DEVELOPING COST PER FLYING HOUR FACTORS FOR THE OPERATIONS AND MAINTENANCE PHASE OF THE SATELLITE LIFE CYCLE

THESIS

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Abstract

The purpose of this thesis was to develop cost per flying hour factors for the operations and maintenance (O&M) phase of the satellite life cycle. At a time when space system platforms are becoming some of the most strategic weapons in the military arsenal, it is critical that accurate cost models and factors be developed to assist in budgeting for the O&M of these assets.

A relative comparison was made between the components that make up the model for the aircraft cost per flying hour factors and those that constitute a majority of the O&M costs for the satellite cost per flying hour factors. Although the specific components are very different for the two models, the method by which they are used must be similar if there is to be an accurate baseline for comparison.

Research was conducted on two specific space systems: Global Positioning System (GPS) and Military Strategic and Tactical Relay Satellite System (MILSTAR). The cost components chosen for inclusion in the model for both satellite configurations are captured in the following Element of Expense Investment Codes (EEIC): Critical Space Contract Operations (554), Critical Space Operations—Direct Support (555), and Depot Level Repairables—Non-Flying (645).

By modeling budget and accounting data from the 50th Space Wing, satellite cost per flying hour factors were developed which can be used by those responsible with the financial planning of the two systems. Further research should be conducted to validate the factors that were developed and observe trends in the data and factors over several years.

DEVELOPING COST PER FLYING HOUR FACTORS FOR THE OPERATIONS AND MAINTENANCE PHASE OF THE SATELLITE LIFE CYCLE

I. Introduction

"Money, modernization and mind power are the keys to the United States' future in space"
Gen. Ralph Eberhardt (Warren, 2001)

Background

For several decades, space systems have provided the U.S. military with a great deal of information covering everything from weather patterns to movement of military personnel around the globe. Recently, satellites (and space systems in general) have become some of the most strategic assets the Department of Defense (DoD) has in its arsenal. In the 2001 Quadrennial Defense Review (QDR), Secretary of Defense Donald Rumsfeld explains the importance of the space arena, "Creating substantial margins of advantage across key functional areas of military competition (e.g., power projection, **space,** and information) will…hedge against and dissuade future threats" (DoD (bb), 2001: 15).

In recent years, satellites have been invaluable to the near-instantaneous transfer of information, enabling the warfighter to discern new or changing targets within a matter of seconds. The DoD is examining options to develop a Standing Joint Task Force, in which one of its goals is to develop the capability to continuously locate and track mobile targets at any range and rapidly attack them with precision (DoD (bb), 2001).

The current and future status of the space program was a major topic of concern discussed in the 1998 Air Force Congressional Issue Papers. The point addressed was the necessity of the Evolved Expendable Launch Vehicle. The key message:

> Our nation depends on routine, affordable, and reliable access to space. Current small, medium and heavy expendable space launch systems meet today's warfighter requirements. However, they are expensive and lack operating features critical to meeting future employment strategies (SAF/LL, 1998: 6).

Rumsfeld reiterates the critical nature of space, and the reliance upon it. "Space and information operations have become the backbone of networked, highly distributed commercial civilian and military capabilities" (DoD (bb), 2001: 7). He also states, "This opens up the possibility that space control – the exploitation of space and the denial of the use of space to adversaries – will become a key objective in future military competition" (DoD (bb), 2001: 7).

With the heavy reliance upon satellites as the primary means of gathering data, it is imperative that financial managers and space operations decision makers are able to incorporate new satellites, repairs, and upgrades into the budget planning process. Without a firm grasp of the total cost of space systems, personnel will not have the ability to properly budget for those costs. Therefore, DoD will not be able to sustain the operations envisioned by its leaders. The term "support" could be used instead of maintenance to describe the post-production work on space systems, but for the purposes of this thesis, maintenance will be used. The Air Force, along with all DoD agencies, must be able to accurately measure all costs of satellite and space systems in order to withstand “modernization of the aging space surveillance infrastructure” (DoD (bb), 2001: 45).

In order to effectively budget and account for the operations and maintenance (O&M) costs of space systems and their components, a model must exist which produces a factor that can be used to track satellite costs. To date, a comprehensive factors-based model has yet to be developed, and as a result, this deficiency has created problems at various levels for the accurate tracking, allocation, and budgeting future O&M costs.

Motivating the Problem

There are measures being taken to eliminate the problems mentioned in the 1998 Air Force Congressional Issue Papers. Specific focus is on need for affordable systems, instead of issues dealing with such problems as the current high cost of launch systems. The changes affect the entire weapon system, not just their individual components. In two speeches given by Secretary of the Air Force, F. Whitten Peters, he stated that the Air Force already provides between 85 to 90 percent of the national defense space budget and an equivalent percentage of the personnel who work the space program (Peters (a) and (b), 2000). Having that much control over the space program, it is imperative that strong budgetary controls are in place to monitor funds, plan for future needs, and develop the affordable space systems.

Headquarters Air Force Space Command (AFSPC) is the central location where a majority of military space activity is conducted. Recently, AFSPC has been working with the Air Force Cost Analysis Agency (AFCAA), the Air Force Cost Analysis Improvement Group (AFCAIG), and other installations within the command to identify methods for more accurately controlling and budgeting costs of space programs. One potential way to accomplish this goal is through the development of comprehensive, reliable cost per flying hour factors for the O&M phase of satellites.

The issues affecting space (information) and satellites, along with the steps taken to resolve those issues, encompass the concept that is driving the military of the 21st century—Transformation. "The purpose of transformation is to maintain or improve U.S. military preeminence in the face of potential disproportionate, discontinuous changes in the strategic environment" (DoD (bb), 2001: 30). "Transformation should focus on emerging strategic and operational challenges and the opportunities created by these challenges" (DoD (bb), 2001: 30). Since there has been a gradual shift in emphasis towards increasing the number of space assets and their capabilities, it is inevitable that leadership would pay closer attention to the budget aspect of these changes. One of the six critical operational goals for the DoD's transformation efforts includes "Enhancing the capability and survivability of space systems and supporting infrastructure" (DoD (bb), 2001: 30).

Appendix A lists the six critical operational goals (DoD (bb), 2001: 30). By examining each goal, it can be argued that each one, at least indirectly, incorporates some aspect of space systems. This verifies the importance of space in the future and the inherent need for accurate budgeting, as the money funneled into the space program will greatly increase (Peters (b), 2001).

A proven solution to managing and controlling the budgetary inflows and outflows of a program is to have a specific pool of money set aside for that program. This solution works well only when implemented and refined to a routine process. A result of the assessment of the national security space management and organization, the commission mentioned that "there is no DoD appropriation that identifies and aggregates funding for space programs" (Levin, 2001: 28). Instead, "Space funding is an aggregate of many appropriations spread across DoD and Intelligence Community budgets" (Levin, 2001: 28). The commission further states, "When satellite programs are funded in one budget, and corresponding ground terminals funded in another, this decentralized arrangement can result in program disconnects and duplication" (Levin, 2001: 28). Additionally, this decentralized structure could potentially have a severe impact on the acquisition of space systems and their ground control assets due to the lack of synchronization (Levin, 2001).

Although the current budget structure does not account for space funds separately, the Space Commission discussed the possibility of establishing a "virtual" Space Major Force Program (Department of the Air Force (a), 2002). A primary concern with having a Major Force Program dedicated solely for space programs is that all the money for those programs are restricted to one specific pool. If a certain space system needs more money, they have to pull from another space system. The current funding arrangement is that if a space system requires more funding, then decision makers can pull funds from a variety of different programs outside of the space arena. Essentially, a major force program would eliminate most, if not all, of the flexibility in moving funds within the space program (Mehrman, 2002).

The Air Force space budget has seen some significant changes for planning horizons that will drastically improve the program. In a September 2000 speech, F. Whitten Peters stated that, "[in 2000], space systems would account for 31 percent of the Air Force's modernization budget" (Peters (b), 2000). He also highlighted that, "Every major space system is being modernized or replaced" and "By 2005, 55 percent of the Air Force's science and technology budget would be dedicated to the space mission" (Peters (b), 2000).

More directly related to this research effort are comments by Brig. Gen. Brian Arnold in an Air Force News release from April of 2000. He states in the article that, "Air Force Space Command project areas seeing funding increases are wide-ranging. Global Positioning System (GPS) modernization, upgrades to the GPS Operational Control System and Anti-Jam development and testing dollars are growing substantially, virtually doubling from the FY 2000 budget" (Roney, 2000). Gen. Ralph Eberhardt echoed a similar future and potential concerns when he stated that, "the nation will have to invest the capital—both the intellectual capital and the dollars—to stay on course and realize its destiny in space…by making sure America's space launch bases and range can compete by modernizing the ranges and better understanding the cost of space launch" (Warren, 2001).

Research Focus

This research focuses on developing cost per flying hour factors for two satellite configurations in the Air Force inventory – Global Positioning System (GPS) and Military Strategic and Tactical Relay Satellite System (MILSTAR). These two satellite configurations were chosen for three primary reasons: 1) they are two of the more high-profile and common satellite systems, 2) these systems have Expense Element Investment Codes (EEIC) attributed specifically for their programs, and 3) it allows for the comparison between old (GPS) and new (MILSTAR) space systems (Mehrman, 2002). The EEIC is a part of the accounting classification that identifies a specific type of cost under which the item falls. Later on in the research, a more specific sub-classification of the EEIC, the responsibility center/cost code (RCCC), will be used.

The satellite age factor results in a unique perspective of satellites with different missions and maturity levels. Other satellite systems that might have been of research interest involved considerable subjectivity when selecting a percentage of a total dollar cost pool associated with each system. By comparing multiple systems, the results will indicate whether the same satellite components can be used in the satellite configurations and the potential impact the components have on the cost per flying hour factors. Those cost-driving components that comprise the portion of the total cost of the O&M portion of the satellite configurations deemed to be essential will be used to develop the model. The data used to create the model has been provided by HQ AFSPC and the 50th Space Wing (SW) at Schreiver AFB, CO.

The satellite cost per flying hour model will be developed using the same fundamental methodology as the aircraft cost per flying hour model. The aircraft model is well-established and will provide an excellent template from which to derive the satellite model. Therefore, significant portions of Chapters Two and Three will incorporate the aircraft flying hour program and the cost per flying hour model associated with it. The goal of this research is to take the aircraft model and develop the satellite model that will be implemented into budget exercises for more accurate accounting of satellite O&M costs.

Research Questions

The following questions will address concepts that are fundamental in establishing a foundation for this and future research:

1) Can a cost per flying hour model, similar to that for aircraft, be developed and implemented for satellites? If so, what major differences exist between the two?

2) What are the major cost drivers for the satellite O&M environment?

3) Are the factors derived for a space system unique? Are they stable?

4) How could the factors developed for space systems be implemented into the budget process?

Thesis Progression

Having established a basis for the purpose of conducting this research, the remainder of this thesis probes into much greater detail concerning the structure of the aircraft cost per flying hour model and the results of applying that concept to satellite O&M costs. Chapter Two contains a literature review that compiles research that has been previously conducted on aircraft and satellites (primarily cost per flying hour initiatives). It also details the aircraft cost per flying hour model (factors) – the framework on which the satellite model is based. Chapter Three looks at the methods used for developing the model to include what cost components are included in the model and how the process flows for developing a model that produces useful cost factors. Also included in Chapter Three are the assumptions that must be made to implement and justify the factors and the intricacies that the satellite cost per flying hour model addresses that the aircraft model does not. Chapter Four details the analysis of the entire model, explaining each step and how the final factors were derived. Chapter Five reviews the research conducted and results produced. Limitations of the results are addressed and follow-on research that could enhance this model is identified.

II. Literature Review

Introduction

This chapter introduces the concept of a cost per flying hour factor (CPFH) and the overarching flying hour program. Some of the areas that will be addressed are as follows:

1) The basis for a cost per flying hour.
2) How the flying hour program and associated factors are used in Air Force budgets.
3) The components included in establishing each cost per flying hour factor.
4) How satellite cost per flying hour factors would fit into the aircraft concept.

The following sections focus primarily on the aircraft cost per flying hour concept. The reason for its inclusion in this research is that the model for the satellite cost per flying hour will be built based upon the aircraft model. After providing the foundation for the CPFH in the first section by defining it and explaining how it is used, the next section will address the importance of tracking data and programs in a comprehensive manner, specifically from a "unit cost" perspective. Following sections address both aircraft and satellites, taking an in-depth look at the structure of the CPFH. The section devoted to aircraft CPFH includes discussions that demonstrate the importance of the data to the decision-makers.

Budgeting Concepts

The CPFH concept, although in existence as far back as 1962, catapulted to the forefront of O&M funds management in the early 1990s as a result of the Defense Management Review and downsizing of budgets (Rose, 1997). The CPFH program is used at every base that has a flying mission, and it is the backbone of the O&M funds planning at those locations. "Good operation and maintenance skills are important in a wing's flying hour program; equally important though, is a successful cost-per-flying-hour program" (Wiley and Dick, 1997: 17). The significance of the flying hour program is captured in Rose's summary on CPFH factors, "Flying hour program funding based on CPFH factors represents a large percentage of a MAJCOM's and wing's O&M budget and provides funding for the core mission of the Air Force" (Rose, 1997: 9).

The foundation for this research lies in the fundamental theory of a CPFH. "Cost Per Flying Hour is a metric used to estimate the costs of fuel, consumables, and depot level repairables (DLR) to operate a particular weapon system (aircraft) for a one-year period" (Rose, 1997: 4). More recently, the government purchase card has been included as a factor in the flying hour program (Lies, 2002 and Myers, M., 2002). "Flying hours are the basic element for measuring aircraft usage to train aircrews for wartime taskings" (Rose, 1997: 4).

"The basis for flying hour funding is the number of programmed hours multiplied by the projected cost per flying hour rate" (GAO, 1999: 8). This rate drives the development of the required funding estimate, assuming that the programmed flying hours remain relatively stable. For instance, the FY 2003 Budget Estimates from the Office of the Secretary of Defense (OSD) reports, "The Air Force fully funds a flying hour program of 1.3 million flying hours at levels commensurate with historic cost growth to ensure aircrews of the world's premier air force receive training crucial to combat readiness" (DoD (d), 2002: 35).

Importance of the CPFH component.

The primary relevance of this vital program is that it is a highly-visible part of the president's budget which has to be approved by Congress. In the FY 2003 Budget Estimates submitted by OSD in February of 2002, there are numerous references throughout the document focusing on the flying hour program. Each service branch has its own "unit cost" program and any reduction or increase to any component of the program is explained (DoD (b) and (d), 2002). Below is an excerpt from the February 2002 OSD O&M Overview which shows the FY 2003 Budget Estimates. At the highest level of interest, it includes the total flying hours with other Key Activity Indicators.

Table 1. Air Force Key Activity Indicators (DoD (d), 2002: 215).

Indicator	FY 2001 Actuals	Change	FY 2002 Estimates	Change	FY 2003 Estimates
Active Duty Military Personnel (End Strength)	353,571	5,229	358,800	200	359,000
Civilian Personnel	82,589	(2,040)	80,549	(519)	80,030
Total Aircraft Inventory	3,931	(43)	3,888	(140)	3,748
Primary Assigned Aircraft	3,335	23	3,358	(57)	3,301
Flying Hours (000s)	1,257	36	1,293	6	1,299
Training Workloads	25,533	(2,363)	23,170	906	24,073
Military Installations	80	(2)	78	0	78

In an era of "right-sizing" of the military, the focus has become "do more with less." As the Naval Postgraduate School (NPS) handbook describes it, "We are committed to providing increasing quality at decreasing cost – achieving better value for each defense dollar spent. We have to be able to get the job done, but at a cost that is acceptable to the decision-makers" (DRMI, 1995). In Wiley and Dick's article "Cost-Per-Flying-Hour Program: A Foundation for Wing Cost Reduction," they state that within the wing, "the primary goal is to reduce flying hour costs" (Wiley and Dick, 1997: 17). In order to be able to reduce costs, budget personnel must be able to track, document, and monitor those costs.

Benefits to using "unit cost" factors.

In many reports and briefings within the DoD, the financial figures that are discussed tend to reflect a "total cost" perspective. Presumably, this is for ease of briefing and is a simple method for tracking the overall trend of a program. However, this is not the best method when actually analyzing costs. According to the NPS Handbook on Unit Cost, "By relating total cost to outputs (unit cost method), stakeholders are made aware of the real cost of support. To that end, unit cost provides more meaningful information and assists managers and management teams in becoming more effective" (DRMI, 1995). The handbook also points out that service branches have implemented the "unit cost" perspective. Air Force units with flying aircraft manage in terms of "cost per flying hour," Navy units use "cost per steaming hour," and Army units measure according to "cost per tank mile" (DRMI, 1995).

Not only has the CPFH proven to be effective and efficient for tracking costs for the Air Force flying mission, but since it has become a cornerstone of the budget process, it also allows decision makers to pinpoint changes in any of the components that make up the CPFH so they can adjust their estimates accordingly. The NPS handbook focuses on the point that "Monthly comparisons between actual unit costs and unit cost goals enable managers to understand the results of monthly operations and trends over time" (DRMI, 1995). This is why the CPFH program is so important--because each flying unit within the Air Force is limited by its flying hour budget. Monitoring that difference between actual costs and the target is paramount to ensuring units do not overobligate funds or do not have to ground aircraft well before the end of each fiscal year. The end goal is to be able to keep the flying mission fiscally solvent up to the last day of the fiscal year.

Aircraft CPFH

With the basic concepts and applicability of the CPFH established, an in-depth look at how the Air Force develops and implements the aircraft CPFH is necessary. There has been a significant amount of research on numerous facets of this topic that provides valuable insight into the aircraft CPFH model. Each component of the CPFH will be explained at a very detailed level. The standardization of the concept across all flying units, something that is often inherent in a philosophy that has been adopted, implemented, and refined for more than a decade, will be examined to see why it works in such a simple and efficient manner. The following sections are devoted to defining and explaining the CPFH components and analyzing their dynamic nature.

Consumable Supplies (CS).

Rose identifies consumable supplies as "those aircraft parts/supplies that have no authorized repair procedures and are discarded after use" (Rose, 1997: 4). The GAO defines these as "non-repairable supply items used by maintenance personnel in direct support of aircraft maintenance" (GAO, 1999: 9). These supplies are categorized by the organization from which they are purchased, or the division in which they are used.

"Items classified as consumable supplies include disposable aircraft parts, antennas, lights, wiring, windshields, bench stock items, administrative supplies, tools, etc." (Rose, 1997: 5).

Depot Level Repairables (DLR).

"Depot Level Repairables are those aircraft parts removed by wing maintenance personnel and sent to depots for repair" (Rose, 1997: 5). The GAO defines the repairables as "parts that can be repaired at a maintenance facility and are used in direct support of aircraft maintenance" (GAO, 1999: 9). "For these items, repair costs associated with certain maintenance or operations cost centers are considered valid flying hour costs" (Rose, 1997: 5). "These cost centers include Flight Line Maintenance, Fabrication, Propulsion, Avionics, Munitions, Aircraft Generation, Component Repair, related staff, and others connected to the maintenance organization" (Rose, 1997: 5).

Aviation Fuels (AVFuels).

As defined by the GAO, aviation fuel is "the cost of fuel purchased to operate an aircraft" (GAO, 1999: 9). In his CPFH Factors article, Rose states that, "AVFuel is the fuel used during flight and the factor is expressed in gallons per hour, which is converted into a dollar per hour factor based on DoD established prices for each fuel type" (Rose Jr., 1997: 5).

Government Purchase Card (GPC) Items.

This newly-added component of the model includes all the purchases on the GPC that go towards acquiring aircraft components. The GPC Consumables consist of base-level flying hour-related items such as de-icing fluids, hydraulic fluids, etc. (Lies, 2002).

Since this item was a recent addition to the cost per flying hour model, its inclusion in past reports is limited.

Application and Analysis of Component Factors.

How are these components used in the analysis of weapon systems? Table 2 provides an example of the data that is compiled on CPFH factors. The complete report actually contains the component factors for every aircraft system, sorted by command. Table 2 includes only the data from Air Combat Command (ACC) on the B-2A.

Table 2. Logistic Cost Factors Per Flying Hour (Federation of American Scientists).

LOGISTIC COST FACTORS PER FLYING HOUR (in dollars)								
Command: ACC Weapon System: B-2A								
	FY97	**FY98**	**FY99**	**FY00**	**FY01**	**FY02**	**FY03**	**FY04**
DLR	$4,174	$8,822	$7,647	$8,667	$8,667	$8,667	$8,667	$8,667
FUEL	$1,990	$1,990	$1,990	$1,990	$1,990	$1,990	$1,990	$1,990
GSD	$1,221	$1,416	$1,273	$1,271	$1,269	$1,269	$1,269	$1,269
SSD	$1,531	$1,644	$1,617	$1,615	$1,612	$1,612	$1,612	$1,612
Subtotal	$8,916	$13,872	$12,527	$13,543	$13,538	$13,538	$13,538	$13,538

In Table 2, GSD and SSD stand for General Support Division and System Support Division, respectively. With this data, rough estimates of future years' data, with some adjustments based on knowledge of how the variables may change, can be forecasted. Through 2001, there appears to be some general stability in the supplies, a standard cost factor for fuels, and some fluctuation in DLR's (with a leveling off at the end of the planning horizon).

Table 2 contains information on only one weapon system platform within one command, and doesn't explain in sufficient depth the idea that each component of the flying hour program is reasonably dynamic in nature. Rose addressed the dynamic nature of the factors in his article. His overall view of the three primary aircraft CPFH components was that AVFUEL factors are usually close to actual rates, (until recently) consumable supplies were fairly consistent from one year to the next, but DLR's had yet to develop a stable baseline from which to forecast requirements (Rose Jr., 1997).

The July 1999 GOA Defense Budget Report on the CPFH Program indicated that the consumable supplies demonstrate a significant level of volatility. Table 3 identifies the price changes to repairables and consumable parts that occurred throughout FY 1998.

Table 3. Price Changes for Aircraft Parts in 1998 (GAO, 1999: 12).

Examples of Price Changes During Fiscal Year 1998					
Type of Part	Initial Price	Second price	% Change from Initial to Second price	Third price	% Change from Second to Third price
Cell assembly	$9,939	$13,152	32.3	$14,503	10.2
Duct assembly	$17,544	$19,340	10.2	$23,516	21.6
Case, turbine	$9,235	$10,199	10.4	$16,795	64.7
#3 bearing	$3,981	$5,654	42	$5,106	-9.7
Liner	$10,893	$12,141	11.5	$2,700	-77.8
Case, gas turbine	$1,478	$204,413	13,730.4	No change	No change

The impact of the repetitive price changes has a significant impact on planning, programming, and budgeting within DoD. "Each change creates a rift through all levels of command and ultimately requires current and future year adjustments" (GAO, 1999: 15). The GAO report also states that, "The methodology used by the Air Force to cost out the flying hour program depends heavily on stable prices for its repairable and consumable spare parts" (GAO, 1999: 3). Additionally, "The lack of accurate and stable prices for depot-level repairables and consumable parts caused a great deal of concern among the flying commands" (GAO, 1999: 12). Even after Congress approved a $300M increase to cover a shortage due to rising DLR and consumable costs, numerous price changes made it difficult for commands to determine if they had been provided adequate funding to complete the flying hour program (GAO, 1999). This is just one example where there were requests for additional funding due to price changes of the CPFH components.

Another example of the instability of the rates is demonstrated in the OSD 2003 Budget Estimates. The report describes in great detail any changes to a funding category. Under Budget Activity Code 1, there was a "Decrease of $28.2 million in the cost of the Flying Hour Program to reflect changes in the Flying Hour Program including changes to consumption, program, and aircraft and a reduction in fuel costs" (DoD (d), 2002: 39).

Similar changes are contained in the FY02 Amended President's Budget. Under the Program Increases and Decreases in the combat-related operations section of O&M, there was a $901M increase to the FY 2001 Flying Hour Consumption Changes (DoD (aa), 2001: 154). The explanation for that increase was as follows: The FY 2001 Flying Hour Program was repriced to reflect the latest CY 2000 AFCAIG approved cost factors which are based on the most current consumption data available (DoD (aa), 2001: 154). Included in this reprice are AVPOL, DLRs, and consumable supplies (DoD (aa), 2001: 154).

It is evident by this repricing that not only is there a lag period in the projection of the effective cost rates, but there are also repetitive updates to the rates when more current information becomes available. In the section of Primary Combat Forces for Air Operations in the FY 2003 Budget Estimates, this lag period is again addressed: "The FY 2003 budget also reflects reduced flying hour costs to capture the approved cost factors based on FY 2000 consumption, adjusted for a five-year historical pattern of cost change in flying hour DLRs and consumables (-$93.6 million)" (DoD (d), 2002: 90). Rose explains his view on the impact of repetitive repricing throughout the year, “For instance, funding for FY96 initially showed up in the FY91 Program Objective Memorandum. Each year during the budget exercises, flying hour programs are repriced using the newly approved factors or revised programmed flying hours” (Rose, 1997: 7). The GAO also mentions the following, “The annual AFCAIG process develops costs for the budget 2 years into the future; for example, the 1997 cycle, using the most current cost data available, developed the cost factors used in the fiscal year 1999 budget” (GAO, 1999: 8). Echoing this idea, Rose states that, “the AFCAIG rates use execution data that is almost two years old for CPFH rates being used in the execution year” (Rose, 1997: 7-8).

Knowing that there are price changes and CPFH adjustments which affect the flying hour program, flying wings may request additional funds throughout the year to provide a buffer to avoid a potential funding shortfall. However, the total flying hours are seldom completely exhausted. The table below displays an aggregate total of flying hours programmed and the percentage flown.

Table 4. Air Force Flying Hours: Programmed and Flown (GAO, 1999: 4).

Fiscal Year	President's budget (hours)	Percent Flown
1995	1,453,501	88.7
1996	1,327,155	93.7
1997	1,285,695	91.7
1998	1,290,256	92.5

It must be noted that this is the total compiled from all flying wings, so while some may have executed the program at 100 percent, others did not. It is readily apparent that over 75,000 flying hours were not flown each year. The GAO reports that each command is responsible for reporting why all hours were not used, and not once was the answer a lack of flying hour funding (GAO, 1999: 4).

Concerns over rising costs in the flying hour program.

In the 2001 Air Force Posture Statement, Secretary Roche explicitly mentions problems of rising costs associated with spare parts that tie into the flying hour program. "Maintaining an aging fleet with more expensive spare parts is one of the costs reflected in the increasing cost per flying hour. Over the past five years, our flying hours…have remained relatively constant, but the cost of executing our flying hour program has risen over 45%" (Department of the Air Force, 2001: 36).

Directly related to the increases Secretary Roche discussed above, the Air Force Times published an article titled "Readiness Now, Modernization Later." In this article, flying hour changes were examined in detail. The basic concept was that "operations and readiness requests increased to $23.9 billion from $19.6 billion. The cost of maintaining older aircraft is eroding large amounts of the service's budget, helping drive that 22 percent increase" (Simon, 2001: 12). More specifically, "the number of AF flying hours will remain at 2.1 million hours, but the cost will increase. To meet its flying hour goals, the AF is seeking $6.2 billion for fuel, supplies and spare parts, up from $4.8 billion" (Simon, 2001; 12).

Any number of events can have a significant impact on the actual flying hours, and the flying hour program in general. Less than a year after the AF Posture Statement cited above was released, a DoD New Release on the details of the FY 2003 DoD budget request contained a substantial increase in funding for the flying hour program. "The budget boosts funding for training and readiness to keep pace with the demands of the war against terrorism and other missions. FY 2003 funding, and corresponding increases over 2002 have [total costs for] flying hours up $500 million."(DoD (c), 2002: 2).

The Department of National Interests has produced a graph that provides the best illustration of the rising trends of aircraft O&M costs. Figure 1 shows the aircraft O&M costs over the past 50 years, and the trend shows an overall continuous increase, given that while actual flying hours have decreased by nearly 75 percent in the past 30 years, the O&M cost per flying hour has more than doubled during the same timeframe.

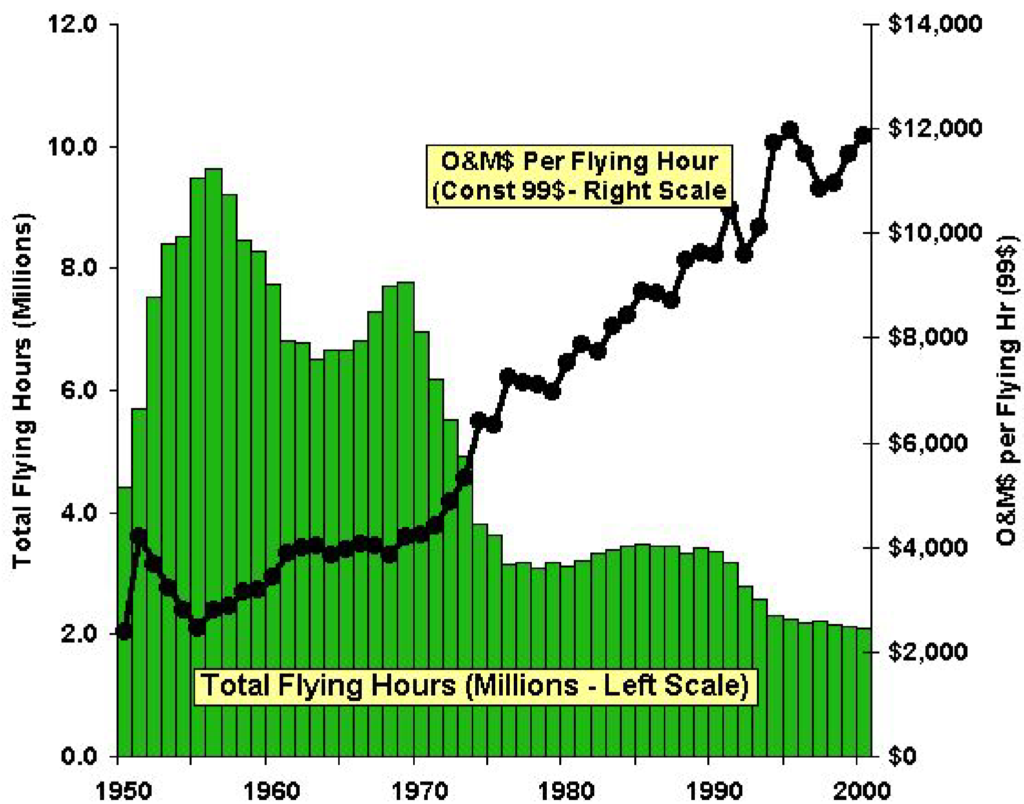

Figure 1. Rising Cost of Flying Hour O&M Costs (Department of National Interests).

Conclusion.

The theory and structure of the aircraft cost per flying hour is very straight-forward and has been effectively used for decades. Four components make up the flying hour program and those components are well-defined. However, the main issue with the program is the inconsistent nature of price changes and updates/adjustments, making it challenging to monitor and forecast the necessary funding. The goal of flying wings is to execute the program to completion (fly all budgeted hours) without running short on funding. Nevertheless, for several years in the late 1990's, flying hour funding had to be turned back in to headquarters (GAO, 1999). On the horizon is a potentially more efficient way to track, analyze and forecast CPFH data. Executive AFCAIG is proposing a methodology change to the conversion rates in the CPFH factor build (Kammerer, 2001). Kammerer states that the Standard Base Supply System data would be used to build MAJCOM/aircraft-unique conversion rates based on three-year averages of consumption (Kammerer, 2001). "The goal is to better reflect MAJCOM requirements and provide the most accurate factors possible" (Kammerer, 2001: 21). With the basic foundation provided for the aircraft CPFH, the focus now turns to the concept of generating a satellite CPFH.

Satellite CPFH

With greater insight into the structure and application of the aircraft CPFH, the research identifies previous work on the operations and maintenance arena for satellites, specifically covering work geared towards any models or components of a model for a CPFH factor for satellites. Most cost research that has been performed on satellites revolved around constructing cost estimates that covered the research and development or production phases of the satellite life-cycle (Bearden, 2001; Wertz and Larson, 1999). One of the primary satellite cost models, Aerospace Corporation's Small-Satellite Cost Model (SSCM), estimated first-unit development and production cost which included such life cycle components as production, integration, assembly, and testing (NASA, 1995). Bradshaw looked at the broad scope of the cost of space missions, noting that, "Various models exist to estimate the cost of space missions…" (Bradshaw, 1997; Larson and Wertz, 1992).

Bearden's article in the Aerospace Corporation's quarterly publication is an in-depth report on their new SSCM. The article commences with the statement, "The forces that drive the costs of today's small satellites are very different from the forces that drive the costs of all other satellites" (Bearden, 2001: 1). In determining criterion for the "small satellite" categorization, Bearden suggests that some establish a mass threshold (e.g., 500 kilograms), others use cost, and yet others use size (Bearden, 2001). In general though, "A system's cost depends on its size, complexity, technological innovation, design life, schedule, and other characteristics" (Wertz and Larson, 1999: 783).

Although these reports and models are pertinent to the study and modeling of satellites enabling more accurate cost estimation and forecasting, they do not specifically incorporate the O&M phase of the life cycle. Since the increased focus on greater utilization of the space arena, documented research on the O&M phase of satellites has not kept pace. The following sections concentrate on the components that would make up a satellite CPFH model, and then on the potential cost estimating methodologies identified for costing satellites. In keeping with the objectives of this thesis, the analysis will focus on the O&M phase of the satellite life cycle, rather than the development/production/testing cycles which most models address. Therefore, the goal of the research is this: Once a satellite has been launched and is fully operational, determine the method that most accurately captures annual space system costs.

O&M Satellite Components.

Wertz and Larson's text, Space Mission Analysis and Design, spells out the categories of the life cycle cost of space mission architecture (Wertz and Larson, 1999). "The O&M phase consists of ongoing operations and maintenance costs, including spacecraft unit replacements and software maintenance" (Wertz and Larson, 1999: 786). The authors note the impact of O&M costs in that, "Although the space, launch, and ground segments are usually the most important elements, O&M can sometimes be the system's most costly one" (Wertz and Larson, 1999: 786). They then break the segments down even farther: "For most space programs, the primary ongoing operations and support costs are ground station operations and satellite spares; for reusable systems such as the Shuttle, this category consists of the ground crew and operations to support them" (Wertz and Larson, 1999: 786).

The O&M phase of the life cycle contains specific cost-drivers that capture a majority of the costs. According to Wertz and Larson, "The operations and support costs during the operational phase of the ground segment consist primarily of contractor and government personnel costs as well as maintenance costs of the equipment, software, and facilities" (Wertz and Larson, 1999: 800). Furthermore, "labor rates include overhead costs and other typical expenses associated with personnel" (Wertz and Larson, 1999: 800).

The table below from Wertz and Larson's book shows how each factor is developed from the different elements that make up the operation and support costs of a space system.

Table 5. Operations and Support Costs (Wertz and Larson, 1999: 801).

Operations and Support Costs in FY00$	
Maintenance	.1 X (SW + EQ + FAC)/year
Contractor Labor	$160K/Staff Year
Government Labor	$110K/Staff Year
Note: SW = Software, EQ = Equipment, FAC = Facilities	

Cost Estimating Methodologies.

There are numerous methodologies from which to choose in selecting a format to estimate costs of different phases of the space system. The method chosen depends upon which phase in the satellites life-cycle the estimate is being performed. It also depends upon the amount of data available and the complexity of the parameter that is being estimated. Wertz and Larson discussed three in their text: detailed bottom-up, analogy-based, and parametric (Wertz and Larson, 1999). They explain each of the three methods and make special mention that all have their advantages and disadvantages, although the parametric method is gradually becoming the most widely used (Wertz and Larson, 1999).

The first of the three methods, detailed-bottom up, "identifies and specifies the low-level elements that comprise the system" (Wertz and Larson, 1999: 787). The authors state that, "it is effective when tailored specifically for a program or contractor;

however, the problem is that it relies upon expert estimates for determining numbers and costs" (Wertz and Larson, 1999: 787).

The next method, analogy-based estimating, "uses similar items and adjusts them accordingly for size and complexity" (Wertz and Larson, 1999: 787). "This method can be employed at any level, and the assumptions are that a similar system does exist and that detailed cost and technical data exists" (Wertz and Larson, 1999: 787).

The final method explained by Wertz and Larson is the parametric method. This is the most common method employed in this type of research. "It is a mathematical relationship based on physical, technical and performance parameters that drive the cost of the system. The equation that relates the parameters is a cost estimating relationship" (Wertz and Larson, 1999, 787).

These methods are all legitimate in analyzing satellite costs, but fell beyond the narrower scope of this research. They applied more to the cost estimating in the earlier life-cycle phases where there are more variables with a much greater degree of complexity. The method that will be used in developing the satellite CPFH will be based upon the aircraft CPFH model That model will be transformed into the satellite model by using certain satellite cost elements to develop a similar structure.

Summary

This chapter has provided the foundation for the CPFH, why this particular measurement of cost is beneficial, previous cost modeling research conducted on aircraft, and the areas of previous work on satellite O&M costs. It is evident in the previous research that the CPFH is a very simple and useful tool in measuring and tracking O&M costs.

The cost per flying hour model has been associated with aircraft for decades, but with a much greater focus within the past 10 years (Rose, 1997). This thesis will attempt to take that template for an aircraft CPFH and transform it so that the same type of data and information can be generated for the O&M portion of the satellite. Chapter Three will walk step-by-step through the methodology of determining the satellite cost per flying hour. It will explain why each cost driver was chosen, justify the use of satellite flying hours for the denominator of the equation, and explain the assumptions and the complexities of the data.

III. Methodology

Introduction

With the conceptual basis and applicability of a cost per flying hour established, this chapter will focus on explaining the methodology that will be implemented to create cost per flying hour factors for satellites. In the last chapter, it was stated that the method of developing the satellite cost per flying hour model employed in this research was mirroring it to the aircraft cost per flying hour model.

Therefore, the first section will begin by explaining how the aircraft CPFH is developed. The next section will take that "template" and apply the same general principles for satellites. There are many assumptions and underlying differences between the two models which will be discussed throughout the chapter. Finally, the lead-in to Chapter Four includes a discussion on how data for the two space systems was collected and categorized.

Aircraft CPFH Factor Development

AFCAIG Background.

As previously discussed, the aircraft CPFH concept has been around for many years (Rose, 1997), and as a result, the process for developing the factor has become fairly standardized. The primary owner of the CPFH factor and the flying hour program is the AFCAIG, whose process will be used to explain how the aircraft factors are developed. That process will then be applied to the development of the satellite factor. It should be noted here that although the owner of this process is the AFCAIG, a large portion of the work with factor development resides with the AFCAA (Lies, 2002). The

AFCAIG is a General Officer/Senior Executive Service level group chaired by the Deputy Assistant Secretary for Cost and Economics (SAF/FMC) (DoD (a), 2002). The AFCAIG's goal is to develop accurate and defendable variable CPFH factors (Lies, 2002). Their objectives are to: (1) validate the forecast of the total CPFH requirement, (2) identify areas of risk, issues, and concerns, and (3) recommend factors to fully fund the flying hour program to the Air Force Corporate Structure (Lies, 2002). This AFCAIG snapshot provides insight into the level of ownership of the CFPH factor, the focus of the CPFH program in place at that level, and how through the years, the procedures for arriving at a factor resulted in a well-refined process.

Factor Development Process.

The process used to arrive at a final CPFH factor is outlined in the OSD Deskbook website, and although it thoroughly describes the entire factor generation process that is followed each year, the concern here is only on the portion of the process from data collection forward. Figure 2 details the steps in the factor development for the aircraft CPFH, beginning with data collection.

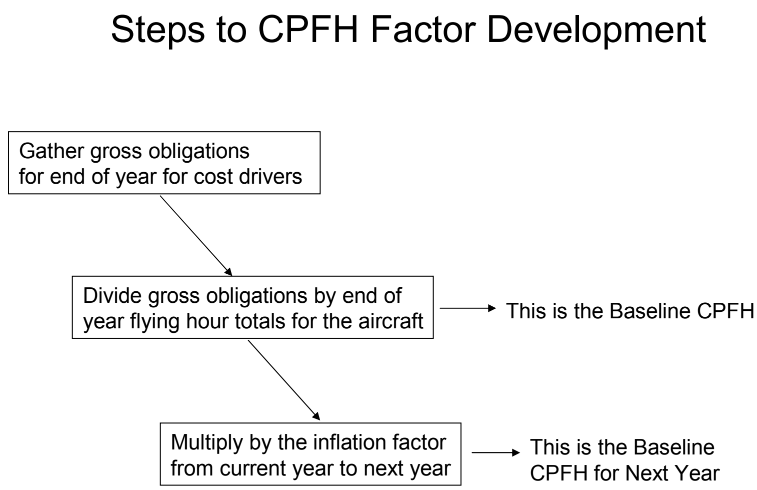

Figure 2. Steps to CPFH Factor Development (DoD (a), 2002).

As indicated in the first step of Figure 2 above, data must be compiled at the end of the fiscal year, where gross obligations for DLRs, Consumables, AVFuel, and GPC transactions are extracted. The DLR data utilizes a two-year consumption amount (average) at each item level, with the applicable adjustments, whereas Consumables and GPC data takes a one year look-back approach on the dollars obligated (Lies, 2002). The AVFuel total differs in that the number used is a three-year average consumption (gallons/hour) of fuel for each aircraft type (Lies, 2002). A more in-depth analysis of the AVFuel calculation will be discussed later on in the chapter.

The next step listed in Figure 2 requires taking the total hours flown in the fiscal year for the aircraft type and dividing the gross obligations for each of the four cost-driver categories by that number. This provides the baseline CPFH factor. Then, using the SAF/FMC inflation tables, multiply each baseline CPFH factor by the appropriate inflation factor. The inflation factor is found by looking in the current year's table, using that as the base year, and locating the following year's factor. The category used for aircraft CPFH factor development purposes is "Operations & Maintenance, Non-Pay, Non-POL (3400)." The number resulting from the multiplication becomes the new baseline CPFH for the next fiscal year.

The AFCAA has developed a diagram that demonstrates this aircraft CPFH process. Figure 3 incorporates the same steps in Figure 2, but also offers emphasis on the future adjustments necessary to achieve the final CPFH factor.

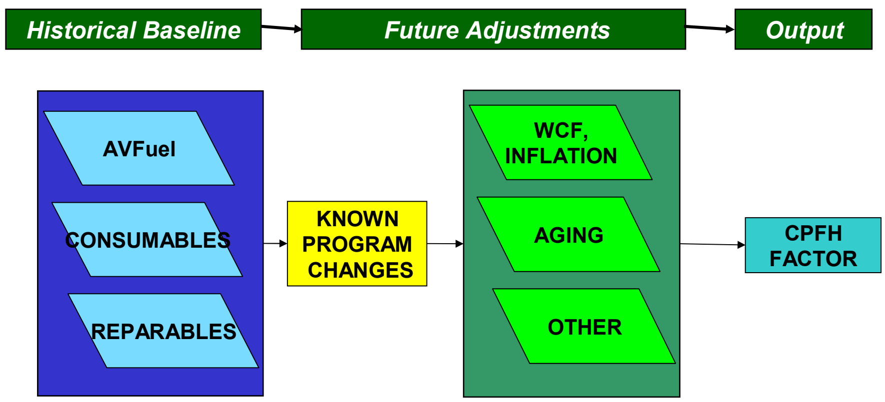

Figure 3. CPFH Methodology (Lies, 2002).

The inclusion of the aging factor shown in Figure 3 is a direct result of the Chief of Staff of the Air Force's direction to include this concept as a part of the CPFH factor (Lies, 2002). It is termed a "Rate of Consumption Increase," and its purpose is to estimate the effects of the aircraft aging one more year (Lies, 2002). Again, it should be noted that this aging and the GPC items have been newly added, resulting in limited data being available to demonstrate the impact on the methodology, model, or the budget in general.

Re-addressing the AVFuel factor, its calculation is significantly different than for other components in the model. The unit measurement resulting from the division mentioned above is gallons/hour. At the end of the fiscal year, the SAF/FM Cost branch derives an average cost per gallon fuel factor for each command and multiplies it by the gallons/hour factor, arriving at the final aviation fuel funded rate per hour. The calculations to project fuel consumption are based on a three-year average (Kammerer, 2001 and Lies, 2002).

After analyzing Figure 3 and reviewing the entire AFCAA cost per flying hour factor development, data collection and the inclusion of known program changes cover the simpler, initial steps in the process. Once these steps are completed, then the more complex aging and price change adjustments are made (Lies, 2002). An adjustment is defined as "an increase or decrease to the baseline CPFH due to a forecasted change in policy, procedure, or situation that will affect the CPFH through the fiscal year defense plan" (McDougall and Taitt, 2002).

The OSD Deskbook website contains several chapters on the cost per flying hour factor development process, with one of those devoted to the adjustment process. There is a list of 13 different adjustments, along with the method of how the adjustments are submitted, which ultimately result in a change in the CPFH factor (DoD (a), 2002). A detailed explanation of these final steps goes beyond the intent of this chapter, although adjustments will certainly be addressed in the development of the satellite factors as the adjustments play an important role in understanding all costs involved in the CPFH factors. The price changes would most likely not play a significant part in the satellite CPFH factor development since it is more manpower-driven; however, adjustments of a different nature will be necessary. The impact of aging is an element that might deserve attention in the future as a potential influence upon the satellite CPFH.

Analysis and Reports.

Factor development is only a part of the overall flying hour program. After the factor has gone through its iterations and is in final form, the analysis and reporting must be completed. This combined step aims to identify and account for as many of the variances in the flying hour program and the CPFH factor as possible (Sullivan, 2002). In the AFCAIG presentation, the definition of this variance analysis process was defined as "Analysis of significant changes in the CPFH rates from one year to the next for each commodity (MSD, GSD, AVPOL) per weapon system" (Sullivan, 2002).

Variance analysis is one of the most important components of the cost per flying hour modeling process. It drives the refinement of the process and provides insight into the validity and necessary adjustments of the factor every year. Analysis is based on airframe type as well as EEIC. The two types of variance analysis are baseline-to-baseline and proposed factors to approved factors. The first requires an explanation of the differences in factors between fiscal years and the second requires the explanation of the proposed factor which would include adjustments (DoD (a), 2002).

A critical distinction between the cost per flying hour analysis of the aircraft and satellites is that for aircraft, variances must be explained for both the obligations (dollar amounts) and the flying hours. For the satellites, variances will only account for the obligations because the hours will remain constant. Clearly, this distinction makes the aircraft CPFH variance analysis more complex and allows for more fluctuation in the final factor because both the numerator and denominator are being altered. As an example, the "planners" for a particular aircraft model may be justifying why the crews didn't fly as many hours this year, and the budget personnel are justifying why consumable spare costs increased more than normal. The conclusion of all the justifications and adjustments is a final factor with supporting documentation.

Satellite CPFH Factor Development

Taking the aircraft CPFH factor development process described in the previous section, it will be applied in a similar structure to space systems. Since there has been such limited research on the O&M portion of the space system life cycle, the assumptions and methodology for the satellite CPFH have been based on numerous discussions by those individuals contributing directly to this research. The next section breaks down the components of the space systems that were selected for research and attempts to fit them as closely to the aircraft CPFH template as possible. Then, the following step analyzes the options of the unit of measurement, that is, the unit by which the total obligations for each cost driver would be divided. Finally, the adjustments are identified and accounted for in the CPFH equation.

Cost Drivers (EEICs).

The first step to factor development for satellites is determining those items that best capture the bulk of the O&M costs for the space systems. Once a satellite is put into orbit, O&M costs begin accumulating. There is a sizeable portion of satellite O&M costs that are consumable (parts)-based, but these costs are distributed among many space systems and it would be difficult to separate those costs for each system. Therefore, the costs that can be effectively and accurately measured tend to be primarily manpower-intensive. For these reasons, throughout the rest of this research, O&M costs will be referred to as manpower-intensive.

Although the types of costs that make up the satellite CPFH are very different from the components of the aircraft CPFH, a similar number of cost areas capture the targeted costs for satellites. Inevitably, there will be areas of the satellite O&M environment that are not incorporated into the model. However, a sufficient amount of the costs are covered by the cost drivers identified and employed here. To mirror the aircraft cost drivers of DLR (EEIC 644), Consumable Supplies (EEIC 609), and AVFuel (EEIC 699), the following cost drivers for satellites were chosen: Critical Space Contract Operations (EEIC 554), Critical Space Operations, Direct Support (EEIC 555), and DLR, Non-Flying (EEIC 645). These three cost drivers were chosen because they constituted a considerable amount of the manpower-based funding. Within the data set that was provided for analysis, the three EEICs above incorporated over 75% of the total cost obligations. Detailed descriptions for each of the EEICs weren't available, but EEIC 554 is comprised of primary contractor labor.

Unit of Measurement.

This collective unit is the activity by which the costs are measured. The unit is the denominator for each factor in the CPFH equation. For both aircraft and satellite CPFH concepts, the unit of measurement is flying hours. For aircraft, flying hours are the total number of hours that a given type of aircraft flew for the entire year. Flying hours for satellites are fixed because the measurement is the time the satellites are continuously in orbit. Since satellites are either constantly being utilized (contacted), or the ground stations which constitute a majority of the O&M cost for satellites are constantly being maintained or used, there are 24 hour-a-day costs incurred for the satellites. Therefore, the flying hour unit of measurement will simply be the 24 hour-a-day time in orbit multiplied by the 365 days in a year, or 8760 flying hours, per year.

Another unit of measurement that was analyzed to determine if it could potentially provide a more accurate measurement of costs was the number of contacts to a satellite in a year. Numbers of contacts are simply the number of times that a ground station contacts a satellite in order to gather data. The data for the number of contacts was readily available; however, as mentioned previously, it was suggested that even if a satellite is not being contacted, there are still on-going O&M costs being incurred that wouldn't be captured.

The problem with this idea was trying to forecast the number of contacts, whether monthly or annually. Not only would the number of contacts randomly fluctuate, but during contingencies and wars, the number of contacts would surge drastically. Another issue arises with the effect of missed contacts. For one particular space system, the satellite is contacted twice a day to retrieve data. The predicament develops when, for any number of reasons, the contact is missed. Since the satellite only has one day's worth of storage, if both contacts are missed, the data is gone. The only feasible chance to still capture the data is to schedule an immediate recovery in order to get the data (Mehrman, 2003).

Additionally, as space systems become more complex and technology advances rapidly, the systems are beginning to perform more than one function. This could complicate the mix of contacts; where one of the functions may be to monitor an area but not gather data until an event activates the gathering of data, another function may be to gather data on a periodic basis throughout a day or week. As each space system could potentially have a drastically different total for the unit of measurement, flaws would develop in making an accurate comparison between systems.

By carrying this contact concept through the entire research, tying the concept into the variance analysis would create significant problems. If the number of contacts per year to a satellite were small, then simply a few immediate recovery contacts would result in potentially major variances in the denominator and ultimately the overall factor. These reasons substantiate the philosophy that number of contacts would be nearly impossible to accurately forecast.

Consideration of the contact concept was important was because for aircraft flying hours, planners sit down and forecast the next year's flying hours based on the previous year's execution rates (Mehrman, 2002). For different aircraft types, planners will project a slight increase or decrease based on whether or not all the hours were flow. The fluctuation from year to year would be minimal due to the refined nature of projecting flying hours and historical trends. The determination needed to be made as to whether this same idea was a viable option for the space systems. However, it is much more complex with the satellites, because it would be nearly impossible to determine how often someone would trigger a contact to a satellite due to a need for information. For these reasons, it was decided that number of contacts would not be the best unit of measurement, but that the actual satellite flying hours would be.

Adjustments.

After obtaining data from the different EEICs to capture the satellite costs, each EEIC's total cost will be divided by the base unit of measurement, 8760 flying hours. The resulting number is the baseline factor for each cost segment. Just as with the aircraft CPFH adjustment elements of inflation and aging, there are necessary adjustments to the baseline satellite CPFH factors.

The unique aspect of the satellite CPFH concept is that the cost drivers are primarily manpower-intensive. As a result, there is an annually recurring cost element that accounts for the contracted personnel cost of living increases. This cost component will be referred to as the Contractor Cost of Living Allowance (CCOLA). These increases are similar to the Basic Allowance for Housing that military members receive. Due to both the location of the numerous radar sites around the world, and the effect of inflation on living expenses, there are specific costs related to this element which must be accounted for in the CPFH equation. The data for the CCOLA is embedded in the schedules of the multi-year contracts. The nature of this data is proprietary; therefore, precautions have been taken to ensure that assumptions and calculations are substantiated, while still maintaining the integrity of the data. Incorporating the CCOLA adjustment into the factor equation is critical for the following reason—the annual percentage increase in CCOLA may fall between 8 and 15 percent, while inflation is only 2 to 4 percent with the effect of a gradual erosion of the funding baseline (Mehrman, 2003).

The calculation of the CCOLA for the projection year involves the assumption that the change (normally an increase) in cost from one year to the next of the same contract is solely the CCOLA. This assumption is only correct as long as there are not additional contract line items introduced in future years, or if there are, that those additional line items have been removed. To capture the costs associated only with the satellites analyzed in this research effort, data will be extracted from the schedules for the three major contracts that affect the two space systems: Operational Space Service and Support (OSSS), Wing Communication (WCOM), and Space Operation and Maintenance (SOM). The Accounting Classification Reference Number (ACRN) in the contract schedule determines the space system to which the accounting line is assigned. The schedules effectively break out each line item, allowing for ease in the gathering of data on both GPS and MILSTAR systems. The difference in the schedules' cost totals between the two years for GPS and MILSTAR will be the CCOLA. Any known unusual or extraordinary line items will be extracted from the line item cost totals with the goal of having only CCOLA remaining as the difference. The CCOLA that results from this step will be added to the original data total for the appropriate EEIC to get the adjusted baseline factors.

Again, inflation is an integral part of the CPFH concept (and any multi-year cost comparison) which must be captured in the CPFH model. The inflation factor applied to the adjusted baseline comes from the SAF/FMC inflation indices, and since the initial data for this research is from 2001 and the goal is to project for 2002, the FY2001 inflation tables must be used. Just as with the aircraft CPFH inflation factors, the inflation factor for the satellite CPFH is extracted from the FY 2002 row and the "O&M, Non-Pay, Non-POL" column of the raw indices.

The last step necessary to get the final CPFH factor is achieved by multiplying the inflation factor by the adjusted baseline factor. The final amount that results from the application of the adjustments is the satellite CPFH factor that will be used to forecast the following year's costs.

It is essential to note that the assumption has been made that the difference in the CCOLA total between years has not had the effect of inflation removed. Therefore, to eliminate the possibility of double-counting inflation, the CCOLA difference will be reduced by the appropriate inflation factor, and the “primary” inflation factor will be re-applied to the model’s equation.

Validation

The final step in the methodology is to validate the usefulness of the factor in forecasting future years’ O&M costs for each space system. Since the data for FY 2002 is available for GPS and MILSTAR, the FY 2001 factors that are generated through the factor development process explained above will be compared to the actual FY 2002 data. The objective in applying the cost per flying hour factors is to accurately forecast the following year’s actual data. Forecasting exactly the next year’s data would be ideal, which would mean accounting for 100 percent of the variance. Since this is unrealistic, a range should be chosen that is acceptable to the decision-makers. An example would be “account for at least 85 percent of the variance between fiscal years.”

Any significant variances between the results from implementing the factors and future year’s data will require a more detailed analysis. There are a variety of reasons for additional costs, most of which would fall into one of the two broad categories of unscheduled maintenance or environmental factors affecting the radar sites. These additional costs will be identified through budgeting and accounting documents. Small differences are acceptable, but by taking these extra costs into account (especially major adjustments), the final factors will provide a good measure of the following year’s costs, with the acceptable error.

Conclusion

This chapter outlined the factor development process for the aircraft CPFH as implemented by the AFCAIG. It then took that template and mirrored each step of the satellite CPFH factor development as closely as possible. While the fundamental process for each are the same, the primary difference between the two that affects the adjustments made on the baseline factors is the fact that the aircraft CPFH is consumption-driven and the satellite CPFH is manpower-driven. After applying the factor development process to satellites, making the necessary adjustments, and applying the inflation component, the final factors should be a good predictor of the following year's cost data for the GPS and MILSTAR satellites.

The next chapter will take the factor development process explained above and implement it using the data from FY 2001 and FY 2002. After the factors are obtained, they will be matched against the FY 2002; any discrepancies other than acceptable error will be explained to provide a valid, effective satellite CPFH factors for use by AFSPC and the 50th SW as a budgeting tool.

IV. Data Analysis

Introduction

In the previous chapters, the foundation was established to justify the need for the development of a satellite CPFH factors-based model, as well as explain how it would be implemented based upon the structure of the aircraft CPFH model. The importance of developing these factors lies in the fact that they can be a useful budgeting tool, just as the aircraft flying hour program is a critical activity (cost-wise) in the Air Force budget (DoD (d), 2002). The last chapter provided a detailed methodology by which the satellite CPFH model will be developed. This chapter takes that methodology and applies the data in order to achieve accurate CPFH factors for the two chosen space systems.

To begin this chapter, however, a detailed description of the two satellite configurations will be presented. Having discussed the purpose, applicability, and desired results of this research with HQ Air Force Space Command, the two satellite configurations chosen for research are the GPS and MILSTAR. Both space system platforms are based out of the 50th SW at Schreiver AFB, CO.

GPS

The Navstar GPS is a constellation of orbiting satellites that provides navigation data to military and civilian users all over the world. The system is operated and controlled by the 50th SW located at Schriever Air Force Base, Colorado. GPS satellites orbit the earth every 12 hours, emitting continuous navigation signals. With the proper equipment, users can receive these signals to calculate time, location, and velocity with extreme accuracy and precision. The GPS constellation is designed and operated as a 24-

satellite system, consisting of six planes, with a minimum of four satellites per plane. The satellites are launched into nearly 11,000-mile circular orbits via the Delta II rocket and have a design life of 7.5 years. (Department of the Air Force (c), 2002).

Playing a particularly important role in this research is the fact that the GPS-dedicated ground system consists of five monitor stations and four ground antennas located around the world. With the launch of the first satellite in 1978, this is by far the oldest of the two satellites being studied (Department of the Air Force (c), 2002). These assets, and the crews that operate them, drive the majority of the O&M cost for the GPS satellite system.

MILSTAR

The MILSTAR is a joint service satellite communications system that provides secure, jam-resistant, worldwide communications to meet essential wartime requirements for high priority military users. The operational MILSTAR satellite constellation will consist of four satellites positioned around the Earth in geosynchronous orbits. Each satellite weighs approximately 10,000 pounds and has a design life of 10 years.

The MILSTAR system is composed of three segments: Space (the satellites), terminal (the users), and mission control. A key goal of MILSTAR is to provide interoperable communications among the users of Army, Navy, and Air Force MILSTAR terminals. The first MILSTAR satellite was set into orbit in February of 1994 (Department of the Air Force (b), 2002).

Data Collection

A crucial step with this research is obtaining enough pertinent data to properly implement the methodology. The data for this research was accumulated from numerous budget and accounting documents through a combined effort of HQ Air Force Space Command and the 50th SW. The data that was gathered contained the potential O&M costs related to each space system being studied for FY 2001 and FY 2002. The comprehensive data sets for both satellite systems for each year are located in Appendices B-E. Below is a simplified table of the cumulative data, with each EEIC containing the rolled-up cost totals.

Table 6. EEIC Roll-up Cost Data (From 50th SW).

	FY 2001	FY 2001	FY 2002	FY 2002
EEIC	**GPS**	**MILSTAR**	**GPS**	**MILSTAR**
554 (Critical Space Contract Ops)	$7,826,344	$5,079,194	$8,133,952	$4,218,510
555 (Critical Space Ops, Direct Support)	$1,066,041	$1,022,566	$1,118,969	$1,150,916
645 (DLR, Non-Flying)	$530,047	$701,425	$527,395	$843,817
TOTAL	$9,422,432	$6,803,185	$9,780,316	$6,213,243

Initial Baseline CPFH Factors

Having compiled the complete data set into a simple, understandable and useable form, the next step is to take each EEIC data point from Table 6 and create initial baseline CPFH factors. This is performed by dividing the data point by the number of satellite hours flown per year. Calculated in the previous chapter, this number is 8760 hours. The initial baseline factors for each space system are shown in Table 7.

Table 7. Initial Baseline CPFH Factors.

GPS (FY 2001)

EEIC	Cost	Hours	Baseline Factor
554	$7,826,344	8,760	$893.42
555	$1,066,041	8,760	$121.69
645	$530,047	8,760	$60.51
TOTAL	$9,422,432	8,760	**$1075.62**

MILSTAR (FY 2001)			
EEIC	Cost	Hours	Baseline Factor
554	$5,079,194	8,760	$579.82
555	$1,022,566	8,760	$116.73
645	$701,425	8,760	$80.07
TOTAL	$6,803,185	8,760	**$776.62**

Adjustments to the Baseline

The variances in the costs of each EEIC are associated with changes in the funding levels. Several cost line-items received dramatic changes in those funding levels between FY01 and FY02 (see Appendices B-E). For GPS EEIC 555, there was an additional obligation for an "Interim Back-up – GPS" in FY02 for $225,742. Two other RCCCs had large increases from FY01 to FY02, one about $63,000 (55564) and another for almost $34,000 (55563). For the GPS EEIC 645, there was an overall decrease of about $3,000, but this is primarily attributed to a large increase of about $12,500 in RCCC 47410W and a decrease in RCCC 978400 of almost $16,000. EEIC 554 will be addressed in the section below that discusses CCOLA.

One limitation with the MILSTAR system is that in the data set provided, the breakout of EEICs (down to multiple RCCCs) is not nearly as extensive as it is with GPS.

Therefore, the ability to determine variations at lower levels is severely limited. All variances will be analyzed further in the validation section

The next step in developing the satellite CPFH factors is to calculate the adjustments to the initial baseline factors. The adjustment continuously present throughout satellites' life will be the Contractor Cost of Living Allowance (CCOLA). This cost component captures the difference in the contractual (expected) costs between each fiscal year. This step of the modeling process will require utilization of data from both FY 2001 and FY 2002.

The data for the CCOLA resides in the contract schedules of the OSSS, WCOM, and SOM contracts. In order to capture only the relevant line items from those contracts, extraneous line items in the contracts such as phase-out costs were removed from consideration. Table 8 contains the differences in the target costs of each contract between the two fiscal years. There cannot be a comparison of the OSSS contract between GPS and MILSTAR because the MILSTAR data for this contract was not incorporated until FY 2003. Additionally, the ACRN coding scheme for WCOM couldn't be verified. Therefore, the assumption made was that it utilized the same "second-letter" code as with the SOM contract. The result is that the ACRN for MILSTAR in FY01 is "CB" and in FY02, it is "DB". For GPS, the ACRN is "CC" in FY01 and "DC" in FY02. Using this assumption, the WCOM contract contained no data for GPS in FY02.

Table 8. CCOLA Cost Differences between Fiscal Years.

Contract and Space System	CCOLA Diff. Between FY2002 and FY 2001
OSSS	

GPS (only)	$ 462,313
WCOM	
GPS	Not Available
MILSTAR	-$38,482
SOM	
GPS	-$174,783
MILSTAR	-$205,121

Upon analysis of the ACRN and the accounting citation, the observation was that for the three separate contracts, the only cost driver that contributes to the CCOLA was referenced by RCCC 5547C, which gets rolled-up into parent EEIC 554. With this knowledge, it is apparent that the CCOLA amount only applies to Critical Space Contract Operations, EEIC 554. To assess the impact of the overall CCOLA, FY02 totals were reduced by the inflation factor. Referencing the SAF/FMC inflation indices, totals for FY02 were multiplied by .983 to get both data sets to the same base year. The totals for each space system from Table 8 were summed, resulting in a GPS CCOLA of $287,530 and a MILSTAR CCOLA of -$243,603, which will be inserted in the CPFH equation for EEIC 554.

Based on CCOLA being applicable only to EEIC 554, the only influencing factor in the two remaining EEICs, besides standard (recurring and non-recurring) O&M costs, is inflation. Therefore, the distinction here is made that the end cost per flying hour model equations for both space systems will utilized different equations, depending upon the EEIC being modeled.

Calculation of Final Factor

With the calculation of the adjustment component finished, the final step in setting up the model involves the application of the inflation factor. The inflation factor used in this equation is located in the SAF/FMC inflation tables with the heading “O&M, Non-Pay, Non-POL” as the most pertinent to this study. Table 9 was taken directly from the SAF/FM website which contains inflation factors from a wide range of base years and provides the corresponding factors for a range of over 100 years surrounding the base year (Department of the Air Force, 2003). Included in the table is a snapshot of a ten-year period encompassing the target base year as well as two other headings in the inflation tables, verifying that the heading used was the most appropriate.

Table 9. SAF/FM Inflation Indices (Department of the Air Force, 2003).

USAF Raw Inflation Indices Based on OSD Raw Inflation Rates Base Year (FY) 2001			
	General Services & Wage Board Pay	Operations & Maint. Non-Pay, Non-POL	Research, Develop., Testing, Evaluation
Fiscal Year	(3400)	(3400)	(3600)
1995	0.820	0.918	0.918
1996	0.842	0.937	0.937
1997	0.866	0.956	0.956
1998	0.890	0.963	0.963
1999	0.920	0.971	0.971
2000	0.961	0.984	0.984
2001	1.000	1.000	1.000
2002	1.036	**1.016**	1.016
2003	1.076	1.032	1.032
2004	1.118	1.054	1.054
2005	1.161	1.076	1.076

The correct inflation index for this research is 1.016, since the base year of the data is FY 2001 and the objective of the research is to assess the predictive capability of the factor for FY 2002.

Now that all the components of the cost per flying hour model are calculated, the development of the actual factors can be accomplished. The equation for the final factors is derived by taking the original FY 2001 O&M cost data from Table 6, adding the CCOLA amount to EEIC 554 only, then multiplying the inflation factor of 1.016 to all three EEICs to get the final satellite cost per flying hour factors. The following equation provides a mathematical representation of the derivation of the factor:

$$F = (D + C)*I \qquad (1)$$

Where F is *factor* (cost per flying hour), D is *data* (point), C is *CCOLA*, and I is *inflation*.

Table 10 below contains all the relevant data needed to arrive at the final cost per flying hour factors for each component of the two space systems. The table utilizes Equation 1 above to develop the final factors.

Table 10. Final CPFH Factors (divided by 8760 hours)**.**

GPS				
EEIC	FY01 Actual Data	CCOLA	Inflation Factor	Final CPFH Factor
554	$7,826,344	$287,530	1.016	$941.06
555	$1,066,041	N/A	1.016	$123.64
645	$530,047	N/A	1.016	$61.48

MILSTAR				
EEIC	FY01 Actual Data	CCOLA	Inflation Factor	Final CPFH Factor
554	$5,079,194	$-243,603	1.016	$560.84
555	$1,022,566	N/A	1.016	$118.60
645	$701,425	N/A	1.016	$81.35

With the final cost per flying hour factors developed, the check now becomes determining how well the factor predicts the future year's cost.

Validation

The usefulness of the FY 2001 satellite cost per flying hour factors depends upon how well they predict the costs incurred by the two space systems in FY 2002. Since the data for FY 2002 was available, the calculation portion of the validation process is very simple. Each data point from FY 2001 (Table 6) has the CCOLA added when applicable and that total is then multiplied by the inflation factor to arrive at an "Expected Cost" for

FY 2002. This expected cost is then compared to the actual costs incurred in FY 2002. The table below provides the comparison of the Expected vs. Actual costs for FY 2002.

Table 11. Validation: Expected vs. Actual Costs for FY 2002.

GPS			
EEIC	FY01 Actual Cost	FY02 Expected Cost	FY02 Actual Cost
554	$7,826,344	$8,243,695	$8,133,952
555	$1,066,041	$1,083,098	$1,118,969
645	$530,047	$538,528	$527,395

MILSTAR			
EEIC	FY01 Actual Cost	FY02 Expected Cost	FY02 Actual Cost
554	$5,079,194	$4,912,960	$4,218,510
555	$1,022,566	$1,038,928	$1,150,916
645	$701,425	$712,648	$843,817

In analyzing only the actual costs from the two years, the transition from FY01 to FY02 for the GPS portion of the table doesn't initially appear to include any cost items for the first two EEICs that would have a dramatic effect on the variance of the program. EEIC 645 does have a slight decrease which indicates that either additional costs were incurred in 2001, or specific costs were lower than normal (or averted) in 2002. However, upon closer scrutiny, the cost total variances do incorporate considerably more causes than just inflation.

Beginning with GPS EEIC 554, the variance between the two years is a $307,608 increase. The variance is much smaller than expected after examining the fluctuation of the RCCC totals for the EEIC in Appendices B and D. Inflation alone would account for 41 percent of the variance. By then applying the CCOLA and the inflation factor to come up with an expected cost, the result is an over-estimation of the cost by 35.6%. Although the specific reasons for this discrepancy are not know, contributing factors could be cost differences embedded in the CCOLA, higher recurring or some non-recurring costs in FY01, similar lower costs in FY02, or any combination of these. A more detailed break-out of the data would help discern these differences.

For GPS EEIC 555, there was an increase of $52,928 between the two fiscal years. The inflation factor accounted for $17,056, or 32.2% of the difference. For EEIC 645, the actual decrease was $2,652. This difference is attributed primarily to a $12,500 increase in RCCC 47410W and a $16,000 decrease in RCCC 978400. The difference between the expected and actual costs resulted in a decrease of $11,133. Therefore, the increase in the negative differential between the two values was 420.8%. There was one other line item that accounted for the rest. Without knowing the detailed breakout of the costs that accounted for those variances, it's difficult to tell what impact the inflation percentage would have had on the difference in expected and actual costs.

However, the data for MILSTAR has much larger variances. The observation that stands out the most from the table above is that there is a decrease of nearly 17% in the costs for MILSTAR in EEIC 554 from FY01 to FY02. Inflation alone would put the expected cost for FY02 at $5,160,461. However, to get the expected cost for MILSTAR, the CCOLA total is included in the expected value equation. With CCOLA is a negative amount, it will drive the expected cost below the original cost since that percentage is greater than inflation. The resulting expected value for MILSTAR's EEIC 554 is

$4,912,960. Given the decrease in the expected value, it accounts for 19.3% of the variance in the actual costs

The remaining EEICs have increases that are larger than expected. EEIC 555 for the MILSTAR system contains an increase of $128,350. The inflation factor accounts for $16,361, or 12.7% of the variance. Again, a more detailed breakout of all the costs associated with EEIC 555 explaining the increases and decreases of RCCC's between the years would result in more confidence of the impact of inflation. The final factor is for MILSTAR's EEIC 645. This cost driver also has a considerable increase in total costs. The variance is an increase of $142,392 of which $11,223, or 7.9%, is captured by inflation. Applying the same stipulations as mentioned previously regarding more detail in the data would affect the result of the factor.

The purpose of the six final cost factors above is to provide a high level of predictive capability, the goal of capturing at least 85% of the variance between the actual data for FY01 and FY02. From the analysis of the data provided, the lack of detail in the data constrained the six factors from achieving this predictive capability level. Based on only the data provided, the percentages in Table 12 identify the predictive capability levels for FY 2002 of the satellite O&M cost factors.

Table 12. Predictive Capability of Cost Factors

Space System and EEIC	Predictive Capability
GPS	
554	135.6%
555	32.2%
645	-420.8%
MILSTAR	
554	19.3%
555	12.7%
645	7.9%

Conclusion

This chapter of the research took the methodology constructed in Chapter Three concerning cost per flying hour factors and applied actual data from two fiscal years. By following the established step-by-step factor development process, all six factors were produced. The validation phase of the process analyzed both sets of actual data as well as making an assessment of the predictive capability of the factor. The goal was to be able to explain at least 85 percent of the difference in consecutive year's data by implementing a cost estimating relationship for each cost driver. Any additional costs that could be accounted for to help increase the accuracy of the model were explained.

The final chapter of the thesis will address the research that has been performed here and develop a final set of results and conclusion concerning the viability, effectiveness and future impact of the cost per flying hour factor for satellites. It will also point out limitations of this research and areas of follow-on research.

V. Results and Conclusions

Introduction

The final chapter of the research on developing cost per flying hour factors for the operations and maintenance phase of the satellite life cycle focuses on the insight gained from applying the aircraft cost per flying hour factor development methodology to space systems. The results attained in the previous chapter will be explained as well as the implications from those results. The applicability of the satellite O&M cost factor as a viable tool for AFSPC budgeting will be addressed. Concluding the chapter will be sections devoted to areas of limitation within the research conducted here and several topics for consideration as topics of follow-on research.

Results and Conclusions

The demand for this research evolved from discussion with personnel at AFSPC. They envisioned a need for more accurate methods of accounting for the O&M costs incurred by satellites. In recent years, there has been great emphasis on space as a strategic domain by both DoD and Air Force leaders alike. As the funds in this arena are projected to increase considerably, better tracking and verification of the need for the funds is essential. Rather than attempting to create a new method for the satellite O&M costs, it was determined that the best approach would be to take the routine aircraft CPFH factor development process and model the satellite O&M costs on that.

The goal that originated from the research was to establish the foundation for assessing how the aircraft CPFH factor development process can be transformed to produce effective cost factors for the satellite O&M arena. Ideally, the research would have produced those verifiable factors. However, with the research taking on more of a "proof of concept" approach than factor validation, the key was providing all the elements to the building of the model. With the aircraft CPFH process so standardized, a straightforward, step-by-step process existed in which a new process could be broken down into its basic elements and then rebuilt into the required product. From legacy deskbooks to multiple-year budget data to published articles and presentation, a substantial amount of literature existed that allowed for understanding of the processes for one weapon system and the ability to transition that process to another weapon system.

An important step to concluding the research is to check the effectiveness of the research in answering the "Research Questions" posed in Chapter One. Listed below are the questions followed immediately by the response, as determined by the research performed:

1) *Can a cost per flying hour model, similar to that of aircraft be developed and implemented for satellites? If so, what major differences exist between the two*?

A cost per flying hour model can be developed for satellites, and its structure is analogous to that of the aircraft cost per flying hour model. The same number of cost drivers captures a majority of the O&M costs associated with each weapon system. An essential part of the analysis of both models is to make all the necessary adjustments to the data as well as accurately account for inflation.

There are several differences between the two weapon systems. The very nature of satellites produces costs with a unique origin. The aircraft O&M costs are consumption-driven based on parts and fuel, while the satellite O&M costs are manpower-driven, primarily by contractor labor costs. Therefore, the satellite model must account for the adjustment of the contractor-based component of a cost of living allowance. However, as a result of the structure of the accounting codes, this CCOLA applied to only one of the three cost drivers for both space systems. The result is essentially two different methods by which to develop the cost factors the space systems, although the one additional component is entered into the equation. The data received from the 50th SW also indicated a unique collection of descriptive titles that encompass the total costs for each EEIC, which made it particularly difficult at times to discern the exact nature of the cost and how it impacted the category in which it fell. For aircraft, the descriptive titles of the accounting codes relate very closely to the actual Consumable Supplies, DLRs, or AVFuel, but for the space systems, the titles describe a wide array of uses for the particular EEIC.

2) *What are the major cost drivers for the satellite O&M arena?*

The cost drivers for the two space systems studied were Critical Space Contract Operations (EEIC 554), Critical Space Operations, Direct Support (EEIC 555), and DLR, Non-Flying (EEIC 645). These are primarily manpower-intensive cost categories; but the reason that the consumable (parts)-intensive segment of the satellite O&M costs aren't included as part of the satellite O&M costs is because the consumable costs are spread over numerous systems. This makes it extremely difficult to determine which costs are specific to GPS and MILSTAR, and would require numerous additional assumptions as well as having to sift through an enormous amount of data.

3) *Are the factors derived for a space system unique, and how stable are those factors?*

The factors for the two space systems evaluated are based on the same cost drivers, and therefore have identical structures. However, they are quite different due to the costs incurred in the maintenance for each. Because of the age difference in the systems and their purpose, the costs in each EEIC take on relatively different values. There are unique environmental and upgrade costs associated with each weapon system, so the costs will inherently be dissimilar. Depending on the two fiscal years, the percentage of the total O&M costs captured by each cost driver also fluctuates.

The factors appear to be somewhat unstable, but this is due largely in part to only having two fiscal years worth of data to analyze. Without knowing the trends in the data, it is difficult to conclude what are the recurring and non-recurring costs without relying on experts. Although routine maintenance is programmed into the budget, non-recurring costs can alter the final factor considerably. Additionally, EEICs 555 and 645 have a relatively low dollar threshold (as compared to EEIC 554), so an unexpected cost of any magnitude will have a substantial impact on the final factor.

4) *How could the factors developed for space systems be implemented into budget drills?*

By knowing what the hourly costs are for the O&M phase of GPS and MILSTAR satellites, budget personnel can accurately measure the amount of funds necessary to keep the space systems operating at a sufficient level. The CCOLA total also has a dramatic effect on the budget of these space systems. If the annual CCOLA increase is 8 to 15 percent and inflation is 2 to 4 percent, then the budget personnel have a verifiable tool by which to counter the possibility of an erosion of the funding baseline. It is also plausible that if outside organizations use these satellites, then by knowing the cost to operate the systems, that organization can be charged a fee for use of the satellites.

Although the basis of the research was "proof of concept," there needs to be a measure of the effectiveness of the factors that are developed. The preference would be to have 100% predictive capability of the factors in capturing the variances of the cost totals between years. However, a range of 80 to 90 percent is more realistic. The following were the predictive capabilities for the GPS satellites element of expense investment codes: 554 – 135.6%, 555 – 32.2%, and 645 – 420.8%. For MILSTAR, the percentages are as follows: 554 – 19.3%, 555 – 12.7%, and 645 – 7.9%. This wide range of percentages is due primarily to the fact that most of the data for both space systems was rolled up to a high level. This lack of detail constrained the research to the point that insight into the line-item costs and comparative measures were virtually eliminated. Nevertheless, the foundation for the satellite cost per flying hour factors now exists and can be expanded on in future research. This model may not end up capturing the appropriate costs for the satellite O&M phase, but for now, it is a start to developing the best cost model in the O&M arena.

Limitations

A number of limitations existed within the framework of this research that made it difficult to completely assess the effectiveness of the model. Those limitations include a lack of previous research on satellite O&M costs, a data set with only two years worth of information, and the inability to have continuous accessibility to the data/database.

The first limitation, lack of previous research on the research topic, is by far the most critical one. Other than a couple pages in the Space Analysis and Design text by

Wertz and Larson, it appears that the O&M portion of the satellite life cycle cost hasn't garnered enough attention to produce any sort of substantial research. The dilemma with working on a "new concept" is that nearly every decision creates a new challenge and simply building a foundation for the concept and possible future research takes great time and effort. Even though this concept was structured according to the aircraft cost per flying hour model, the differences between the two systems produced significant differences in the data as well as the work necessary to achieve the final factor. As a result, many decisions had to be made based on group inputs from the individuals who work with the budget data of the space arena everyday.

The next limitation was the amount of data used in the research. Having data only from fiscal years 2001 and 2002, it is impossible to see trends in the data from the previous years to potentially forecast future trends. This leads to reliance upon the experts to share the knowledge that they have from previous experience on the subject. By having several more years' worth of data to work with, plotting of the data points for each cost driver would lend itself to tremendous insight into satellite O&M costs and what the future may hold in regard to the flying hour costs and the validation of the concept in general.

Another crucial limitation to the research was not having continuous accessibility to the database. With the database and knowledgebase existing at another location is was difficult to maintain a continuous dialogue and be able to get answers or see the data as soon as questions arose. When the all the applicable data is constantly accessible, it becomes much easier to work through the iterations of the process or possibly have questions answered without having to go to the knowledge source all the time.

Additionally, if the complete, detailed data set were available to the researcher, a large number of "less important" questions could be answered by simply scanning and deciphering the data, rather than asking those questions and waiting for the response.

Follow-on Research

A couple of areas within this specific cost model and the overall satellite cost per flying hour concept would be highly recommended as potential future research topics that could provide a more comprehensive, defendable model or would broaden the foundation of research in the satellite O&M cost arena. The topics include obtaining several years' of data and incorporating that directly into the model developed here, performing follow-up work to see how well these factors forecasted future years' costs, reviewing the implementation of the CCOLA, validating that the cost drivers chosen for the model, and researching alternate space systems to ascertain whether their cost drivers have a similar impact.

As discussed in the limitations section above, obtaining several years worth of previous data on the GPS and MILSTAR satellites would enable trend recognition and greatly enhance the validity of the model. Graphing a trend of the cost drivers over a 5-year period would offer much more information and most likely allow for better observation and tracking of extraordinary costs. By employing only FY 2001 and FY 2002 cost data, trends cannot be determined, so in order to explain variances in the model, data has to be scrutinized by individual line items. There was a significant development in FY 2003 concerning the nature of the contracts that were used in this research. WCOM and SOM were combined and became MCOM. So if future research on cost per flying hour factors using these contracts was performed, and it included FY

2003 and beyond, this difference would have to be incorporated and the necessary adjustments made.

Another area of research could be to obtain the actual data from FY 2003 and see how well this model forecasted those costs. At the same time, the assumptions can be reviewed and any changes made to them based on the information acquired from the additional data. Then a new factor can be developed. In addition, a check could be performed to verify whether or not the only factor affecting EEICs 555 and 645 is inflation.

The area with the highest risk of improper application is that of the CCOLA. The impact and method of implementation for the contractor cost of living allowance was based upon discussions with personnel at AFSPC and the 50th SW. This particular portion of the model could be reviewed for accuracy and utilization of the components that make up its factor. Also, the conclusion that was reached here, the fact that only EEIC 554 was affected by the CCOLA should be verified. The CCOLA adjustment is a critical element of the model and should be evaluated periodically. Tied indirectly to the CCOLA through the adjustment process, if it can be determined the cycle by which high-cost recurring maintenance is performed on the space systems, a considerable amount of preliminary variance in data among different years could be alleviated.

It was mentioned several times in the research that the satellite O&M cost drivers used in the model are manpower-based. These represent only a portion of the costs associated with the O&M phase, so it would be beneficial to determine if in fact other cost drivers contribute more to the model and would be better choices. Additionally, there may not be only three cost-driving components as selected in the research. The more cost that can be captured and used to develop the factors, the better it is for the factor development process and the budgeting process.

The final area of follow-on research expands the scope beyond the two space systems analyzed here to look at alternate space systems within the Air Force inventory. While applying the satellite cost per flying hour model built here, it would require determining whether the O&M cost drivers are consistent throughout the satellite inventory. Depending on who "owns" the space systems studied, the CCOLA adjustment might have to be altered, or other assumptions made for it.

Conclusion

This chapter integrated the results of the model implemented in Chapter Four with conclusions about the factor development process for satellites. Based upon the research performed, it also included limitations of the work as well as opportunities for follow-on research that could be conducted. While the cost per flying hour concept itself is not that complicated, taking the process from one weapon system platform and transitioning it to another platform for the first time can present some complexities. There is still a lot of work that needs to be done in order to make this a viable tool for AFSPC, but the concept has proven to be an option in the development of the factors. Substantial progress has been made in the work on the satellite O&M environment and the potential problem areas identified. With repetition and refinement, this concept and process can become as critical to AFSPC or higher levels as the aircraft flying hour program is to the Air Force budget.

Appendix A

ACRONYM	DESCRIPTION
ACC	Air Combat Command
ACRN	Accounting Classification Reference Number
AF	Air Force
AFCAA	Air Force Cost Analysis Agency
AFCAIG	Air Force Cost Analysis Improvement Group
AFSPC	Air Force Space Command
AVFuel	Aviation Fuel
CCOLA	Contractor Cost of Living Allowance
CPFH	Cost Per Flying Hour
DLR	Depot Level Repairables
DoD	Department of Defense
EEIC	Element of Expense Investment Code
FY	Fiscal Year
GAO	General Accounting Office
GPC	Government Purchase Card
GPS	Global Positioning System
MAJCOM	Major Command
MILSTAR	Military Strategic and Tactical Relay (System)
NPS	Naval Post-Graduate School
O&M	Operations and Maintenance
OSD	Office of the Secretary of Defense
OSSS	Operational Space Service and Support
POL	Petroleum, Oils, and Lubricants
QDR	Quadrennial Defense Review
RCCC	Responsibility Center/Cost Code
SAF/FMC	Deputy Assistant Secretary for Cost and
SOM	Space Operations and Maintenance
SSCM	Small Satellite Cost Model
WCOM	Wing Communications

Appendix B

Six Critical Operational Goals for DoD's Transformation Efforts

Protecting critical bases of operations (U.S. homeland, forces abroad, allies, and friends) and defeating CBRNE weapons and their means of delivery
Assuring information systems in the face of attack and conducting effective information operations
Projecting and sustaining U.S. forces in distant anti-access or area-denial environments an defeating anti-access an area-denial threats
Denying enemies sanctuary by providing persistent surveillance, tracking, and rapid engagement with high-volume precision strike, through a combination of complementary air and ground capabilities, against critical mobile and fixed targets at various ranges and in all weather and terrains
Enhancing the capability and survivability of space systems and supporting infrastructure
Leveraging information technology and innovative concepts to develop an interoperable, joint C4ISR architecture and capability that includes a tailorable joint operational picture

(Source: DoD (bb), 2001: 30)

Appendix C

GPS COST DATA FOR FY 2001			
RCCC	**Title**	**EEIC**	**Gross Obligations**
978400	Civilian Overtime	391	$465.12
978400	Civilian Personnel	392	$203,977.80
978400	Civilian Health Benefits	393	$52,471.91
978400	TDY Per Diem MSN	409	$85,587.18
978400	Lease Passenger Vehicle	433	$3,074.56
978400	Other Contracts--CE SVCS	533	$30,627.61
978400	(Roll-up of Critical Space Contract Operations)	554	$7,543,776.76
22121X	Wing Communications (WCOM) contract	55429	$2,187.52
21131G	NPS-GPS OSSS	5545S	$253,680.67
21130G	SOM GPS (Space Ops Contract)	5547C	$26,699.33
978400	Critical Space Operations	555	$962,358.39
211312	2 SOPS, GPS-DIEGO		$10,122.00
21131W	GPS Diego Garcia Support Agreement	55563	$5,267.12
211312	2 SOPS	55564	$870.00
211312	GPS Level 1 Software Maintenance	55568	$87,423.15
271300	Contract Operated Install		$12,012.37
978400		570	$31,487.63
22121X	WCOM		$210.20
978400	General Support Supplies-AFSF	609	$73,561.00
978400	Other Supplies-NAFSF	619	$72,052.01
978400	ADP Equipment-AFSF	627	$369.24
978400	Equipment-AFSF	628	$33,138.01
47410S	Ascension	645	$4,378.97
47410W	Diego Garcia		$409.49
978400	DLR Non-Flying		$525,258.15
	DIRECT - Report Total		$10,021,466.19

Appendix D

MILSTAR COST DATA FOR FY 2001			
RCCC	**Title**	**EEIC**	**Gross Obligations**
978400	TDY Per Diem MSN	409	$146,635.12
211326	Lease Passenger Vehicle	4 SOPS	$826.00
978400	Lease Passenger Vehicle	433	$4,174.00
211326	Printing Copying-DPS	4 SOPS	$1,680.48
978400	Printing Copying-DPS		$18,719.52
978400	(Roll-up of Critical Space Contract Operations)	554	$4,953,736.16
21130M	SOM MILSTAR	5547C	$125,457.86
978400	Critical Space Operations	555	$1,022,565.99
978400	Purchased Maintenance-Other Equipment	569	$21,120.43
22121R	Wing Communications (WCOM)	609	$31.02
978400	General Support Supplies-AFSF		$53,129.68
978400	Other Supplies-NAFSF	619	$127,584.60
211326	4 SOPS, Supplies-IMPAC	61950	$20.13
978400	Equipment-AFSF	628	$52,598.56
978400	FD Bulk Reg. Fuel	641	$333.30
211326	4 SOPS		$20,767.11
978400	DLR Non-Flying	645	$701,424.95
	DIRECT - Report Total		$7,250,804.91

Appendix E

GPS COST DATA FOR FY 2002			
RCCC	Title	EEIC	Gross Obligations
978400	Civilian Personnel	392	$343,150.17
978400	Civilian Health Benefits	393	$85,687.30
978400	TDY Per Diem MSN	409	$110,331.51
271300	Lease Passenger Vehicle	433	$947.85
978400	Lease Passenger Vehicle	433	$2,652.15
211312	2 SOPS	496	$305.38
211312	2 SOPS, Minor Construction-MC Projects	529	$611,897.00
978400	(Roll-up of Critical Space Contract Operations)	554	$2,447,607.85
22121X	Wing Communications (WCOM) contract	55429	$71,459.80
21131G	NPS-GPS OSSS	5545S	$2,057,513.95
211312	2 SOPS, GPS DIEGO	55475	$2,601,743.24
21130G	SOM GPS (Space Ops Contract)	5547C	$955,627.16
978400	Critical Space Operations	555	$646,930.19
211312	GPS Diego Garcia Support Agreement	55563	$40,848.05
211312	GPS -Kwalajalein Support Agreement	55564	$63,594.00
211312	GPS-Cape Canaveral/Ascension	55566	$30,000.00
211312	GPS Level 1 Software Maintenance	55568	$111,854.80
211312	Interim Backup-GPS	5558H	$225,741.78
271300	Contract Operated Install	570	$5,784.76
978400			$17,215.24
211312	Miscellaneous Contractual Services	592	$6,050.00
211312	Other Miscellaneous Contractual Services	2 SOPS	$4,973.00
978400		59290	$4,370.00
271300	Medical-Dental Supplies-AFSF		$215.46
978400		604	$567.55
22121X	WCOM		$6,467.55
47410S	Ascension		$204.16
978400	General Support Supplies-AFSF	609	$82,003.73
978400	Other Supplies-NAFSF	619	$67,366.82
978400	ADP Equipment-AFSF	627	$13,803.75
978400	Equipment-AFSF	628	$10,594.93
22121X	WCOM		$210.98
47410T			$5,105.42
47410W	Diego Garcia		$12,948.58
978400	DLR Non-Flying	645	$509,341.26
	DIRECT - Report Total		$11,155,115.37

Appendix F

MILSTAR COST DATA FOR FY 2002			
RCCC	**Title**	**EEIC**	**Gross Obligations**
978400	(TDY Per Diem MSN)--Assumed	409	$138,318.27
211326	Lease Passenger Vehicle	4 SOPS	$2,614.07
978400	Lease Passenger Vehicle	433	$4,612.23
211326	Printing Copying-DPS	4 SOPS	$1,852.07
978400	Printing Copying-DPS	502	$16,928.50
978400	(Roll-up of Critical Space Contract Operations)	554	$3,577,543.24
22121R	Wing Communications (WCOM)	55429	$621,622.59
21130M	SOM MILSTAR--Space Ops Contract	5547C	$19,344.54
978400	Critical Space Ops	555	$473,568.56
211326	4 SOPS, C3 Tech SV Contract.-MILSTAR	5554M	$643,481.52
211326	4 SOPS, Misc. Contractual Services	55590	$33,865.59
978400	Purchased Maintenance-Other Equipment	569	$57,001.84
211326	4 SOPS, Purchased Maintenance Vehicle		$10,651.12
211326	General Support Supplies-AFSF	4 SOPS	$1,466.68
978400		609	$41,107.53
978400	Other Supplies-NAFSF	619	$152,718.21
978400	Equipment-AFSF	628	$12,980.86
978400	FD Bulk Reg. Fuel	641	$0.00
211326	4 SOPS		$103,078.13
22121R		WCOM	$679.00
978400		645	$843,816.91
	DIRECT - Report Total		$6,757,251.46

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Vita

Captain Anthony K. Kimbrough graduated from Trico High School in Campbell Hill, Illinois. He entered undergraduate studies at Southeast Missouri State University in Cape Girardeau, Missouri where he graduated with a Bachelors of Science in Business Administration (Accounting emphasis) in May 1998. He was commissioned through the Detachment 205A AFROTC at Southeast Missouri State University.

His attended the inaugural 7-week Air and Space Basic Course at Maxwell AFB in July 1998. Upon graduation in August 1998, he remained at Maxwell AFB as the Deputy, Financial Services Officer of the 42nd Comptroller Squadron. In October 1999, he became the Financial Services Officer and then transitioned to Chief, Financial Services Division of Headquarters Air University when the 42nd Comptroller deactivated in March 2000.

In August 2001, he entered the Graduate School of Engineering Management, Air Force Institute of Technology. Upon graduation, he will be assigned to HQ Air Force Space Command as a Cost Analyst.

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14. ABSTRACT

The purpose of this thesis was to establish a "proof of concept" in developing cost per flying hour factors for the operations and maintenance (O&M) phase of the satellite life cycle. At a time when space system platforms are becoming some of the most strategic weapons in the military arsenal, it is critical that accurate cost models and factors be developed to assist in budgeting for the O&M costs of these assets. A relative comparison was made between the components that make up the model for the aircraft cost per flying hour factors and those that constitute a majority of the O&M costs for the satellite cost per flying hour factors.

Research was conducted on two space systems: Global Positioning System and Military Strategic and Tactical Relay System. The three cost components chosen for the model were Critical Space Contract Operations, Critical Space Operations – Direct Support, and Depot Level Repairables – Non-Flying. By modeling accounting data from the 50th Space Wing, satellite cost per flying hour factors were developed which can be a baseline for use by those responsible with the financial planning of the two systems. Further research should be conducted to validate the factors that were developed and observe the trends in the data and factors over several years.

15. SUBJECT TERMS

Cost Per Flying Hour, Satellites, GPS, MILSTAR, O&M, Budget, Space Systems, Transformation, Cost Drivers, Factors

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