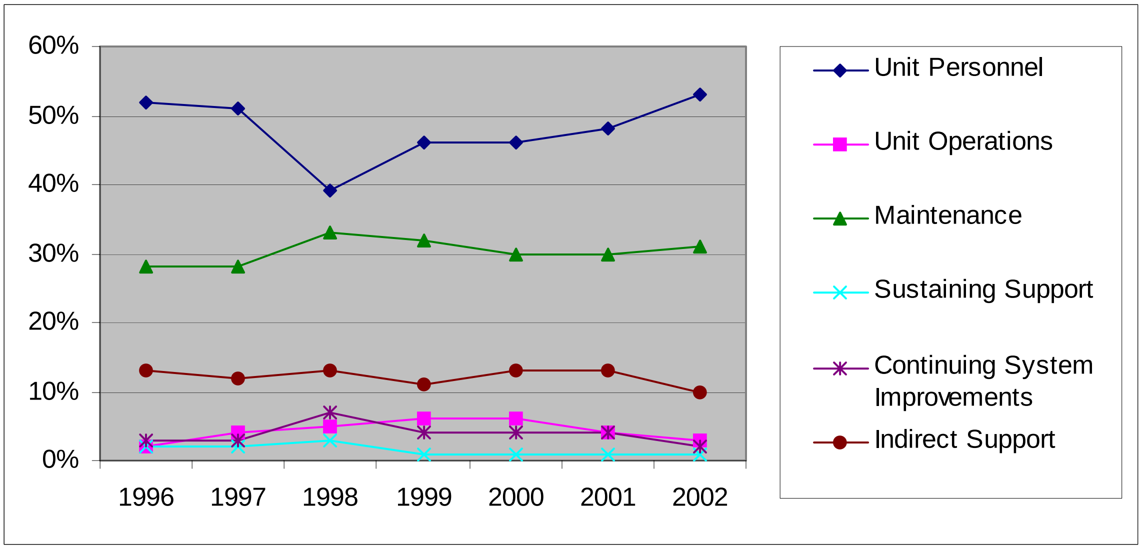

Figure 15. MH-53J/M Total O&S Costs

Consistently, from FY96 through FY02, the largest cost categories are the ones mentioned above. These three categories make up 85 to 94 percent of the total cost in each fiscal year. The only year that stands out from the rest is FY98; Unit Personnel costs drop below 40 percent. This is not due to the fact that the overall cost of Unit Personnel was lower than in previous years, in fact it was almost exactly the same amount as it was in FY97. Unit Personnel costs dropped as a percentage of the whole in FY98 due to the fact that both Continuing System Improvements costs increased from $5.5M to $14.3M and Maintenance costs increased from $44.9M to $69.3M from FY97 to FY98 while the Unit Personnel cost remained virtually unchanged. I believe the main reason for these increases in Continuing System Improvements and Maintenance are because of the electronic upgrades that were installed in FY98. These upgrades were called the Interactive Defensive Avionics System/Multi-Mission Advanced Tactical Terminal (IDAS/MATT), which equipped the helicopter with color digital night-vision capability and provided a threat warning system upgrade.

Actual CPFH vs. Budgeted Submissions

The actual CPFH figures were compared to the budgeted submissions for the MH-53J/M for FY00 to FY02 using the formula explained in Chapter III. The results in table 12 below show that the budgeted figures in FY00 and FY01 were within 11 percent of what the actual costs were. However, in FY02 the reported budget submission was more than 25 percent higher than the actual CPFH in that year giving it a negative variance.

Table 12. MH-53J/M Budget Variances

FY00	FY01	FY02
5.969448	10.82603	-26.6877

Forecasting Options

The first step of forecasting is to graph the data as in Figure 16. This graph shows the positive growth the Air Force has experienced with the CPFH of the MH-53J/M.

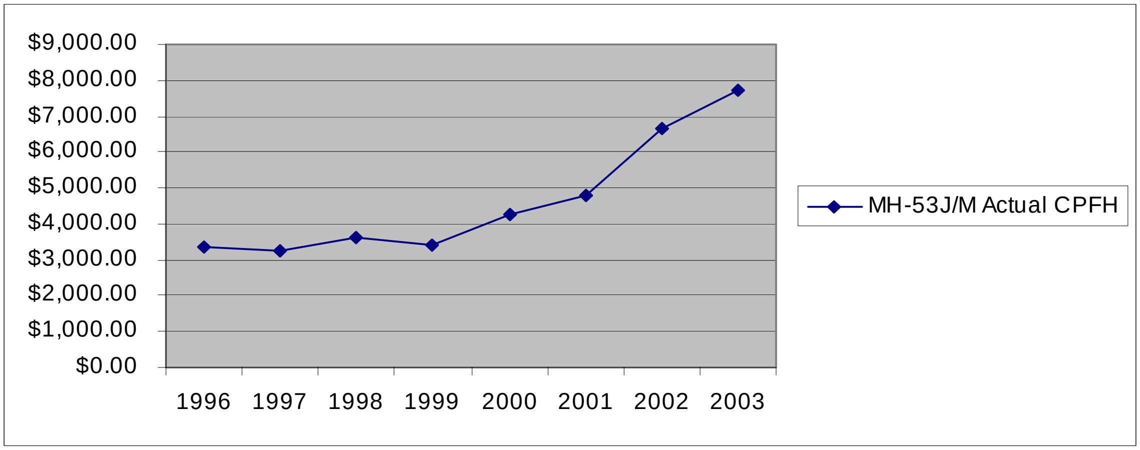

Figure 16. MH-53J/M Pave Low III/IV CPFH

It seems a reasonable assumption that forecasting techniques that do not handle such trends will perform poorly against forecasting techniques that do consider such trends. Of the three forecasting techniques evaluated, the Holt's method proved to be the best method. Table 13 below shows the evaluation measures that were calculated for the MH-53 J/M.

Table 13. MH-53J/M Evaluation Measures

	ME	MAE	MPE	MAPE
MA3	1101.25000	1101.25000	19.87532	19.87532
SES	766.75000	861.25000	13.41062	16.18189
Holt's	502.88550	619.32966	8.61901	12.03379

Initially even the Holt's measurements look high, but if the data series in Figure 16 is divided and evaluated from FY96 to FY99 and then evaluated from FY00 to FY03, it is obvious how stationary the data is in the first four years. From one year to the next during this period the highest jump in CPFH is $350, this is small compared to the changes in the rest of the series. In FY00 to FY02 the series has a very strong positive trend, the increases in CPFH in these fiscal years are $845, $539, and $1,872 respectively. From FY99 to FY02, there was almost a 100 percent increase in the CPFH for the MH-53J/M, from $3,410 to $6,666.

Actual CPFH vs. Forecasted

The forecasted CPFH were compared to the actual CPFH in the same manor and in the same FYs as the budgeted CPFH were earlier, this will provide a basis for comparison. The forecasted variances are shown in Table 14.

Table 14. MH-53J/M Forecasted Variances

FY00	FY01	FY02
16.89777	5.423446	18.9769

The most obvious thing about these figures is that none of the variances are negative; this means that for these three years the forecasted CPFH never exceeded the actual CPFH. When comparing these figures to the budget variances in Table 12, the FY00 forecasted variance is higher than the budget variance, but in FY01 and FY02 the forecasted variances are better than the budget variances by 5 and 8 percent respectively.

Forecasting for FY04

The FY03 actual CPFH figure of $7,706 was added to this time series and then Solver was ran to ensure that the alpha and beta values used were optimized to allow Holt's method to provide the best forecast possible for FY04. The FY04 forecasted figure was $9,215, and the MAPE calculated was 9.63647. By adding this single data point the MAPE improved by more than two percent.

UH-1N Helicopter

The CPFH data of three MAJCOMs flying the UH-1N was analyzed and forecasted. The first MAJCOM assessed was AETC, then the data from Air Mobility Command (AMC) was analyzed and forecasted, and finally Pacific Air Forces Command (PACAF) data was analyzed. The entire analysis and forecasting methodology was completed for each MAJCOM to keep their data separate from the other MAJCOMs being studied.

AETC – Empirical O&S Breakout

Figure 17 shows the percentage of O&S cost by CAIG category for the UH-1N in AETC.

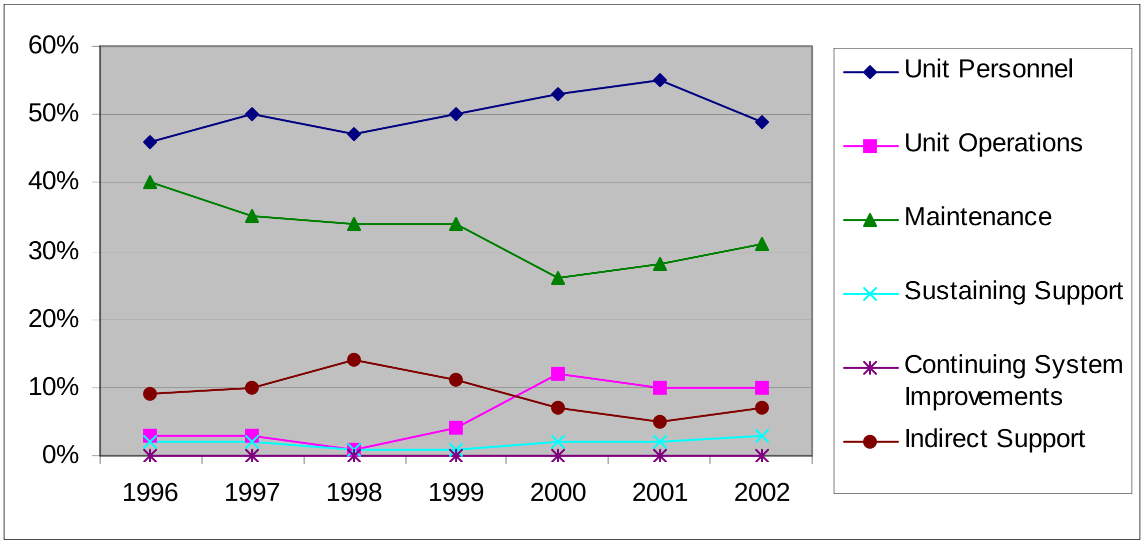

Figure 17. UH-1N AETC O&S Costs

This chart shows that the main cost drivers of O&S cost in AETC for this weapons system are Unit Personnel and Maintenance, making up between 79 to 86 percent of the total cost. The rest of the cost is absorbed in Unit Operations, Indirect Support, or Sustaining Support. The chart also shows that the percentage of total cost of Continuing Systems Improvements is zero in all fiscal years. The most likely reason for this cost category to have nothing reported could be that all of the modifications taking place to the UH-1N were part of the pre-planned product improvement program placed on contract during the initial acquisition of the system. If this were the case then those costs would not be accounted for in Continuing Systems Improvements.

AETC – Actual CPFH vs. Budgeted Submissions

Table 15 below shows the UH-1N budget variances for AETC. In FY00 the variance is negative meaning that the budgeted figure was more than the actual in that year; but the budgeted figure was within 10 percent of the actual CPFH. The only variance beyond the acceptable range in this table is the high variance in FY01, because the variance for FY02 shows that the budgeted and actual CPFH cost were almost the same.

Table 15. AETC UH-1N Budget Variances

FY00	FY01	FY02
-7.27848	20.02762	0.86741

AETC – Forecasting Options

The time series for AETC in Figure 18 appears unstable, but when the scale is taken into consideration it is a lot better than initially thought. Except for the FY96 CPFH figure, almost all of the changes in the series are approximately 10 to 15 percent.

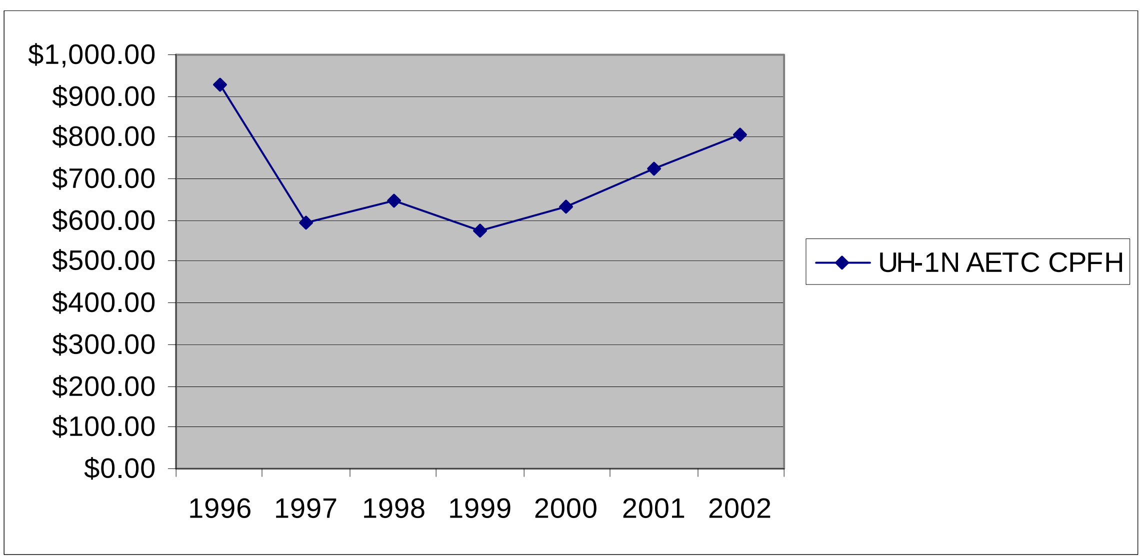

Figure 18. UH-1N AETC CPFH

Of the three forecasting techniques evaluated, Holt's easily outperformed the other two methodologies. The summary statistics for this time series are shown in Table 16 below.

Table 16. AETC UH-1N Evaluation Measures

	ME	MAE	MPE	MAPE
MA3	37.39417	110.49083	3.43172	16.11947
SES	43.16040	78.05040	5.22008	11.27611
Holt's	29.77480	30.13770	4.43836	4.48334

Both the MAE and the MAPE for the Holt's forecast were twice as good as the MAE and MAPE for the other two forecasts.

AETC – Actual CPFH vs. Forecasted

The variances for the forecasted figures for AETC are summarized in Table 17.

Table 17. AETC UH-1N Forecasted Variances

FY00	FY01	FY02
10.12658	7.734807	-0.12392

These variances are all within 10 percent of the actual CPFH figure, and show that the Holt's forecast was a good fit for this data. Compared to the budget variances in Table 15, the FY00 forecasted variance is slightly higher, but the variance is positive, meaning that the forecasted figure was less than the actual CPFH. The FY01 forecasted variance is more than twice as good as the budget variance, and in FY02 the forecasted figure was almost equal to the actual CPFH figure.

AETC – Forecasting for FY04

The FY03 actual CPFH figure of $853 was added to this time series and then solver was ran to ensure that the alpha and beta values used were optimized to allow Holt's method to provide the best forecast possible for FY04. The FY04 forecasted figure was $912, and the MAPE calculated was 4.67774. When this data point was added the MAPE increased two-tenths of a percent. The next MAJCOM to be analyzed and forecasted for the UH-1N is AMC.

AMC – Empirical O&S Breakout

Figure 19 shows the empirical breakout of the CAIG O&S cost categories for AMC.

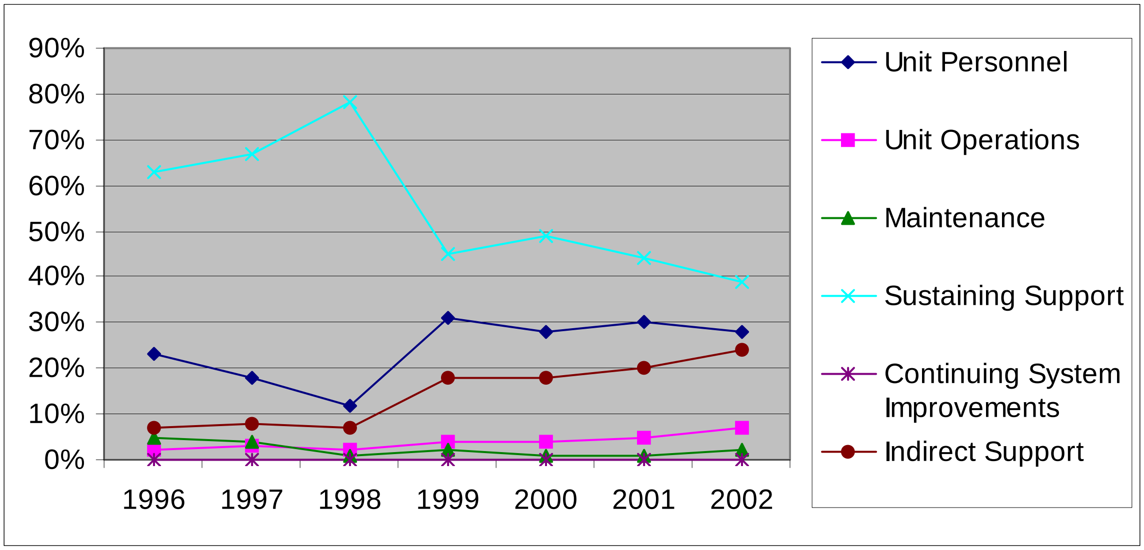

Figure 19. UH-1N AMC O&S Costs

The most notable difference between this chart and the other empirical charts is the high percentage of total O&S cost that is attributed to Sustaining Support within AMC. The first explanation of this could be that these costs have been captured in the wrong category, but this could also be the product of the way in which AMC conducts business. The large percentage of Sustaining Support could be due to the fact that AMC is capturing the reimbursements for the use of their assets by other units in this category. All of the other cost categories seem consistent to one another in their changes from year to year, except Continuing Systems Improvements, which is again zero in all years.

AMC – Actual CPFH vs. Budgeted Submissions

The budget variances of AMC for the UH-1N are shown in Table 18 below. They show that in FY00 the actual CPFH figure was higher than the budgeted figure in that year giving it a variance that is just outside of the desired 10 percent goal. That year is followed by the FY01 variance that is more favorable, but in FY02 the budgeted figure is more than 25 percent less than the actual CPFH.

Table 18. AMC UH-1N Budget Variances

FY00	FY01	FY02
13.24627	-2.74725	25.17321

AMC – Forecasting Options

The time series for AMC in Figure 20 looks very stable from FY96 to FY01 with just a slight positive trend. However, in FY02 the stability of this time series is weakened when the CPFH cost increases by almost 60 percent over the previous year. This large increase, from $546 to $866 per flying hour, explains why the budget variance is so high for FY02, and will also prove more difficult to forecast accurately.

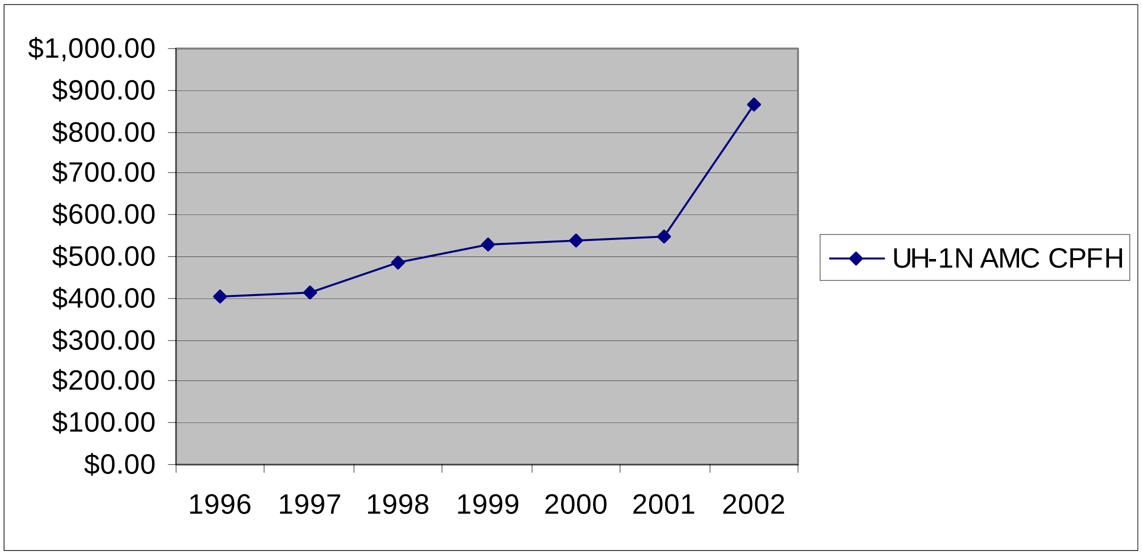

Figure 20. UH-1N AMC CPFH

The best forecasting method for this time series was again Holt's method, however this could possibly change with the addition of the FY03 CPFH figure. The summary statistics for AMC are listed in Table 19 below.

Table 19. AMC UH-1N Evaluation Measures

	ME	MAE	MPE	MAPE
MA3	127.72667	127.72667	18.02205	18.02205
SES	94.77250	94.77250	12.02436	12.02436
Holt's	81.57250	85.17750	9.79777	10.46452

The Holt's statistics are good, especially considering that 85 to 95 percent of these error terms are attributed to error terms for FY02 in which the 60 percent increase in cost occurred. This also explains the high forecasting variance in this same year.

AMC – Actual CPFH vs. Forecasted

The forecasted variances for AMC are given in Table 20. They are what should be expected when trying to forecast for this time series.

Table 20. AMC UH-1N Forecasted Variances

FY00	FY01	FY02
-0.74627	-0.73260	35.33487

The FY00 and FY01 forecasted variances are almost nonexistent because there is very little change in the data during these years and the error is very small. The FY02 variance is extremely high, however, this does not mean that the forecasting of FY04 will hold to this same pattern. It does mean that more work will have to be done once the FY03 actual CPFH figure is added to this series. It will not just be a matter of adding the FY03 figure and then forecasting for FY04. Once the figure is added all three forecasting options will be reevaluated to determine the best method in forecasting for FY04.

AMC – Forecasting for FY04

The FY03 actual CPFH figure of $782 was added to this time series and then solver was ran to ensure that the alpha and beta values used were optimized to allow Holt's method to provide the best forecast possible for FY04. The FY04 forecasted figure was $796, and the MAPE calculated was 9.18981. By adding this single data point the MAPE improved by 1.5 percent. This section ends with the final UH-1N MAJCOM analyzed and forecasted for, PACAF.

PACAF – Empirical O&S Breakout

The empirical O&S breakout in Figure 21 below shows that every cost category appears stable from FY96 to FY00 as a percentage of the total O&S cost. It appears that Unit Personnel costs increase dramatically starting in FY01, but it actually only increased slightly in total cost. The main cause of this percentage increase to Unit Personnel is that Unit Operations had decreased in total cost and Maintenance costs experienced a slight decline in costs. This causes Unit Personnel to make a much larger percentage of the smaller total cost in FY01 and FY02.

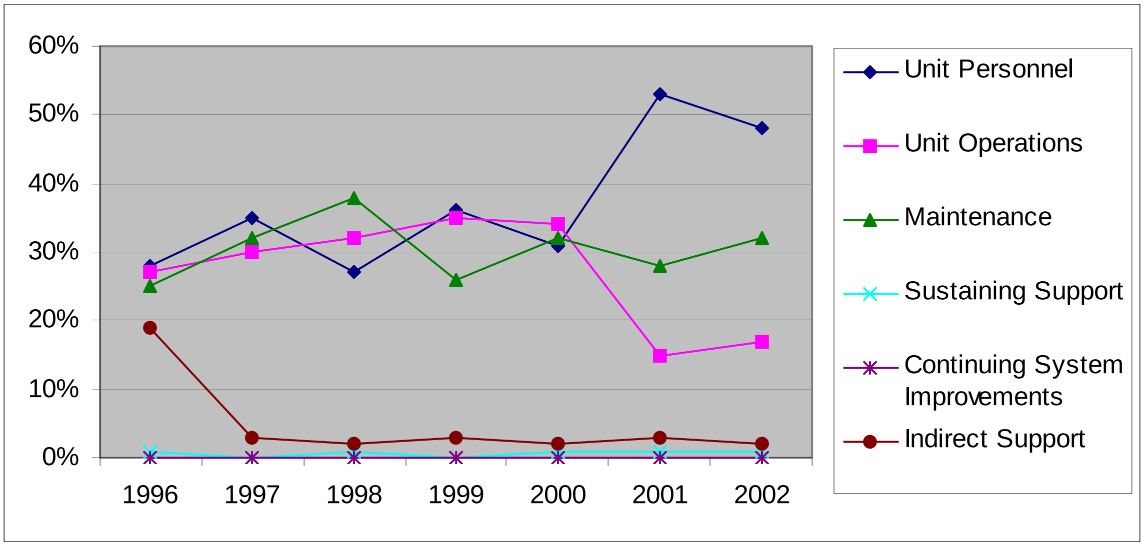

Figure 21. UH-1N PACAF O&S Costs

In FY96 the Unit Personnel, Unit Operations, and Maintenance cost categories make up 80 percent of the total cost. In FY97 to FY02 these same categories make up 96 to 97 percent of the total cost. Again, with the UH-1N, this time in PACAF, we see that the total value for Continuing System Improvements from FY96 to FY02 is zero.

PACAF – Actual CPFH vs. Budgeted Submissions

Table 21 shows the budget variances for the UH-1N in PACAF. These figures start in FY00 with a large negative variance. Then in FY01 the negative variance is just within 10 percent of the actual CPFH. The final variance in FY02 shifts in the opposite direction and becomes an extremely large positive variance.

Table 21. PACAF UH-1N Budget Variances

FY00	FY01	FY02
-14.059	-9.81595	33.58116

The reason for these questionable variances, as well as very similar forecasted variances, will become clearer as the time series is evaluated in the next section.

PACAF – Forecasting Options

Figure 22 shows how volatile the CPFH time series is for PACAF. There is a steep positive upward trend from FY96 to FY98 in which the CPFH figure grows about 60 percent. Then there is a large negative trend from FY98 to FY00 in which a 55 percent decrease is experienced. From FY99 to FY01 the data seems to be more stable, until the 65 percent increase from FY01 to FY02.

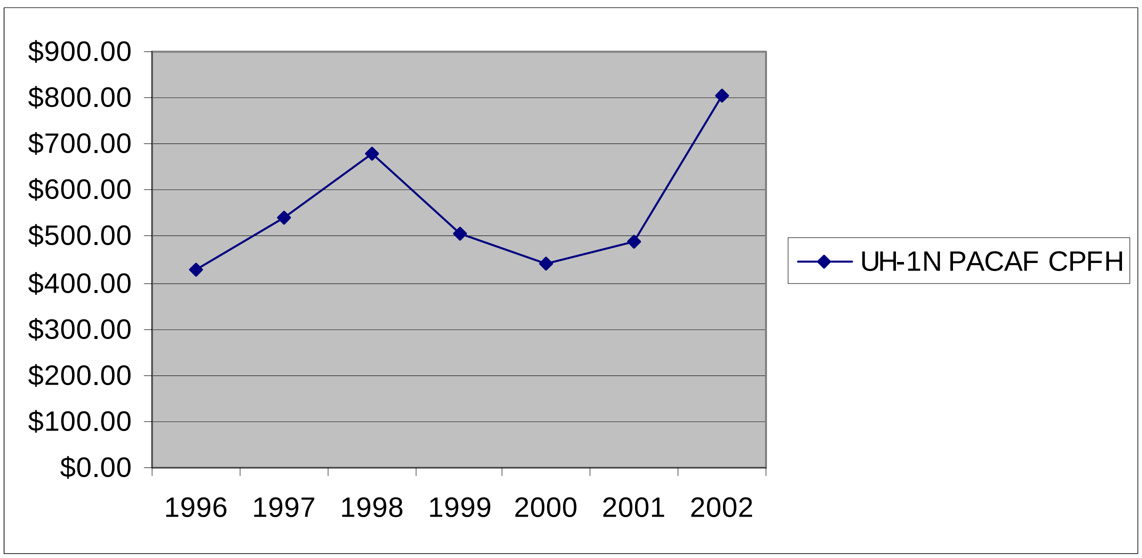

Figure 22. UH-1N PACAF CPFH

Because this time series deals with multiple drastic trends, Holt's method will generally not do a very good job of forecasting for it. This was definitely the case here and the SES method was chosen having the best evaluation statistics of all three methods. The summary statistics for the SES method in Table 22 are good considering the time series from which they were taken. The fluctuation between the ME and the MAE, and between the MPE and the MAPE are due negative errors off setting positive errors in both the calculations for the ME and MPE.

Table 22. PACAF UH-1N Evaluation Measures

	ME	MAE	MPE	MAPE
MA3	24.06417	139.70750	-2.33573	22.63892
SES	62.08510	95.69620	5.98381	13.57675
Holt's	-38.80783	173.31283	-13.58446	30.25939

Taking the absolute value of the errors before calculating the MAE and MAPE combats these cancellations of errors.

PACAF – Actual CPFH vs. Forecasted

Table 23 below lists the forecast variances for PACAF. These figures show that in FY00 the negative forecast variance is almost exactly the same as the budget variance from Table 24. The FY01 forecast variance is good, but this mainly has to do with the fact that the data is stable from FY99 to FY01. Looking at FY02 and we see a forecast variance that is even higher than the large budget variance in the same year. This again will call for more forecasting work to be accomplished as the FY03 CPFH is added to this time series to ensure that the best forecast is made for FY04.

Table 23. PACAF UH-1N Forecasted Variances

FY00	FY01	FY02
-14.7392	-0.6135	39.15737

This positive forecast variance in FY02 is exactly what one would expect to see after looking at the time series in Figure 22.

PACAF – Forecasting for FY04

The FY03 actual CPFH figure of $794 was added to this time series and then solver was ran to ensure that the alpha value used was optimized to allow the SES method to provide the best forecast possible for FY04. The FY04 forecasted figure was $616, and the MAPE calculated was 16.66245. By adding this single data point the MAPE increased by 3 percent, but this is understandable looking back at the plot of actual CPFH data in Figure 22. If the FY03 data point were added to the graph it would be clear that the series would experience another direction change in the trend. The analysis will now switch to the final Air Force helicopter being evaluated and forecasted for, the HH-60G.

HH-60G Pave Hawk

The CPFH data of four MAJCOMs flying the HH-60G was analyzed and forecasted in this section. The first MAJCOM assessed was AETC, and then the data from Air Combat Command (ACC) was analyzed and forecasted. This was followed by analyzing and forecasting for the Air Force Reserve Command (AFRC) and then the last MAJCOM to be evaluated will be Pacific Air Forces Command (PACAF).

AETC – Empirical O&S Breakout

The empirical O&S breakout for AETC in Figure 23 shows that Maintenance costs is the biggest driver for this MAJCOM. One explanation could be that a large portion of the Maintenance cost in AETC is due to contractor maintenance that is properly captured in this cost category. For FY96 through FY02 Maintenance and Unit Personnel account for 77 to 93 percent of the total O&S cost.

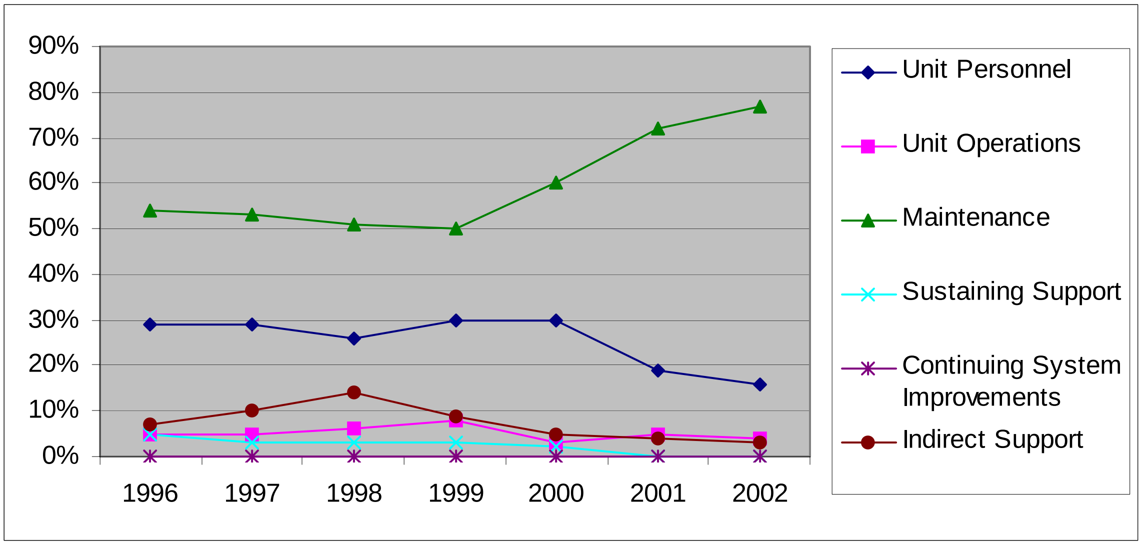

Figure 23. HH-60G AETC O&S Costs

AETC – Actual CPFH vs. Budgeted Submissions

The budget variances for FY00 to FY02 are listed in Table 24 below. The variances for FY00 and FY02 are both within 4 percent of the actual CPFH figures in those years, the only downfall that they might have is that both variances are negative which means that AETC over-budgeted in both these years. The FY01 variance on the other hand is very high; the budgeted figure was more than 25 percent less than the actual CPFH.

Table 24. AETC HH-60G Budget Variances

FY00	FY01	FY02
-3.66492	27.96436	-3.62047

AETC – Forecasting Options

The CPFH data for FY96 to FY00 in Figure 24 below shows a stable data set from FY96 to FY99 with a slight negative trend from FY97 to FY99. Then from FY99 to

FY02 the data has a sharp positive trend. During this three-year period the CPFH rose nearly 54 percent from $1,044 to $1,602

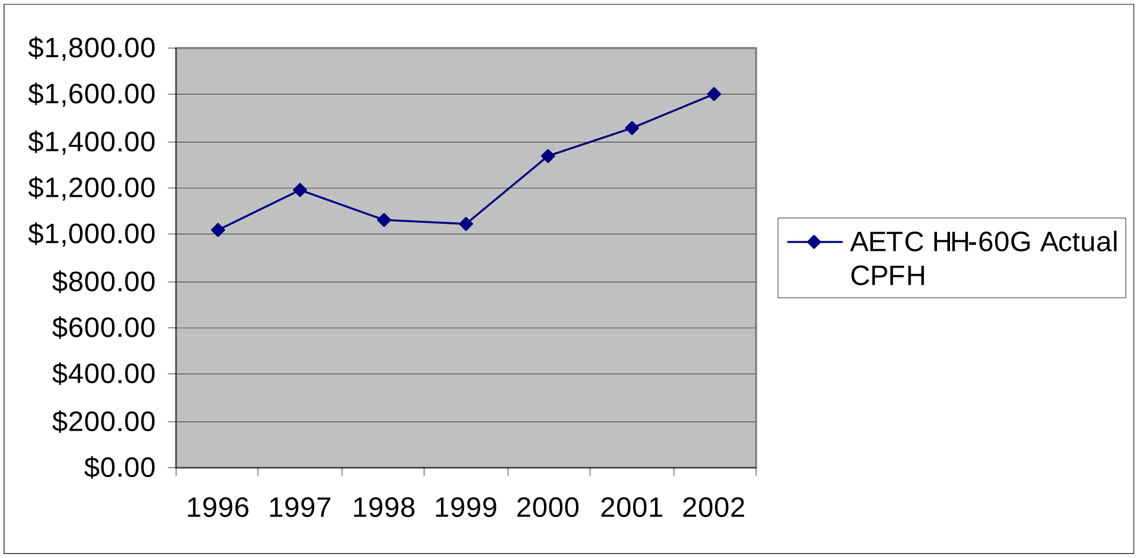

Figure 24. HH-60G AETC CPFH

Holt's method was selected as the best forecasting method for this time series. The summary statistics for AETC are in Table 25 below. The Holt's method statistics are very low and provide credit to how well the Holt's method forecasted this data set.

Table 25. AETC HH-60G Evaluation Measures

	ME	MAE	MPE	MAPE
MA3	206.28333	229.57500	13.70052	15.93247
SES	134.73000	144.66500	9.33748	10.28950
Holt's	63.46287	93.68374	4.83761	6.90956

AETC – Actual CPFH vs. Forecasted

The forecasted variances in Table 26 below are what one would expect after looking at the plot of the data in Figure 24 and using Holt's method. The variance in FY00 is not within the desired range, but it is understandable when one looks at how the data jumped in FY00 after a three year negative trend. Taking that into consideration, the next variance is small, especially when compared to the budget variance for the same year (see, Table 24). The forecasted variance in FY02 is a little misleading, the forecasted figure was not the exact same as the actual CPFH for that year, it was off by 82 cents.

Table 26. AETC HH-60G Forecasted Variances

FY00	FY01	FY02
23.41062	-4.11241	0

AETC – Forecasting for FY04

The FY03 actual CPFH figure of $2,420 was added to this time series and then solver was ran to ensure that the alpha and beta values used were optimized to allow Holt's method to provide the best forecast possible for FY04. The FY04 forecasted figure was $2,6191,234, and the MAPE calculated was 11.49583. By adding this single data point the MAPE increased by 4.5 percent. The next MAJCOM that will be evaluated and forecasted for is ACC.

ACC – Empirical O&S Breakout

The empirical O&S breakout for ACC in Figure 25 is more status quo than the empirical O&S breakout from AETC in Figure 23. Here, Unit Personnel is the dominant cost category in each fiscal year. All cost categories are populated for the first time in this particular area of the research. Once again, Unit Personnel, Maintenance, and the Indirect Support cost categories account for 85 to 90 percent of the total cost.

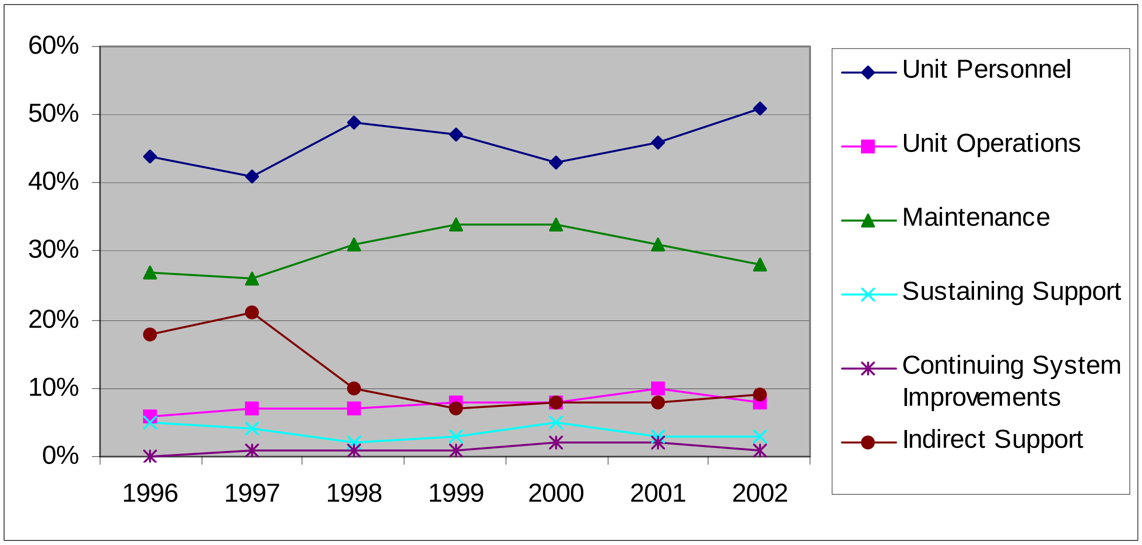

Figure 25. HH-60G ACC O&S Costs

ACC – Actual CPFH vs. Budgeted Submissions

The budget variances for the HH-60G for ACC are presented in Table 27 below. One immediate point to be made is that all three variances are negative, meaning that the budgeted CPFH figure was larger than the actual CPFH figure in all three years. The variances for both FY00 and FY01 are very favorable, however, the FY02 variance is the highest variance experienced in this research.

Table 27. ACC HH-60G Budget Variances

FY00	FY01	FY02
-8.23953	-7.76004	-68.254

ACC – Forecasting Options

The CPFH time series for ACC in Figure 26 below shows that the series is very stable from FY97 to FY00, experiencing a slight positive trend from FY98 to FY00. Then in FY01 the trend switches directions and is 25 percent less than the FY00 CPFH figure. This negative trend then continues in FY02.

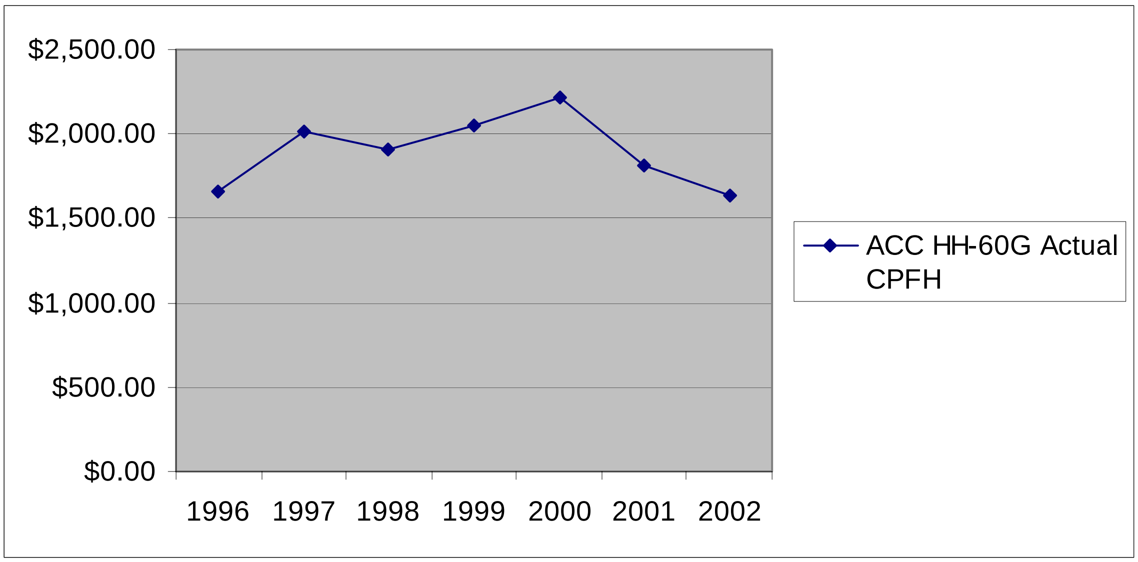

Figure 26. HH-60G ACC CPFH

Holt's method was the best of the three methods at forecasting for this time series. The evaluation measures can be seen in Table 28 below. Although this series of data experiences many directional changes, the MPE and the MAPE for the Holt's method are very low. Most of the error present in the MAPE, 86 percent of it, is accounted for because of the change in direction of the trend in FY01.

Table 28. ACC HH-60G Evaluation Measures

	ME	MAE	MPE	MAPE
MA3	-54.29583	262.56250	-4.44217	14.17511
SES	150.59526	240.11025	6.37107	11.83727
Holt's	-110.94330	166.50355	-6.33662	8.93591

ACC – Actual CPFH vs. Forecasted

The forecasted variances in Table 29 are also victim of the shift that occurred in the series in FY01. However, the variance for FY00 is les than 3 percent and the variance for FY02 is zero because Holt's method was able to forecast the actual CPFH. There is no room for improvement for the FY02 forecasted variance of zero, and comparing it to the budgeted variance of -68.254 from Table 27 lends credit to how powerful a tool these forecasting techniques can be.

Table 29. ACC HH-60G Forecasted Variances

FY00	FY01	FY02
2.701486	-30.5449	0

ACC – Forecasting for FY04

The FY03 actual CPFH figure of $3,440 was added to this time series and then solver was ran to ensure that the alpha and beta values used were optimized to allow Holt's method to provide the best forecast possible for FY04. The FY04 forecasted figure was $4,234 and the MAPE calculated was 18.61453. This MAPE increased by 9.7 percent, and is almost unacceptable. However, the increase in MAPE can be directly attributed to the 3-year negative trend that precedes this 48 percent increase in CPFH. The next MAJCOM that will be evaluated and forecasted for is AFRC.

AFRC – Empirical O&S Breakout

The empirical O&S breakout for AFRC in Figure 27 below is very similar to what was seen with ACC in Figure 25. Consistently from FY96 to FY02, Unit Personnel is the largest cost category representing 49 to 60 percent of the total cost. The top three cost categories are Unit Personnel, Maintenance, and Indirect Support. These three cost categories account for 90 to 93 percent of the total O&S cost in each fiscal year.

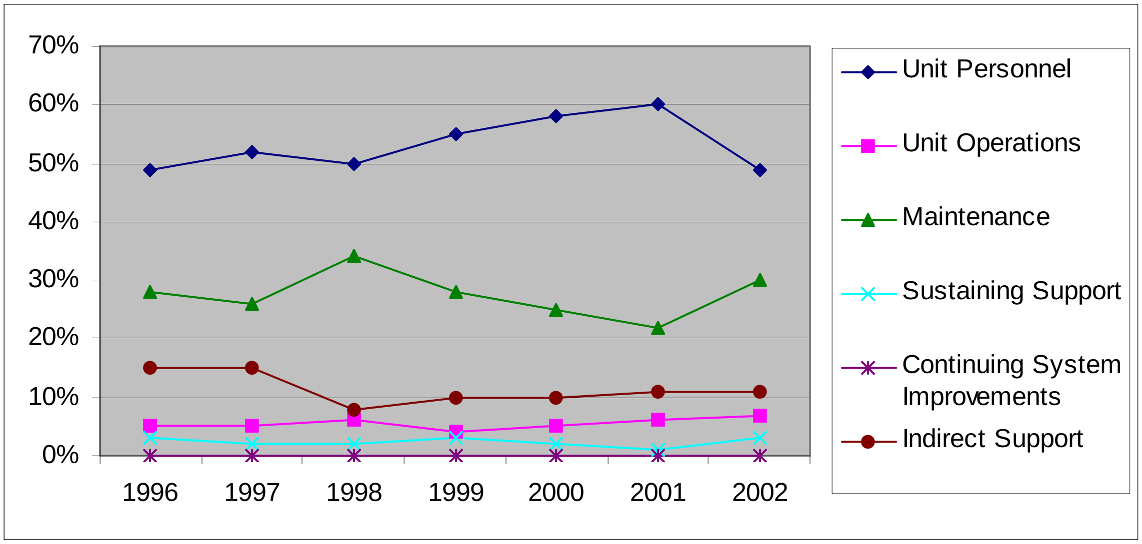

Figure 27. HH-60G AFRC O&S Costs

AFRC – Actual CPFH vs. Budgeted Submissions

The budget variances for AFRC in Table 30 start with a low variance in FY00. This is followed by a variance just over 10 percent in FY01, and then in FY02 the variance is unacceptably greater than 20 percent. It is hard to explain the large positive variance in FY02, especially with the negative variances from FY00 and FY01, and the fact that those negative variances increase from FY00 to FY01. The reason for this large variance will become a little clearer as the time series is explored in the next section.

Table 30. AFRC HH-60G Budget Variances

FY00	FY01	FY02
-2.81074	-10.4969	23.80755

AFRC – Forecasting Options

Figure 28 below shows the time series of CPFH for AFRC. The series is stable in FY96 to FY99 with a positive trend. From FY99 to FY01 the data remains virtually constant. This period of almost no change is then followed by a sharp change in FY02 where the CPFH increased by over 50 percent from the previous year.

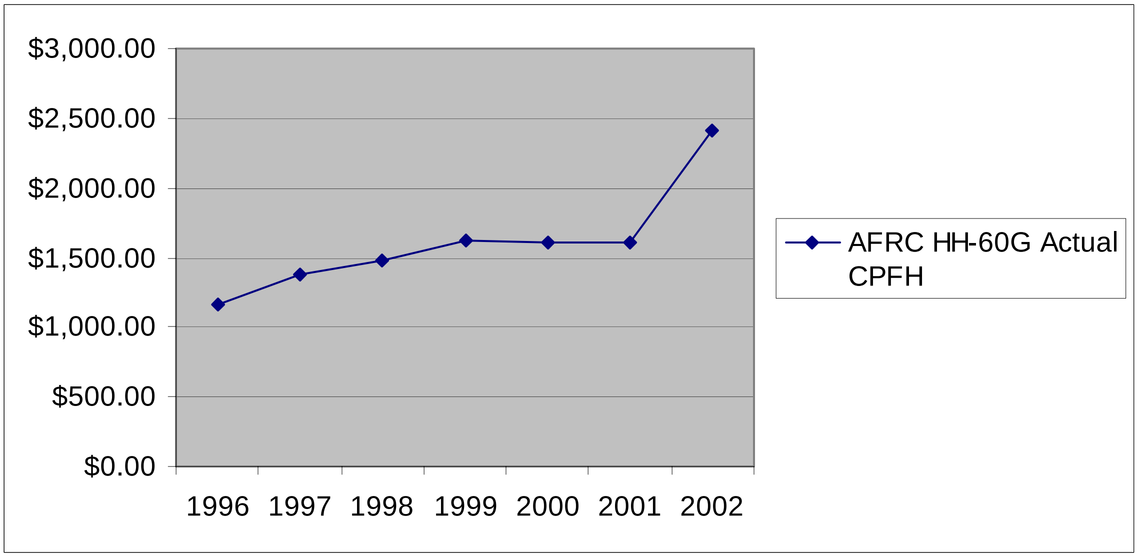

Figure 28. HH-60G AFRC CPFH

The increase in CPFH in FY02 is responsible for the large budget variance in Table 30, and was also the culprit causing the error measurements in Table 31 below to be a bit higher than expected. Holt's method was the best forecasting method for this time series with a MAPE that is just slightly above 11 percent. The large increase in FY02 accounts for almost 75 percent of the error reported in the MAPE.

Table 31. AFRC HH-60G Evaluation Measures

	ME	MAE	MPE	MAPE
MA3	309.69167	309.69167	15.08391	15.08391
SES	234.39000	244.02000	10.40581	11.00728
Holt's	153.36766	245.28208	5.39856	11.13373

AFRC – Actual CPFH vs. Forecasted

The forecasted variances in Table 32 below are very similar to the budget variances of Table 30. Both tables show acceptable negative variances in FY00 and FY01 and then report a very large positive variance in FY02. The large forecasted variance in FY02 means that as the FY03 CPFH figure is added to the series the forecasted methods will be reevaluated to ensure the best forecast is made for FY04.

Table 32. AFRC HH-60G Forecasted Variances

FY00	FY01	FY02
-9.36914	-2.04969	33.05682

AFRC – Forecasting for FY04

The FY03 actual CPFH figure of $3,777 was added to this time series and then solver was ran to ensure that the alpha and beta values used were optimized to allow Holt's method to provide the best forecast possible for FY04. The FY04 forecasted figure was $5,126, and the MAPE calculated was 12.61557. By adding this single data point the MAPE increased by 1 percent. The final MAJCOM evaluated and forecasted for was PACAF.

PACAF – Empirical O&S Breakout

The empirical O&S breakout for PACAF, Figure 29 below, is almost identical to both ACC and AFRC. Once again Unit Personnel is the biggest cost category for every fiscal year, accounting for 49 to 56 percent of the total cost. In PACAF the top three cost drivers were Unit Personnel, Maintenance, and Unit Operations, which account for 93 to

94 percent of the total cost in each year. This graph is the most stable O&S breakout that has been analyzed; the percentages from FY96 to FY02 remain very constant.

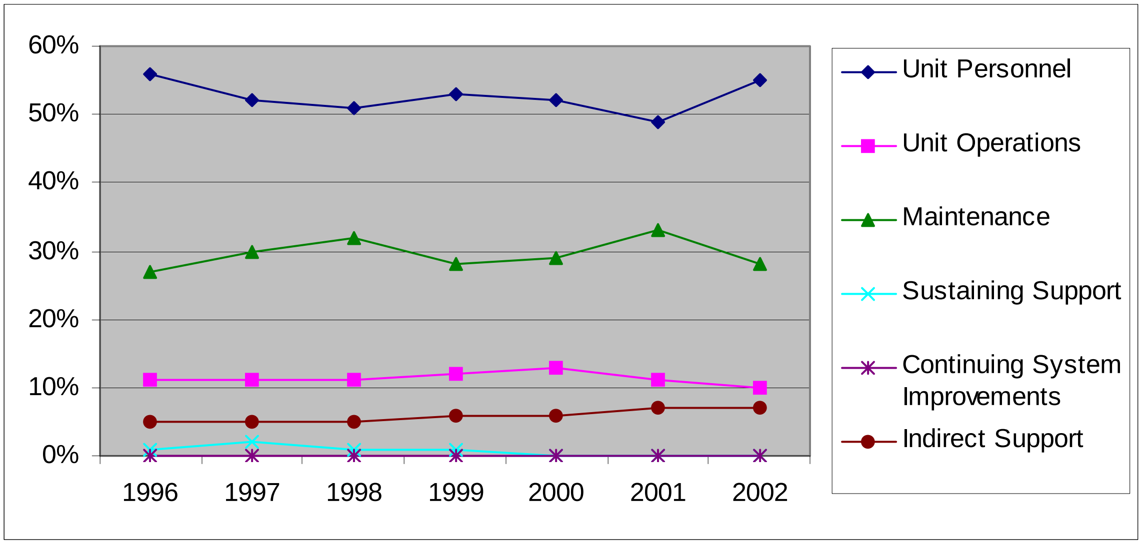

Figure 29. HH-60G PACAF O&S Costs

PACAF – Actual CPFH vs. Budgeted Submissions

The budget variances for PACAF are in Table 33 below. In all fiscal years the variances are positive. The variance in FY00 is favorable, as well as the variance for FY02. However, the variance in FY01 is extremely high, the budgeted figure was more than 37 percent lower than the actual CPFH figure in that year.

Table 33. PACAF HH-60G Budget Variances

FY00	FY01	FY02
6.755594	37.17277	1.416804

PACAF – Forecasting Options

The time series for PACAF is below in Figure 30. The data is stable from FY96 to FY00; during this period the fluctuation from year to year is never more than $300. Then the data experiences a positive shift of about 30 percent in FY01 and maintains this same CPFH level in FY02. This shift in FY01 explains why the budget variance in Table 33 above is so high.

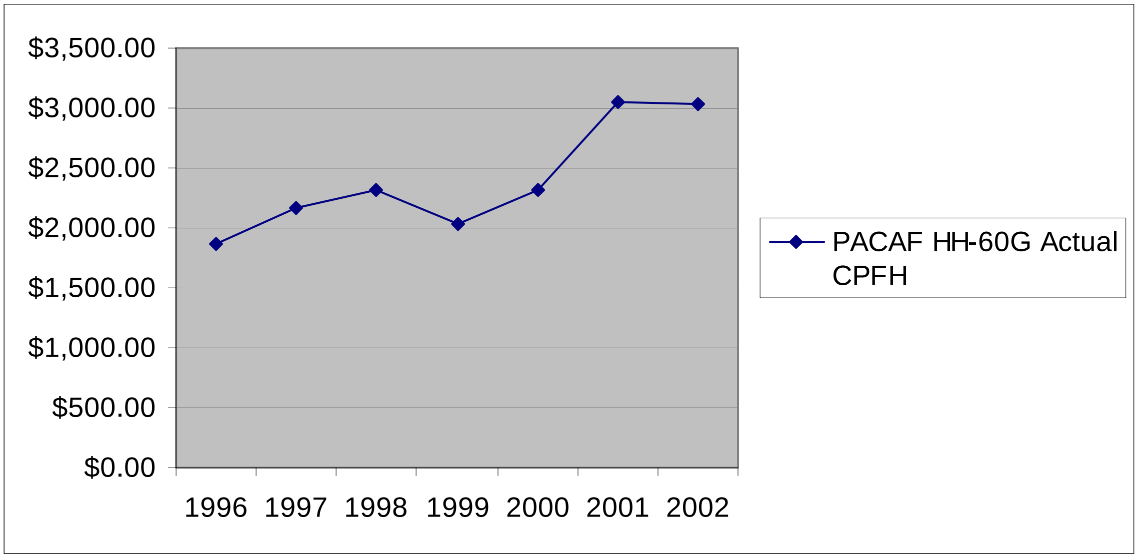

Figure 30. HH-60G PACAF CPFH

The best forecasting method for this time series was SES. Table 34 lists the evaluation measurements for PACAF. The MAPE for the SES forecast is just slightly above 12 percent. It is important to note that 50 percent of the error reported in the MAPE comes from the forecasted CPFH in FY01 when the large increase noted earlier takes place. Because the MAPE calculated for each forecast is so similar, the forecasting method used will be reevaluated when the FY03 CPFH figure is added to the time series.

Table 34. PACAF HH-60G Evaluation Measures

	ME	MAE	MPE	MAPE
MA3	367.04250	404.58417	12.12564	13.96702
SES	186.14328	322.76009	5.68980	12.39074
Holt's	-111.10055	334.40055	-6.00096	13.30682

PACAF – Actual CPFH vs. Forecasted

The forecasted variances for PACAF are in Table 35 below. They show a variance in FY00 that is almost 12 percent. The variance in FY01 is very large, but is smaller than the budget variance in FY02 from Table 33. The large discrepancy in both the budget variance and forecast variance in FY01 is due to the large increase to the CPFH in that FY. The variance in FY02 is zero for the SES method because this method correctly forecasted the FY02 CPFH figure to the penny.

Table 35. PACAF HH-60G Forecasted Variances

FY00	FY01	FY02
11.9191	24.21466	0

PACAF – Forecasting for FY04

The FY03 actual CPFH figure of $3,150 was added to this time series. Because the evaluation measures in Table 34 were so similar the forecasting methods were reevaluated to provide the best forecast possible for FY04. When this was accomplished Holt's method outperformed the other methods. The FY04 forecasted figure was $3,410, and the MAPE calculated was 11.49909. By adding this single data point and switching forecasting methods, the MAPE improved by 1 percent.

Chapter Summary

This chapter analyzed and forecasted costs for the three helicopters in the Air Force inventory. The analysis of each MAJCOM started with an empirical study of the CAIG O&S costs breakout in order to identify the main cost drivers. Budget variances were calculated and evaluated for each MAJCOM. Then, forecasting options for each time series were evaluated to ensure that the best methodology was chosen to forecast the series. Of the methods evaluated, Holt's method was chosen for six of the series and SES was chosen for two. After the forecasting was accomplished, forecasting variances were calculated and evaluated for each MAJCOM. These forecasted variances were compared to the budget variances calculated earlier. In 5 of the 8 MAJCOMs the forecasted variance was better than the budget variance. In those three MAJCOMs where the budget variance was better, both the variances were above 20 percent. In all three of these MAJCOMs the forecasting methodology was reevaluated prior to performing the final step of the research, forecasting for FY04. For all of the time series FY03 figures were added, then the forecasts for FY04 were made and the evaluation statistics were recalculated.

V. Conclusion

Problem Revisited

Operating and Support costs constitute the majority of the total life cycle cost for Air Force weapons systems. The first step in being able to control these costs is to understand the elements that comprise these costs and the proportion each element contributes to the total cost. The understanding of the nature of these costs will lead to more accurate budget submissions and better fiscal responsibility. The discrepancy between budget submissions and actual expenditures for CPFH programs lends itself to the need for the research conducted within this thesis. The primary objective of this research was to provide OSD/CAIG with a useful tool to forecast CPFH for Air Force rotary aircraft. These forecasts would then be used by the OSD/CAIG to analyze both the budget submissions of the Air Force and the independent cost estimates of the OSD/CAIG.

Limitations

As useful a tool that was developed in this research it does need routine maintenance and call for additional analysis as new data is added. The forecasts that were developed for each MAJCOM cannot simply be extended as the next fiscal year's data becomes available. In order to be consistent with the methodology used and described in Chapter III in providing the most accurate forecast possible for the fiscal year in question; as data is added to each time series the applicable alpha and beta levels of each forecast must be recalculated. After this is accomplished all three forecasting methods can be extended one period and then reevaluated using the four-evaluation measure also described in Chapter III. Also, as new data becomes available it will be necessary to evaluate the time series to ensure that all of the data being used is still relevant when forecasting for the next period. It is possible that a change in CPFH reporting procedures could produce a cost level shift that could cause prior years data to become irrelevant when trying to predict the future costs.

Summary of Literature Review

The literature review starts by explaining how O&S costs have become an important issue within the DoD and then describes the initiatives of the DoD to control these costs. The rest of the literature review is broken down into two major categories: Major O&S Guidance, and Past Research. The Major O&S Guidance section gives an overview of Title 10 that establishes the legal requirement for O&S cost estimating and reporting. This section also provides an overview of the DoD directives and guidance that tailor the O&S cost estimating and reporting to the specific needs of the DoD. This section continues by explaining the establishment of both the VAMOSC and AFTOC systems, and then ends with a brief summary of the three helicopters being studied. The Past Research section includes the details and results of four other theses and four professional reports that directly relate to the material of this research. This section contains studies of CPFH and O&S cost reduction from the Army, Navy, and the Air Force. Although none of the literature of this section is an exact match of the research of this thesis, it does provide a solid background and show the necessity of the research contained within this thesis.

Review of the Methodology

The methodology of this research starts with a description of the AFTOC database and the necessary steps to extract the data from it for the empirical O&S breakout portion of the research. The methodology also describes the formulas used to evaluate the actual CPFH against the budget submissions for FY00-FY02, and the actual CPFH against the forecasted figures for FY00-FY02. The methodology thoroughly describes each of the three forecasting methods being employed within this research and provides in depth detail of the four evaluation measures being utilized to determine the overall best forecasting method for each time series. The methodology concludes with an explanation of forecasting for FY04, which is the final step of the research conducted.

Restatement of Results

The analysis performed for the MH-53 J/M Pave Low was very encouraging. The empirical O&S breakout analysis depicted results that were very consistent from FY96 to FY02 with Personnel, Maintenance, and Indirect Support comprising 85 to 94 percent of the total cost in each year. The forecasting method used provided very good evaluation measures, which reported a MAPE of 12.03379. The forecasted variances for FY01 and FY02 proved to be far superior when compared to the budget variances in the same years.

The analysis for the UH-1N Helicopter started with AETC. The empirical O&S breakout analysis showed some volatility between Indirect Support and Unit Operation, but combined the categories accounted for less than 20 percent of the total cost for any year. The main cost drivers for AETC were Unit Personnel and Maintenance, which combined for 80 percent of the total O&S cost. The evaluation measures for AETC were the lowest of all of the time series analyzed with a MAPE of 4.48334. Again the forecasted variances calculated were far better than the budget variances for FY01 and FY02.

The next MAJCOM analyzed for the UH-1N was AMC. The empirical O&S breakout analysis yielded results very unique when compared to the rest of the MAJCOMs for the UH-1N, however, upon further investigation it was discovered that the results were almost identical to other platforms within AMC. The most noticeable difference was that the largest cost driver in all years, FY96 to FY02, was Sustaining Support, which made up between 40 to 78 percent of the total cost. The evaluation measures for this time series were very good, but highly influenced by the 60 percent increase to the CPFH from FY01 to FY02. This large increase also affected the forecast for FY02 in which there was a very poor forecasted variance, however, the forecasted variances for FY00 and FY01 were both less than 1 percent.

The last MAJCOM analyzed for the UH-1N was PACAF. The empirical O&S breakout analysis shows a lot of volatility between Maintenance, Unit Personnel, and Unit Operations for FY96 to FY00, but these cost categories made up 96 to 97 percent of the total cost in FY97 to FY02. The CPFH data for PACAF was very unstable with two changes in trend direction from FY96 to FY02. The evaluation measures achieved were reasonable, with a MAPE of 13.57675, considering the CPFH actuals being forecasted. Even though the forecasted variance for FY01 was less than 1 percent, the 65 percent increase in actual CPFH from FY01 to FY02 caused both the budget variance and the forecasted variance to reach unacceptable levels above 30 percent.

The analysis for the HH-60G Pave Hawk starts with AETC. The empirical O&S breakout analysis showed that 77 to 93 percent of the total cost in each year from FY96 to FY02 consisted of Maintenance and Unit Personnel. The CPFH data for AETC has a very dominant and stable positive trend, this stability allows the forecasting technique to provide some of the lowest evaluation measures of this research anchored by a MAPE of 6.90956. The forecasted variances of -4.11241 percent for FY01 and 0 percent for FY02 were a vast improvement when compared to the budget variances for the same years.

The next MAJCOM analyzed for the HH-60G was ACC. The empirical O&S breakout analysis was stable for FY96 to FY02 in which Unit Personnel, Maintenance, and Indirect Support comprised 85 to 90 percent of the total cost. The evaluation measures achieved for this data were very good with a MAPE of 8.93591. When comparing the forecasted variances to the budget variance, FY02 tells a very convincing story for the forecasting methodology. In FY02 the budget variance was –68.254 percent and the forecasted variance was 0 percent.

AFRC was the next MAJCOM analyzed for the HH-60G. The empirical O&S breakout analysis for AFRC was also stable in all years examined. The top three cost categories were Unit Personnel, Maintenance, and Indirect Support, which together accounted for 90 to 93 percent of the total O&S cost in each year. The evaluation measures for this time series were acceptable. The MAPE was 11.13373 with 75 percent of the error reported being directly contributed from the 50 percent increase in CPFH from FY01 to FY02. Although the forecasting technique used was able to improve the FY01 forecasted variance by 8.5 percent when compared to the budget variance, the 50 percent increase in CPFH from FY01 to FY02 caused both the FY02 budget and forecasted variances to be unacceptable.

The last MAJCOM analyzed for the HH-60G was PACAF. The empirical O&S breakout analysis for the HH-60G was more stable when compared to the O&S breakout for PACAF with the UH-1N. Each cost category for the HH-60G changed less than 8 percent from one year to the next. Unit Personnel, Maintenance, and Unit Operations accounted for 93 to 94 percent of the total cost in each year. The evaluation measures for this time series were acceptable, and anchored by a MAPE of 12.39074. For FY01 and FY02 the forecasted variances were an improvement over the budget variances, and again the forecasted variance for FY02 was 0 percent because the forecasted figure matched the actual CPFH figure.

Recommendations

The forecasting techniques used in this research proved to be very powerful in predicting future CPFH figures. The methodology and results of this research provides the OSD/CAIG with a valuable tool that aids in O&S cost estimating and oversight functions. This same benefit might also be achieved if this research methodology were applied to other Air Force platforms. This methodology could also be tailored and applied as a budgeting tool. There could possibly be situations where the Air Force Cost Analysis Agency, as well as financial managers within system program offices and local budget offices, could employ forecasting techniques because the benefit of performing such analysis could be an improvement over current methods used.

Possible Follow-on Theses

The research of this thesis only touches a very small portion of several important and interesting topics. There are many more areas the Air Force could employ forecasting, and the efforts to realize O&S cost savings will be addressed for a long time. This research has shed light on other research opportunities. Here are some suggestions:

- Apply this same analysis and forecasting methodology to other Air Force platforms, such as: fighter, bomber, or cargo aircraft.
- Explore other forecasting techniques that could be used to determine CPFH factors for Air Force aircraft.
- Analyze the method used to allocate costs within the AFTOC database.
- Repeat this research on the same helicopters as FY04-FY06 data becomes available.
- Analyze the CPFH figures forecasted for FY04 to the actual CPFH for FY04 and determine reasons for any disconnects that are present.
- Determine useful applications of forecasting techniques in budgeting for other Air Force costs.
- Create a program that will apply the methodology of this thesis to a time series to forecast other CPFH factors.
- Explore the effects of deployments on total O&S costs.
- Analyze the different methodologies used by each service in determining CPFH factors and determine if better methods are available.

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REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 074-0188*

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1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
23-03-2004	**Master's Thesis**	Jun 2003 – Feb 2004

4. TITLE AND SUBTITLE	
ANALYSIS AND FORECASTING OF AIR FORCE OPERATING AND SUPPORT COST FOR ROTARY AIRCRAFT	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER**
Laubacher, Matthew E., First Lieutenant, USAF	**5e. TASK NUMBER**
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Street, Building 641 WPAFB OH 45433-7765	AFIT/GCA/ENV/04M-05
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
OSD/PA&E Attn: Ms. Krystyna M. Kolesar 1800 Defense Pentagon Washington DC 20301-1800 (703) 695-4177	**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This research explores forecasting techniques to estimate the Cost per Flying Hour for Air Force Helicopters. Specifically, this research evaluates three separate forecasting techniques to predict the CPFH for better estimating and budgeting by the USAF. It starts by empirically analyzing the Operating and Support cost by CAIG categories for each helicopter. For forecasting purposes the actual CPFH figures were compiled from FY96 to FY03 for a total of eight MAJCOMs flying the MH-53J/M, the HH-60G, or the UH-1N helicopters. The research explores the use of a 3-year moving average, the single exponential smoothing method, and the Holt's linear method. These forecasting techniques were used to forecast for FY02 in evaluating the best methodology to forecast the CPFH for FY04. By comparing both the budgeted and forecasted figures for FY00 to FY02 to the actual CPFH figures in the same years, the forecasting methods were able to more accurately predict the actual CPFH for all of the MAJCOMs that achieved a budget variance of less than 20 percent. It was discovered that the Holt's linear method was the best forecasting method for 75 percent of the time series analyzed since they contained positive trends. Finally, these techniques were employed to provide the best possible forecast of the CPFH for FY04.

15. SUBJECT TERMS
Cost per Flying Hour (CPFH), Forecasting, Rotary Wing Aircraft, Cost, Operations and Maintenance (O&M), Holt's Linear Method, Single Exponential Smoothing (SES), Air Force Total Ownership Cost (AFTOC), MH-53J/M, UH-1N, HH-60G

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Michael A. Greiner, Maj, USAF (ENV)
REPORT	**ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)*
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