ANALYSIS AND FORECASTING OF ARMY OPERATING AND SUPPORT COST FOR ROTARY AIRCRAFT

THESIS

John C. Hawkins, First Lieutenant, USAF

AFIT/GCA/ENV/04M-03

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GCA/ENV/04M-03

ANALYSIS AND FORECASTING OF ARMY 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

John C. Hawkins, AS, BSA
First Lieutenant, USAF

March 2004

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AFIT/GCA/ENV/04M-03

ANALYSIS AND FORECASTING OF ARMY OPERATING AND SUPPORT COST FOR ROTARY AIRCRAFT

John C. Hawkins, AS, BSA
First Lieutenant, USAF

Approved:

/signed/	20 Feb 2004
Michael A. Greiner, Maj, USAF (Chairman)	**date**
/signed/	20 Feb 2004
Marvin A. Arostegui, Lt Col, USAF (Member)	**date**
/signed/	20 Feb 2004
Krystyna M. Kolesar (Member)	**date**

AFIT/GCA/ENV/04M-03

Abstract

This research explores forecasting techniques to estimate the Cost per Flying Hour for Army Helicopters. Specifically, three separate forecasting techniques are evaluated to better predict the CPFH for better estimating and budgeting by the US Army. To begin, the three cost categories are empirically analyzed for each helicopter. For forecasting purposes, actual CPFH figures were compiled from 1995 to 2003 for all MACOMs flying the AH-64A, the CH-47D, and the UH-60A helicopters. The number of MACOMs is then reduced to the top three in regards to total CPFH expenditure. The use of a 3-year moving average, the single exponential smoothing method and the Holt's linear method are explored for each helicopter's data. These forecasting techniques are used to forecast for FY03 in evaluating the best methodology to forecast the CPFH for FY04. By comparing both the budgeted and forecasted figures for FY00 – FY02 to the actual CPFH figures in the same years, an accurate CPFH forecast for all of the MACOMs was possible. When data became available, a comparison of the actual, budgeted, and forecasted CPFH for FY03 was performed. The Holt's linear method was discovered to be the best forecasting method for 78 percent of the time series analyzed since they contained positive trends. Finally, the best forecast to be provided for FY04 is calculated with the chosen forecasting method.

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 work experience, as well as his academic expertise dealing with complicated thesis issues, helped reduce the many stressors associated with the thesis process. I would also like to thank my committee members, Lt Col Marvin Arostegui, and Ms Krystyna Kolesar. They both provided information and guidance at critical points during this research to make it as thorough as possible.

I would also like to thank my thesis team members and friends, Capt Christopher Wilkes and Lt Matt Laubacher, for making this effort an enjoyable and successful experience. I am also grateful to the following professionals outside of AFIT that provided me with guidance and hard-hitting critiques that kept my work accurate and fair: Kathleen O'Bryan at OSMIS; Mr. Bill Vinson, budget analyst for the Army's CPFH program; Maj John Ferguson at HQ Army; and Mr. Kirk Bowie, contractor at OSMIS.

.

John C. Hawkins

Table of Contents

List of Figures

Figure **Page**

Figure **Page**

List of Tables

Table **Page**

Table **Page**

ANALYSIS AND FORECASTING OF ARMY 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.

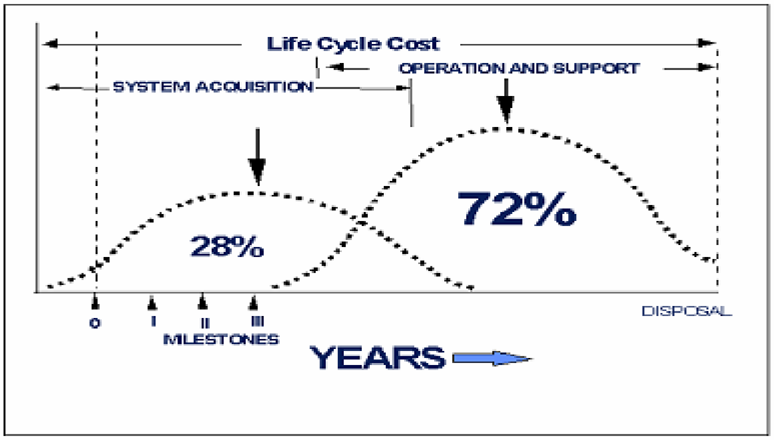

Figure 1. Nominal Cost Distribution

(TYPICAL 1980 DOD ACQUISITION PROGRAM WITH A SERVICE LIFE OF ABOUT 30 YEARS)

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 Army'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 Army 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 Army'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 Army 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 Army 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 budget submissions in the same years?
    - To what extent did the budget submissions deviate from actual CPFH figures in FY00-FY02?

- What are the major O&S cost drivers, by MACOM, for each weapon 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 Army. 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 Army 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 Army rotary aircraft. At the same time this research is being conducted, similar research efforts will be conducted for the Air Force and Navy. Lt Laubacher examines the O&S CPFH for Air Force rotary aircraft. Lt 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

OSMIS system will be used extensively to extract O&S cost information for Army rotary aircraft.

The OSMIS database will be used to sort O&S cost information by rotary aircraft model and MACOM 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 OSMIS database contains all rotary aircraft information during the years 1995-2002. This data will then be compared to the budgeted 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 MACOM 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, lists the current Army 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 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 break-out of the life-cycle costs for a typical weapon system.

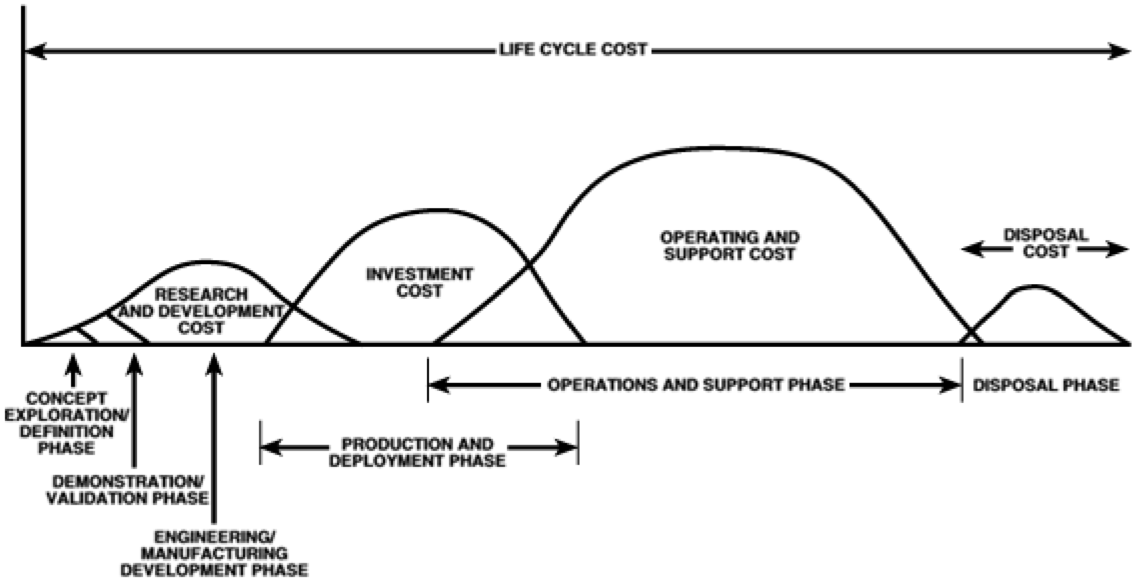

Figure 2. Program Life Cycle (Illustrative)[1]

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 is taken from the OSD CAIG *Operating And Support Cost-Estimating Guide* (Ref 8). The figure is used for illustrative purposes only. Actual program results may vary.

Table 1. DoD 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 percent in 1985 to nearly 40 percent in 2003. The percent of real cost growth in O&M funding increased 15.5 percent 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.

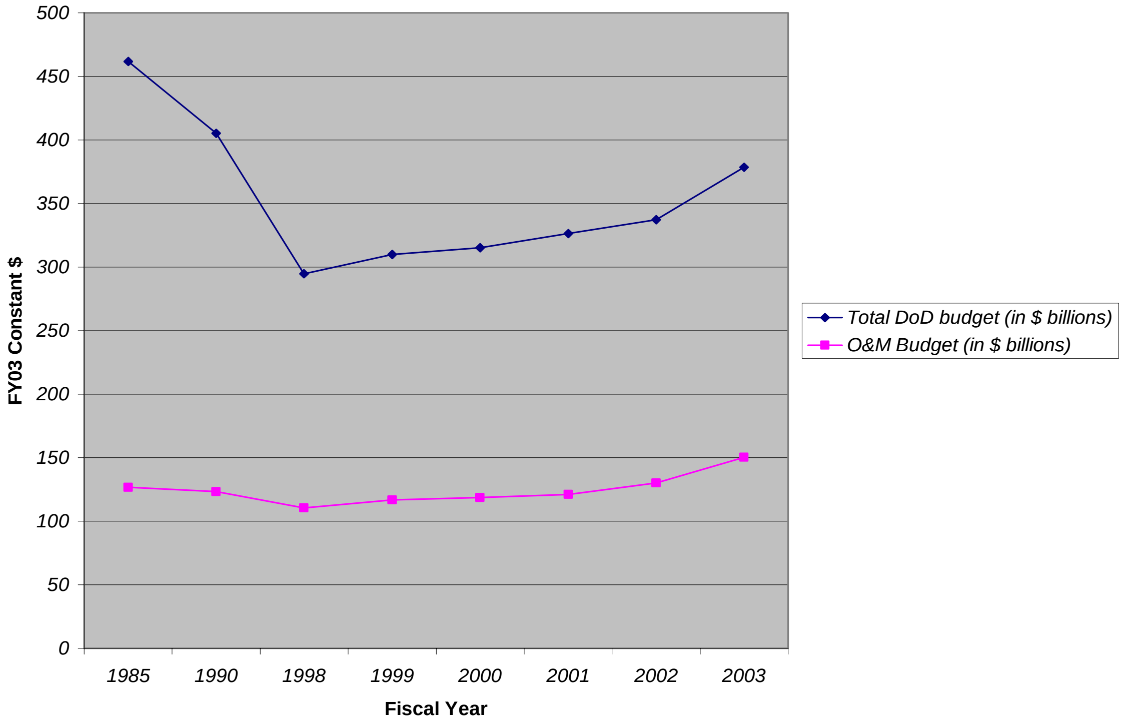

Figure 3. DoD Annual Budget and O&M Funding

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 Army rotary aircraft. Figure 4 depicts a list of rotary wing aircraft within the Army arsenal. Forecasting tools will be applied to predict O&S CPFH for Army 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.

Aircraft, Rotary Wing

- Apache Longbow – AH64A
- Blackhawk – UH60A
- Chinook – CH47D

Figure 4. Listing of United States Army Rotary Wing Aircraft[2]

Figure 5. Apache Longbow- AH64A (4)

The Apache is a heavy division/corps attack helicopter (4). With it, the Army conducts rear, close, and shaping missions as well as precision strikes against relocatable targets (4). Figure 5 shows the Apache Longbow in flight.

---

[2] List taken from the United States Army fact file: http://www.army.mil/fact_files_site/aircraft.html (Ref 4).

Figure 6. Blackhawk-UH60A (4)

The Blackhawk is a utility tactical transport helicopter that provides air assault, aeromedical evacuation, and command and control and special operations support (4). It has enhanced the overall mobility of the Army due to improvements in troop capacity and cargo lift capability by replacing the UH-1 Huey (4). Figure 6 shows a Blackhawk in flight.

Figure 7. Chinook-CH47 (4)

The Chinook is a transport helicopter, used to transport ground forces, supplies, ammunition, and other critical cargo in support of worldwide combat and contingency operations (4). It has been in service since 1962 and has been through numerous upgrades (4). Figure 7 shows a Chinook being utilized to transport troops.

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 (5:1). 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 (5:1). 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 (5:1). 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 to define the total costs associated with the acquisition and fielding of a weapon system within the different branches of the armed services (5:1). The objective divided the total Life Cycle Cost (LCC) of a system into two main categories: acquisition costs and ownership costs (5:2). The ownership costs, known together as O&S costs, were the area for concern and what most interested the DoD. Figure 8 shows a detailed breakdown of what constitutes the different stages of total ownership costs for Navy aircraft.

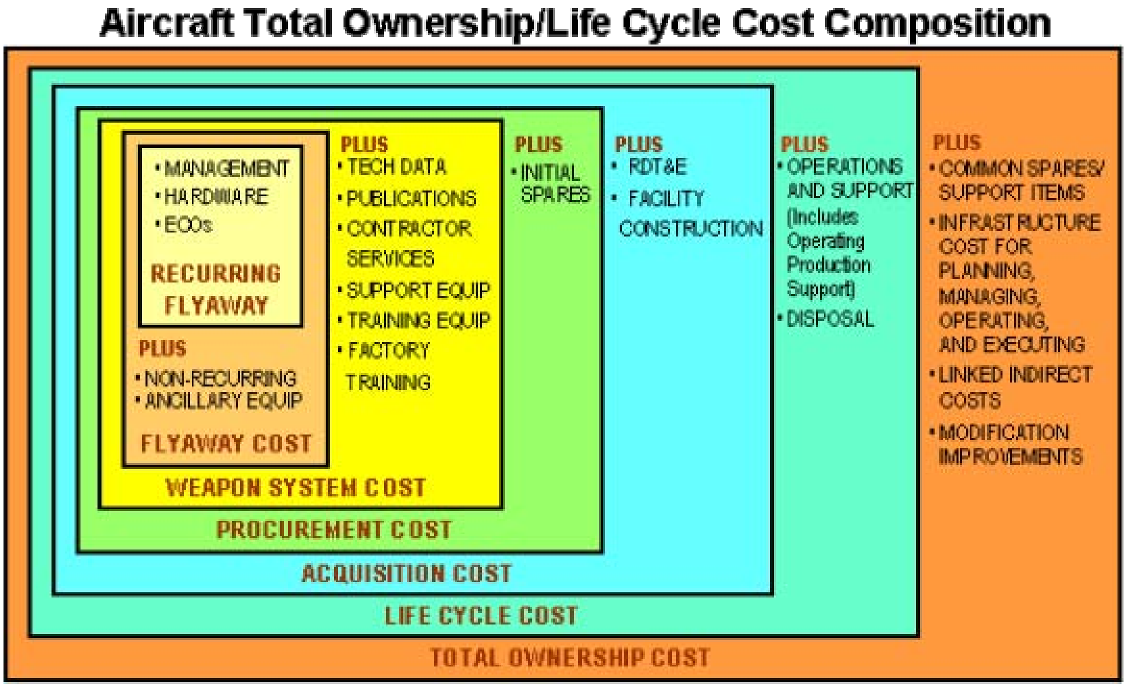

Figure 8. Aircraft Total Ownership/Life Cycle Cost Composition (23)

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” (6:53). 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 (6:53). “VAMOSC data shall be used as a basis for decisions concerning affordability, budget development, support concepts cost tradeoffs, modifications, and retention of current systems” (6:53). 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 (6:55). 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 (7).

The Secretary of Defense shall prescribe regulations governing the content and submission of these required estimates (7). 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 (7). 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 (7).

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) (6:8).

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; i.e., costs that would not occur if the program did not exist (6:48).

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 (8:1). 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 (8:1). The O&S cost element structure is divided into six major categories:

- Unit Personnel
- Unit Operations
- Maintenance

- Sustaining Support
- Continuing System Improvements
- Indirect Support (8:2)

The Unit Personnel element includes the costs of all operator, maintenance, and support personnel at operating units (8:2). Unit Personnel include active and reserve military, government civilian, and contractor personnel costs (8:2). 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 (8:3)).

Unit Operations includes the unit-level consumption of operation materials such as fuel, POL, electricity, expendable stores, training munitions and other operating materials (8:5). 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 (8:5). Unit-funded service contracts for administrative equipment as well as unit-funded equipment and software leases are included in this portion of the estimate (8:5).

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 (8:7). All maintenance costs provided through a system support contract will be separately identified within the appropriate cost element (8:7).

Sustaining support includes support services provided by centrally managed support activities not funded by the units that own the operating systems (8:10). 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 (8:10).

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 (8:12). These costs include government and contract labor, materials, and overhead costs (8:12). Costs are required to be separated into government and contactor costs within each cost element (8:12).

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 (8:12). 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 (8:12). Improvements designed to be incorporated in production lots (e.g., 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 (8:12-13).

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 (8:13). The three levels of Indirect Support include Installation Support, Personnel Support, and General Training and Education (8:14-15).

DoD 5000.4-M - Establishment of Visibility and Management of Support Costs and Operating and Support Management information System.

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 (8:53).

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 (8:53). 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 (8:54). VAMOSC is to provide visibility of O&S costs so they may be managed to reduce and control program life-cycle costs (8:54). 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 (8:54).

The OSD/CAIG is charged with executive oversight of VAMOSC (8:55) 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 (8:55).

The Operating and Support Management Information System (OSMIS) is the Army's database which supports the DoD's Visibility and Management of Operating and Support Costs (VAMOSC) Program (9:171). OSMIS is managed by the U.S. Army Cost and Economic Analysis Center (USACEAC) and is a source of standardized historical O&S cost information for over 500 systems deployed in Active, Guard, and Reserve tactical units (9:171).

Recent Army Issues with O&S Costs

"The high cost of operating and supporting the Army's weapon systems is absorbing an increasing share of its budget and is reducing funds available for buying new systems" (10:1). The DoD and Army budgets have declined significantly in the past decade (11:1). O&S costs comprise an increasing share of resources and consistently consumed half of the Army's budget (11:1). Since support costs for current weapon systems are rising, funds for new weapon systems are unavailable (10:1). As the current systems age, support costs continue to escalate, resulting in even fewer funds for modernization (10:3). This dilemma has been characterized as the "death spiral" by the Under Secretary of Defense (Acquisition, Technology, and Logistics) (10:3).

In April 1998, DoD placed more responsibility on the program managers of acquisition programs for the total life cycle cost of new weapon systems under development (10:1). In the past, program managers focused mainly on meeting acquisition cost, schedule, and performance requirements (10:2). The cost of the system after it was fielded was not emphasized or realistically estimated.

Under the 1998 initiative, each service was to designate 10 new development programs to test O&S reduction efforts (10:1). In January 1999, DoD focused similar efforts on current weapon systems already in the services' inventory. By fiscal year 2000, new weapons under development were expected to have estimated life cycle costs lower than the systems they were replacing, from 20 to 50 percent (10:1). Current systems in inventory were expected to reduce O&S costs by 20 percent by fiscal year 2005 (10:1).

The Army has been criticized for not focusing efforts on reducing O&S costs. In a report to the Chairman of the Subcommittee on Readiness and Management Support, Committee on Armed Services, the Army's efforts as a result of the two DoD initiatives were found to be ineffective by the Governmental Accounting Office (GAO). Although the Army had identified possible reductions for current weapon systems, it did not place the priority needed for O&S reduction efforts to meet the DoD's goals (10:2). For developmental programs, the Army did not assign accountability for O&S cost reductions and did not establish requirements that each fielded system maintain these costs at or below a specified level (10:2). Also, the Army was criticized for not collecting and maintaining data on all elements of O&S costs for its weapon systems (10:2).

The Army had tried to respond to the increasing pressure to reduce O&S costs before the DoD's initiatives. One effort involved contracting out logistic support as a method of cost reduction, a concept called Prime Vendor Support (PVS) (11:1). "Prime Vendor Support is an initiative with industry that saves operations and support (O&S)

costs by having the prime contractor assume responsibility for total performance of a weapon system and its modernization by integrating modernized spare parts (11:1).” PVS was a way for the Army to realize cost reductions without committing additional funds by taking advantage of commercial best practices (11:1). The main concern for this new concept was that it be effective in peacetime, during contingency operations, and in war (11:2). It also had to provide and guarantee uninterrupted support and be invisible to the end user, the warfighter (11:2).

In April 1997, the Army received a proposal from Boeing-Lockheed Martin for implementing a PVS for the Apache helicopter (11:2). The proposal would transfer responsibility for complete wholesale support for the Apache to a limited liability company known as Team Apache Systems (TAS) (11:2). TAS would eliminate government personnel and facilities formerly needed to acquire, manage, store, and distribute spare parts for the Apache (11:2). “The major advantages of such an arrangement would be improved system readiness based on increased availability of spare parts and a significant reduction of O&S costs that could provide badly needed funds for system modernization” (11:2). The Apache PVS proposal was expected to provide performance guarantees that would reduce the average flying-hour cost by approximately 20 percent (11:2).

Some of the disadvantages associated with PVS include civilian contractors on the battle-field and legal issues with the use of funding used for contracting out maintenance and repair (11:3). Despite the Army’s optimism, the overall savings from the PVS proposal have been questioned by the GAO (10:7).

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) (12:4).

(1) Consumable supplies include aircraft parts and supplies that are not repaired and are discarded after use (12:4-5).

(2) Depot-level reparables are aircraft parts that are removed by maintenance personnel and sent to a depot for repairs (12:5).

(3) AVFUEL is fuel used during flight (12:5).

The cost associated with the Air Force flying hour program is calculated by using a metric known as Cost Per Flying Hour (CPFH) (12:4). "Flying hours are the basic element for measuring aircraft usage to train aircrews for wartime taskings" (12:4). 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 (12:6). A separate factor for consumables, DLRs, and AVFUEL will be included in the submission (12:6).

The CPFH development begins by creating a baseline rate using the most recent year-end totals for obligations and flying hours (12:6). "Year-end obligations corrected for one-time obligations divided by hours flown develop the baseline CPFH" (12:6). The next step involves adjusting the four approved factors due to economic conditions, such as inflation/deflation (12:6). 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 (13:8-9).

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 (12:7). The four CPFH factors are adjusted according to price changes forecast by managers of the AFWCF (13:10).

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 (12:7).

"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" (13:10). The AFWCF is a revolving fund that sells items necessary to support troops, weapon systems, aircraft, communications systems, and other military equipment (13:10). 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 (13:10). 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 (13:12). This price increase forced the Air Force to request supplemental funding to correct the projected shortfall (13:12). The AFWCF price instability has been known for some time and efforts to correct it are currently in progress (13:14).

The Army follows a similar method for computing factors used in the CPFH budget estimates. Cost factors are calculated by major command and by system based on historical data from the last three fiscal years. Demand for parts and flying hours for the system are averaged over the three-year period to obtain an average demand and flying hour for the system. The average demand for parts is multiplied by the updated parts price in effect for the upcoming fiscal year and this product is divided by the average hours flown over the three-year period (14:10).

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 (15: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 (15: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 (15: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 (15:I-8). These figures are a combination of substantial reductions in military personnel costs and substantial increases in O&M costs (15: 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 (15: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.

Table 2. Attack Helicopter Data (Cost Data in Constant FY96 Dollars)

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

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 (15: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 9 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 (15:II-8).

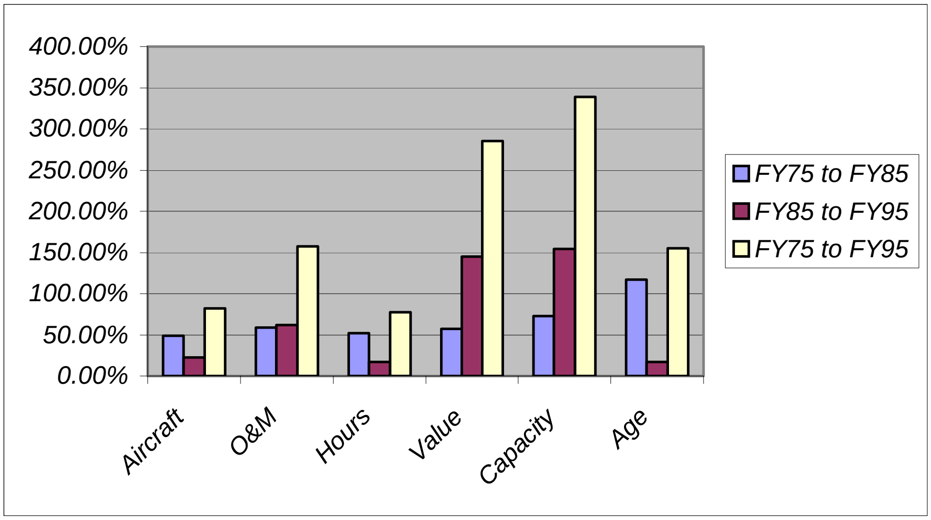

Figure 9. Attack Helicopters

The per unit section of Table 2 and Figure 10 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 (15:II-8).

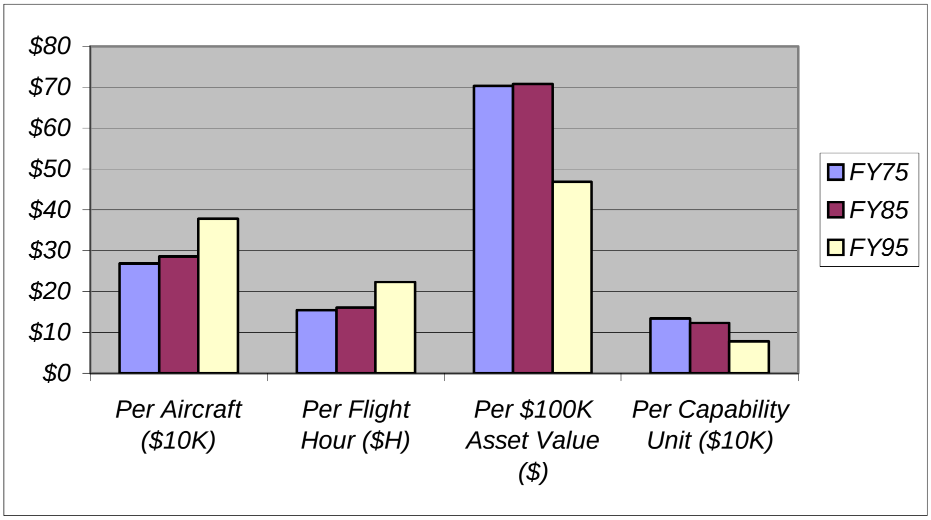

Figure 10. Attack Helicopter O&S Cost Ratio Changes

During the FY 1975 to FY 1995 period there was a marked increased modernization of attack helicopters (15: 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 (15: 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 (15:II-10).

Table 3. Attack Helicopter Modernization & Annual O&M Costs (FY96 $)

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 (15: 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 (15: 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 (15: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 3 (15:II-11).

Observation Helicopters.

For Observation Helicopters Table 4 and Figure 11 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 (15: II-11).

Table 4. Observation Helicopter Data (Cost Data in Constant FY96 $)

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

The per unit section of Table 4 and Figure 12 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 (15: II-12)

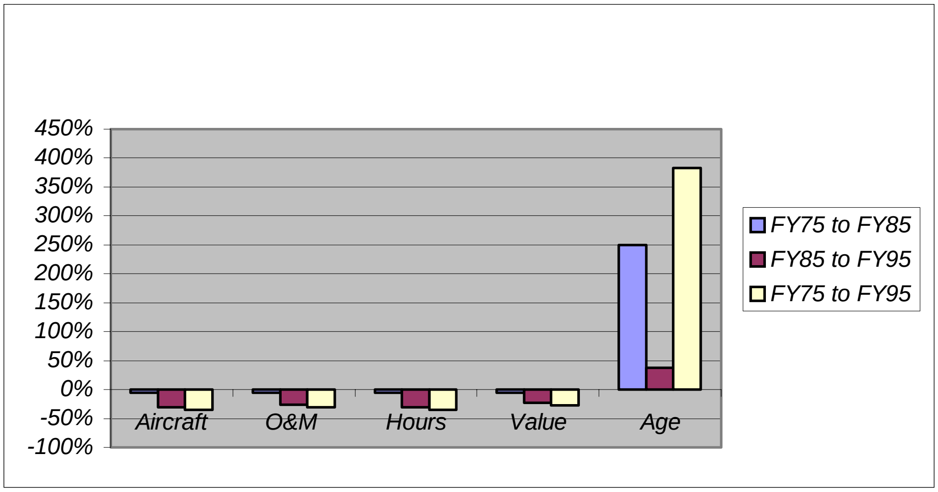

Figure 11. Observation Helicopters Total Resource and Performance Changes

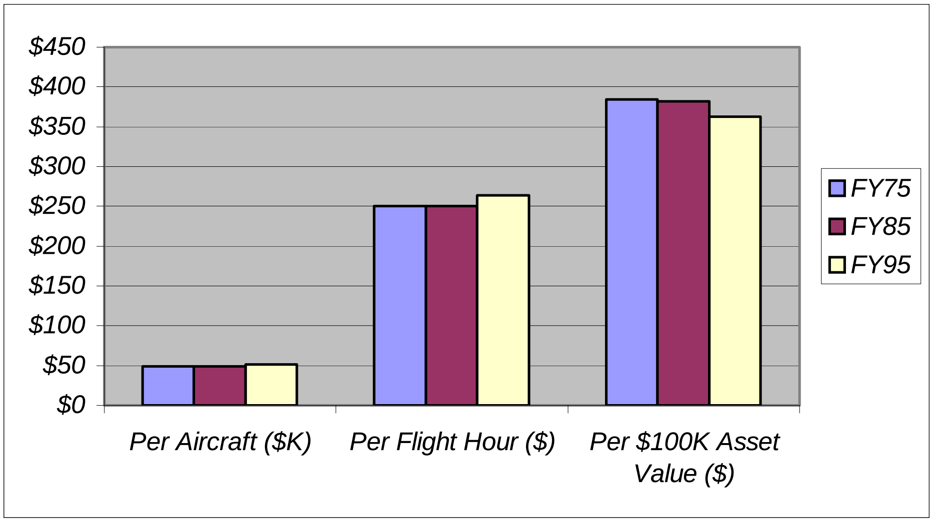

Figure 12. Observation Helicopter O&S Cost Ratio Changes

The Army bought new models of observation helicopters and reduced the size of its fleet during this period (15: 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. (15: 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 (FY96 $)

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 (15: 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 (15: 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 5 (15:II-14).

Utility Helicopters.

For Utility Helicopters, Table 6 and Figure 13 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. (15: II-14).

Table 6. Utility Helicopter Data (Cost Data in Constant FY96 Dollars)

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

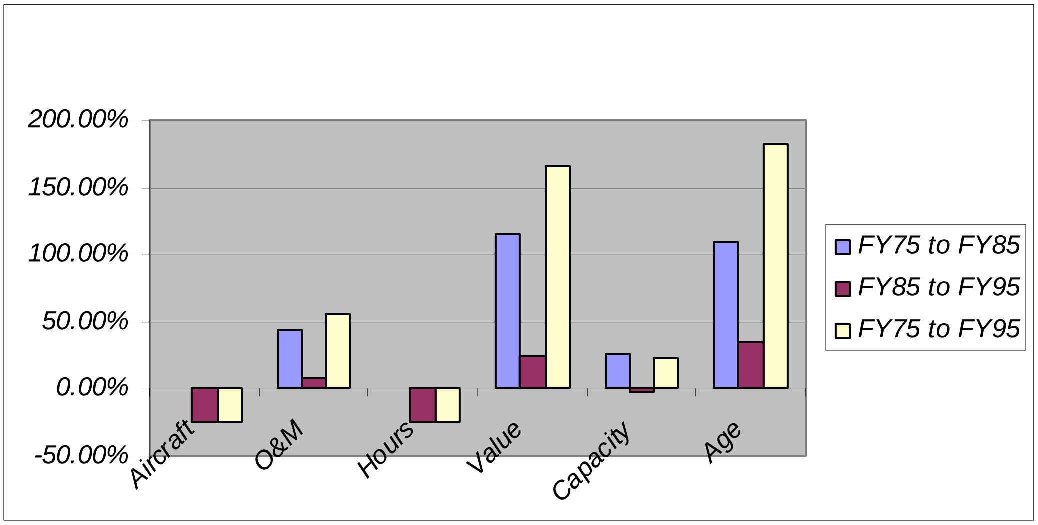

Figure 13. Utility Helicopters Total Resource and Performance Changes

Looking at the per unit section of Table 6 and Figure 14, we see that between FY 1975 and FY 1995 the O & M cost:

- Per aircraft increased by 107 percent,
- 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 (15: II-14).

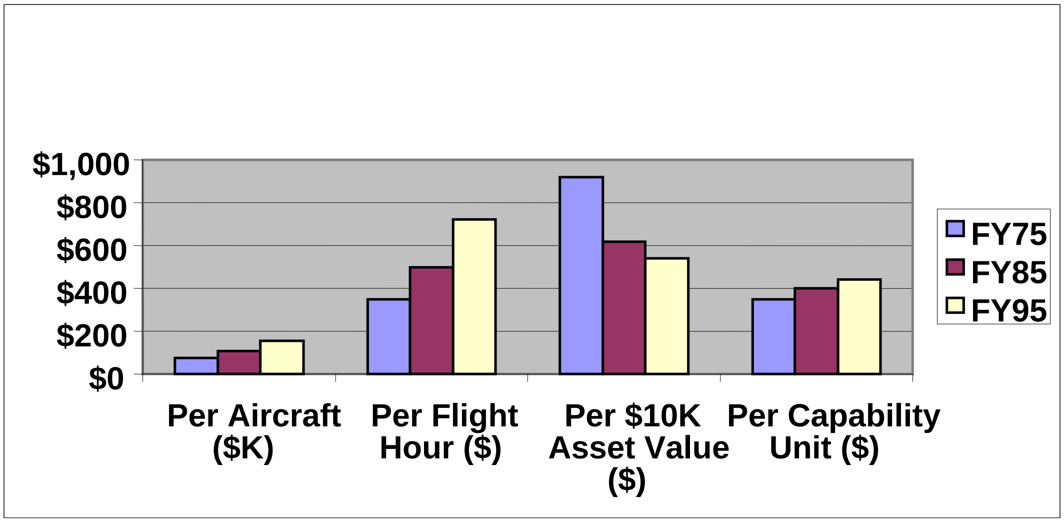

Figure 14. Utility Helicopter O&S Cost Ratio Changes

The Army modernized its utility helicopters during this period and reduced the size of its fleet (15: II-16). Table 7 focuses on Utility Helicopter inventories for the time period of this study. Over 2,300 older UH-1 models were phased out during the period and over 1,200 new UH-60s were introduced (15: 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 (15: II-16).

Table 7. Utility Helicopter Modernization & Annual O&M Costs (FY96 $)

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 7 (15: 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 (15: II-17).

However, in the case of utility helicopters, O&M cost per unit of capability is up (15: 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 (15:II-19).

Table 8. O&S Cost&Characteristics for Attack Helicopters (Cost Data in CY FY96 $)

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 (15: II-20). Consumables and component repair (repairables) showed much larger than average increases while ammunition, intermediate maintenance, and depot end-item maintenance were less (15: II-20).

The AH-64A is larger, heavier, and faster than the AH-1S and has a more sophisticated armament and fire-control system (15: 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 (15: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 Huey (UH-1H) and Blackhawk (UH-60A) utility helicopters (15: 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) (15: 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 (15: 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 (15: II-20).

Table 9. O&S Cost&Characteristics for Utility Helicopters (Cost Data in CY FY96 $)

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 (15: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 (15: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 (16:5). 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 (16:10). 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) (16:14). Multiple Type/Mission/Series (T/M/S) 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 (16:18).
- Annual O&S cost observations are random samples and drawn from a hypothetical population of aircraft (16:18).

In the multivariate model, the following independent variables were used to examine significant effects on O&S costs (16:34):

- **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 (16:40). 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 for O&S costs. The results prove more reliable than the other regression-type models. Tree models successively split data into homogeneous subsets (16:46). 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” (16:46).

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 (16:48). 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 (16:58-68).

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" (16:69). 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 (CER) 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 (17:2). 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) (17:5-6). 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 (17:37-40). 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 (17:49).

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 (18:2). The Navy has 54 in its inventory and has projected the first replacement CH-60 to occur in the year 2008 (18:2-3). Even though the H-3 fleet recently underwent an overhaul process, maintaining these old aircraft will become increasingly expensive (18:2).

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 (18:10). 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 (18:11). 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 (18:13-15). Finally, the CH-60 will have self protection available, making it equipped to perform many of its duties in more hostile environments if necessary (18:16). "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 (18:15-16)."

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 (18:21). 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 (18:21). 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) (18:21-22). 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 (18:27). 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) (18:28).

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 (18:29). 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 (18:29). The HH-60H Sea Hawk was determined to be the best surrogate for CH-60 O&S costs (18:31). Data was available for the Sea Hawk from 1990 to 1996 (18:32). The estimated cost per flight hour for the HH-60H was $3,347. (18:38).

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 (18:40-41). The total savings achieved by replacing the H-3 now as opposed to much later was $36.5 million annually (18:45).

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 (18:42). The proposed plan involved accelerating the procurement by eight years and increasing the first purchases up to 36 aircraft (18:44). The total O&S savings for the period from 2000 to 2010 were found to be $292.1 million (18:45).

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 (18:46). 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 (18:46). 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 (18:47)." The procurement cost per unit would be lower, compensating the cost of replacing the helicopters sooner (18:47).

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 (19:65). 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 (19:65).

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 (19:65-66).

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 (19:66). 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 (19:72).

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 (20:1)." 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 (20:1).

For years, the financial community had worked diligently on the task of clearly defining and properly measuring the flying hour consumable supplies program (20:1). With the decentralization of DLRs and AVPOL, the work was left unfinished and a more clear-cut definition was not made available (20:1).

Since 1980, financial analysts had significant problems with the planning, programming, and budgeting for flying hour consumable supplies (20:2). 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 (20:2). Another issue that arose involved the different philosophies among the MAJCOMs (20:2). "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 (20:2)."

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 (20:2-3). 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 (20:3).

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 (20:8). 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 (20:8). Due to cost reduction efforts DoD wide, more accurate information is critical for leaders to make informed decisions (20:8).

A formal definition of what qualifies as flying hour consumables must be developed and distributed (20:9). “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 (20:9).” 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 (20:9).

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 (21:6). 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” (21:7). 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” (21:3-4). Edwards claims that FHP estimates are not correct during budget formulation because FHP funds are capped by Congress (21:2). 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 (21:1-2). 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. The 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 (21:17).
- (Allowed Crews) x (Aircrew Manning Factors) = Budgeted Crews per Squadron (21:18).
- (Budgeted Crews) x (Req. Hrs/Crew/Month) x (12 mos.) = Annual Flying Hours Required per Sqdn (21:18).
- (Ann. Flying Hrs Req. per Sqdn) x (Number of Sqdns) = Total Annual Flying Hours Required (21:18).
- (Total Ann. Flying Hrs Req.) x (Primary Mission Readiness percentage) = Annual Budgeted Flying Hours (21:18).
- (Ann. Budgeted Flying Hours) x (CPFH) = Annual Budgeted Cost, Active Duty forces (converted to "then-year" dollars) (21:18).

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 (21:42). 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 (21:42). 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" (21:43). 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 (21:45). 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" (21:46).
- **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 (21:47).

- **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” (21:48).
- **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 (21:48).
- **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 (21:49-50).

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 (22:3). 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 (22:3). The Navy and Air Force had at least six individuals committed to the program, while the Army dedicated only one (22:4).

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 (22:4). Despite this positive trend, then Executive Secretary to the Defense Resources Board (Programming

Phase) David 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 (22:4). 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 (22:4).

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 (22:16). 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 (22:12). Training requirements were broken out to include: qualification training, refresher training, mission training and initial as well as refresher night vision goggle training (22:13). 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 (22:13). 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 (22:13-14). The commander also estimated how much training could be accomplished collectively, as well as the hours required for maintenance activities (22:14-15). 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 (22:19). 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 (22:19-20).

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 (22:23). 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 (22:23). Typically, aviation units are undermanned, leading to an overstatement of requirements with the airframe based methodology (22:23).

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 (22:25). 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 (22:25). This rate was applied to the active component's six combat commands (22:25). For example, the Air OPTEMPO rate for fiscal year 89 was 15.0 hours (22:25). 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 (22:25). Since the airframe based methodology assumes one aircrew per airframe, this lead to a requirement overstatement (22:26). After applying this procedure across the entire service, Army headquarters was seeking more hours than the individual units could fly (22:26). This situation gave the impression that the Army was either very inefficient in executing its flying hour program or very inaccurate at predicting requirements (22:26).

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 Army rotary winged aircraft. This chapter begins with a brief description of the OSMIS database and explains how data was collected for this study. The chapter then focuses on the details of the empirical breakout of the total CPFH expenditures by MACOM for each helicopter type, which consists of consumable and depot-level reparable parts and petroleum, oil, and lubricants (POL). The next step is to compare the actual expenditure CPFH to the budget submissions of each MACOM 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 are analyzed by comparing them with the actual expenditures. The results of this comparison will then be 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 MACOM.

Database

As mentioned in Chapter I, the OSMIS database will be used to gather the necessary data for the analysis and forecasting for this research. The database includes all major Army weapon systems. OSMIS was developed to satisfy Congressional O&S reporting requirements and contains unclassified operating costs associated with a weapons system. The information contained in OSMIS is a collection of data from various sources. It contains actual flying hours from the Unit Level Logistic System-Aircraft/Ground (ULLS-A/G), parts information from the Continuing Balance System Expanded (CBS-X), and parts pricing from the Army Master Data File (AMDF).

The necessary CPFH data for analysis and forecasting is accessed through three separate queries options: (1) Class IX data captures all consumables and depot-level reparable parts (DLRs); (2) JP8 fuel consumption, which is the main fuel for the Army; and (3) lubricant oil. The components of the two separate queries for fuel make up the total costs for the POL portion of the CPFH for the aircraft. Upon selecting Class IX Single Stock Fund 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 one to select the fiscal year (FY) of the data requested and the type of helicopter. Parts cost is calculated based on pricing from the Army Master Data File (AMDF), a database that contains all parts currently in the Army's inventory. Currently, pricing for parts in OSMIS only includes years 2001 quarter 1 to 2002 quarter 4. The default pricing for 2002 quarter 2 will be used throughout the data retrieval process.

Table 10. FY95 AH-64A Apache Parts Costs for FORCOM

MDS	*MDS Name*	*MACOM Name*	*FY*	*QTR*	*CONS*	*REPS*	*TOTAL*	*Density*	*Activity*
AH-64A	*APACHE*	*FORSCOM*	*1995*	*1*	*$7,711,893*	*$18,132,718*	*$25,844,612*	*262*	*9,654*
AH-64A	*APACHE*	*FORSCOM*	*1995*	*2*	*$7,250,761*	*$15,225,885*	*$22,476,646*	*247*	*7,980*
AH-64A	*APACHE*	*FORSCOM*	*1995*	*3*	*$7,029,692*	*$15,437,743*	*$22,467,435*	*247*	*6,562*
AH-64A	*APACHE*	*FORSCOM*	*1995*	*4*	*$5,719,573*	*$13,899,942*	*$19,619,515*	*274*	*9,187*

When the parts data is retrieved, consumables and DLR parts are separated to allow further analysis on individual pieces of the CPFH, if necessary. The activity level, or actual hours flown, for a particular fiscal year is also obtained from this same query.

Table 10 is an example of a parts query for the Apache. For fuel consumption, JP8 and oil are obtained in two separate queries for each FY by helicopter. Tables 11 and 12 are examples of these retrievals.

Table 11. FY95 AH-64A Apache JP8 Costs for FORSCOM (Then Years)

MDS	MDSNAME	FY	QTR	MACOM NAME	FUEL TYPE	FUEL NOMENCLATURE	ACTIVITY HOURS	TOTAL
AH-64A	APACHE	1995	1	FORSCOM	JP8	TURBINE FUEL, KEROSINE	9,654	$808,523
AH-64A	APACHE	1995	2	FORSCOM	JP8	TURBINE FUEL, KEROSINE	7,980	$668,325
AH-64A	APACHE	1995	3	FORSCOM	JP8	TURBINE FUEL, KEROSINE	6,562	$549,568
AH-64A	APACHE	1995	4	FORSCOM	JP8	TURBINE FUEL, KEROSINE	9,187	$769,411

Table 12. FY95 AH-64A Apache Oil Costs for FORSCOM (Then Years)

MDS	MDSNAME	FY	QTR	MACOM NAME	FUEL TYPE	FUEL NOMENCLATURE	ACTIVITY HOURS	TOTAL
AH-64A	APACHE	1995	1	FORSCOM	OIL	LUBOIL ATE MIL-L-7808 1 QT CN	9,654	$1,931
AH-64A	APACHE	1995	2	FORSCOM	OIL	LUBOIL ATE MIL-L-7808 1 QT CN	7,980	$1,596
AH-64A	APACHE	1995	3	FORSCOM	OIL	LUBOIL ATE MIL-L-7808 1 QT CN	6,562	$1,312
AH-64A	APACHE	1995	4	FORSCOM	OIL	LUBOIL ATE MIL-L-7808 1 QT CN	9,187	$1,837

The data for parts and flying hours was extracted from OSMIS for FY93-FY02 for each of the three helicopters. Fuel data only covers FY95-FY02. All data will be placed into a consolidated table in order to calculate a historical CPFH to be used in a forecasting model. The individual pieces will be maintained to allow individual analysis, if necessary. Since parts costs are provided in 2002 dollars, they will be converted to Then Year similar to the fuel data, which is in Then Year dollars upon retrieval. The conversion will be based on the factors for Then Year to Base Year/Constant Year for Air Force appropriation 3400, O&M funds, provided in the SAF/FMC inflation conversion tables. Table 13 is an example of the consolidated information for the AH-64A for FORSCOM.

Table 13. Calculated CPFH, AH-64A - FY95 - 02

FY	Consumables	DLRs	POL	Hours Flown	Actual CPFH
1995	*$25,572,442*	*$57,855,869*	*$2,714,372*	*33,383*	*$2,580*
1996	*$20,359,261*	*$50,836,519*	*$2,848,314*	*31,662*	*$2,339*
1997	*$15,059,526*	*$46,920,165*	*$3,049,272*	*31,803*	*$2,045*
1998	*$14,295,582*	*$43,911,050*	*$2,842,753*	*29,792*	*$2,049*
1999	*$16,295,243*	*$46,000,357*	*$2,848,656*	*28,991*	*$2,247*
2000	*$12,716,551*	*$43,532,546*	*$1,744,354*	*24,813*	*$2,337*
2001	*$14,227,517*	*$36,156,838*	*$1,593,330*	*16,592*	*$3,133*
2002	*$14,004,176*	*$63,571,277*	*$2,324,120*	*19,241*	*$4,153*

Empirical CPFH Breakout

The three different pieces of the flying hour program total cost will be used for the empirical breakout. Each helicopter will be evaluated for FY00-02 in total showing total expenditure by MACOM for the flying hour program. Pie charts will be created showing the percentage that each MACOM contributes to the entire cost for that FY. Table 14 and Figure 15 is an example of this breakout for the AH-64A for FY00. The top three MACOMs in terms of total expense for a given fiscal year will be used for the cost category breakout. Table 3-6 and Figure 16 is an example of this breakout. The percentage that each of the three categories contribute to total cost should provide 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 helicopter the total percentage breakout for each FY will be compared to one another to analyze any trends that might be present.

Table 14. Total CPFH Expenditure, AH-64A - FY00

2000	USAR	USAREUR	FORSCOM	ARNG	EUSA	TRADOC
Consumables	*$1,029,118*	*$14,519,971*	*$12,716,551*	*$9,434,765*	*$5,359,617*	*$5,477,922*
DLRs	*$5,297,704*	*$42,353,173*	*$43,532,546*	*$25,946,384*	*$12,198,989*	*$16,109,898*
POL	*$380,815*	*$1,338,512*	*$1,744,354*	*$879,242*	*$883,109*	*$1,264,767*
Tot Expense	*$6,707,637*	*$58,211,656*	*$57,993,451*	*$36,260,391*	*$18,441,715*	*$22,852,588*

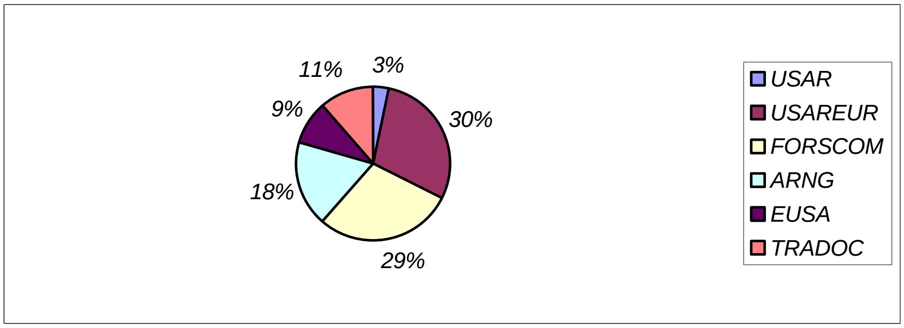

Figure 15. Total CPFH Expenditure, AH-64A - FY00

Table 15. CPFH Cost Category Breakout, AH-64A - FY00

2000	USAREUR	FORSCOM	TRADOC	Total
Consumables	*$14,519,971*	*$12,716,551*	*$5,477,922*	*$32,714,444*
DLRs	*$42,353,173*	*$43,532,546*	*$16,109,898*	*$101,995,617*
POL	*$380,815*	*$1,744,354*	*$1,264,767*	*$3,389,936*
Tot Expense	*$57,253,959*	*$57,993,451*	*$22,852,588*	*$138,099,997*

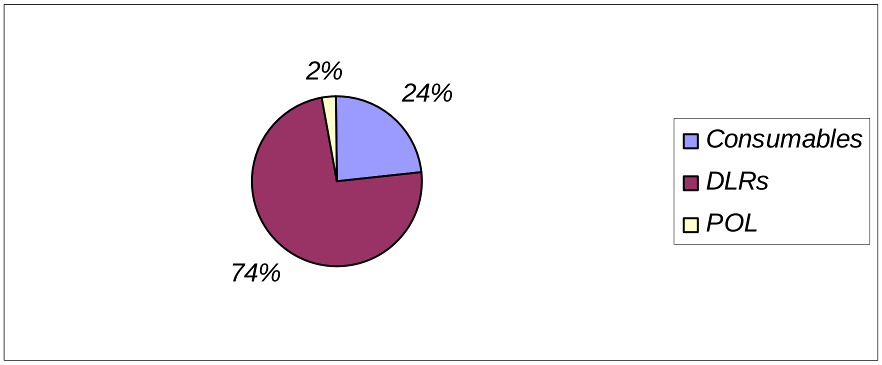

Figure 16. CPFH Cost Category Breakout, AH-64A - FY00

Actual Cost per Flying Hour Versus Budget Submissions

The Army budgets the CPFH by MACOM. In this section, the budget submissions of the CPFH of the helicopters for FY00-FY02 will be evaluated for selected MACOMs by comparing them to the actual CPFH calculated from the OSMIS database.

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. 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 MACOM being analyzed, three different forecasting techniques will be used to evaluate the CPFH data extracted from the OSMIS database. The three forecasting techniques being employed will be a 3-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 (24:142). The formula for an MA3 calculation is:

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

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 due to its simplicity; it is very easy to use and explain. The reason the order of the MA is three and not higher, such as five, is due to the fact that the data series is so small. Although a higher order would result in a better, smoother forecast, it 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 (24:146).

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 (24:147). The downfall of this forecasting method is the same as the MA3 in that it doesn't handle trends very well and will trail any trend in the actual data (24:148).

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

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

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

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

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 the trend of the previous period, and m is the number of periods ahead to be forecasted (24:158). This method of forecasting was selected because unlike the previous two methods, Holt’s can handle trends within the data (24:158). This method is also useful because it can forecast more than one period ahead, if needed. One of the drawbacks 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 (24:161). The main disadvantage 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). 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 the error (observation – forecast), and n is the number of observations.

However, the ME is likely to be small since positive and negative errors tend to offset one another (24:43). 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:

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

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:

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

Where PE_t is 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:

$$\mathrm{MAPE} = \frac{1}{n} \cdot \sum_{t=1}^{n} \left| \mathrm{PE}_t \right| \tag{10}$$

These four summary statistics will measure the goodness of fit of the model to the historical data (24:45). 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 individual summary statistic.

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 extracted from the OSMIS database 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 within the OSMIS database. The method chosen for each MACOM 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 and the 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 tables provide insight into the OSMIS database and what to expect for the empirical CPFH Breakout section of Chapter IV. The formulas and their descriptions provide an in-depth look at the statistics used to evaluate not only the forecast, but also the budget submissions of each MACOM. Following the steps laid out in this chapter will definitely provide answers to the research questions/objectives listed in Chapter I.

IV. RESULTS AND DISCUSSION

Chapter Overview

This chapter details the results of all analysis performed on the data retrieved from the Army's OSMIS database. The chapter begins with the breakout of total expenditure for the flying hour program across all MACOMs that utilize each of the helicopters being studied: the AH-64A Apache, the CH-47D Chinook, and the UH-60A Blackhawk. The top three MACOMS, with the most expense for the flying hour program, was used for further detailed analysis and forecasting purposes. The next step involved a percentage breakout of the three pieces of the flying hour program across the top three MACOMs previously selected. A historical CPFH for the top three MACOMs was then calculated and compared to the budgeted CPFH that was reported for FY00-FY02. Finally, the historical CPFH for each MACOM was used in three different forecasting scenarios to determine which one results in an accurate tool to be utilized for forecasting a FY 04 CPFH. The forecasts from the most appropriate model were compared to the historical and budgeted CPFH to determine if the results from these forecasting methods are valid for comparison to results from current budgeting procedures.

AH-64A Apache

Total Expenditure Breakout by MACOM.

The total expenditure breakout involves all MACOMs that utilize the AH-64A. Table 16 is a sample of this breakout for the Apache for FY00. The dollar figures show total expense for each command for the three CPFH components.

Table 16. Total CPFH Expenditure, AH-64A - FY00

2000	USAR	USAREUR	FORSCOM	ARNG	EUSA	TRADOC
Consumables	*$1,029,118*	*$14,519,971*	*$12,716,551*	*$9,434,765*	*$5,359,617*	*$5,477,922*
DLRs	*$5,297,704*	*$42,353,173*	*$43,532,546*	*$25,946,384*	*$12,198,989*	*$16,109,898*
POL	*$380,815*	*$1,338,512*	*$1,744,354*	*$879,242*	*$883,109*	*$1,264,767*
Tot Expense	*$6,707,637*	*$58,211,656*	*$57,993,451*	*$36,260,391*	*$18,441,715*	*$22,852,588*

In order to determine the top three MACOMs in terms of expense, a percentage chart provides a graphic example. Figure 17 shows all the MACOMS relevant for analysis. All MACOMS that did not report flying hours for the fiscal year, or made up 1 percent or less of the total expense across all MACOMs, were excluded from the breakout. Also, only active duty MACOMs were considered as part of the top three, ruling out all expenditures reported by the ARNG and USAR commands. These commands were included in the analysis if they met the percentage threshold and flying hour requirements but were not used for further analysis.

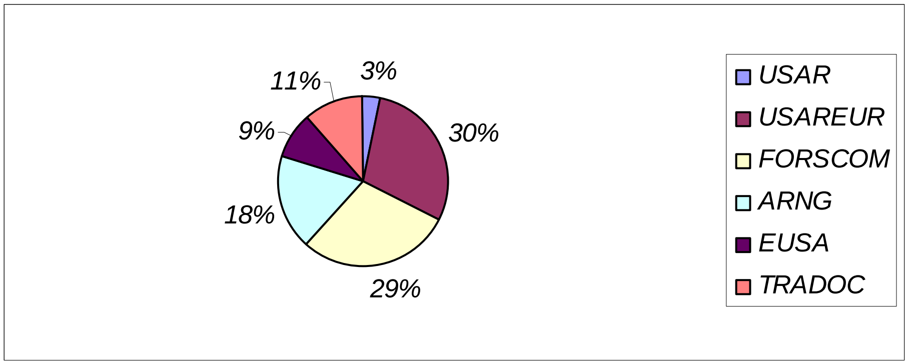

Figure 17. Total Expenditure Breakout, AH-64A - FY00

The top three MACOMs for the Apache in FY00 were the USAREUR, FORSCOM, and TRADOC commands. Figures 18 and 19 show the breakouts for FY01 and FY02.

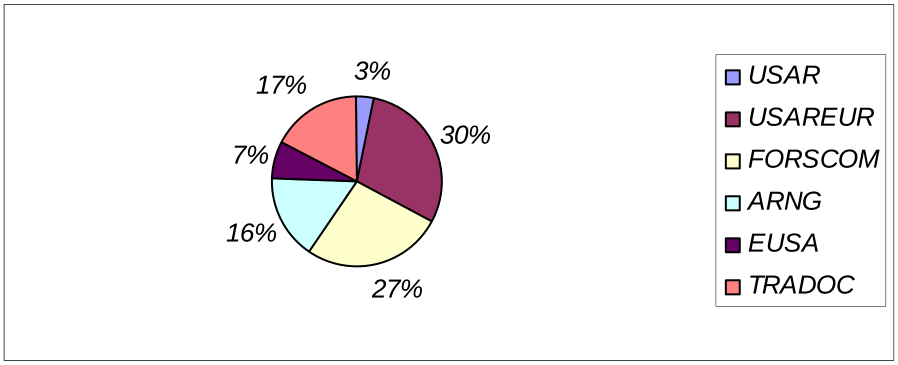

Figure 18. Total Expenditure Breakout, AH-64A - FY01

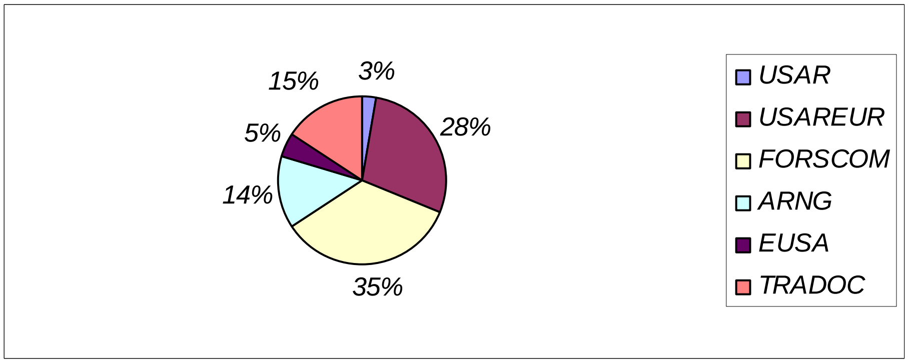

Figure 19. Total Expenditure Breakout, AH-64A - FY02

The top three MACOMs for FY01 and FY02 are similar to FY00. FORSCOM, USAREUR, and TRADOC will be the focal point for the remaining analysis and forecasting for the AH-64A Apache. Now that the MACOMS were reduced to the top three according to total expenditure, a breakout of the three cost categories was next.

CPFH Cost Category Breakout - AH-64A.

The cost category breakout involved the total amount expended on consumables, DLRs, and POL across the top three MACOMs selected for the AH-64A. Table 17 provides an example of the data consolidated for the AH-64A for FY00.

Table 17. CPFH Cost Category Breakout, AH-64A - FY00

2000	USAREUR	FORSCOM	TRADOC	Total
Consumables	$14,519,971	$12,716,551	$5,477,922	$32,714,444
DLRs	$42,353,173	$43,532,546	$16,109,898	$101,995,617
POL	$380,815	$1,744,354	$1,264,767	$3,389,936
Tot Expense	$57,253,959	$57,993,451	$22,852,588	$138,099,997

The category breakout provides a percentage that each piece of the flying hour program contributes to the entire expense for a given year. Figure 20 shows the percentages for the three cost categories for the AH-64A for FY00.

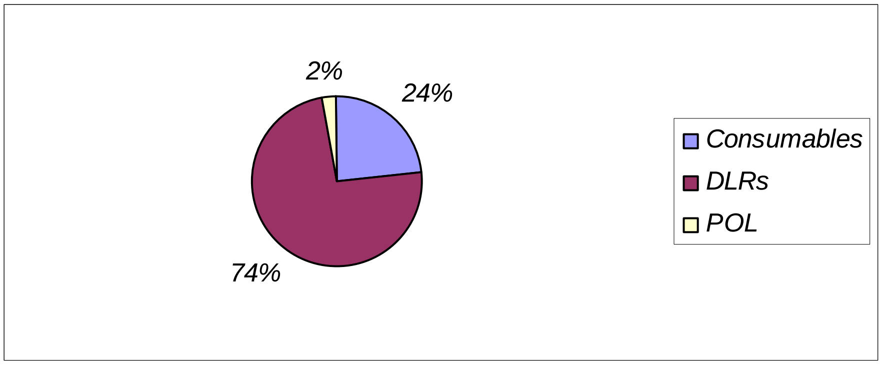

Figure 20. CPFH Cost Category Breakout, AH-64A - FY00

The largest percentage of the total was DLRs at 74 percent, followed by 24 percent and 2 percent for consumables and POL, respectively. Figures 21 and 22 show the breakouts for FY01 and FY02.

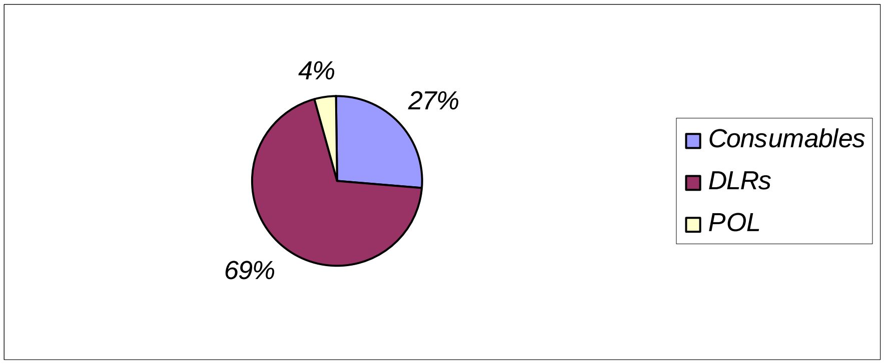

Figure 21. CPFH Cost Category Breakout, AH-64A - FY01

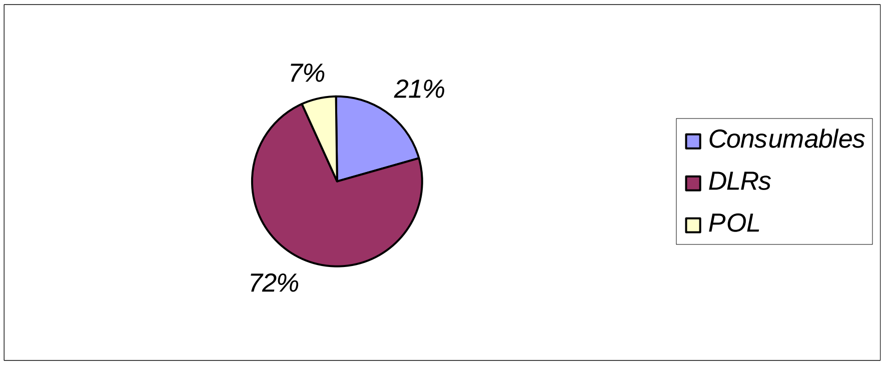

Figure 22. CPFH Cost Category Breakout, AH-64A - FY02

The breakouts for the three fiscal years show no significant deviation in the makeup of the CPFH in the three cost categories. The amount spent by the three MACOMS in total was consistent from FY00-FY02.

Historical CPFH Calculation - AH-64A.

In order to forecast future CPFHs for the AH-64A, the historical cost was calculated. For the AH-64A, data was available for all three cost categories from FY95-FY02. The parts data was priced at FY02 pricing, and fuel was Then Years. The parts data was converted to Then Years to ensure that a consistent cost figure was used. The three cost categories were added together and divided by the amount of hours flown by the helicopter in a given fiscal year. Table 18 details the CPFH calculation for the AH-64A for FORSCOM.

Table 18. FORSCOM - Calculated CPFH, AH-64A - FY95-02

				Hours	Actual
FY	**Consumables**	**DLRs**	**POL**	**Flown**	**CPFH**
1995	$25,572,442	$57,855,869	$2,714,372	33,383	$2,580
1996	$20,359,261	$50,836,519	$2,848,314	31,662	$2,339
1997	$15,059,526	$46,920,165	$3,049,272	31,803	$2,045
1998	$14,295,582	$43,911,050	$2,842,753	29,792	$2,049
1999	$16,295,243	$46,000,357	$2,848,656	28,991	$2,247
2000	$12,716,551	$43,532,546	$1,744,354	24,813	$2,337
2001	$14,227,517	$36,156,838	$1,593,330	16,592	$3,133
2002	$14,004,176	$63,571,277	$2,324,120	19,241	$4,153

Table 19 is a consolidated table for all the MACOMs for which a future CPFH will be forecasted.

Table 19. AH-64A Historical CPFH

FY	FORSCOM	USAREUR	TRADOC
1995	$2,580	$2,132	$1,361
1996	$2,339	$3,319	$1,377
1997	$2,045	$3,401	$1,317
1998	$2,049	$2,388	$1,358
1999	$2,247	$4,719	$1,586
2000	$2,337	$3,007	$1,270
2001	$3,133	$2,088	$1,827
2002	$4,153	$4,326	$2,123

AH-64A Budget vs. Actual CPFH.

Before forecasting techniques were applied to the historical data to determine a future CPFH, a comparison was made between the actuals and the budgeted data from the same fiscal years. Table 20 shows the percent difference, or deviation, between the actual CPFH and the CPFH that was budgeted for the same fiscal year.

Table 20. AH-64A CPFH Actual vs. Budget Comparison

FY	Type	TMS	FORSCOM	TRADOC	USAREUR
2000	**Actual**	**AH-64A**	$2,337	$1,270	$3,007
	Budget	**AH-64A**	$2,727	$1,652	$3,756
		% Deviation	-17	-30	-25
2001	**Actual**	**AH-64A**	$3,133	$1,827	$2,088
	Budget	**AH-64A**	$2,389	$1,966	$2,789
		% Deviation	24	-8	-34
2002	**Actual**	**AH-64A**	$4,153	$2,123	$4,326
	Budget	**AH-64A**	$2,531	$2,819	$3,226
		% Deviation	39	-33	25

Positive numbers indicate the CPFH was under-budgeted for that fiscal year. Negative numbers indicate an over budget situation. An under-budget situation arises when the actual CPFH expense is higher than what was originally budgeted or estimated. An over-budget situation occurs when the actual expense is lower than the budgeted CPFH. In only three out of the nine cases, across all fiscal years and MACOMs, was there an under-budget situation: in FY01 for FORSCOM and in FY02 for FORSCOM and USAREUR. For all others, the actual CPFH was lower than the budgeted figure, as much as 33 percent for TRADOC in FY02.

AH-64A Forecasts.

To start the forecasting process**,** it was necessary to graph the original data to detect any underlying trend. Figure 23 shows the actual CPFH for all three MACOMs under analysis.

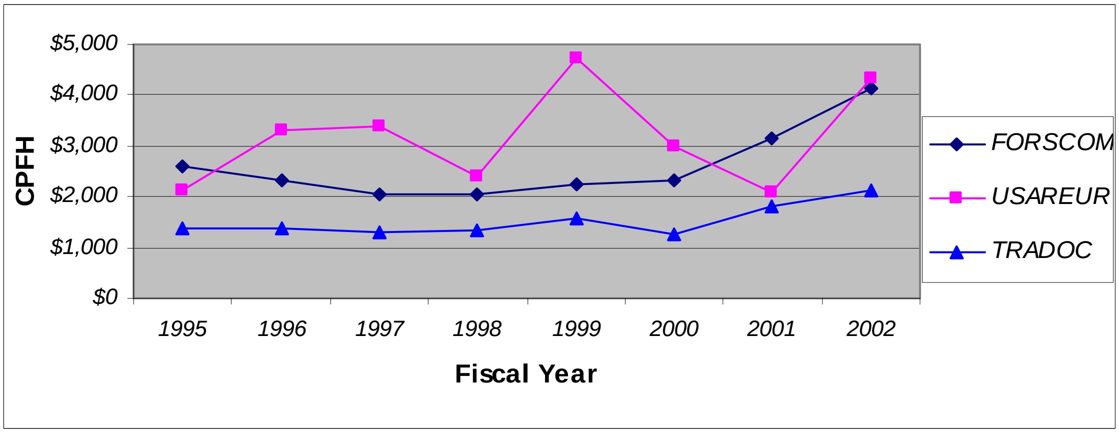

Figure 23. AH-64A Historical CPFH, FY95-FY02

The data shows a steady increasing trend for FORSCOM from FY98 to the present, with the trend increasing dramatically from FY00-FY02. TRADOC shows a steady data series, with a gradual trend from FY00-FY02. The USAREUR data is volatile, with extreme spikes in the data in FY00 and FY02. These graphs give guidance as to which of the three forecasting methods should result with the most accurate forecast.

Figure 24 shows the results of the three forecasting techniques applied to the CPFH for FORSCOM. After performing forecasts with all three methods, Holt's resulted in a MAPE of 8.3254, the lowest of the three. SES and MA produced higher MAPEs at 12.50 and 18.98, respectively. The graph revealed Holt's method most accurately reflects the actual data, tracing it closely from FY95 to FY00 and accounting for the trend component in the actual data with the evident increase in FY01 and FY02. The MAPE was minimized with an alpha and beta of one.

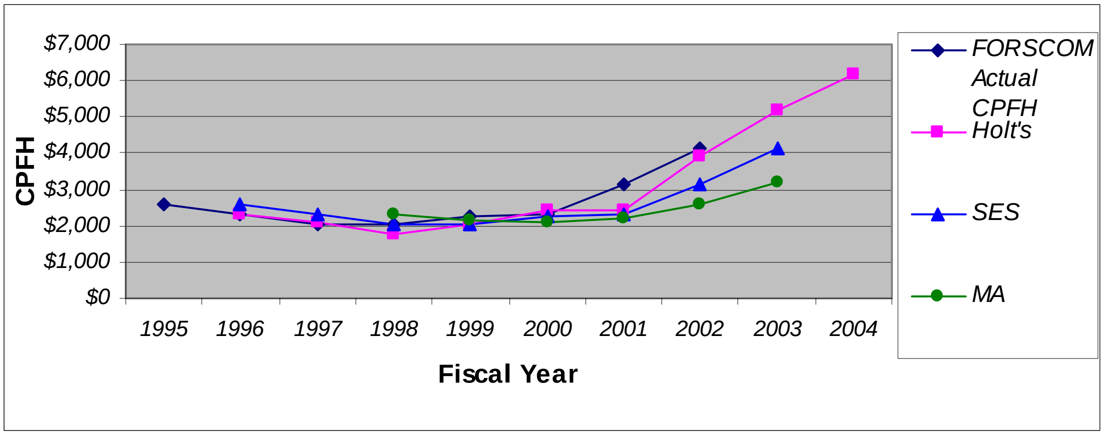

Figure 24. FORSCOM Actual CPFH vs Forecasting Methods, AH-64A

For USAREUR, the data was much more volatile, and selecting a forecasting technique was more difficult with the limited amount of data available. Figure 25 shows the results of the three techniques along with the actual CPFH for USAREUR.

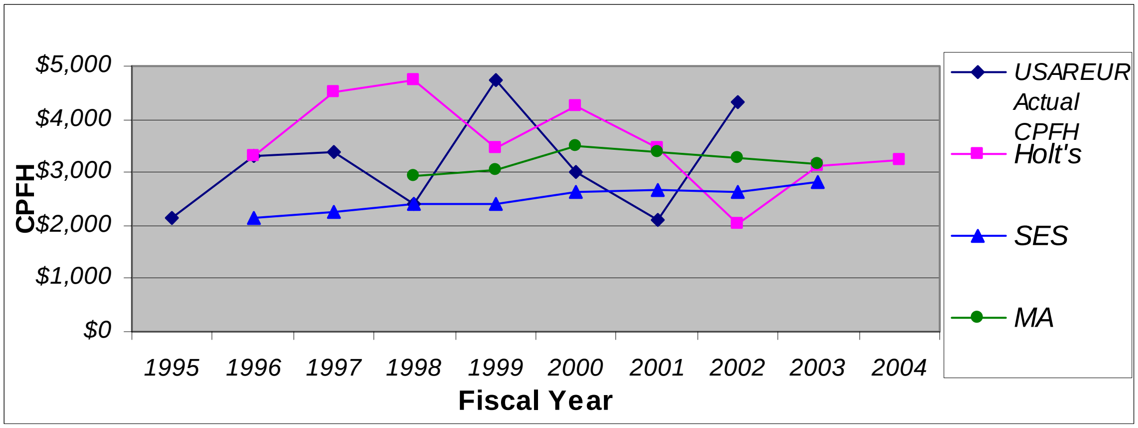

Figure 25. USAREUR Actual CPFH vs Forecasting Methods, AH-64A

The lowest MAPE obtained for USAREUR is 28.38695 with the SES forecasting method. The MAPE was minimized with an alpha of 0.1102. The MAPE for the Holt's method was the highest at 45.35, followed by MA at 32.31. With the data available, SES was the most accurate of the three. In this case, the choice for the best forecasting method came down to the lowest MAPE obtained from each one. The graph provides no visual confirmation because no method accurately reflects the actual figures. SES and MA, which do not account for trend, show no trend component in their forecasts. The Holt's method, which does account for trend, cannot correct quickly enough due to the extremes in the real data so it appears to lag behind the actuals. There is no consistent trend in the actual data for Holt's to reflect accurately. With a MAPE so high, a naïve method could be just as accurate, which would simply use the previous year's CPFH as the forecast for the next year. The graph does not provide any guidance to the best method because none of the forecasts reflect the actual data with any accuracy.

Finally, for TRADOC, Figure 26 shows the actual CPFH with the results of the three forecasting techniques. Although Holt's and SES both obtain very close MAPEs at 11.702 and 12.21, respectively, the Holt's forecast is closer in line with the actual data according to the graph. The increasing trend in the actual data is being mirrored by the Holt's forecast. MA, with the highest MAPE at 15.330, and SES show a close similarity when compared to the actual data and do not appear to be tracking the trend successfully. The MAPE in the Holt's forecast was minimized at an alpha of 0.3359 and a beta of 1.

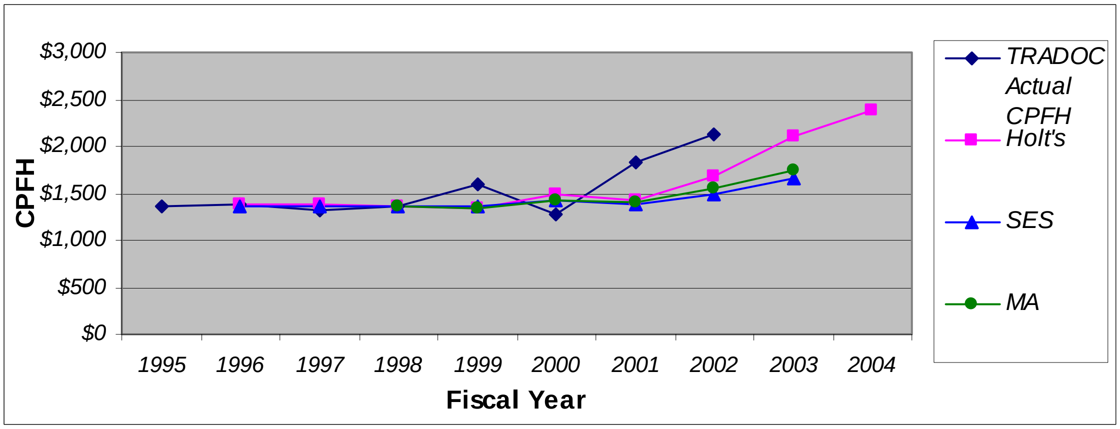

Figure 26. TRADOC Actual CPFH vs Forecasting Methods, AH-64A

In summary, for the AH-64A Apache, the most accurate forecasting tool for FORSCOM was the Holt's method. SES would result in the best forecast for USAREUR, although the extreme changes in the data available makes even this method not very reliable. Finally, the most accurate forecasting method for TRADOC command would be the Holt's method. Now that a forecasting method had been selected, a comparison was made between the actual, budgeted, and forecasted CPFH for FY00-FY02.

AH-64A CPFH Actual and Budgeted vs Forecast.

Although some of the forecasting methods produced very high MAPEs, a comparison to budgeted CPFH can reveal how the forecasting methods performed by comparing them to the results of an established procedure used historically every year for budget submissions. Table 21 shows a summary of the actual CPFH versus the budgeted, as well as forecasted CPFH, for FY00-FY02 for the three MACOMs under analysis.

Table 21. AH-64A CPFH Actual vs. Budget & Forecast Comparison

FY	Type	FORSCOM	TRADOC	USAREUR
2000				
Actual vs.	**Budget**	-17%	-30%	-25%
	Forecast	-5%	-18%	12%
2001				
Actual vs.	**Budget**	24%	-8%	-34%
	Forecast	23%	23%	-29%
2002				
Actual vs.	**Budget**	39%	-33%	25%
	Forecast	5%	21%	39%

Positive numbers indicate an under-budget situation as well as a situation in which the forecast under estimated the actual CPFH. Negative numbers indicate an over budget situation and situation in which the forecast over estimated the actual CPFH. For FORSCOM, the Holt's forecasting method produced results that deviated from the actual CPFH less than the budgeted figure. Although some cases show a deviation as high as 23 percent for FORSCOM, as in FY01, the budgeted number shows a deviation of 24 percent.

For TRADOC in FY01 and USAREUR in FY02, the forecasting method performed with less accuracy when compared to the actual CPFH. The forecast deviated more than the budgeted from the actual CPFH in only two out of nine occasions. Now that the AH-64A Apache had been studied, the CH-47D Chinook was analyzed and a forecast developed.

Ch-47D Chinook

Total Expenditure Breakout by MACOM.

As with the AH-64A, the total expenditure breakout for the flying hour program involved all MACOMs that utilize the CH-47D. Table 22 is an example of the breakout for the Chinook for FY00. The dollar figures show total expense for each command for the three CPFH components.

Table 22. Total CPFH Expenditure, CH-47D - FY00

2000	USASOC	USAREUR	FORSCOM	ARNG	USARPAC	EUSA	TRADOC
Consumables	$2,516,457	$2,177,475	$5,574,719	$5,615,214	$2,640,769	$3,878,485	$3,371,634
DLRs	$2,818,060	$8,130,967	$25,588,245	$15,321,124	$7,332,355	$22,357,087	$7,185,693
POL	$1,596,698	$1,617,150	$6,660,097	$11,935,063	$3,546,189	$2,780,943	$2,928,716
Tot Expense	$6,931,214	$11,925,592	$37,823,060	$32,871,402	$13,519,312	$29,016,515	$13,486,043

The total expenditure breakout included FY00-FY02. The top three MACOMs with respect to total cost was used for further analysis and forecasting. Figure 27 shows the percentage breakout by MACOM.

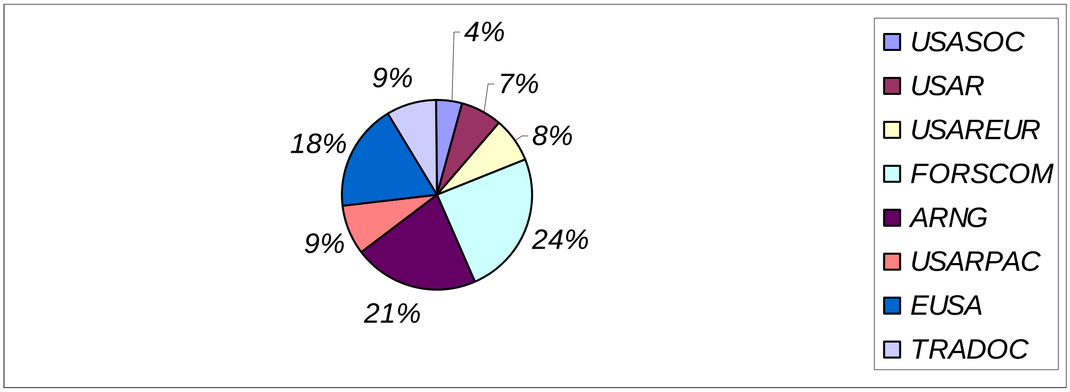

Figure 27. Total Expenditure Breakout, CH-47D - FY00

All MACOMs that did not report flying hours for a particular fiscal year, or made up 1 percent or less of the total expense across all the MACOMs, were excluded from further analysis. Additionally, only active duty MACOMs were considered candidates for the top three, excluding all expenditures reported by ARNG and USAR commands. These commands were included in the analysis if they met the flying hour requirement and percentage threshold but were not used for further analysis. Figures 28 and 29 show the remaining breakouts for FY01 and FY02.

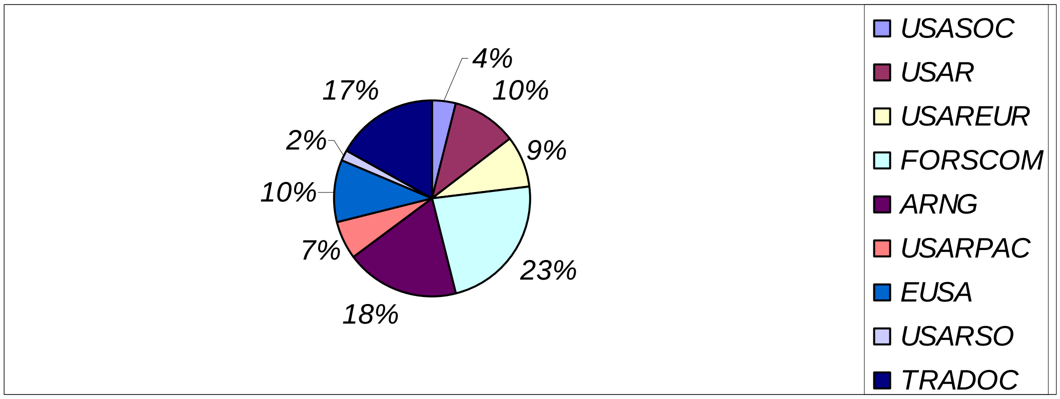

Figure 28. Total Expenditure Breakout, CH-47D - FY01

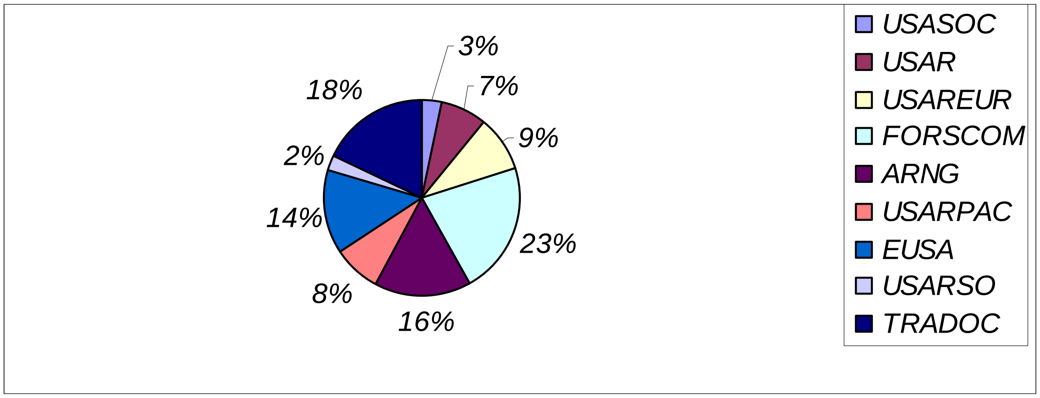

Figure 29. Total Expenditure Breakout, CH-47D - FY02

The top three MACOMs for FY00-FY02, excluding ARNG, are FORSCOM, EUSA, and TRADOC commands. These three commands were the focal point for the remaining analysis and forecasting for the CH-47D Chinook. Now that the MACOMs were reduced to the top three according to total expenditure, a breakout of the three cost categories was next.

CPFH Cost Category Breakout - CH-47D.

The cost category breakout involves the total amount expended on consumables, DLRs, and POL across the top three MACOMs selected for the CH-47D. Table 23 provides the data for Chinook for FY00.

Table 23. CPFH Cost Category Breakout, CH-47D - FY00

2000	FORSCOM	EUSA	TRADOC	Total
Consumables	$5,574,719	$3,878,485	$3,371,634	$12,824,838
DLRs	$25,588,245	$22,357,087	$7,185,693	$55,131,025
POL	$6,660,097	$2,780,943	$2,928,716	$12,369,756
Tot Expense	$37,823,060	$29,016,515	$13,486,043	$80,325,619

The category breakout provides a percentage of what each piece of the flying hour program contributes to total expense for a given fiscal year. Figure 30 shows the percentages for the three pieces across the three MACOMs in FY00.

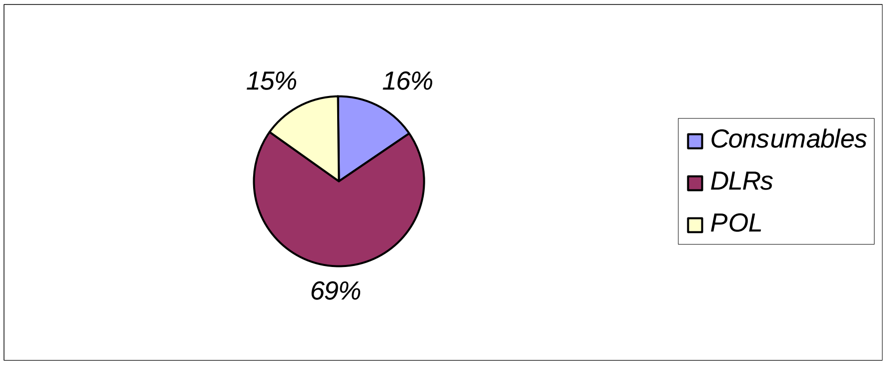

Figure 30. CPFH Cost Category Breakout, CH-47D - FY00

The largest percentage of the total is DLRs, similar to the Apache, followed by consumables and POL. Figures 31 and 32 show the breakout for FY01 and FY02.

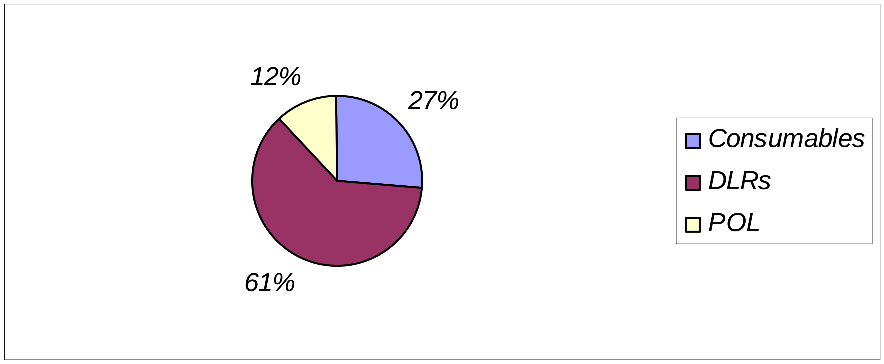

Figure 31. CPFH Cost Category Breakout, CH-47D - FY01

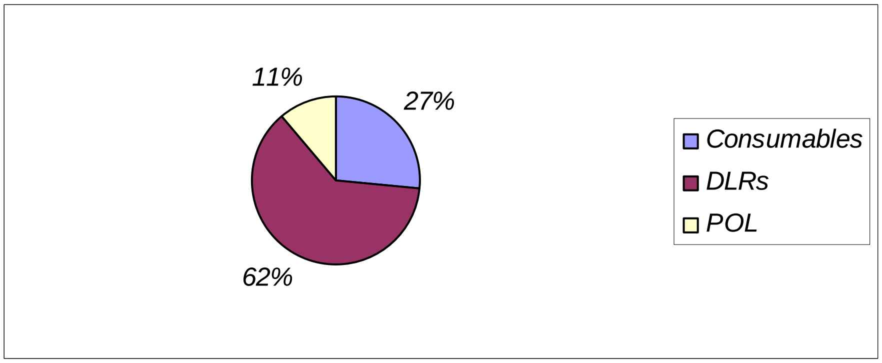

Figure 32. CPFH Cost Category Breakout, CH-47D - FY02

POL comprises more of the total cost for the Chinook than the Apache. There was a considerable increase in the percentage for consumables from FY00 to FY01, but the percentages were consistent with minimal deviation from FY01 to FY02. Now that total costs, as well as the three categories, had been examined, a historical CPFH was calculated for each MACOM to be used for forecasting.

Historical CPFH Calculation - CH-47D.

In order to forecast a CPFH for the Chinook, the historical cost must be calculated. The historical cost was determined for each fiscal year by dividing the total expense across the three cost categories by the total hours flown by the helicopter. For the CH-47D, complete parts and POL data was available from FY95 through FY02. The parts data was priced at FY02 pricing and POL data was in Then Year dollars. The parts data was converted to Then Year dollars to ensure a consistent cost figure was used. Table 24 is an example of the CPFH calculation for the CH-47D for FORSCOM.

Table 24. FORSCOM - Calculated CPFH, CH-47D - FY95-02

FY	Consumables	DLRs	POL	Hours Flown	Actual CPFH
1995	$6,880,886	$14,856,239	$4,309,816	17,386	$1,498
1996	$6,923,130	$14,842,546	$3,514,279	13,225	$1,912
1997	$7,299,052	$18,741,388	$3,893,005	13,746	$2,178
1998	$4,943,111	$16,082,752	$3,217,539	11,417	$2,123
1999	$5,760,551	$24,084,744	$3,616,805	12,461	$2,685
2000	$5,574,719	$25,588,245	$6,660,097	14,197	$2,664
2001	$7,684,808	$17,211,180	$4,095,094	14,429	$2,009
2002	$12,717,828	$21,377,755	$5,462,787	15,182	$2,606

Table 25 is a consolidated table for all the MACOMs for which a future CPFH will be forecasted.

Table 25. CH-47D Historical CPFH

FY	FORSCOM	EUSA	TRADOC
1995	$1,498	$1,246	$1,364
1996	$1,912	$1,683	$1,696
1997	$2,178	$2,927	$1,279
1998	$2,123	$2,253	$1,447
1999	$2,685	$2,558	$1,874
2000	$2,664	$4,895	$2,160
2001	$2,009	$2,188	$3,479
2002	$2,606	$3,948	$3,722

CH-47D Budget vs. Actual CPFH.

Before the three forecasting techniques were applied to the historical data, a comparison was made between the actuals and the budgeted data from the same fiscal years. As with the AH-64A, the comparison was made for the Chinook for FY00-FY02. Table 26 shows the percent difference, or deviation, between the actual CPFH and the one that was budgeted for the same fiscal year.

Table 26. CH-47D CPFH Budget vs. Actual Comparison

FY	Type	TMS	FORSCOM	EUSA	TRADOC
2000	**Actual**	**CH-47D**	$2,664	$4,895	$2,160
	Budget	**CH-47D**	$1,709	$1,889	$1,470
		% Deviation	36	61	32
2001	**Actual**	**CH-47D**	$2,009	$2,188	$3,479
	Budget	**CH-47D**	$1,869	$2,378	$1,617
		% Deviation	7	-9	54
2002	**Actual**	**CH-47D**	$2,606	$3,948	$3,722
	Budget	**CH-47D**	$2,336	$3,015	$1,959
		% Deviation	10	24	47

The positive deviations indicate the CPFH was under-budgeted compared to the actual expense. Negative deviations reveal an over-budget scenario. In all but one instance, EUSA in FY01, the CPFH was under-budgeted for the Chinook during FY00-FY02. The deviation was at its highest in FY00 for EUSA, at 61 percent Now that a historical cost was calculated, a forecast could be calculated for the Chinook using the three techniques previously discussed.

CH-47D Forecasts.

To start the forecasting process for the Chinook, it was necessary to graph the historical CPFH that was calculated for the top three MACOMs. This graph will help detect any trend that exists and also aid in the determination of which forecasting method will produce the best results. Figure 33 shows the historical CPFH for FORSCOM, EUSA, and TRADOC for the CH-47D.

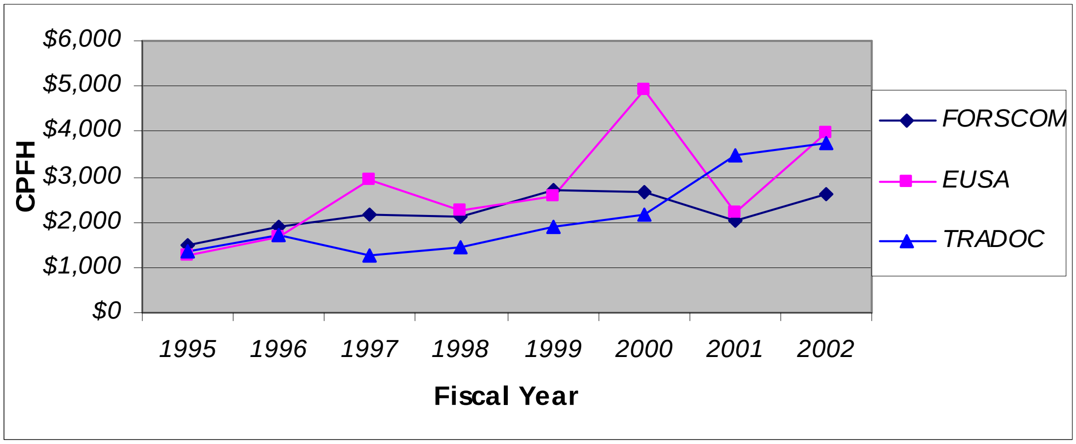

Figure 33. CH-47D Historical CPFH, FY95-FY02

The data reveals a steady series for TRADOC for FY95-FY98, with an increasing trend from FY98 to FY02. The trend is pronounced for FY00-FY02. For FORSCOM, there was a mild increasing and decreasing trend in the data series. EUSA had the most volatile data, with sharp increases and decreases in FY00-FY02.

Figure 34 shows the results of the three forecasting methods applied to the CPFH data for FORSCOM, along with the actual CPFH. The lowest MAPE resulted from the Holt's method at 13.00. Both MA and SES resulted in similar MAPEs at 15.52 and 15.91, respectively. With the MAPE and graph together, it was determined that the Holt's method would result in the most accurate forecast for FORSCOM. Once again, due to the trend in the data, the Holt's forecast traces the actual data better than either the SES or MA method. Both the MA and SES method lag behind the data series. MA is flat with no trend. The MAPE was minimized with an alpha of 0.314 and beta of 1.

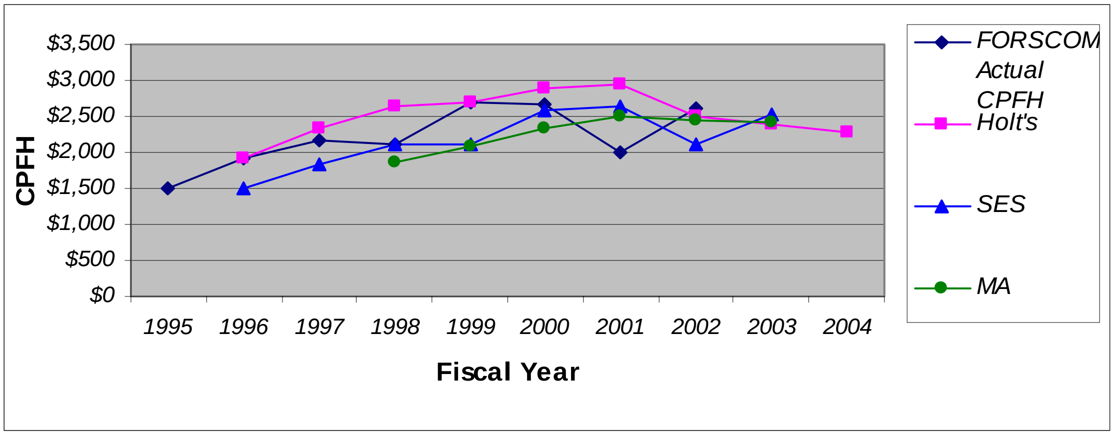

Figure 34. FORSCOM Actual CPFH vs Forecasting Methods, CH-47D

As with USAREUR and the Apache, the EUSA data for the Chinook is volatile, with significant differences in FY00-FY02. Due to the limited amount of data points, the lowest MAPE was the only reliable measuring tool to determine which method would be the most accurate. By looking at the graph for EUSA's actual CPFH compared to the forecasting methods, it was clear that none of the three performed accurately with the data series. Figure 35 shows the results of the three methods.

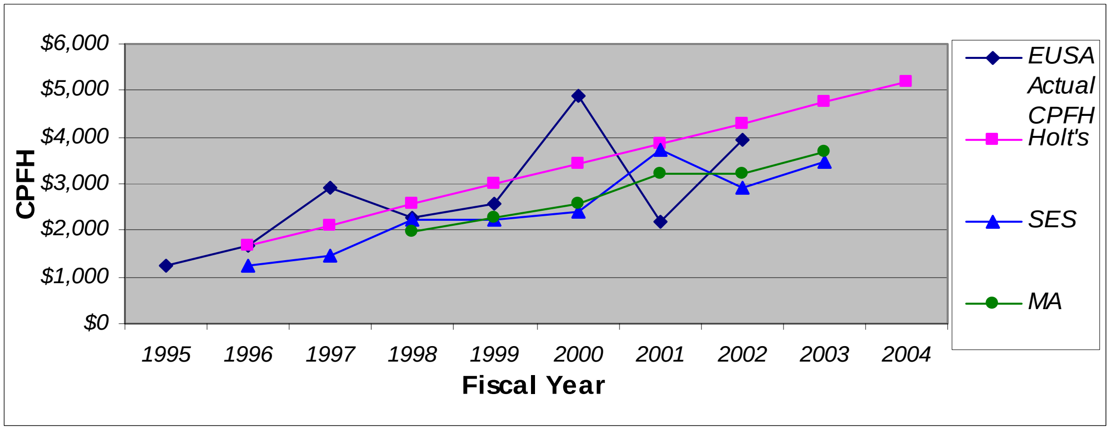

Figure 35. EUSA Actual CPFH vs Forecasting Methods, CH-47D

The best choice in this case would be the method with the lowest MAPE, which was Holt's at 24.85. In some cases, the lowest MAPE is not necessarily the best choice. The

MAPE, along with the graphed data, should be used together to make the choice. In EUSA's forecast, it was once again the choice of the lowest MAPE. None of the forecasts account for the extreme points in the data. Holt's traced a straight upward trend. SES and MA also produced an upward trend but much lower, and also under or over estimated at the end of the data series. With more data points, the forecast would eventually overcome these extremes and start accounting for changes more accurately. The MAPE for Holt's was minimized with an alpha of zero and a beta of 0.4992. With a MAPE so high, a naïve method would be just as appropriate. The MA and SES methods produced MAPEs of 27.54 and 33.60, respectively.

Finally, for TRADOC, the three methods were applied to the actual data and the results are pictured in Figure 36.

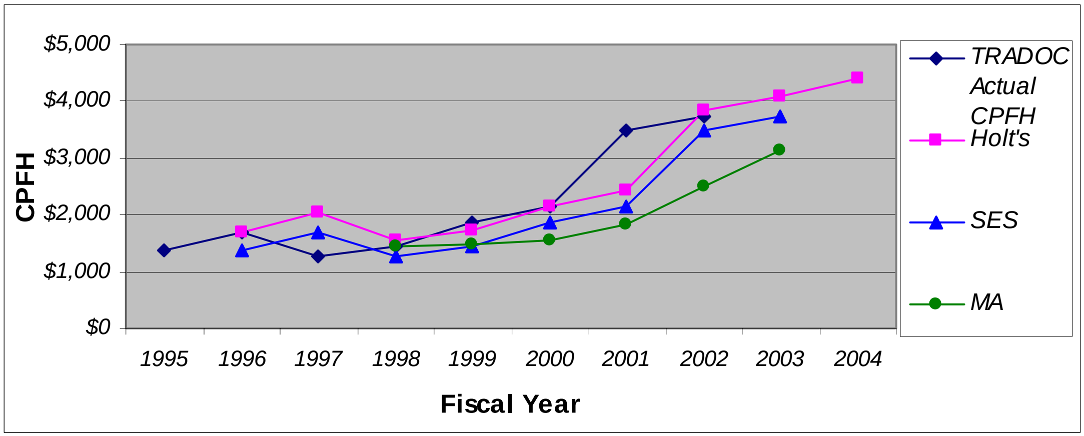

Figure 36. TRADOC Actual CPFH vs Forecasting Methods, CH-47D

The graph shows that both SES and Holt's are very close in relation to the real data, with Holt's closer and accounting for the increasing trend more accurately. The MAPEs for the two methods are 20.60 for SES and 15.29 for Holt's. MA actually resulted in a lower MAPE than SES at 16.03, but the graph shows that the other two methods were better at tracing the real data series. They are both accounting for the upward trend in the data, with Holt's closer to the actual. For TRADOC, the Holt's method was selected and the MAPE minimized with an alpha of one and a beta of 0.0640577.

In summary, for all three MACOMs, the Holt's method was determined to be the best forecasting method to predict future CPFH for the CH-47D. Now that a forecasting method was selected for each MACOM, a comparison was made between the actual, budgeted, and forecasted CPFH for FY00-FY02.

CH-47D CPFH Actual and Budgeted vs Forecast.

The forecasting methods selected for the CH-47D, in some cases, produced very high MAPEs. A similar situation occurred with the AH-64A. By comparing the forecasts to both the actual and budgeted CPFH, the performance of the methods chosen could be measured against a procedure used to formulate budget submissions every year. Table 27 shows this comparison for each MACOM for FY00-FY02.

Table 27. CH-47D CPFH Actual vs. Budget & Forecast Comparison

FY	Type	FORSCOM	EUSA	TRADOC
2000				
Actual vs.	**Budget**	36%	61%	32%
	Forecast	-8%	30%	0%
2001				
Actual vs.	**Budget**	7%	-9%	54%
	Forecast	-47%	-77%	30%
2002				
Actual vs.	**Budget**	10%	24%	47%
	Forecast	4%	-9%	-3%

Positive numbers indicate an under-budget situation as well as a situation in which the forecast under estimated the actual CPFH. Negative numbers indicate an over budget situation and situation in which the forecast over estimated the actual CPFH. For FY00 and FY02, the selected forecasting method performed better when compared to the budgeted CPFH. In some cases, the forecast deviated as much as 30 percent, such as EUSA in FY00, but the budget deviated by 61 percent. Even though both are off, the forecast performed with greater accuracy. FY01 forecasts show extreme deviations from the actual. With the limited number of data points available, sharp increases or decreases cause the forecasts to deviate by a significant margin. Overall, the forecasting methods selected can be used to predict future CPFH for the selected MACOMs with accuracy. Now that the CH-47D Chinook had been studied, the final helicopter, the UH-60A Blackhawk was analyzed and a forecast developed.

UH-60A Blackhawk

Total Expenditure Breakout by MACOM.

Similar to the AH-64A and CH-47D, the total expenditure breakout involves all MACOMs that utilized the UH-60A Blackhawk. The total includes the three pieces of the CPFH program as reported by the different MACOMs in the OSMIS database. Table 28 is a breakout for the Blackhawk for FY00.

Table 28. Total CPFH Expenditure, UH-60A - FY00

2000	USAREUR	FORSCOM	ARNG	USARPAC	EUSA	TRADOC
Consumables	$7,324,507	$6,457,348	$10,698,399	$2,445,043	$3,370,392	$3,919,074
DLRs	$26,840,790	$29,379,092	$32,956,091	$7,298,237	$19,457,618	$11,529,102
POL	$2,975,610	$4,576,816	$12,362,940	$2,173,302	$3,448,164	$3,268,797
Total Expense	$37,140,907	$40,413,255	$56,017,430	$11,916,583	$26,276,174	$18,716,973

The top three MACOMs according to this total expense breakout were again used from this point forward in the remaining analysis and forecasting. A percentage chart for the UH-60A for FY00 provides a graphic example of this breakout, indicated by Figure

37. The same criteria were applied as before when selecting the top three MACOMs. All MACOMs that did not report flying hours for the fiscal year, or those that made up 1 percent or less of the total expense across all MACOMs, were excluded. Additionally, only active duty MACOMs were considered for part of the top three, excluding ARNG and USAR commands. These commands were included in the analysis if they met the percentage threshold and flying hour requirements but were not considered from any point beyond that.

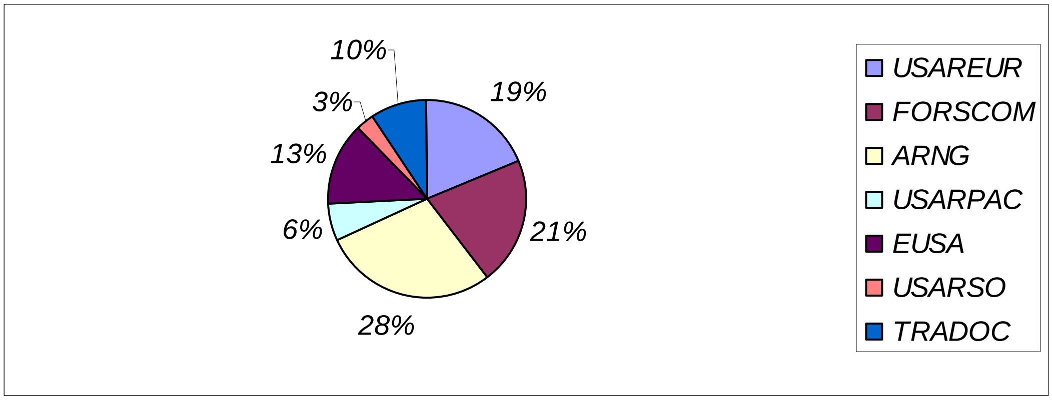

Figure 37. Total Expenditure Breakout, UH-60A - FY00

In FY00, the top three MACOMs in terms of total expense were FORSCOM, USAREUR, and EUSA. Figures 38 and 39 show the breakouts for FY01 and FY02.

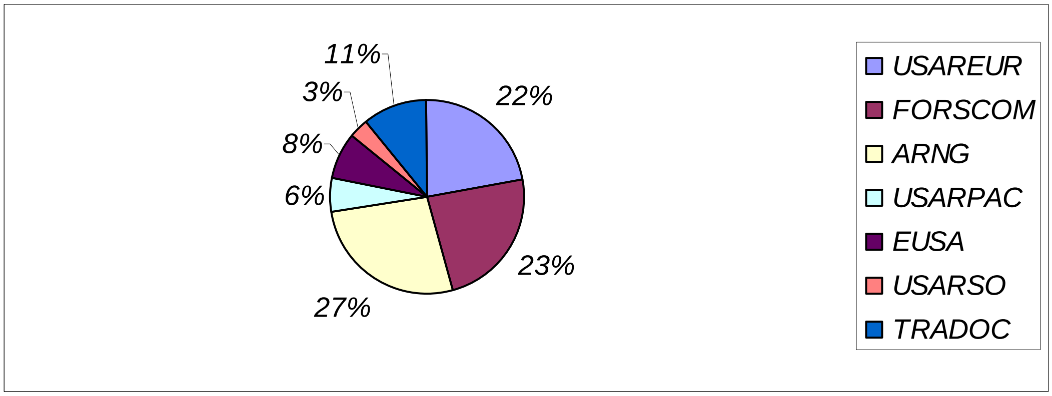

Figure 38. Total Expenditure Breakout, UH-60A - FY01

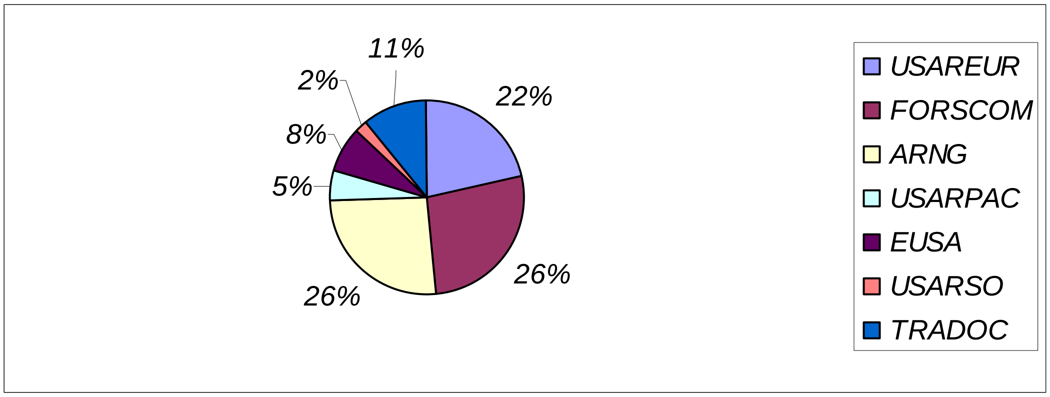

Figure 39. Total Expenditure Breakout, UH-60A - FY02

For FY01 and FY02, the top three MACOMS were FORSCOM, USAREUR, and TRADOC. Since TRADOC was present in two out of the last three years, I chose it as the third MACOM. FORSCOM, USAREUR, and TRADOC were used for the remaining analysis and forecasting. Now that the top three MACOMs were determined, a breakout of the three cost categories was accomplished.

CPFH Cost Category Breakout - UH-60A.

The cost category breakout included the total amount expended by the top three MACOMs selected for the UH-60A on consumables, DLRs, and POL. Table 29 provides the expenses for FY00 for the UH-60A.

Table 29. CPFH Cost Category Breakout, UH-60A - FY00

2000	USAREUR	FORSCOM	TRADOC	Total
Consumables	$7,324,507	$6,457,348	$3,974,863	$17,756,718
DLRs	$26,840,790	$29,379,092	$19,029,253	$75,249,134
POL	$1,884,723	$2,770,268	$2,190,063	$6,845,054
Total Expense	$36,050,019	$38,606,708	$25,194,179	$99,850,906

The cost category breakout provides a percentage that each piece of the flying hour program contributes to the total expense for the top three MACOMs in a given fiscal year. Figure 40 shows this breakout for the UH-60A for FY00.

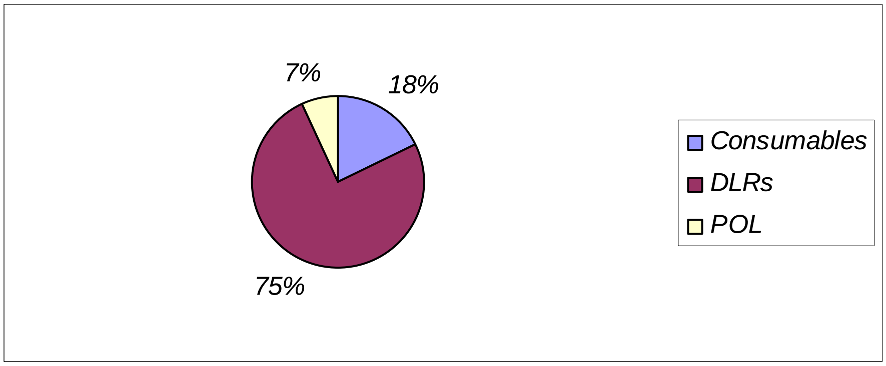

Figure 40. CPFH Cost Category Breakout, UH-60A - FY00

As with the AH-64A and CH-47D, DLRs makes up the largest percentage at 75 percent, followed by consumables at 18 percent and POL at 7 percent. Figures 41 and 42 show the breakouts for FY01 and FY02.

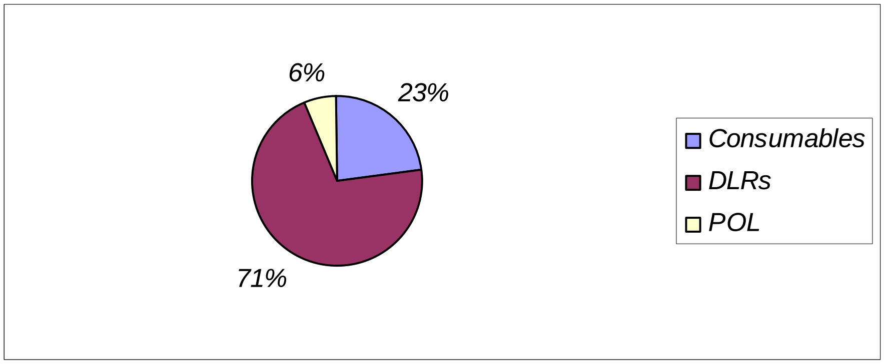

Figure 41. CPFH Cost Category Breakout, UH-60A - FY01

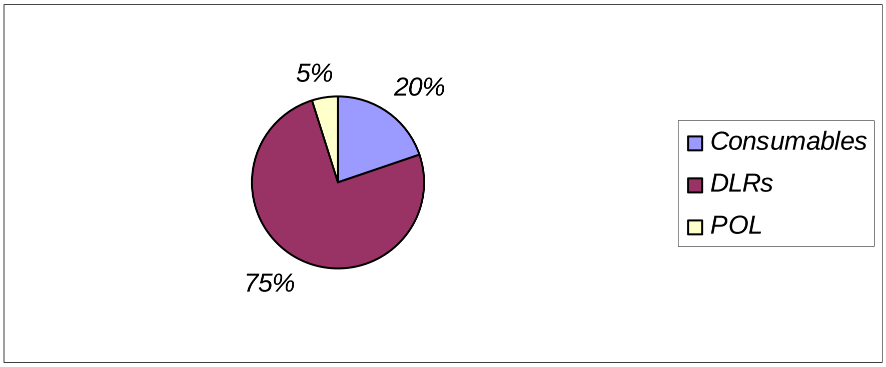

Figure 42. CPFH Cost Category Breakout, UH-60A - FY02

The percentages show no significant deviations in the CPFH spending makeup from year to year. The percentages of the three categories were fairly consistent across the three MACOMs for FY00 through FY02.

Historical CPFH Calculation - UH-60A.

Similar to the AH-64A and the CH-47D, a historical CPFH was calculated for the UH-60A to be used in all three forecasting scenarios. It also allowed the comparison between the actual and budgeted CPFH to see how budgeting procedures have performed over the last three fiscal years. The historical cost was determined for each fiscal year by dividing the total expense across the three cost categories by the total hours flown by the helicopter. For the UH-60A, complete parts and POL data was available from FY95 through FY02. The parts data was priced at FY02 pricing and POL data was in Then Years. The parts data was converted to Then Year dollars to ensure a consistent cost figure was used. Table 30 is an example of the CPFH calculation for the UH-60A for FORSCOM.

Table 30. FORSCOM - Calculated CPFH, UH-60A - FY95-02

FY	Consumables	DLRs	POL	Hours Flown	Actual CPFH
1995	$7,239,902	$27,835,793	$2,459,651	29,861	$1,257
1996	$6,882,839	$29,422,699	$2,417,441	27,390	$1,414
1997	$7,883,874	$25,996,631	$2,738,942	29,116	$1,258
1998	$8,201,915	$33,561,465	$3,027,730	32,351	$1,385
1999	$8,736,882	$36,064,543	$2,836,768	29,424	$1,619
2000	$6,457,348	$29,379,092	$2,770,268	29,301	$1,318
2001	$9,536,092	$30,210,048	$2,277,837	24,186	$1,738
2002	$11,900,362	$47,747,686	$2,770,268	23,453	$2,661

Table 31 is a consolidated table that shows the historical CPFH for the top three MACOMs for the UH-60A Blackhawk. The actual CPFH figures was used for the three forecasting scenarios.

Table 31. UH-60A Historical CPFH

FY	FORSCOM	USAREUR	TRADOC
1995	$1,257	$1,794	$853
1996	$1,414	$2,145	$829
1997	$1,258	$1,650	$783
1998	$1,385	$2,176	$627
1999	$1,619	$2,171	$893
2000	$1,318	$1,892	$843
2001	$1,738	$1,345	$1,277
2002	$2,661	$3,202	$1,359

UH-60A Budget vs. Actual CPFH.

Before the different forecasts were performed, a comparison was made between the actual and budgeted CPFH. Table 32 shows the percent difference, or deviation, between the calculated historical CPFH and the budgeted CPFH. Positive numbers indicate the CPFH was under-budgeted for that fiscal year. Negative numbers indicate an over budget situation. An under-budget situation arises when the actual CPFH expense is higher than what was originally budgeted or estimated. An over-budget situation occurs when the actual expense is lower than the budgeted CPFH.

Table 32. UH-60A CPFH Budget vs. Actual Comparison

FY	Type	TMS	FORSCOM	USAREUR	TRADOC
2000	**Actual**	**UH-60A**	$1,318	$1,892	$843
	Budget	**UH-60A**	$1,446	$2,151	$851
		% Deviation	-10	-14	-1
2001	**Actual**	**UH-60A**	$1,738	$1,345	$1,277
	Budget	**UH-60A**	$1,377	$1,859	$768
		% Deviation	21	-38	40
2002	**Actual**	**UH-60A**	$2,661	$3,202	$1,359
	Budget	**UH-60A**	$1,461	$1,785	$1,018
		% Deviation	45	44	25

All three MACOMs show an over-budget situation for FY00. For FY01 and FY02, there was only one occasion where a MACOM was over-budget, USAEUR in FY01. For all other situations, the actual CPFH was far above and beyond the budgeted figure. The highest deviation was found in FY02 for FORSCOM at 45 percent over budget.

UH-60A Forecasts.

To begin forecasting for the UH-60A**,** the first step was the same as for the AH-64A and the CH-47D, a graph of the original data. This graph helped detect any underlying trend that may be present. Figure 43 shows a plot of the historical CPFH for all three MACOMs being studied for the UH-60A.

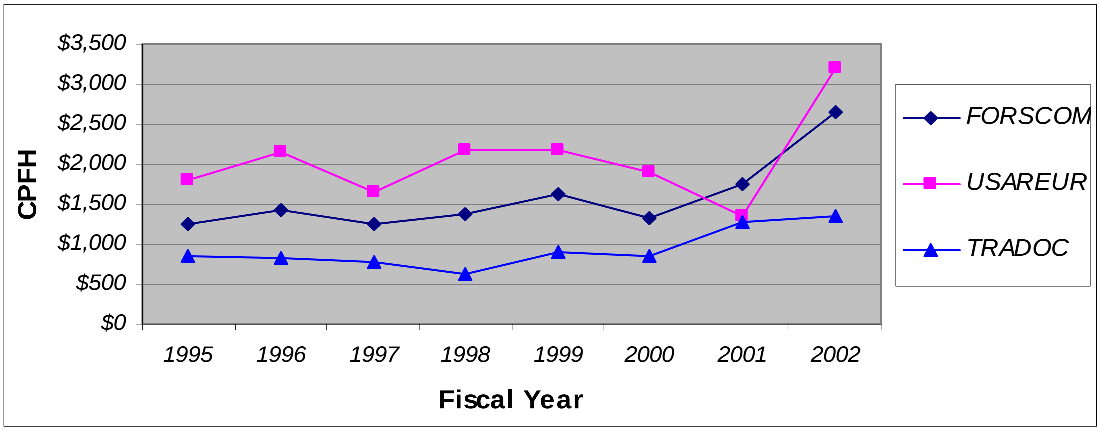

Figure 43. UH-60A Historical CPFH, FY95-FY02

FORSCOM shows mild increases and decreases from FY95 through FY00, with a sharp increase in FY01 and an even greater jump in FY02. TRADOC shows a mild decreasing trend until FY98, with a sharp increase in FY01 and FY02. Finally, USAREUR shows a trend for the UH-60A similar to USAREUR for the AH-64A and CH-47D. The data is volatile, especially from FY00 through FY02, with an increase in CPFH of over $2,000 per hour. The trends that have been pointed out should be handled better with the SES or Holt's method of forecasting.

Figure 44 shows the results of the three forecasting methods used with the FORSCOM data, along with the actual CPFH. The Holt's forecast most closely resembles the real data and also had the lowest MAPE at 14.994. SES and MA result in very similar plots in relation to the actual data, with MAPEs of 15.94 and 17.65, respectively. With the graph, the Holt's method was the chosen method because it accounts for the upward trend in the data more so than SES or MA, which are fairly flat. The MAPE was minimized with an alpha of 0.5471 and a beta of zero.

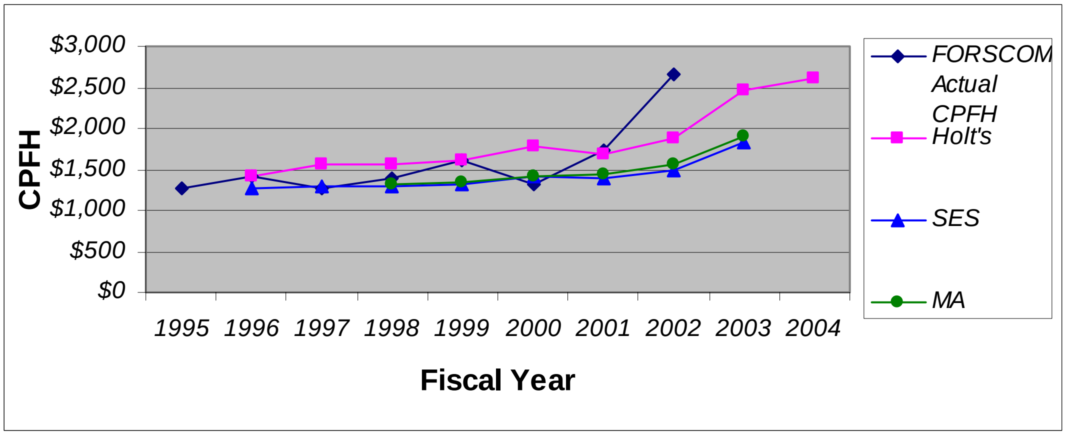

Figure 44. FORSCOM Actual CPFH vs Forecasting Methods, UH-60A

Figure 45 shows the plot of the three forecasts along with the actual data for USAREUR. The data has extreme values, especially for FY00 through FY02. This situation makes it difficult to choose the best method with the limited amount of data available, which was similar for USAREUR with the AH-64A. The lowest MAPE results from the SES method. From the graph, it was difficult to say which method presents the best representative for the actual data. SES and MA are flat and do not account for the highs and lows of the data, while Holt's does not show to recover from the extremes until the very end of the series. With more data points, Holt's could correct for the data's extremes. The MAPE was the final indicator. Since SES produces the lowest one with USAREUR's data, it was chosen as the best method for forecasting. The MAPE is minimized at an alpha of 0.082278.

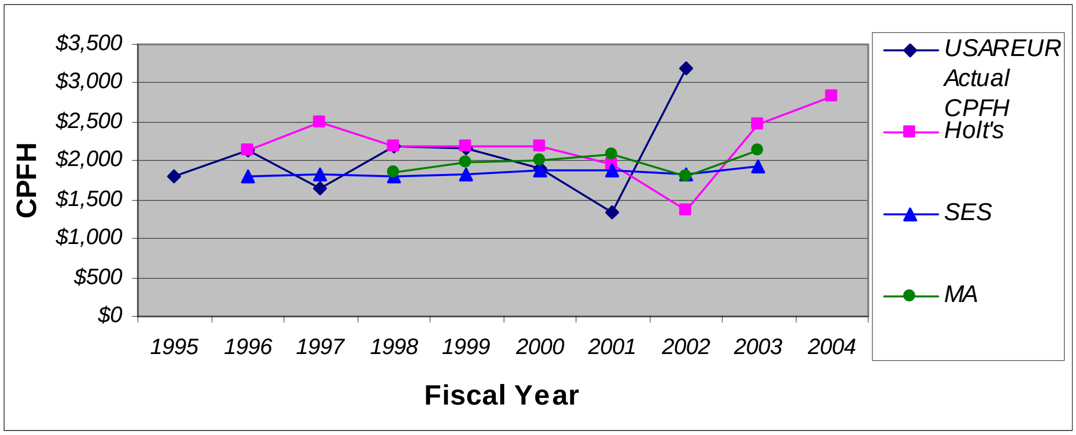

Figure 45. USAREUR Actual CPFH vs Forecasting Methods, UH-60A

Finally, Figure 46 shows the three forecasts with the actual CPFH for TRADOC. The Holt's forecast was more like the actual data according to the graph and resulted in the lowest MAPE at 13.10. The MAPE gets worse with SES and MA at 15.50 and 24.15, respectively. For TRADOC, the most accurate forecasting method would be the Holt's method. The MAPE was minimized at an alpha of 0.6381 and a beta of 0.82776.

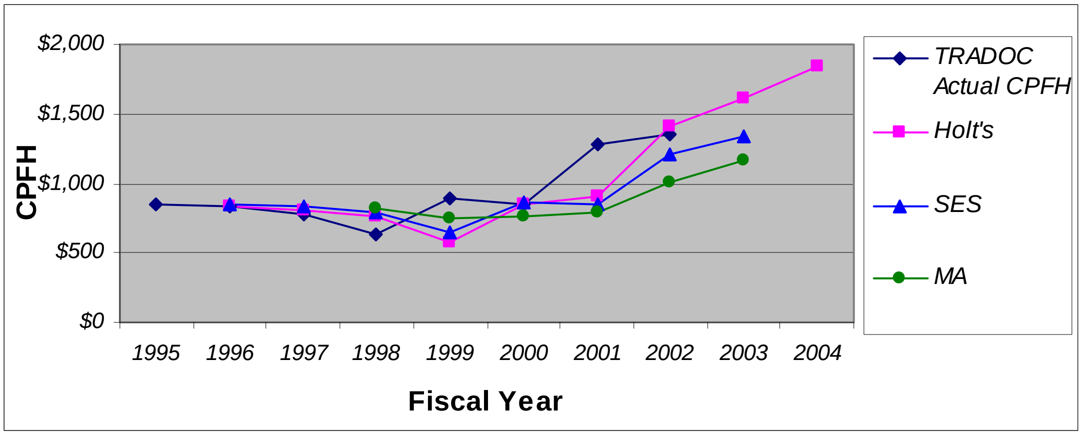

Figure 46. TRADOC Actual CPFH vs Forecasting Methods, UH-60A

In summary, the Holt's method is appropriate for FORSCOM and TRADOC's data, while SES is the method to use for USAREUR. Now that the forecasting method for TRADOC had been selected, a comparison was made between the forecasts, actuals, and budgeted CPFH for FY00-FY02.

UH-60A CPFH Actual and Budgeted vs. Forecasts.

Table 33 shows the comparison between the three different CPFHs. A positive number indicates an under-budget and forecast percent deviation. A negative number shows an over-budget and forecast percent deviation. Even though budget as well as forecasts deviated from the actuals in all cases, in only two cases did the budgeted figure perform better than the forecast: FORSCOM in FY00 and USAREUR in FY01. For the data available, the forecasting methods would be a useful tool in predicting future CPFHs for the UH-60A.

Table 33. UH-60A CPFH Actual vs. Budget & Forecast Comparison

FY	Type	FORSCOM	USAREUR	TRADOC
2000				
Actual vs.	**Budget**	-10%	-14%	-1%
	Forecast	-35%	1%	0%
2001				
Actual vs.	**Budget**	21%	-38%	40%
	Forecast	3%	-39%	29%
2002				
Actual vs.	**Budget**	45%	44%	25%
	Forecast	30%	43%	-3%

FY 2004 CPFH Forecasts.

In order to calculate the most accurate forecast possible for FY04, FY03 actual data is needed for the three pieces of the CPFH for each helicopter. Currently, this data is unavailable from the OSMIS database. It is projected to be available 1 March 2004. For the methods selected for each MACOM, a FY04 forecast can still be calculated but with less reliability. For the Holt's method, a forecast can be developed with the latest data available, FY02, for as many steps ahead as necessary. For the SES method, the FY04 forecast is simply the same forecast for FY03. Due to the limitation of available data, this is the best forecast for FY04 that can be calculated at this time. Table 34 shows the FY04 forecast for the AH-64A for the three MACOMs under analysis.

Table 34. AH-64A FY04 Forecast

AH-64A	Method	FY04 Forecast	MAPE
FORSCOM	*Holt's*	*$6,192*	*8.33*
USAREUR	*SES*	*$2,807*	*28.39*
TRADOC	*Holt's*	*$2,391*	*11.70*

For FORSCOM and TRADOC, the Holt's method produces a two-steps ahead forecast based on the formula described in chapter III, where m=2. For USAREUR, the FY04 forecast is the same forecast for FY03. The MAPEs are the same for the models when the FY03 forecast was calculated.

For the CH-47D and UH-60A, the same method was used to forecast the CPFH for FY04 due to the limited data availability. Tables 34 and 35 list the methods, forecast, and resulting MAPEs for these helicopters.

Table 35. CH-47D FY04 Forecast

CH-47D	Method	FY04 Forecast	MAPE
FORSCOM	*Holt's*	*$2,274*	*13.00*
EUSA	*Holt's*	*$5,181*	*24.85*
TRADOC	*Holt's*	*$4,412*	*15.30*

Table 36. UH-60A FY04 Forecast

UH-60A	Method	FY04 Forecast	MAPE
FORSCOM	*Holt's*	*$2,616*	*14.99*
USAREUR	*SES*	*$1,939*	*20.33*
TRADOC	*Holt's*	*$1,848*	*13.10*

Chapter Summary

In this chapter, the top three MACOMs in terms of total expense were used to compare the budgets prepared for their flying hour program and the actual expenditures for the AH-64A Apache, CH-47D Chinook, and the UH-60A Blackhawk. Three different forecasting methods were used to determine which one best forecasts the CPFH for FY03. Based on the MAPEs and a graph of the forecasts with the actual data, it was determined that, for FORSCOM and TRADOC, the Holt's method was the most appropriate for all the data series for the three helicopters. For USAREUR, the data for the AH-64A Apache and UH-60A Blackhawk included extreme values that made it difficult to say with accuracy which method would produce the best forecast. The lowest MAPE was used to determine that, with the data available, the SES method was the most appropriate for these data sets. The situation was the same with EUSA and the CH-47D Chinook. Extreme values, and a limited amount of data points, make the lowest MAPE the most reliable indicator for the best forecasting method. SES was chosen for the CH-47D and the EUSA MACOM. Even though the MAPEs for these forecasts were high, the budgeted figures deviated from the actual CPFH on seven occasions compared to only two for the forecasts of the same FY.

V. Conclusion

Problem Revisited

Operations 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 Army rotary aircraft. These forecasts would then be used by the OSD/CAIG to analyze both the budget submissions of the Army and the independent cost estimates of the OSD/CAIG.

Limitations

Even though a useful a tool 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 MACOM 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, the applicable alpha and beta levels of each forecast must be recalculated as data is added to each time series. After these parameters are recalculated, 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 OSMIS 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 OSMIS database and the necessary steps to extract the data from it for the empirical CPFH 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 AH-64A Apache included FORSCOM, USAREUR, and TRADOC commands. For all MACOMs, the CPFH cost category breakout was consistent from year to year, with DLRs being the biggest percentage of the total. The Holt's Linear method provided the lowest MAPE and best indicator of the actual data for FORSCOM and TRADOC, with the MAPEs being 8.3254 and 11.702, respectively. The best forecast for USAREUR produced a very high MAPE at 28.387 with the SES method due to extremes in the data points near the end of the series. The actual CPFH went from approximately $3,000 per hour in FY00 down to approximately $2,000 per hour in FY01, and then more than doubled to approximately $4,300 for FY02. The graph provided little help due to all forecasts not tracing the series very well. In this case, a lack of data points and the volatility of the data indicate that a naïve method could possibly be just as good as the three methods. After comparing the actual, budgeted, and forecasted CPFH for FY00-FY02, it was shown that the forecast deviated from the actual

CPFH less than the budgeted figure in all but two of the nine cases for the AH-64A, TRADOC in FY01 and USAREUR in FY02.

The analysis for the CH-47D helicopter included FORSCOM, EUSA, and TRADOC. The empirical CPFH breakout showed that POL made up a larger portion of the total expense for the Chinook than for the Apache. DLRs are again the largest percent of the total, with little deviation across the three MACOMs, especially FY01-FY02. The Holt's method provided the best forecast for all three MACOMs. For FORSCOM and TRADOC, the MAPE was at its lowest with Holt's at 13.00 and 15.29, respectively. A graph of the actual data and forecasts show that Holt's traces the data series the closest. For EUSA, the situation is similar to USAREUR for the Apache. The data series is so volatile that the best method can only be found by using the lowest MAPE, which is Holt's at 24.85. The CPFH goes from approximately $4,900 per hour in FY00, down to less than half that for FY01, and almost doubles again in FY02. The graph does not provide a good indicator. Once again, a naïve method may be just as appropriate. When comparing the actual, budgeted, and forecasted CPFH, it was revealed that the forecasts deviated from the actual less that the budgeted CPFH for all MACOMs in FY00 and FY02, as well as TRADOC in FY01. For FORSCOM and EUSA in FY01, the forecast performed poorly, with a deviation from the actual as high as 77 percent. The high deviation for these two MACOMs can be explained by the volatility of the data series.

Finally, the UH-60A Blackhawk was analyzed for FORSCOM, USAREUR, and TRADOC . The empirical CPFH breakout revealed no drastic changes from FY00 - FY02. For FORSCOM and TRADOC, the Holt's method produced the lowest MAPEs at

14.994 and 13.10, respectively. The graph of the three forecasts for FORSCOM and TRADOC trace the actual data better than the MA or SES method. For USAREUR, it is similar to USAREUR for the Apache, with the data being very volatile, especially from FY00 - FY02. For FY00, the CPFH is approximately $1,350 per hour and more than doubles in FY02. With the limited number of data points, it is difficult to select the most accurate forecasting method. In this case, the MAPE is the only indicator. SES provides the lowest MAPE for the Blackhawk for USAREUR at 20.33. After comparing the actual, budgeted, and forecasted CPFH for the three MACOMs for the UH-60A, it was shown that the forecast deviated less from the actuals than the budgeted figure in all but two situations, FORSCOM in FY00 and USAREUR in FY01.

The FY04 forecasts were calculated based on data available through FY02 due to FY03 data being unavailable at the time. Although this technique does not produce as accurate a forecast, with limited data available it is the best forecast that can be produced at this time.

Recommendations

The forecasting methods used in this study are basic models that can be expanded or changed to more complex models when more data becomes available. The methods chosen can be easily explained to a decision maker and can yield results quickly and with little adjustment. There is not one overall model that forecasts all the data series with the same accuracy. For now, it is recommended to use the specific models that have been identified for each data series. To restate them: the Holt's method is appropriate for each helicopter's data. For USAREUR and EUSA, SES is the best for the data available. All three methods can be evaluated when data is added to them, but it is recommended to focus on the Holt's method whenever possible because this method accounts for the increasing trend that would be evident in the CPFH data series. The data that currently works best with SES will eventually have enough data points that make it more conducive to the Holt's method. Finally, when data is added to the models, the user should verify all formulas and run the Solver function again to minimize the MAPE to obtain the best forecast possible.

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 Army 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 Army platforms, such as: tanks, land vehicles, and fixed-wing aircraft.
- Apply this same analysis and forecasting methodology to the different pieces of the CPFH expense for rotary wing aircraft.
- Analyze the method used to allocate costs within the OSMIS 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 Army 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.

Bibliography

1. Department of Defense. *Cost Analysis Guidance And Procedures.* DoD Directive 5000.4. Washington: Government Printing Office. 16 Nov 1994.

2. The Congress of the United States Congressional Budget Office. *The Effects of Aging on the Costs of Operating and Maintaining Military Equipment.* Washington: GPO, August 2001.

3. Rumsfeld, Donald H., Secretary of Defense, Annual Report to the President and the Congress, Appendix A.

4. Department of the United States Army, *United States Army Fact File*. [On-line] http://www.army.mil/fact_files_site/aircraft.html

5. Recktenwalt, Thomas J. "Visibility and Management of Operating and Support Costs, System II (VAMOSC II)." Presentation to the Sixteenth Annual Department of Defense Cost Analysis Symposium. October 4-7, 1981.

6. Department of Defense. *Cost Analysis Guidance and Procedures*. DoD Directive 5000.4-M. Assistant Secretary of Defense, December 1992

7. United States Congress. Title 10, Subtitle A, Part IV, Chapter 144, Section 2434.

8. Department of Defense. *Operating and Support Cost Estimating Guide*. DoDR 5000.4-M. Washington D.C.: May 2002.

9. Department of the Army. *Cost Analysis Manual*. U.S. Army Cost and Economic Analysis Center, May 2002.

10. Wiggins, James F. "Defense Acquisitions-Higher Priority Needed For Army Operating and Support Cost Reduction Efforts," *FDCH Government Account Reports*, 29 September 2000.

11. Gavora, William M. "Prime Vendor Support—the Wave of the Future" *Army Logistician*, 31: 70-71 (January/February 1999).

12. Rose, Pat A. Jr., Captain, USAF. "Cost Per Flying Hour Factors: A Background and Perspective of How They are Developed and What They Do," *The Air Force Comptroller,* 4-9 (July 1997).

13. United States General Accounting Office. *Defense Budget: Observations on the Air Force Flying Hour Program.* Washington, D.C.: Government Printing Office. GAO/NSIAD-99-165. July 1999.

14. Young, Robert W., Deputy Assistant Secretary of the Army (Cost and Economics). "Cost Factor Process." Presentation at the OPTEMPO Cost Factor Conference. Woodlands Hotel and Conference Center, Williamsburg, Virginia. 21-24 January 2003.

15. Graves, Timothy J., Joseph S. Domin, and Ronald E. Porten. "Trends in Weapon System Operating and Support Cost," IDA Paper P-3313. October 1997.

16. Donmez, Mustafa, *A Parametric Cost Model for Estimating Operating and Support Costs of U.S. Navy Aircraft*. MS thesis, Naval Postgraduate School, Monterey, CA, December 1992 (ADA389448).

17. Wu, Ming-Cheng, *Estimating Operating And Support Models for U.S. Air Force Aircraft*. MS thesis, Naval Postgraduate School, Monterey, CA, March 2000 (ADA-376488).

18. Croeber, Hans K. *Financial Analysis of Operating and Support Costs for H-3 Aircraft Versus CH-60 Aircraft to Complete Helicopter Combat Support Missions.* MS Thesis, Naval Post Graduate School, Monterey, CA, March 1998.

19. Birkler, John and John C. Grasser. "Assessing Competitive Strategies for the Joint Strike Fighter: Opportunities and Options," Rand MR 1362. November 2001.

20. Limon, Juan F., Captain, USAF. "Flying Hour Consumable Supplies: More than Mere Nuts and Bolts." College for Professional Development, Air University, Maxwell AFB AL, 1995 (ADA293093).

21. Edwards, Michael V., *Flight Hour Costing at the Type Commander and Navy Staff Levels: An Analytical Assessment*. MS thesis, Naval Postgraduate School, Monterey, CA, December 1992 (ADA-261977).

22. Cordrey, Ted D., Lieutenant Colonel, USA. "The Army Flying Hour Program: Is the Methodology Flawed?" U.S Army War College, Carlisle Barracks, PA, 1989 (ADA208668).

23. Department of the Navy. Naval Center for Cost Analysis. [On-line] http://www.ncca.navy.mil/images/aircraftcostcard.gif

24. Makridakis, Spyros, Steven C. Wheelwright, and Rob J. Hyndman. *Forecasting: Methods and Applications* (3rd Edition). New York: John Wiley & Sons, Inc. 1998.

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

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

4. TITLE AND SUBTITLE

ANALYSIS AND FORECASTING OF ARMY OPERATING AND SUPPORT COST FOR ROTARY AIRCRAFT

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Hawkins, John C., First Lieutenant, USAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)

Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/ENV)
2950 Hobson Way, Building 641
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GCA/ENV/04M-03

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

OSD/PA&E
Attn: Ms. Krystyna M. Kolesar
1800 Defense Pentagon
Washington DC 20301-1800 (703) 695-4177

10. SPONSOR/MONITOR'S ACRONYM(S)

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 Army Helicopters. Specifically, three separate forecasting techniques are evaluated to better predict the CPFH for better estimating and budgeting by the US Army. To begin, the three cost categories are empirically analyzed for each helicopter. For forecasting purposes, actual CPFH figures were compiled from 1995 to 2003 for all MACOMs flying the AH-64A, the CH-47D, or the UH-60A helicopters. The number of MACOMs is then reduced to the top three in regards to total CPFH expenditure. The use of a 3-year moving average, single exponential smoothing and Holt's linear method are explored for each helicopter's data. These techniques are used to forecast for FY03 in evaluating the best to use for FY04. By comparing both the budgeted and forecasted figures for FY00 – FY02 to the actual CPFH figures in the same years, an accurate CPFH forecast for all of the MACOMs was possible. When data became available, a comparison of the actual, budgeted, and forecasted CPFH for FY03 was performed. The Holt's method was discovered to be the best forecasting method for 78 percent of the time series analyzed since they contained positive trends, followed by single exponential smoothing. Finally, the best forecast to be provided for FY04 is calculated with the chosen forecasting method.

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 **U**	**ABSTRACT** **U**	**c. THIS PAGE** **U**	UU	130	**19b. TELEPHONE NUMBER *(Include area code)*** (937) 255-6565, ext 4588; e-mail: Michael.Greiner@afit.edu

Standard Form 298 (Rev: 8-98)
Prescribed by ANSI Std. Z39-18