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Cost Valuation:
A Model for Comparing Dissimilar Aircraft Platforms

By: Eric J. Long

December 2006

Advisors: Douglas A. Brook,
William Gates

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COST VALUATION: A MODEL FOR COMPARING DISSIMILAR AIRCRAFT PLATFORMS

Eric J. Long, Captain, United Stated Marine Corps

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

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December 2006

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The purpose of this MBA Project was to investigate and provide an overview of current cost valuation methods used to compare aircraft and then determine if the current methods were satisfactory for comparing dissimilar aircraft platforms. The goal of the project was to develop a model using O&S and procurement cost inputs together with aircraft inventory and utilization data in order to produce a cost per unit hour for any given aircraft. A demonstration of the model's validity using aircraft and cost data from the Predator UAV and the F-16 was then performed to illustrate how it can be used to aid comparisons of dissimilar aircraft platforms that perform similar missions.

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EXECUTIVE SUMMARY

As missions for UAV's and manned aircraft converge, both the operational and budgeting communities must adjust their future plans to ensure that an effective balance is achieved and avoid over-duplication of requirements. For the budgeting community, this requires a better method for comparing program costs than what is currently available.

This research project provides one solution to the problem of comparing dissimilar platforms with like missions. By applying the common costs associated with separate programs and combining them with inventory and utilization data, the comparison of dissimilar platforms is possible on a cost per unit hour basis.

In order to demonstrate the model two aircraft were selected; the F-16 and its variants, and the Predator UAV. Data were then collected for each aircraft from the Air Force Total Ownership Cost (AFTOC) database in the areas of procurement cost, O&S cost, inventory, and annual flight hours. The data were then sorted and individually placed into a model based on the formula $[(C1+C2)/h] / i$ = aircraft cost per unit hour.

There were five trends observed when the calculations for each aircraft were completed. The first trend was that O&S costs increase as a function of time and not in proportion to any other variable. The second trend was that as the number of aircraft increase, the cost per unit flight hour decreases. Trend three revealed that as flight hours increase, the cost per unit flight hour decreases. Fourth was that procurement cost has very little effect on cost per flight hour in a mature system while O&S costs represent a significant portion of the final cost per unit flight hour. Lastly, O&S costs and procurement costs have equal influence on systems that have not reached full production. These trends were then interpreted and explained with particular reference to their application in the budgeting function.

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I. INTRODUCTION

A. BACKGROUND

A recent report by the Congressional Research Service identified that growth rates for Unmanned Aerial Vehicles (UAV's) has increased sharply in recent years (Geer and Bolkcom, 2004). The budgeting community is concerned that some UAV systems may be duplicating current manned systems, while proponents argue that not only do they duplicate capabilities, they also accomplish the mission at a lower cost. Additionally, there are some that think the systems are being developed too quickly and that we are therefore making sacrifices in terms of quality and efficiency. According to the report prepared by Geer and Bolkcom (2004), many members of Congress "appear to want assurances that tax-payer dollars are being well spent" (p.9) which would require some method of cost valuation.

Additionally Geer and Bolkcom (2004) suggested that with new unmanned systems being designed to carry munitions, this would indicate a changing mission for UAVs from reconnaissance to strike missions. This is evidenced in the new Predator B and the most recent version of Predator dubbed the "Hunter-Killer". Comparisons with similar manned counterparts for budget purposes may also be necessary in the near future.

There are some areas that Geer and Bolkcom (2004) do not specifically state a need for research, such as the number of aircraft necessary to meet mission requirements, the number of flight hours that the platform logs annually, O&S costs associated with the program, and the mishap rates of the aircraft. These are areas of cost, inventory, and utilization that help define a workable cost structure solution and should be considered when drafting a cost structure intended for use as a comparative tool.

The Planning, Programming, Budgeting, and Execution System (PPES) framework provides an opportunity to examine previous year's decisions and compare them with a changing environment. Ultimately, this system places money in the hands that need it most, and delivers the best mix of combat equipment to commanders that are fighting the current assessed threat (DAU, 2003). The system is effective to this end; however, it depends upon the Budget Estimate Submission (BES) that the service submitted for that year. If changes are to be made after the DOD budget has been "locked" and sent to OMB, they can only be made inside of what has been budgeted to that service component by removing money from one program and placing it into another. While Congress could make changes during the appropriations process, this is based on a generic assumption that they would not. It is imperative then, that the proper investment split has been made at the Office of the Secretary of Defense (OSD) level prior to submitting the military component of the President's budget so that over duplication of capabilities will not occur, and to ensure that our capabilities are in agreement with the current assessed threat. According to the U.S. Department of Defense (2003), this is accomplished through the individual service component's accurate reporting of program costs to the Undersecretary of Defense (USD).

Unfortunately, given the nature of the different manned and unmanned programs, it is difficult, if not impossible, to select one type of cost valuation to achieve a fair comparison between platforms. This has resulted in a need for a system that can compile all relevant costs as well as usage, and number of units, into a single usable metric that will allow comparison of similar and dissimilar systems.

B. PROBLEM STATEMENT

A report recently released by the Congressional Research Service addressed some of the issues surrounding the rapid acquisition and development of Unmanned Systems within DoD (Geer and Bolkcom, 2004). Among their concerns were how lawmakers would determine the best investment split between manned and unmanned systems in order to match the capability of the US with the current assessed threat and which systems can best neutralize the threat at what cost. Additionally, as unmanned systems become more technically sophisticated and mature, capabilities between manned and unmanned systems are becoming less discernable and the need to predict a clear winner from a cost standpoint has become increasingly important to lawmakers. At the center of the problem is the lack of a common cost structure between manned and unmanned programs that would level the playing field and allow the effective comparison of the costs between those systems currently in production or under development.

C. PURPOSE

For the purpose of demonstration two aircraft have been selected for comparison (the F-16 and its variants, and the Predator UAV in both A and B variants) in a model that will result in a cost represented in a unit hour format. This cost structure will take into account the similar and recurring elements of cost associated with the two types of aircraft.

D. RESEARCH QUESTIONS

The primary research question of this project is: **What is a cost valuation method that can be used to compare a manned aircraft platform to an unmanned aircraft platform with like missions?**

Secondary research questions include: 1) What are the current methods of cost comparison? 2) What are the common elements of cost that should be used to compare unlike platforms with similar missions? 3) What other cost considerations should be taken into account?

E. SCOPE

This report includes an overview of current cost comparison methods, an analysis of current O&S cost data adjusted for current year dollars, an analysis of current mishap data and an estimate of replacement cost adjusted for current year dollars in each program, and a comparison of relevant cost data within a model between the sample data provided for F-16 and Predator programs based on a cost per unit hour as calculated by the model.

F. METHODOLOGY

This graduate research project consisted of the following steps: 1) A thorough review of GAO reports, Congressional Research Service Reports, and DoD publications that were relevant to the area of study; 2) The compilation of cost, operational, and inventory data pertaining to each of the selected aircraft: the F-16 and its variants and the Predator UAV; 3) A study of the cost data to determine relevant and common costs associated with the 2 types of systems; 4) The creation of a model that uses the cost, flight, and inventory data that calculates a cost per unit flight hour; 5) An evaluation of the model's strengths and limitations; 6) An analysis of trends associated with each platform's data; 7) A summary of findings and areas that could possibly require further research.

G. ORGANIZATION OF STUDY

Chapter I, Introduction, provides the rationale for the research and why there is a need for a cost valuation method that allows the bottom line comparison of manned to unmanned systems, similar to those currently in use to compare manned to manned and unmanned to unmanned systems. This chapter also addresses the primary and secondary research questions, the scope of the study, the methodology used within the study, and the organization of contents.

Chapter II, Current Methods of Cost Valuation, examines the current, as well as some historical methods of cost valuation used by DoD to compare systems of similar missions and type. The chapter also provides an overview of O&S costs, how they are used, and what they contain.

Chapter III, Data, provides a descriptive overview of what data was used within the model and how it was used. This chapter also describes the significance of the operational data that was used, such as flight hour data, and how it relates to the inventory data.

Chapter IV, Analysis, describes how the model was constructed, what data were used and how the data were manipulated in a formula to arrive at the cost per unit flight hour metric. Limitations in the data are also discussed in this section.

Chapter V, Conclusions, restates the project objectives as well as primary and secondary questions. A summary of the research, findings, limitations, and suggested areas for additional research, as it relates to the objectives and research questions, are also included in this chapter.

H. PRIMARY CONTRIBUTIONS

The results of the research will culminate in the creation and demonstration of a working model that may be used to compare dissimilar aircraft programs for the purpose of cost savings and suitability within the defense budget. Further, the study will provide researchers with a template that will demonstrate the effects of various costs on the final output of the model and on the final costs of similar programs.

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II. CURRENT METHODS OF COST VALUATION

A. INTRODUCTION

Cost valuation is the method of comparison used by OSD to track the progress of a given program. These valuations are reported quarterly and are instrumental in determining the budget and policy decisions at the OSD level. It is imperative that the numbers reported by Program Manager’s accurately reflect the programs success or failure without bias in order to provide the decision makers within the chain the best information possible from which they can base their budgeting decisions. There are four types of valuations that are typically used by OSD for budget purposes, they are Unit Flyaway Costs (UFC), Program Acquisition Unit Costs (PAUC), Average Unit Procurement Cost (APUC), and Unit Flyaway Price (UFP). The methods differ in respect to what is included in the valuation and what is left out.

B. UNIT FLYAWAY COSTS

Unit Flyaway Costs (UFC, ‘Flyaway Costs’) are usually referred to as flyaway costs and are simply those costs that are associated with a specific end item of a system. For instance, the flyaway cost of a manned aircraft would be the cost of the actual airframe and all government furnished equipment (GFE) such as engine, cameras, armament, and avionics. The flyaway cost would not include such items as ground support equipment (GSE), specialized test equipment, or training costs. In simple terms, flyaway costs include all costs that can be applied to the aircraft as it is equipped (less pilot) for a given mission. Other costs that are included in flyaway costs are nonrecurring initial production costs and an allowance for changes. These costs are fixed and can therefore be divided into the total expected production run to arrive at the cost per unit of production (DoD, 2003; DoD, 1992; Gates, 2004).

Flyway costs are typically used for manned aircraft, but can be applied to unmanned aircraft with some difficulty. For instance, to pilot an unmanned aerial vehicle (UAV), one needs an assortment of GSE, such as the ground control station (GCS). The problem is that the GCS is part of a system that operates several air vehicles and does not need to be reconfigured to do so. To further complicate this, flyaway costs by definition exclude any equipment that is not physically part of the aircraft, hence they exclude GSE. The exclusion of this expensive and vital piece of equipment makes the flyaway cost of a UAV misleading when compared to the flyaway cost of its manned counterpart.

C. AVERAGE PROCUREMENT UNIT COST

Average Procurement Unit Cost (APUC) is another cost metric that goes beyond flyaway costs; it includes all of the elements of flyaway costs and also the costs of procuring Technical Data (TD), training, support equipment, and initial spares. The resulting number is called total procurement cost, which, when divided by the number of units to be procured, results in the APUC (DoD, 2003). APUC is normally used to describe what costs are attributed to an entire system on a per unit basis.

D. PROGRAM ACQUISITION UNIT COST

Program Acquisition Unit Cost (PAUC) is composed of two elements; the program acquisition cost and the program acquisition quantity. The program acquisition cost is the estimated cost of procurement, plus all research, development, testing and evaluation (RDT&E), and military construction (MILCON) that is necessary and related to the system's acquisition. The other component of PAUC, program acquisition quantity, is the total number of fully configured end items intended for purchase over the life of the program, and includes research and development units (DoD, 2003). Where PAUC differs from APUC is that it takes into consideration the cost of the entire program, rather than just the unit procurement cost, by accounting for RDT&E as well as MILCON for a given program.

E. UNIT FLYAWAY PRICE

The UFP is no longer a DoD recognized method, but was used by the Air Force for contractual purposes on the Global Hawk program for the initial air vehicles 1 through 10; it is included here to demonstrate how cost valuation methods can produce inaccurate results when certain costs are excluded. The problem with the UFP is that it excluded many of the UFC elements. Essentially, the UFP was the flyaway cost minus system and project management, software allowance for changes, system test and nonrecurring tooling, manufacturing, and engineering. These costs, had they been included, would have superficially escalated the cost of Global Hawk because it has not reached production numbers that would exploit economies of scale. The UFP was abandoned in 2000 in favor of the UFC for various reasons, but mainly because it was more accurate in tracking and reporting cost over larger scale production (Drezner and Leonard, 2002).

F. O&S COSTS

O&S costs, as described by the Congressional Budget Office (2001), include those costs associated with the operation and maintenance of the individual system as well as military personnel. Some of the categories of costs include, fuel, civilian personnel, military construction, contract support costs, training munitions, health care, equipment lease and rental, and Temporary Duty costs, such as housing, transportation, and subsistence. O&S costs represent a very significant portion of costs in either system and are treated separately in the budget process.

G. CURRENT COST VALUATION SHORTCOMINGS

According to Geer and Bolkcom (2005), the UAV programs that are currently fielded as well as those that are under development are numerous. The problem with so many programs is that it requires oversight to ensure that they are well coordinated and that capabilities are not duplicated. Additionally, UAVs that were once considered to perform missions separate from manned aircraft are now competing for manned aircraft missions. As they evolve, UAVs are now possibly duplicating the capabilities of manned aircraft. To determine an investment split and avoid duplication, Congress has positioned itself to provide oversight that will ensure the taxpayer's financial resources are not wasted. Cost valuation is one of the ways that UAV costs can be quantified and gain the proper investment split.

The first problem with using cost valuation is deciding which valuation method has the best fit for the purpose of comparing manned aircraft to unmanned aircraft. Due to the relatively new UAV designs, the program acquisition unit costs in the early years of development are relatively high. As the technology advances and matures, the costs will begin to fall, but unit cost comparisons between an established aircraft platform and a new design always favor the developed aircraft because the development costs have already been absorbed through production units (Drezner and Leonard, 2002). The use of flyaway costs limits this error to an extent but falls short of ideal in other ways.

Flyaway costs are useful in determining the replacement cost of an aircraft as equipped for flight if it does not return from a mission; using flyaway costs for comparing aircraft platforms, however, is not necessarily an accurate measure. Specifically, flyway costs can be used when comparing manned aircraft against manned aircraft, but its use for comparing manned aircraft to unmanned aircraft is flawed. Flyaway costs exclude key equipment that is necessary to UAV flight operations and this exclusion significantly devalues the flyaway costs.

For example, using flyaway costs to compare Predator to the F-16 would at first seem to be fair, given that only the systems required for flight are compared and the pilot is excluded in both cases. From a practical standpoint however, neither system can fly without a pilot. So if the pilot were included, the F-16 would be able to establish and sustain flight while the Predator UAV would remain on the ground. The Predator, like all other UAV's, requires a sophisticated communication system in order to fly. While the manned aircraft has a pilot inside the aircraft manipulating the controls, an unmanned aircraft has a man inside a control station manipulating controls that are then communicated to the aircraft. For this reason, the control station should be included; without it, the aircraft would never be able to establish and sustain flight. Conversely, if both aircraft were lost in flight, the F-16 would lose everything in the flyaway costs, and possibly even the pilot, while the UAV would lose everything on the aircraft as well, but the pilot and the control station could still be used on another UAV. Therefore, Flyaway costs do have an application in this comparison but only in the form of projected losses in the case of a Mishap.

III. DATA

A. INTRODUCTION

This chapter presents and discusses the data that was collected and used in the model that will be described in the analysis chapter. The data that will be discussed in this section are those that are most relevant to aircraft operation and cost analysis. Those elements of data include: 1) flight hours, which represents the amount the aircraft is used annually, 2) O&S costs, which are the operating costs associated with the aircraft (operation and maintenance plus military personnel), 3) procurement cost, which is the initial cost of purchasing the aircraft, 4) aircraft inventory, or the number of aircraft that are available for flight annually, and 5) flight hours, which represents actual aircraft usage.

Each subject area will be discussed as it pertains to the F-16 and the Predator UAV. The O&S cost, aircraft inventory, and flight hour data for each aircraft were collected from the AFTOC database; for the years FY 1996-2005 for the F-16 and its variants, and FY 1999-2005 for the Predator and its variants. Procurement data was collected from P1 sheets accessed at the OSD/OMB website. In order to get the most complete data, raw data was collected in the areas of: flight hours by aircraft and tail number, O&S costs by aircraft and category, and procurement costs by aircraft.

While inventory data were available for each aircraft platform, inventory data that was extracted from the flight hour data was used rather than the reported inventory data. This ensures that unused aircraft do not dilute the calculated cost per unit fight hour with aircraft that do not contribute to the flight hours logged annually for the given platform. To accomplish this, first the flight hour data was obtained from the AFTOC database and then sorted by aircraft tail number. The data by tail number was then compiled to extract the annual flight time per aircraft. When this was completed, it isolated the annual flight hours per aircraft and the inventory of the aircraft that logged them. The resulting inventory data was then separated from the flight hour data and organized in a separate table to display trends in aircraft attrition.

B. O&S COST

Raw O&S cost data were collected from the AFTOC database and were organized by fiscal year, type of aircraft and category of cost. The raw data was separated by aircraft to eliminate those types of aircraft that were not relevant to the research. Then the individual elements of cost were analyzed separately by aircraft and fiscal year to determine patterns in O&S cost behavior. While O&S costs included O&M costs plus military personnel, a categorical cost breakout of O&S costs is provided in figure 1.

Civ PCS	Education & Training	Purchased Equip	S/W Maintenance
Civ Personnel	Equip/Fac Lease & Rental	Supplies	Health Care
Communications	Maint, Repair, Minor Constr	TDY	AVFUEL
Contr Logistics Supt	Mil Personnel	Transportation	Purchased Equip Maint
Contract Services	Misc Expense	Vehicle Rental	
DLR-Flying	Printing	Training Munitions	
DLR-Nonflying	Purch Equip & S/W Maint	Purchased Utilities	

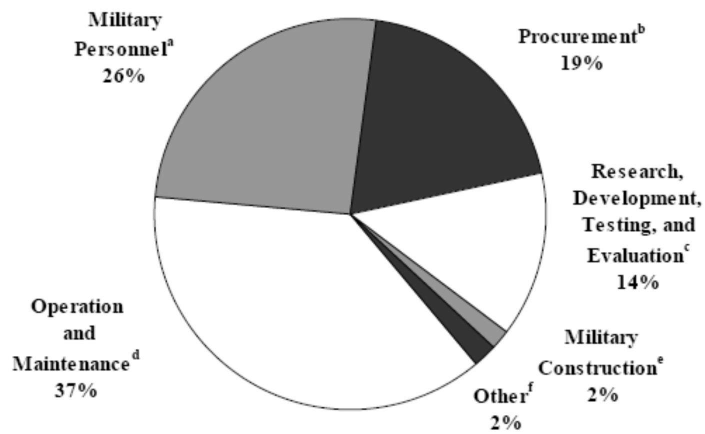
Figure 1. O&S Cost Categories

During the collection and compilation of data, there were some similarities and differences noted between the data collected for F-16 and the data collected for Predator UAV. However, there was no significant trend to note in O&S costs as they relate to individual aircraft, flight hours, or inventory numbers.

1. Similarities

For both aircraft, O&S costs represented a significant category of cost and for that reason were included in this study. In fact, O&S costs represent a significant portion of the DoD budget as a whole, as can be seen in Figure 2 (CBO, 2001). In contrast to the F-16 where O&S costs represent the majority of costs, O&S costs in the case of Predator are not nearly as dominant. In spite of this dissimilarity, the research data still suggests that O&S costs do not vary in direct proportion to number of aircraft or number of hours flown, but rather as a function of time. O&S costs for Predator, while significant enough to be included in the study, are not significant enough to dominate the procurement costs at this point in the aircraft's service life.

MAKEUP OF THE DEPARTMENT OF DEFENSE'S BUDGET,
FISCAL YEAR 2000



SOURCE: Congressional Budget Office based on data from the Department of Defense.

a. "Military Personnel" includes spending on salaries and benefits.

b. "Procurement" includes purchases of new equipment and paying for major modifications of existing systems.

c. "Research, Development, Testing, and Evaluation" covers the costs of developing and testing new systems and subsystems.

d. "Operation and Maintenance" (O&M) includes spending on fuel, spare parts, and overhauls of military equipment. O&M also includes spending on such items as health care, management (by, for example, the Office of the Secretary of Defense, the Joint Staff, and service staffs at headquarters), environmental programs (for example, pollution prevention and environmental restoration), real property maintenance (for example, the maintenance and repair of buildings, roadways, and runways), base operating support (for example, child care and family support), and communications (for example, telephone systems and computer infrastructure).

e. "Military Construction" pays for building new facilities and support structures for military installations.

f. "Other" includes spending on family housing and management of working capital revolving funds.

Figure 2. O&S costs as part of the DoD budget (CBO Report, 2001, p. 3)

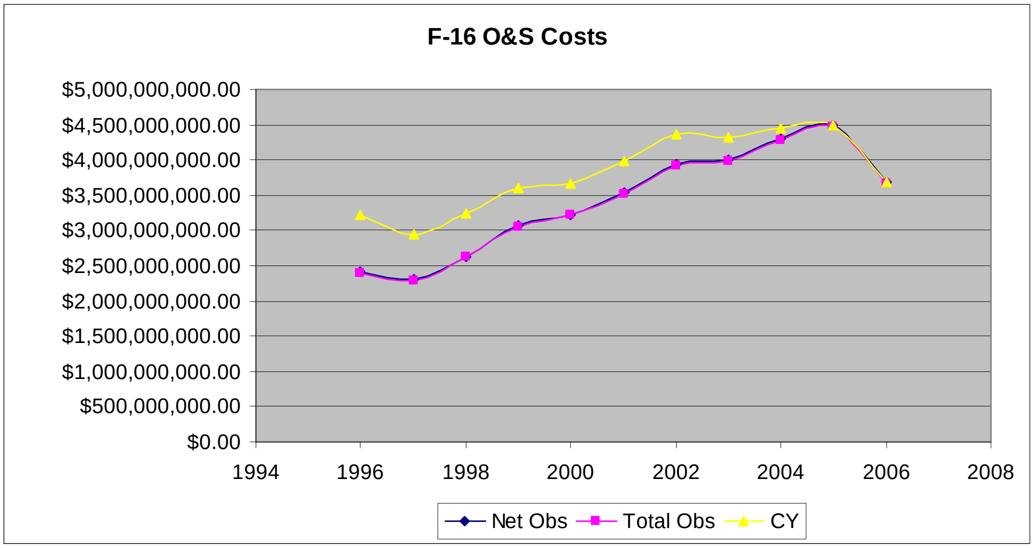


Figure 3. F-16 O&S Cost Trend

In Figures 3 above and 4 below, the similarities in O&S cost data between F-16 and Predator are depicted. Observe that the O&S costs show a gradual rise in costs over the period covered in each case. While this trend might be attributed to a continuous rise in GDP, an adjustment made to express costs in constant year dollars continues to show an increase in O&S costs over time.

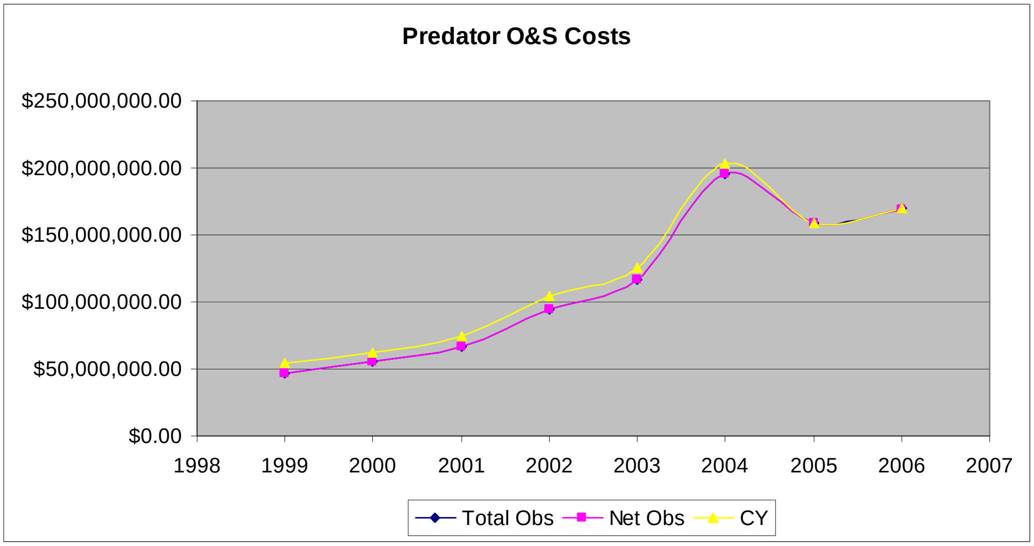


Figure 4. Predator UAV O&S Cost Trend

2. Differences

While cost data for this category was obtained from the same source for each aircraft, there were some categories of cost that did not pertain to the Predator UAV. These categorical differences were; training munitions, purchased utilities, S/W maintenance, health care, aviation fuel, and purchased equipment maintenance.

Another difference to note is the trend discovered in Contractor Logistic Support and Military Personnel. While Military personnel costs dominate the F-16 data, they merely represent the most significant category for Predator UAV in the first three years of data, after which Contractor Logistics Support supersedes as the most significant cost. Furthermore, in FY 2004 we see an increase in Contractor Logistic Support that doubles from the previous year and then continues to dominate for the remaining years of data. Concurrent with the increase in the Contractor Logistic Support is a significant increase in flight hours, which consequently doubled in 2004. This correlation of data is one possible explanation for the significant jump in Contractor Logistic Support and likely a direct result of combat operations worldwide.

C. PROCUREMENT COST

1. Similarities and Differences in the Procurement Cost Category

Procurement data was obtained through P1 sheets accessed on the OSD/OMB website. The P1 sheets list the procurement cost by fiscal years and include a description of how the funds were used. In the case of aircraft procurement, the P1 sheet lists the number of aircraft procured in a given fiscal year, as well as how many are expected in future years. In the case of block upgrades, the P1 sheet lists what the block upgrade is, how much was spent on it and how many kits will be delivered in a given fiscal year.

Since procurement data for each aircraft platform was taken from different stages in the aircraft's development, the data is dissimilar throughout the sample years. In spite of the dissimilarity of cost data in this category, the data can still be used to demonstrate how to compare the two platforms. Unfortunately, limitations in the F-16 data do not allow for a complete life cycle cost as the initial development and acquisition costs from the start of the program are not included as part of the procurement cost.

2. F-16 Observations

Figure 5 depicts the procurement cost data collected on the F-16. The data compiled for this project was based on observations from 1996–2006. Therefore, the data does not reflect initial procurement or development costs. The procurement cost represented by this data does, however, include the additional block developments and upgrades to the system over the years covered as well as several new aircraft. Block upgrades included in the research were blocks 30, 32, 40, 42, 50 and 52, as well as upgrades to the aircraft that will allow it to reach its 8,000 hour service limit, including the Falcon Star, which is an airframe modification, and the Falcon 229 engine upgrade. Other improvements were made to the aircraft in areas that included, but were not limited to, avionics, communications and weapons system integration.

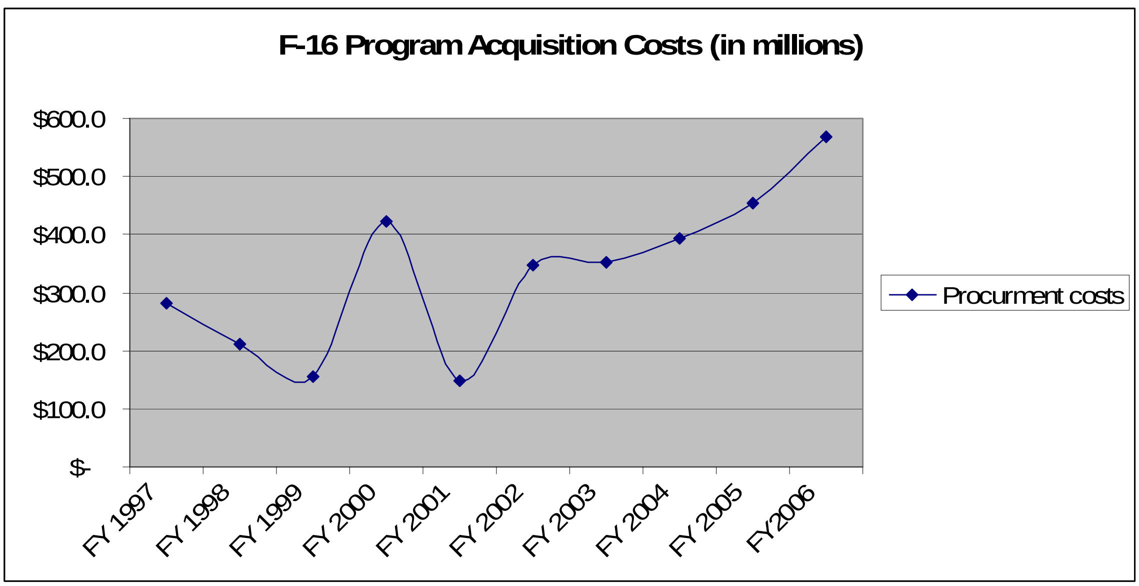


Figure 5. F-16 Program Acquisition Cost Data (in nominal dollars)

3. Predator UAV Observations

Figure 6 depicts procurement cost data collected on the Predator UAV. The data compiled for this project was based on observations from 1999–2006 and includes initial aircraft procurement, as well as additional aircraft deliveries and block improvements. Unlike F-16, the Predator is unique in that it is designed to be modular, meaning that any ground control station or support equipment can be used to operate any air vehicle. The procurement cost therefore includes not only the cost of the air vehicle and also the Ground Control Station (GCS), Launch and Recovery Elements (LRE), Ground Communications Systems (Predator Primary Satellite Link (PPSL)) and Ground Data Terminals (GDT). Additionally, initial spares, Readiness Spares Package (RSP), support equipment and initial technical data and training are included as part of the procurement costs. As with F-16, all models of Predator UAV were included in the data. These include the MQ-1 Predator (medium altitude) and the turbo-prop hunter-killer version, the MQ-9 Predator B (medium to high altitude).

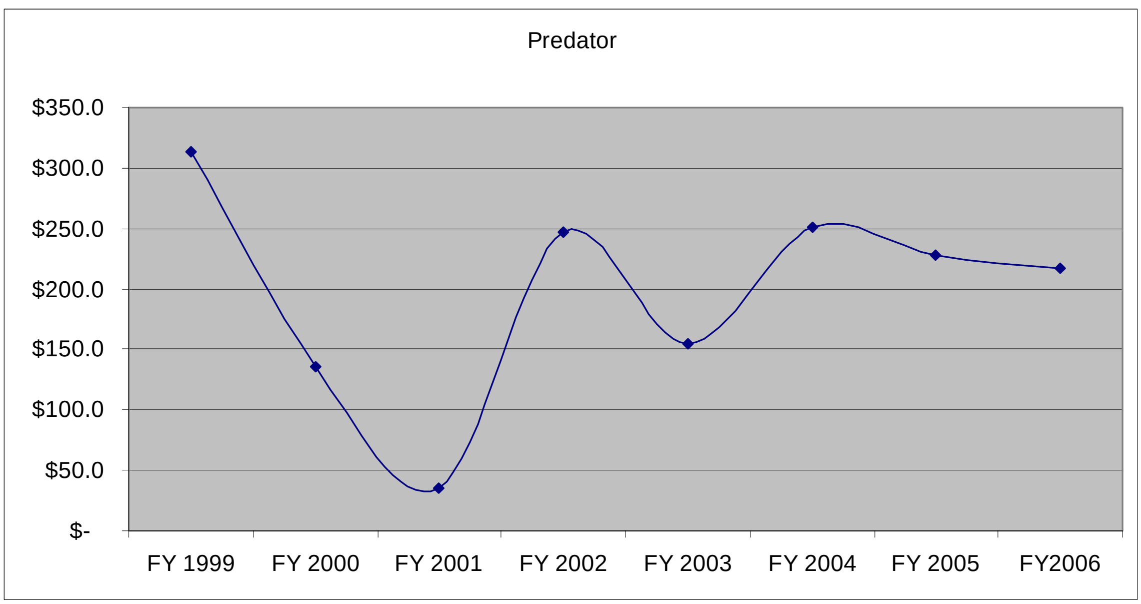


Figure 6. Predator UAV Program Acquisition Cost Data (in nominal dollars)

D. AIRCRAFT INVENTORY

1. Introduction

Data for aircraft inventories was collected concurrently with flight hour data; if an aircraft had not flown in a given year, its tail number was not included in the inventory count. Various reasons can account for why any given aircraft did not fly in any given year, however, each of the aircraft types displayed trends consistent with the age of the program.

2. F-16 Inventory Data

F-16 inventory data was collected for the years 1996 through 2006. The data collected represents only those aircraft that flew during each of the years for which data was collected. The inventory data reflects a steady downward trend during the 10 years sample period. This is the sort of trend that is consistent with an aging aircraft fleet. Various reasons exist for aircraft attrition, including mishaps, cannibalism, service limit and extensive repair or modification. In some cases, aircraft will return to service, but in most cases the aircraft drops from the inventory permanently. Figure 7 shows the F-16 aircraft inventory trendline form 1996 through 2006.

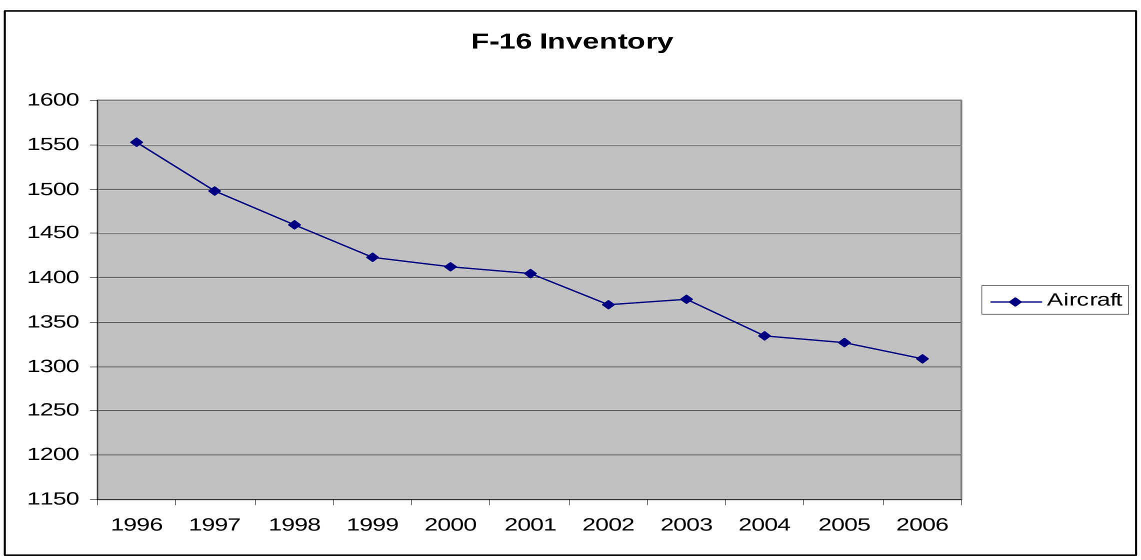


Figure 7. F-16 Aircraft inventory Data

3. Predator UAV Inventory Data

Predator UAV inventory data was collected for the years 1999 through 2006. Like the F-16 data, the Predator UAV data only represents those aircraft that flew during each of the years for which data was collected. Unlike the F-16, Predator UAV inventory data displays a linear trend with significant steps during the sample period of 8 years. In this case, the data trendline reflects that which is expected of a new design aircraft that has yet to reach its inventory total strength. While the trend is consistent with ongoing acquisition, there may still be a degree of attrition in the aircraft inventory due to mishaps, cannibalism and extensive repair or modification. Similar to F-16, those aircraft not included may still return to service at a later date. Figure 8 shows the Predator UAV aircraft inventory trendline form 1999 through 2006.

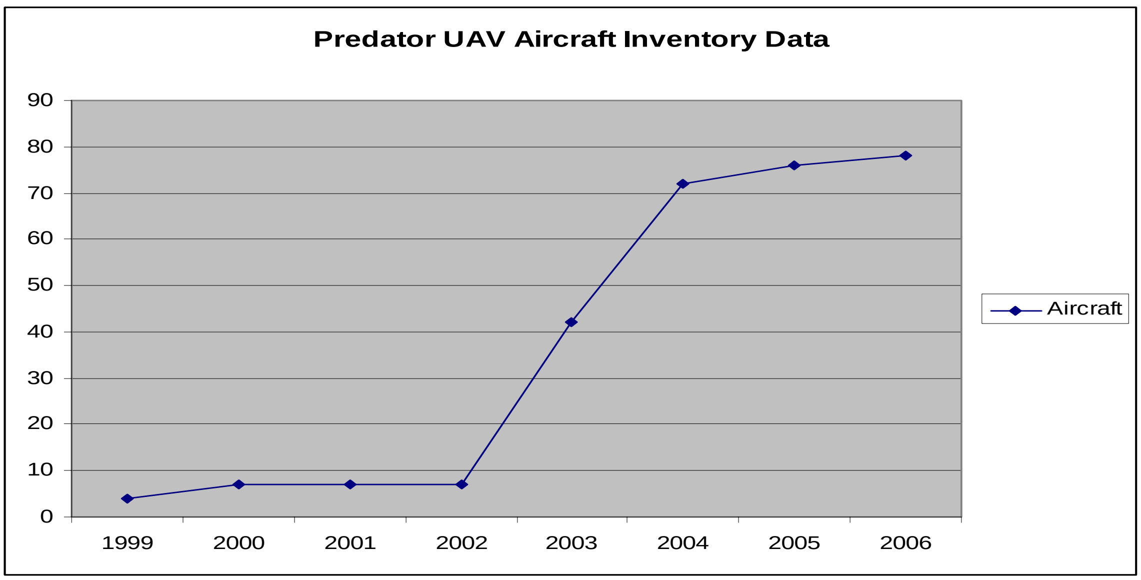


Figure 8. Predator UAV Aircraft Inventory Data

E. FLIGHT HOURS

1. Introduction

Flight hour data collected for the F-16 and Predator were broken down by hours per year as well as hours per aircraft. While the F-16 clearly flew more hours than the Predator, the Predator flew significantly more hours per aircraft. There are several possible explanations. The F-16 has a larger inventory and therefore fewer hours per aircraft are required to meet mission requirements. Secondly, since Predator can fly multiple aircraft off one GCS, it is possible to fly more than one aircraft at a time and fly them using only one pilot – a feat that is impossible in manned aircraft. This capability allows Predator to reduce manpower requirements and utilize aircraft more extensively.

2. F-16 Flight Hour Data

F-16 flight hour data was collected for the years 1996 through 2006. The data has been organized by year to show the hours accumulated, as well as an average flight time per aircraft. Figure 9 displays the flight hour data collected for the F-16.

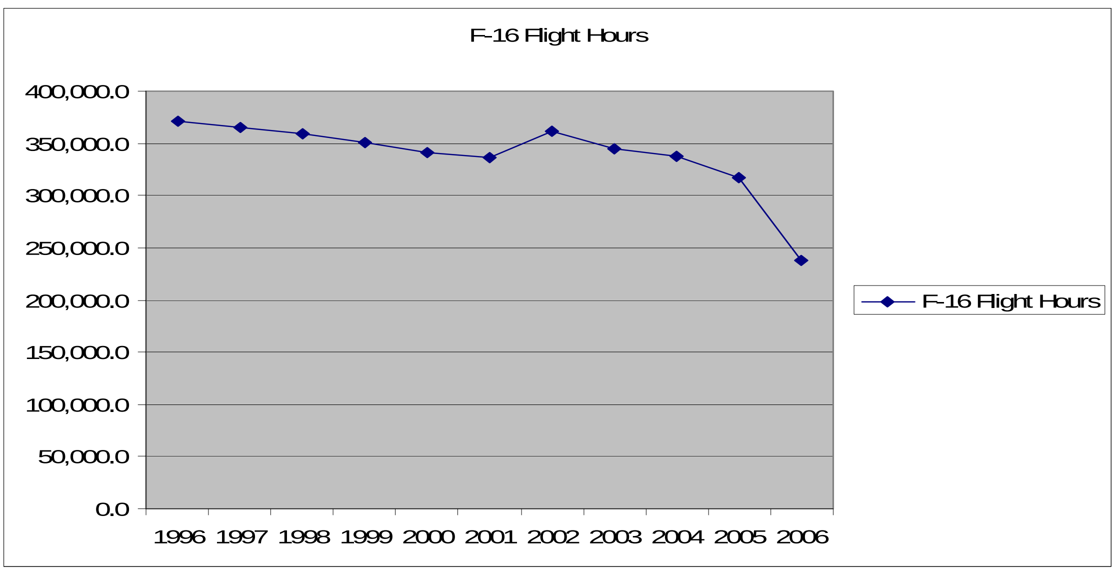


Figure 9. F-16 Flight Hour Data

3. Predator UAV Flight Hour Data

Predator flight hour data was collected for the years 1999 through 2006. The data has been organized by year to show the amount of hours accumulated, as well as an average flight time per aircraft. Figure 10 displays Predator flight hour data.

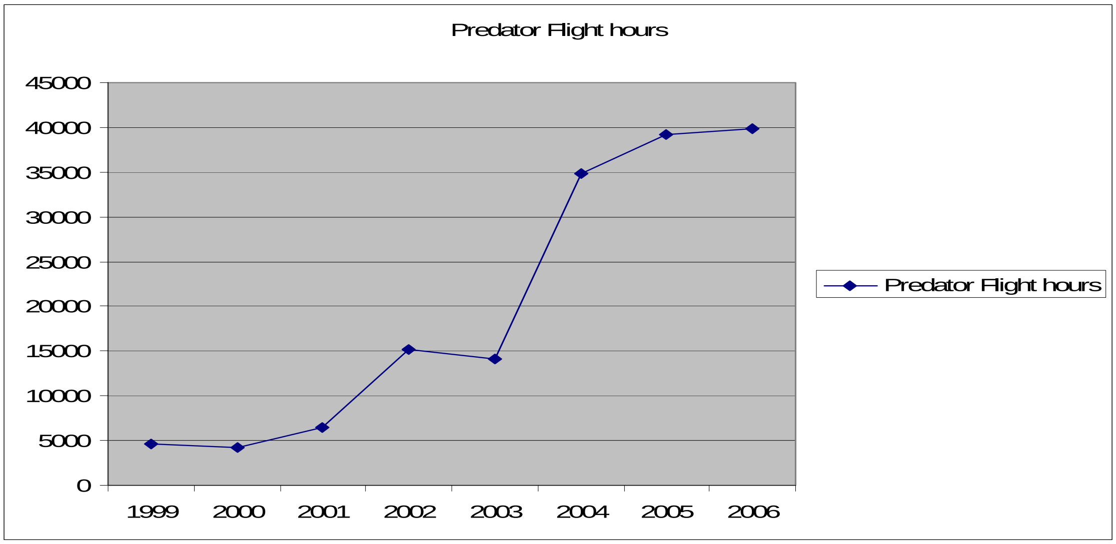


Figure 10. Predator Flight Hour Data

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IV. ANALYSIS

A. INTRODUCTION

This chapter organizes the data presented in Chapter III and then analyzes the data using a simple model that calculates a cost per unit hour for each platform. First, the chapter will describe the model and then it will explain the variables. This is followed by an explanation of the limitations of the model itself and discuss how and how much the lack of historical data can affect the output.

B. MODEL

1. Introduction

The model used for the purpose of comparing costs was a simple model constructed in Microsoft Excel. The model uses various cost inputs, procurement cost and O&S cost, and then combines the flight hour data and inventory data to calculate a cost per unit hour. The objective of this cost is to standardize dissimilar platforms with like missions to compare them and decide where funds are most needed. From the outputs of the model, we can determine the trends in a given system and quantify them in terms of cost per unit hour, which can then be used to compare dissimilar systems and measure relative efficiency. The intent of the cost per unit hour is not to replace any current cost structure, nor is it intended to be an all inclusive answer to cost comparison, but is rather a way to determine the direction and rate that the most significant costs in a given platform are going. A simplified formula is shown in Figure 11.

$$\frac{(C1+C2)/h}{i}$$

Where: C1 = Procurement cost
C2 = O&S cost
h = Total hours (annual)
i = Aircraft inventory

Formula for calculating cost per unit flight hour

Figure 11. Cost per unit flight hour formula

2. Results

In addition to the O&S cost trend that is consistent with research conducted previously by Greenfield and Persselin (2002) and CBO (2001), several other new trends were discovered when the data was placed into the model. The trends as they relate to the operating cost per unit flight hour are: 1) O&S costs increase as a function of time and not in proportion to any other variable; 2) As the number of aircraft increase, the cost per unit hour decreases; 3) As flight hours increase, the cost per unit hour decreases; 4) Procurement cost has very little effect on cost per hour in a mature system, while O&S costs represent a significant portion of the final cost per unit hour; 5) O&S costs and procurement costs have equal influence on systems that have not reached full production.

Previous research by Greenfield and Persselin (2002) and CBO (2001) suggests that there is also a correlation between O&S costs and the age of the aircraft. Studies show that the increase in O&S costs typically results from an increase in maintenance costs (CBO, 2001). Furthermore, O&S costs typically follow a life cycle cost curve that, after Milestone "C", represents the most significant costs in any given aircraft design (McKinney, 2005). The trends found in O&S costs for both Predator and F-16 also follow this lifecycle cost curve. For comparison however, F-16 is nearing the top of the O&S cost curve whereas Predator is in the early stages of procurement and the associated O&S costs are comparatively low.

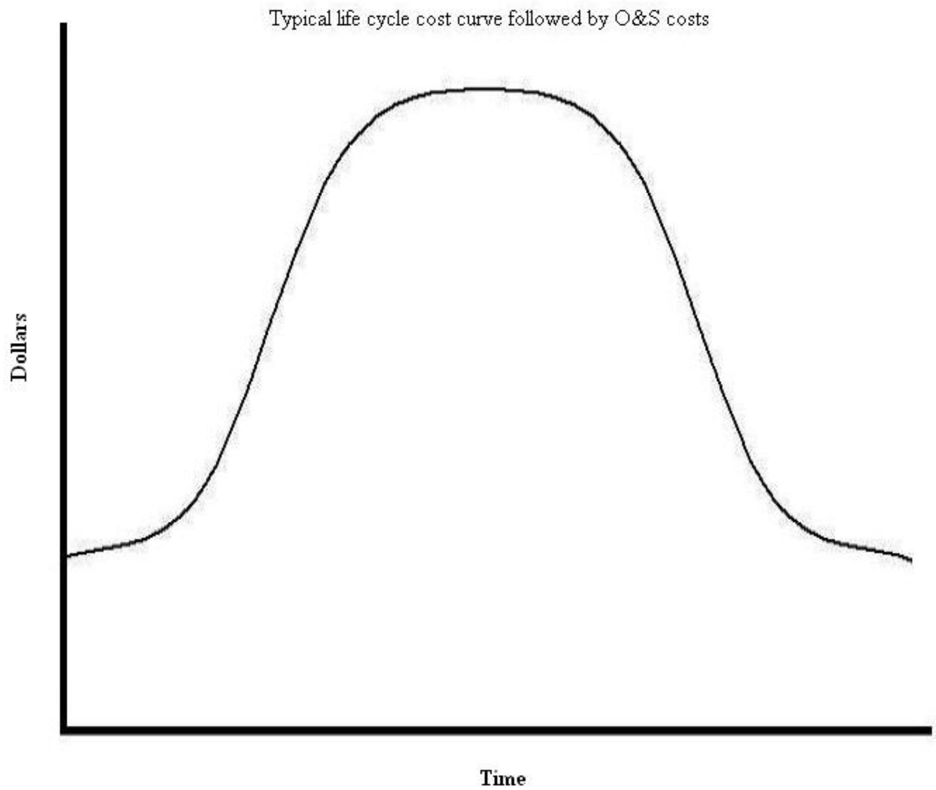

Figure 12. O&S lifecycle cost curve (Source: McKinney, 2001)

While the O&S costs typically follows a bell shaped curve, as depicted in Figure 12 above, the cost per unit flight hour follows a “U” shaped curve, where the greatest cost per unit hour is realized in both the beginning stages of acquisition (due to high initial acquisition costs) and at the end (with the lowest number of operational aircraft in the aircraft’s life cycle). This “U” shaped curve is depicted in Figure 13. As a mature aircraft, F-16’s cost per unit flight hour is represented near the bottom of the curve while Predator, still under procurement, is currently near the top of the cost per unit flight hour life cycle cost curve.

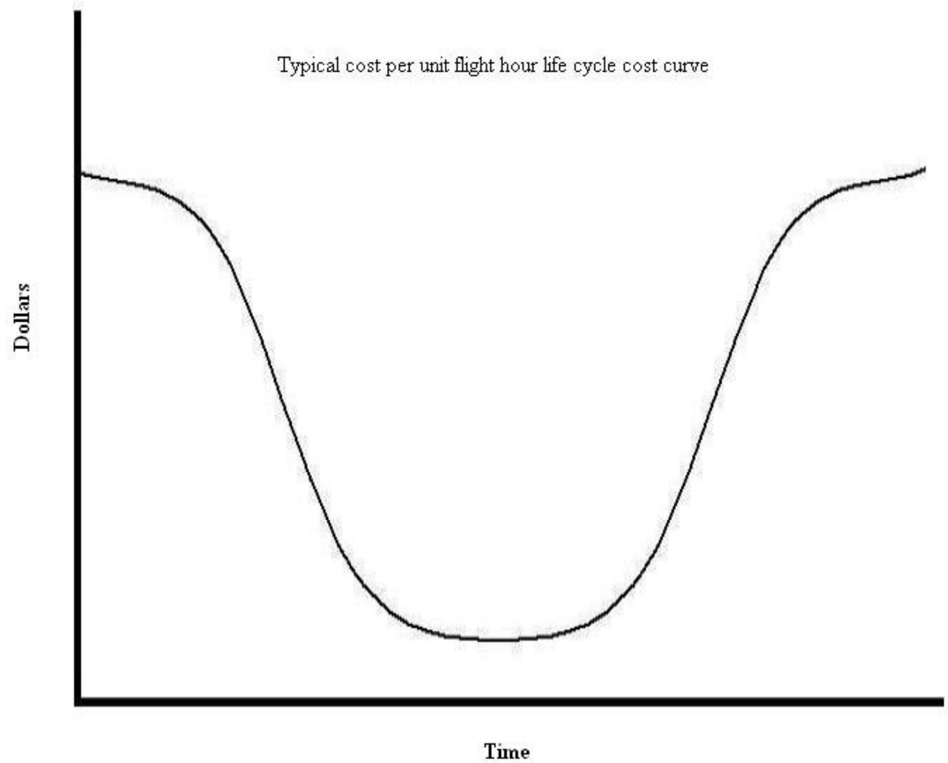

Figure 13. Cost per unit flight hour lifecycle cost curve (Source: Author)

3. Trend Analysis

This section will interpret each of the previously noted trends and show how the interpretations can be applied in budget decisions. These trends are based on correlations observed in the available data. When more data becomes available, these trends should be statistically tested using the appropriate regression analysis. Given the early stage of the predator UAV program, that analysis is not feasible at the current time.

Trend 1: O&S costs increase as a function of time and not in proportion to any other variable. Observing the rise and fall of O&S costs on the two aircraft platforms researched reveals no direct relationship between the annual changes in aircraft inventory or flight hour variables but does show a steady increase over time. Another possible explanation for the sharp increase seen in Predator is that it correlates with combat operations and extensive use in Iraq. This steady increase gives an indication of what

O&S costs will be in coming years, based on historical data, but does not appear to be influenced by any of the other parameters observed for the cost per unit flight hour model. This cost relationship, or lack thereof, is depicted in Figures 14 through 17. Note that while O&S costs increase over time, they do not appear correlated with flight hours or inventory. The observations for F-16 in this area are more conclusive than those seen in Predator due to the mature status of F-16 as opposed to the aggressive inventory buildup as seen in Predator,. The Predator buildup does appear to have some correlation with an increase in O&S costs when the Predator's inventory spikes between 2003 and 2004.

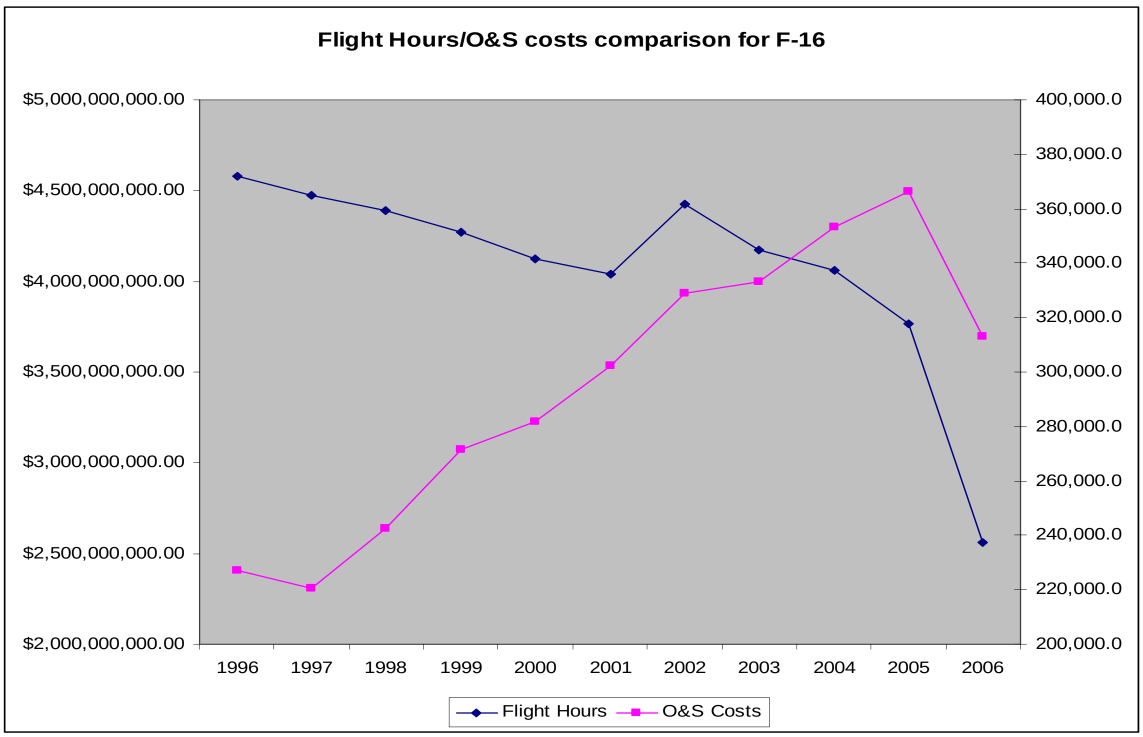

Figure 14. F16 O&S costs compared to flight hours (in nominal dollars)

In Figure 14 above, O&S costs and flight hours do not show any obvious relationship. While initially there seems to be an inverse relationship, both flight hours and O&S costs take a sharp drop in 2005, indicating a direct relationship. In Figure 15 below, the data again shows an inverse relationship for most periods but a direct relationship in the last period. Since the data contradicts itself in both cases, a conclusion can not be reached based on trends in the data presented. When there is sufficient data, a more detailed statistical analysis might help explain these seeming contradictions.

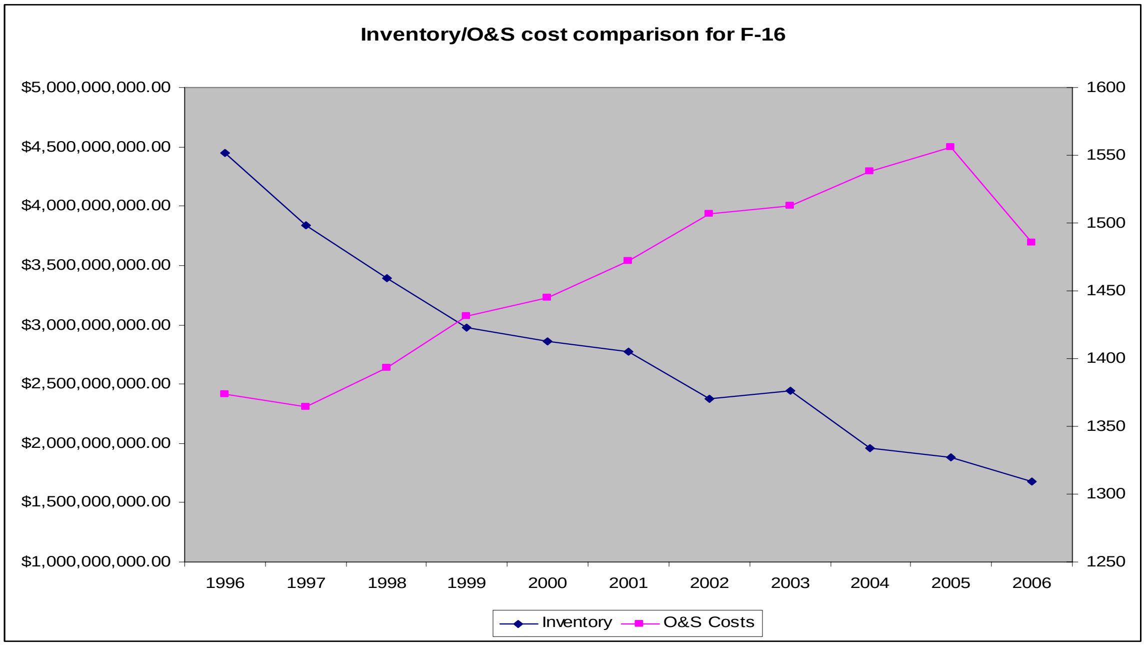

Figure 15. F16 O&S costs compared to aircraft inventory (in nominal dollars)

Figures 16 and 17 depict Predator data in similar graphs to those used for F-16. In the case of Predator, the aircraft inventory, flight hours and O&S costs are rising. This seems to correlate closely until 2004, when O&S costs drop sharply while both flight hours and inventory continue to increase. Since the data again contradicts itself, as seen with F-16, the data is inconclusive if there is a direct relationship between O&S costs and either flight hours or the number of aircraft. However, as seen in Figures 3 and 4 from Chapter III, O&S costs do tend to increase as a function of time, independent of changes in other cost inputs.

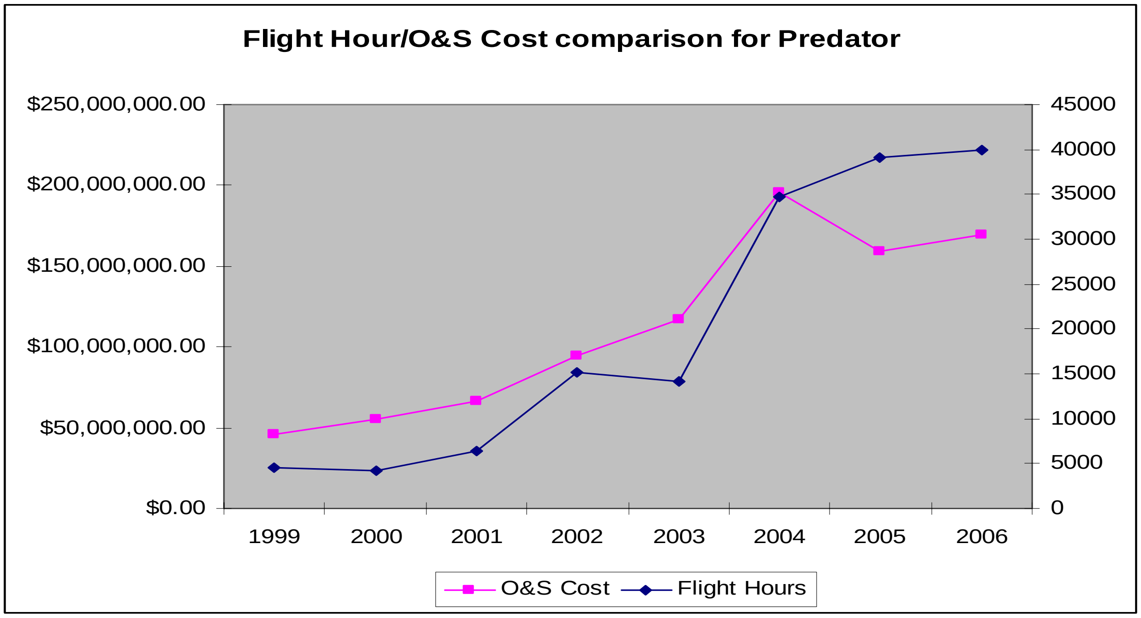

Figure 16. Predator O&S costs compared to flight hours (in nominal dollars)

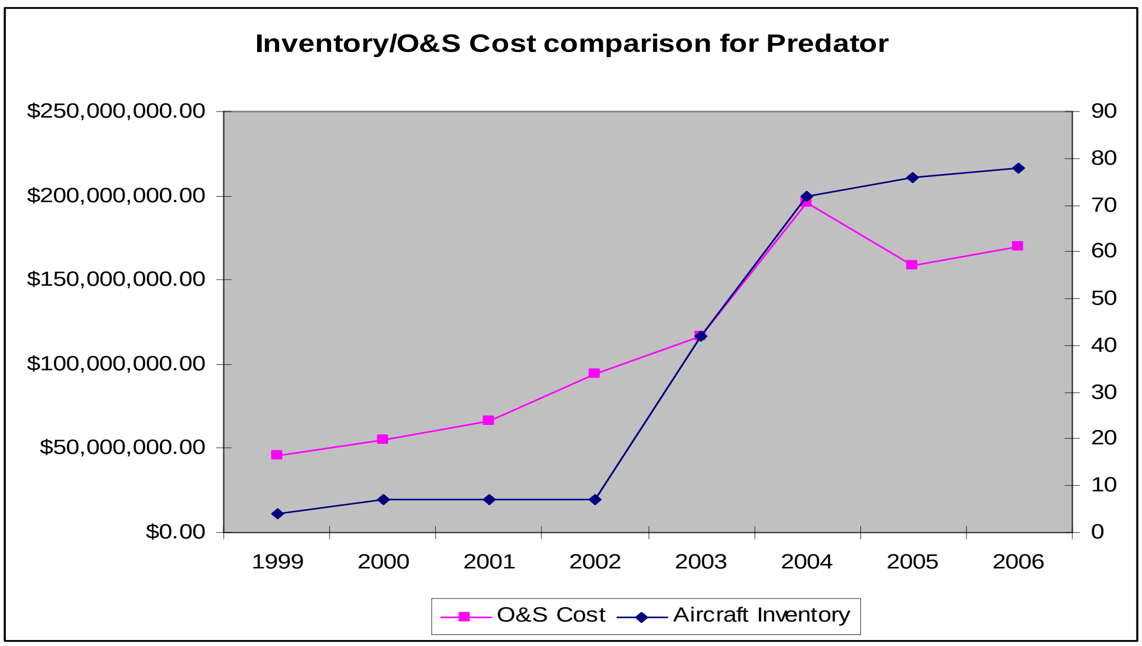

Figure 17. Predator O&S costs compared to aircraft inventory (in nominal dollars)

Trend 2: As the number of aircraft increases, the cost per unit flight hour decreases. This relationship tells us that adding aircraft decreases our cost per unit hour because O&S costs can be spread over more aircraft. The relationship holds because total O&S costs remain relatively stable, growing slightly over time, and do not vary directly in proportion to the number of aircraft. In addition, when observing F-16 data the procurement costs over this period, largely representing block improvements, are lower than O&S costs. While procuring a complete aircraft might significantly raise procurement costs, and hence cost per unit flight hour, block improvements would not. This indicates that the use of block improvements to upgrade existing aircraft in an aging fleet may be a more cost effective solution to aircraft attrition than the procurement of new aircraft. This relationship is more recognizable in the F-16 data due to the maturity of the aircraft and stability of the inventory.

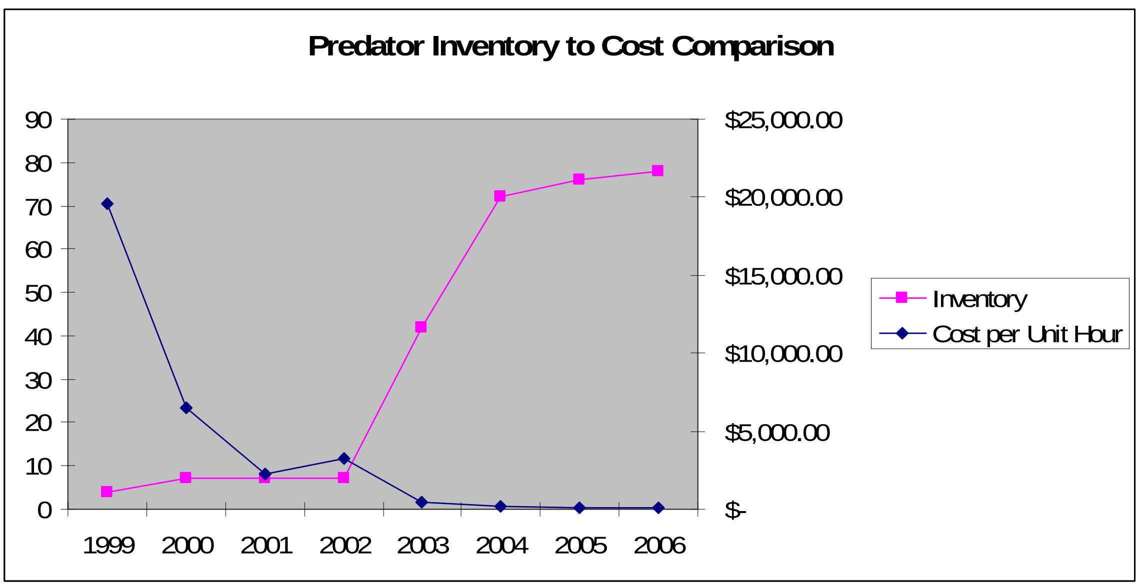

Figure 18. Predator Inventory versus Cost per Unit Flight Hour (in nominal dollars)

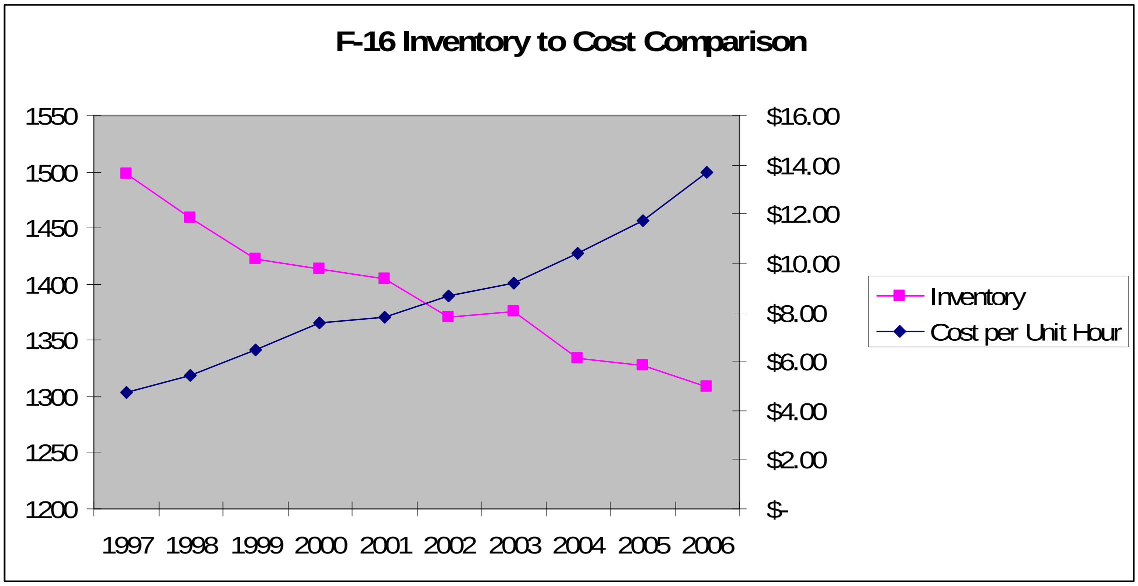

Figure 19. F-16 Inventory versus Cost per Unit Flight Hour (in nominal dollars)

Trend 3: As flight hours increase, the cost per unit flight hour decreases. While O&S costs do not show any direct relationship to flight hours, flight hours do have a direct effect on cost per unit flight hour; the cost per unit flight hour can be reduced by using the aircraft more. A problem with this approach concerns the limited service life of the aircraft. To maximize the use of aircraft without over usage prior to replacement, the annual flight hours per aircraft should be budgeted on a per aircraft, per year schedule. This would optimize use of the aircraft over the projected service life. Additionally, from manipulating trend 1 to include more aircraft, a greater number of flight hours can be accumulated annually, which will further reduce the cost per unit flight hour. One problem associated with the data, however, is that the cost per unit flight hour as calculated here for the F-16 is sensitive to the timing within the platform and does not reflect the true lifecycle costs associated with that program. Figure 20 illustrates how the Predator's cost per unit flight hour decreases as flight hours increase, while figure 21 demonstrates the opposite trend, the F-16's cost per unit flight hour increases as flight hours decrease.

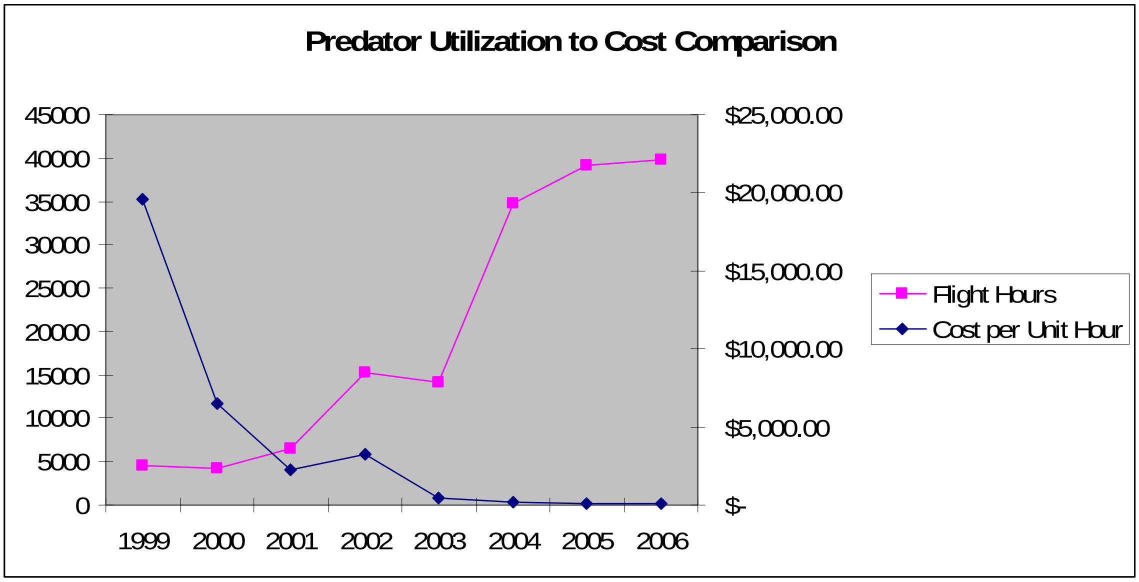

Figure 20. Predator Utilization to Cost Comparison (in nominal dollars)

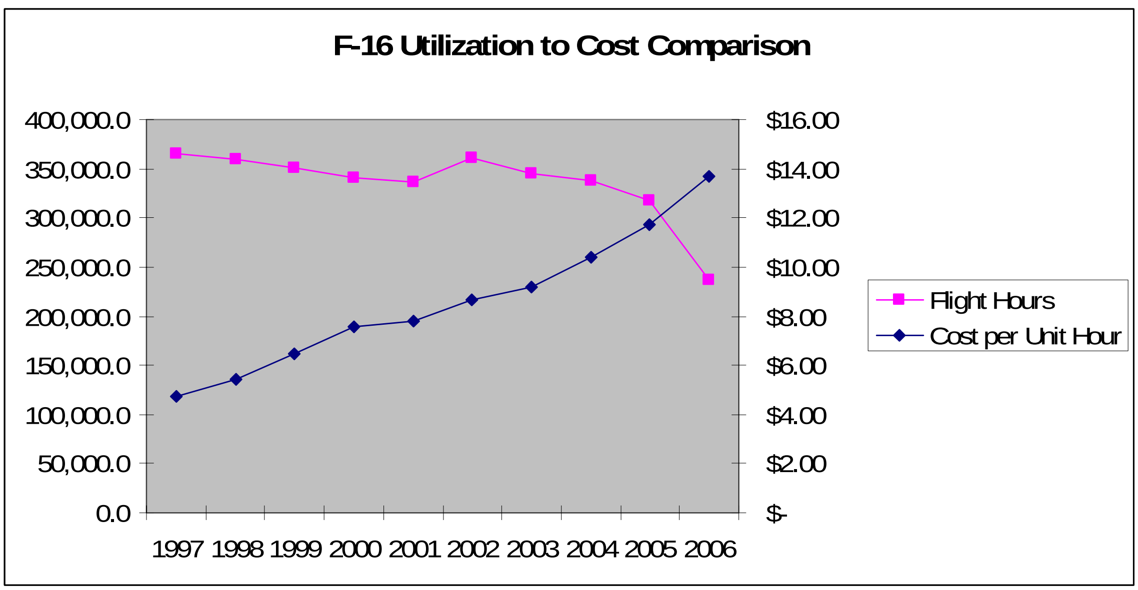

Figure 21. F-16 Utilization to Cost Comparison (in nominal dollars)

Trend 4: Procurement cost has very little effect on cost per unit flight hour in a mature system while O&S costs represent a significant portion of the final cost per unit flight hour. Using block upgrades to increase the service life or capability of an existing, mature, aircraft design has very little effect on the cost per unit flight hour. While any procurement costs, including block improvements, add to the cost per unit flight hour, this added cost is superficial when the additional flight hours made possible by the block improvement are considered. If the block improvement allows additional flight hours for a particular aircraft, then the aircraft can be utilized more resulting in reduced cost per unit flight hour over time. Short term fiscal effects will slightly increase cost per unit flight hour, but the costs for block improvements are small compared to the stabilized O&S costs. Additionally, a more comprehensive lifecycle cost per unit flight hour would correct for this effect by including both procurement and block improvement costs in the cost metric. Figure 22 illustrates the relationship between time, procurement costs, and O&S costs.

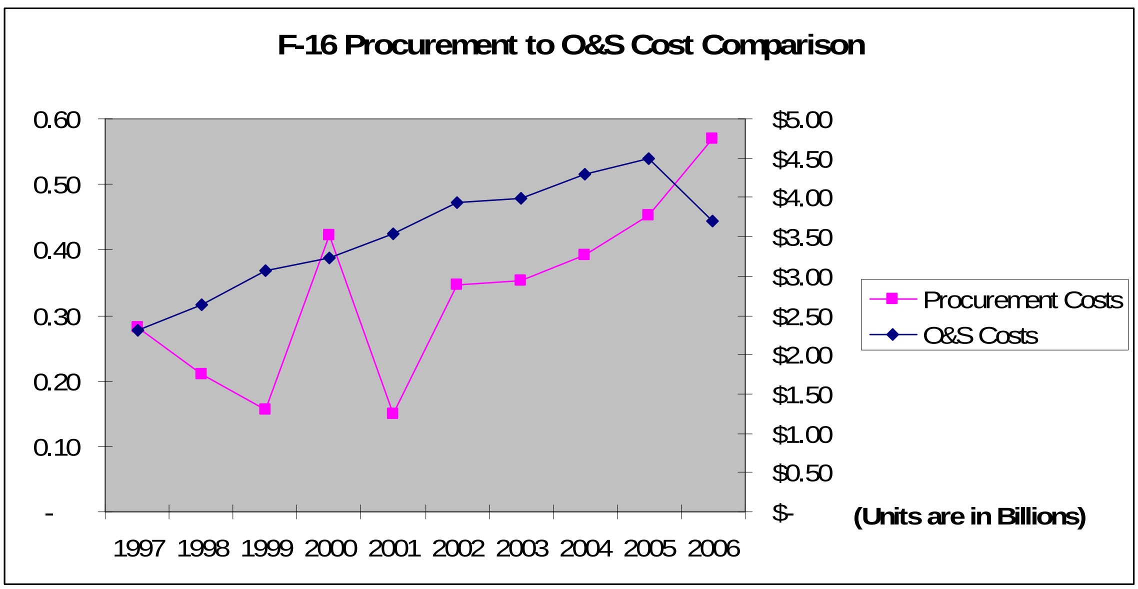

Figure 22. F-16 Procurement to O&S Cost Comparison (in nominal dollars)

Trend 5: O&S costs and procurement costs have equal influence on systems that have not reached full production. Since procurement costs are highest at the beginning of any aircraft program and O&S costs increase steadily over time, their effects on cost per unit flight hour are balanced. Once the design has reached Milestone "C" however, O&S costs become the predominant program cost (McKinney, 2005). Therefore, changes in procurement at the beginning of a program will have significant effects on the initial cost per unit flight hour; as aircraft are delivered and enter operation, flight hours will increase and drive the cost per unit flight hour down, as shown in the model. Since O&S cost increase over time, their effect remains constant. Figure 23 illustrates the observed relationship between time, procurement costs, and O&S costs.

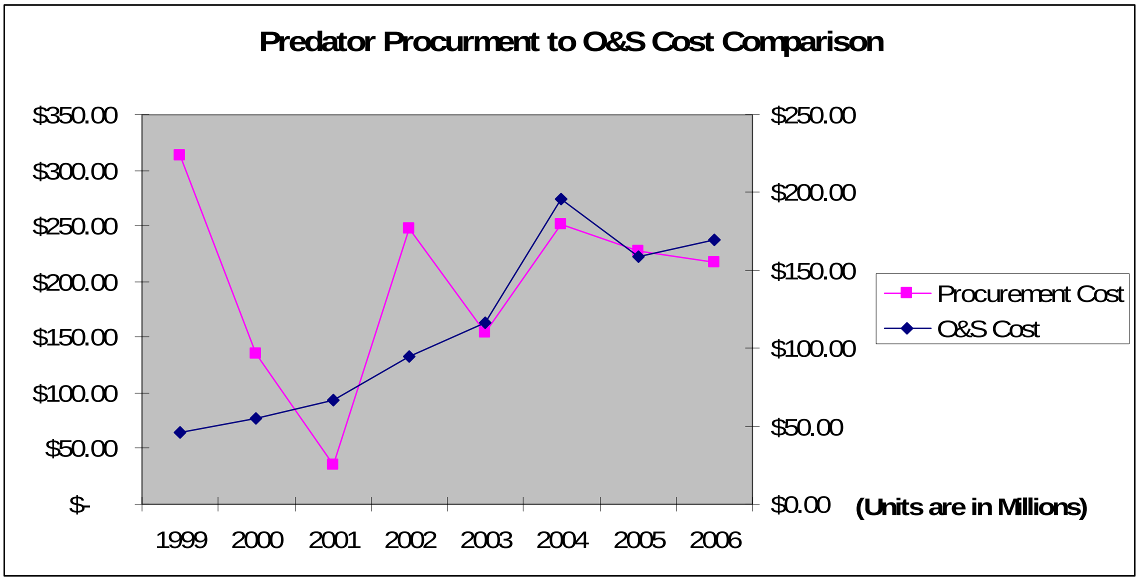

Figure 23. Predator Procurement to O&S Cost Comparison (in nominal dollars)

4. Limitations

The data collected and utilized for the model were accurate and current but there were some important limitations to note. However, in spite of these limitations the analysis is reliable within the scope of the cost model developed for this research. The limitations concerning inventory data, mishap data, and program age are detailed below.

a. Inventory Data

While the cost per unit flight hour is functional and displays trends that can help decision makers gain a perspective on the factors underlying cost per unit flight hour, there are some limitations to its use. While adding aircraft in the case of Predator is continuing throughout the time period considered, the final delivery of the last F-16 has already occurred; procurement costs for the F-16 are limited to the block upgrades made to existing aircraft, enabling their subsequent return to service. The functional value of the model is not lost, however, as the rate of attrition can be calculated and applied to the model to determine how the cost per unit flight hour would be effected by the current rate of attrition. In the case of Predator, both the rate of attrition and the rate of delivery can be applied to the model to aid in determining a delivery schedule.

b. Mishap Data

Aircraft mishaps that result in the loss of an aircraft have a negative effect on inventory levels and contribute to attrition; however, the replacement cost of the aircraft would have little effect on the cost per unit flight hour. Nevertheless, mishap data would aid in determining the true rate of attrition and future inventory levels. What is important to note is that any mishap that reduces the inventory of a new program would have a more significant effect on cost per unit flight hour than would one toward the end of an aircraft's service life. Therefore, mishaps are more costly at the beginning of a program than they would be at the end in terms of cost per unit flight hour. While mishaps were not studied during the course of this research, the effects of mishaps should not be ignored and should be researched further.

c. Program Age

To demonstrate the utility of the cost per unit flight hour model, historic data was only gathered to 1996 for the F-16. Further analysis of the additional historic data would provide more detailed statistical analysis of cost trends and would allow more accurate rate calculations in O&S cost creep. While the model can be used to compare the F-16 and the Predator in terms of current cost per unit flight hour, the lack of historical data on F-16 and subsequent GDP cost adjustment to CY, makes comparing the two aircraft at like stages impossible. The addition of this data and CY adjustment would facilitate greater accuracy in comparing the two aircraft in the initial stages of their respective programs.

V. CONCLUSIONS

A. INTRODUCTION

This chapter summarizes and discusses the research findings and limitations, based on the primary and secondary research questions, and then presents suggestions for further research and study.

B. SECONDARY RESEARCH QUESTIONS

1. What are the Current Methods of Cost Comparison?

The current methods of cost valuation include the Unit Flyaway Cost (UFC), Average Procurement Unit Cost (APUC), and Program Unit Acquisition Cost (PAUC). While Unit Flyaway Price (UFP) has been used in the past, it is no longer a current cost metric. O&S costs are used for comparison, but they are treated separately because they are not part of any one cost valuation method.

2. What are the Common Elements of Cost that Should be Used to Compare Unlike Platforms with Similar Missions?

O&S costs are common to every aircraft platform and are the most significant single cost in any aircraft platform beyond Milestone "C" (McKinney, 2002). Therefore O&S costs should be used when comparing dissimilar aircraft platforms that perform similar missions. Additionally, PAUC represents the most complete per unit cost of an aircraft platform and should be used in the initial stages of a program, and also when considering block upgrades and in conjunction with O&S costs.

3. What Other Cost Considerations Should be Taken into Account?

Other considerations that should be considered when comparing one aircraft platform to another are inventory data and utilization data. These variables complete the cost landscape by providing a method to determine over, under, or optimum usage of an aircraft platform based on the inventory. In addition, the inventory data and flight hour data provides a simplified metric to compare separate platforms on a per unit flight hour basis.

C. PRIMARY RESEARCH QUESTION

1. What is a Cost Valuation Method that Can be Used to Compare a Manned Aircraft Platform to an Unmanned Aircraft Platform with Like Missions?

This research has shown that the current valuation methods do encompass a broad enough scope of costs to allow a fair and true comparison between manned and unmanned aircraft platforms. To accomplish a fair and reasonable comparison, O&S costs must be considered; current valuation methods do not use O&S costs as a factor. Furthermore, other elements, such as inventory and utilization, must be considered when valuing an aircraft. The cost per unit flight hour valuation, while simple, considers these variables, in addition to the PAUC, to estimate a cost that fits a historical curve. The cost per unit hour can then be interpreted and used to predict the trends of expenses and what actions need to be taken to ensure the needs of the government are met while budget dollars are properly managed.

D. SUGGESTED AREAS OF FURTHER RESEARCH

1. Historical Mishap Data

Historical mishap data were explored for the purpose of the research, but limited data precluded their inclusion in the model. Historical mishap data is important and can be used to produce statistical projections for inventory losses and can then be used to further refine the results of the model. Considerations for including the data would be the aircraft utilization as a percentage of its useful service life at the time of loss, replacement value of the aircraft and the installed equipment, and loss of military personnel, if applicable. Given the degree of variability in the mishap data, and the availability of the data required for such an analysis, developing this input to the model was considered beyond the scope of demonstration and therefore excluded from the study.

2. Regression Analysis

Regression analysis can be used as an input to the model in a similar fashion to mishap data. Since aircraft attrition is expected with age independently of mishaps, a rate of expected attrition can be calculated and applied to the model to help determine when the aircraft will become too costly to operate. Then using that data, the model could work backwards to determine the point where investment in a new or alternate platform should increase, and when the investment in the current platform should taper off and at what rate in order to achieve the most utilization of the aircraft in terms of service life.

Regression analysis can also be used to statistically verify the cost relationships described in this analysis. Regression analysis simultaneously examines the impacts of several variables on unit cost per flight hour, determining the relative impact of each on the overall cost metric. This would help determine the interactive impacts of the variables examined, and would enable the analysis to include over potential explanatory variable (e.g., inflation, attrition, deployment in a conflict, etc.). Additional historical data for the F-16 might provide sufficient data for regression analysis in this program. Regression analysis for the Predator UAV will require additional years in the program lifecycle to obtain sufficient data.

E. SUMMARY

The data presented for Predator and F-16 has shown that O&S costs variance between platforms are too significant to be considered separately when comparing the operating costs of dissimilar aircraft. For this reason, the cost per unit hour method of valuation and comparison is a more accurate summary of the most significant costs associated with the operation of a given aircraft platform. Furthermore, the utilization and inventory data provides an ideal metric for comparison. Further research in this area of cost valuation and comparison would allow more refinement to the model and provide even greater accuracy for comparison. It is therefore recommended that the benefits of the model be explored further, and more research conducted in the areas noted.

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