



**MINUTEMAN III COST PER ALERT HOUR ANALYSIS**

THESIS

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**Abstract**

This thesis analyzes the cost associated with the Minuteman III (MM III) weapon system. The research develops three models for determining MM III costs per alert hour (CPAH). The first model is based on the Air Force Cost Analysis Improvement Group cost per flying hour model. The model is modified to include depot level reparable, consumables, and personnel costs. The second model is based on the Office of the Secretary of Defense, Cost Analysis Improvement Group cost per flying hour model and is formulated using service-wide data from the Air Force Total Ownership Cost tool. The third model is a comprehensive model including indirect costs associated the ICBM-supporting installations.

Additionally, this thesis includes a CPAH for each echelon or level of management for the MM III. As expected, the costs to operate the weapon system increase as more functions are included at each level of management. The data reveals a relatively small marginal CPAH at the lowest levels. However, due to the robust support structure for the MM III, the models reveal significant fixed alert-hour costs. Finally, the thesis discusses the workings of the MM III cost structure that may benefit future budgeting decisions. Specifically, the step functions associated with each level of management and the large fixed costs. This thesis presents the three models as a starting point for developing a CPAH predictive model in future research.

*Proverbs 16:3*

*I am eternally grateful for such a lovely wife and vibrant children; without your patience and support, I would never have been able to accomplish this endeavor.*

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I am grateful to Billy Kirby from Air Force Materiel Command for helping me understand the Air Force's cost per flying hour program and how it could relate to a missile system. Lieutenant Tubesing and the finance office at Malmstrom AFB were vital to gathering needed data.

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Allen R. Miller

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# MINUTEMAN III COST PER ALERT HOUR ANALYSIS

## I. Introduction

*“Deterrence can be limited and simple or, as it turned out, expansive and complex.”*

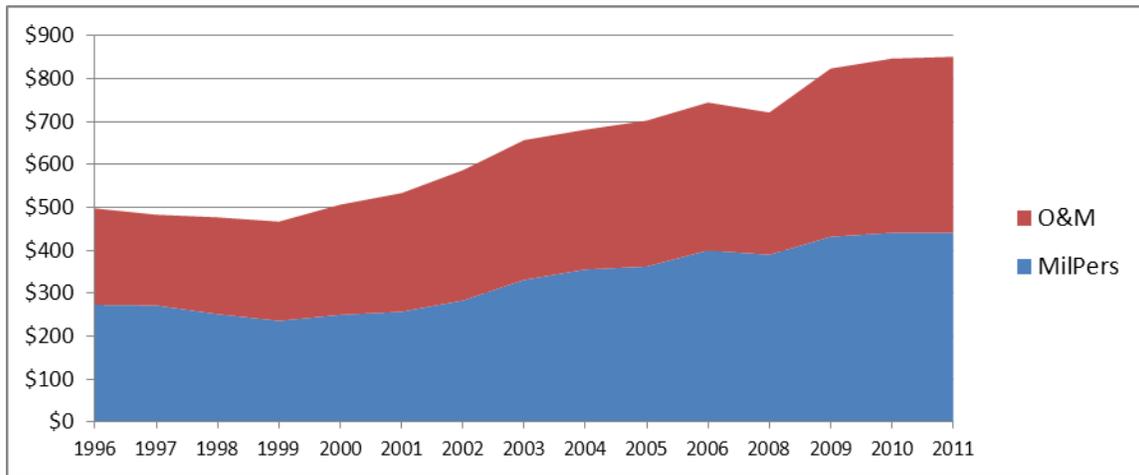
Hans M. Kristensen-director of Nuclear Information Project

### General Issue

Why study intercontinental ballistic missile (ICBM) cost per alert hour (CPAH)?

The September 2008 Report of the Secretary of Defense Task Force on DOD Nuclear Weapons Management, more commonly known as the *Schlesinger Report* identified many shortcomings of the nuclear community and laid the groundwork to bolster the defense community’s understanding of the enterprise. A part of this encompassing effort was to create a deeper understanding of the nuclear enterprise workings. One such vehicle is an advanced academic degree from the Air Force Institute of Technology (AFIT) focusing on the nuclear enterprise and how it relates to logistics and supply chain management. An integral part of the degree is a collaborative thesis with experts in the field in focused areas needing additional research. These above situations have culminated in the need for a deeper understanding of the nuclear enterprise, which is addressed in part by understanding the cost factors associated with keeping our Minuteman III (MM III) missiles on alert. Mr. Michael Donley, Secretary of the Air Force, and General Norton Schwartz, Air Force Chief of Staff, have identified Nuclear Deterrence Operations as the first of twelve “Air Force Core Functions.” Within this core function are three elements, two of which are directly relate to the costs of maintaining and operating our ICBMs: upgrading the MM III system and replacing the

UH-1N helicopters that fly in the missile complexes (SAF/FM, 2011:34). The stated objective is to maintain the current ICBM force through 2030. With the historical O&M and military personnel increases in cost (see Figure 1), it is imperative to ensure that keeping our ICBMs viable can be obtained within the given budget.



**Figure 1: ICBM O&M and Military Personnel Costs (in millions) (AFTOC, 2012)**

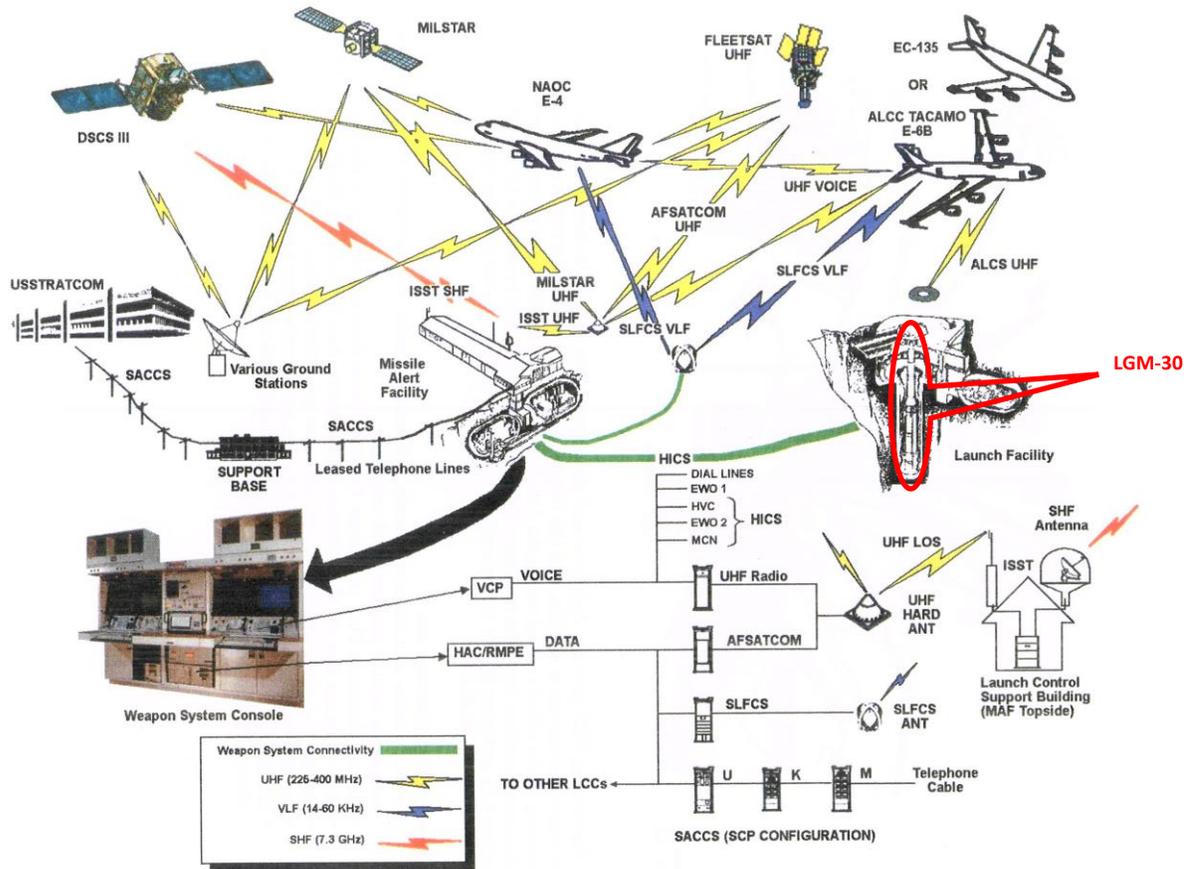
ICBM procurement and sustainment have always been complex endeavors. Neil Sheehan describes the political and commercial influences of the early missile developments in his biographical-novel about Bernard Schriever’s foundational work on the ICBM enterprise (Sheehan, 2009). The complexity has continued into the current missile support structure. Much of the complexity is inherent due to the size of the weapon system (WS); moreover, some complexity is present by design for security reasons. Lastly, as with any large program, there are likely some areas that should be streamlined.

All figures for this thesis are based on fiscal year 2011 (FY11) figures unless otherwise stated. Historical figures have been converted from “then year dollars” to

FY11 dollars to account for inflation. The 2011 budget for the entire Air Force was 170.78 billion dollars. Within this overall budget was the major category of O&M or *readiness* that comprised 26.8% or 45.79 billion dollars of the AF total budget. The readiness portion contains the costs to operate and maintain the Air Force's weapon systems and by extension, the 4.8 billion dollars calculated in the active duty cost per flying hour (CPFH) program (SAF/FM, 2011:21). The Air Force uses CPFH models for the majority of its weapons systems and has the goal to develop a CPFH model for every system. The current CPFH model has been shown to be accurate for only a narrow range of circumstances and that more robust models exist (Laubacher, 2004:64). The Air Force has continued with its current model for decades, partially because the effectiveness of alternative models has not been communicated to decision makers (Armstrong, 2006:1)

The cost associated with operating a weapon system is quite complex. Different bases, major commands (MAJCOMs), the Air Force Cost Analysis Improvement Group (AFCAIG) and the Office of the Secretary of Defense, Cost Analysis Group (OSD CAIG) have different methods of interpreting nuances when calculating a weapon system's CPFH. Moreover, some detail is blurred as data is aggregated at each level. ICBM cost-data are just as complicated as other weapon systems, possibly more so given their unique support attributes. The missile alone is not operational; it requires a silo, launch equipment, support equipment, personnel, and communication platforms to function. The system in its entirety is called WS-133A/M and includes the many elements shown in Figure 2. This thesis is focused on the costs most directly attributable to the actual missiles and peripheral equipment. The MM III weapon system mission

design (MD) is LGM-30 and is outlined in Figure 2. The mission design series (MDS) is LGM-30G, but there is only one MDS currently operational within the MD, so this thesis will use LGM-30 throughout.



**Figure 2: LGM-30 vs. WS-133A/M (GTE, 1980)**

Some of the other items can be readily added to the cost of a missile, for example the calculated CPFH for the support helicopters, the UH-1N, is \$11,703 (AFCAIG, 2011). The helicopters' primary mission is supporting the MM IIIs. However, other systems that support MM III operations such as communication satellites are used by many other systems and the satellites cannot accurately be added to the MM III cost to operate. Ideally, one would be able to assess every system that supports a MM III to any

degree, find the percentage of that support, and the costs of operating each supporting system. Such an endeavor would be virtually unmanageable in scope and definition. Thus, the scope of this thesis focuses on the costs associated with the LGM-30 instead of the WS-133A/M.

## **Implications**

This study (and subsequent follow-on analyses) may aid in future ICBM structuring. In strategic guidance released January 2012, President Obama and Defense Secretary Leon Panetta state: "It is possible that our deterrence goals can be achieved with a smaller nuclear force, which would reduce the number of nuclear weapons in our inventory as well as their role in U.S. national security strategy" (DOD, 2012:5). The future budget environment may lead policy makers to decide to reduce the overall costs incurred by our ICBM force. As will be shown, closing one launch facility (LF) by taking one missile off-line would not reduce the overall cost. In fact, removing one missile can actually increase cost due to the inherent dependency of the sub-systems and increased maintenance visits. To reduce significantly the cost of maintaining the sites, an entire squadron of 50 missiles would need to be taken off-line (Harlow, 2011). A squadron closure is a strategic decision more than an economic decision. For example, it may be more cost effective to close a base and concentrate ICBMs at one location; yet it may be strategically necessary to maintain a dispersed presence. There are international implications when dealing with such a large deactivation. Therefore, it is not within the scope of this thesis to suppose any recommendations on reductions in force structure. Rather, this thesis will look at the costs that can be attributed to operating an ICBM at the

lowest level (LF) and compare those costs with the costs of operating larger groups of missiles at higher echelons. There are necessary costs incurred at the higher levels of management that do not directly affect the missiles, yet the costs are required at those levels. An example is the quality of life items at a base. A base dining facility is not a direct part of launching a MM III. However, the personnel needed to support the system must eat. Therefore, the dining facility is an additional cost that does not directly go into the cost of maintaining a silo, but does affect the costs of maintaining an ICBM wing.

### **Problem Statement**

This thesis seeks to analyze the costs of operating a LF and determine how the CPAH model changes as higher levels of management are incorporated into the model.

### **Research Questions**

1. Can the Air Force Cost Analysis Improvement Group (AFCAIG) and Office of the Secretary of Defense, Cost Analysis Improvement Group (OSD CAIG) aircraft cost per *flying* hour models be used to develop cost per *alert* hour models for the LGM-30 weapon system? If so, what are the differences?
2. Do cost per alert hour factors change significantly based on the level of management?
3. What cost drivers should be included in developing a comprehensive CPAH model for the LGM-30 weapon system?
4. What is the relationship of costs and alert hours?

## **Summary**

This thesis develops the above ideas in Chapter II by providing a review of past CPFH research along with related concepts such as AFCAIG and OSD CAIG cost categories and ICBM specific attributes. Chapter III builds upon the prior literature and develops three models for determining ICBM CPAH figures. The first is based on AFGAIG elements, the second is based on OSD CAIG elements, and the final model is a unique comprehensive look at ICBM cost. In Chapter IV, the author presents the analysis of the data. Finally, Chapter V includes a summary of the results and provides a brief description of the possible implications of the models. The thesis concludes with recommendations for future analyses and research efforts.

## **II. Literature Review**

### **Chapter Overview**

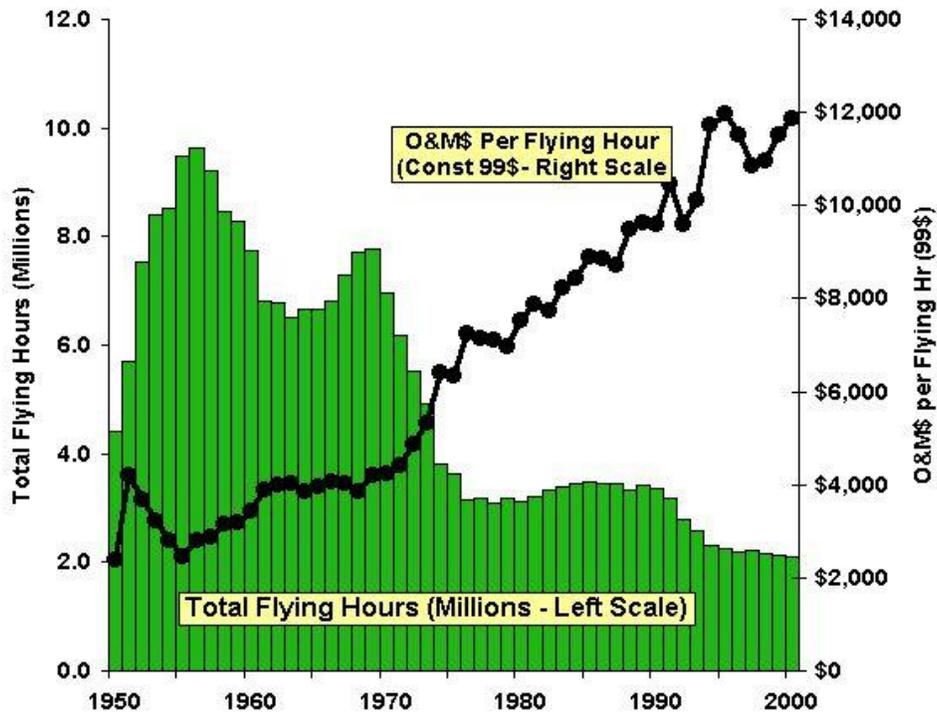
This chapter first looks at the general mechanics of a cost per flying hour (CPFH) program. Next, applications from the commercial sector are related to the flying hour program. Then, this chapter expands the workings of the Air Force's CPFH program by reviewing examples of how the flying hour program has been used recently. Next, an example of a non-traditional cost per flying hour assessment is reviewed. Finally, this chapter reviews elements that are specific to the intercontinental ballistic missile (ICBM) mission, including funding history (an insourcing versus outsourcing decision), force structure, and other aspects of the weapon system (WS) that relate to how much it costs to operate per hour.

### **The Cost per Flying Hour Program**

The CPFH idea dates back as far as 1962 (Kimbrough, 2003:10). The focus on managing a CPFH program was brought the forefront by Air Force costs analyst during the early 1990s as Cold War budgeting practices changed and the Defense Management Review called for more budget justifications (Rose, 1997:5).

The basic flying hour (FH) program is based on the Operation and Maintenance (O&M) costs for a particular mission design series (MDS). The O&M costs have increased at a faster rate, accounting for an increasingly larger portion of the budget (Defense, 2006). Increased O&M costs mean other areas such as research, development, and modernization efforts reduce proportionally to the budget. The FH program

proportional relationship is defined as one where no costs are incurred if zero hours are flown and a 1% increase in hours results in a 1% increase in costs (Van Dyk, 2008:1). However, as the budget has increased, the actual number of hours flown has decreased, (see Figure 3).



**Figure 3: Rising Cost of O&M per Flying Hour (Defense, 2006)**

The basic FH program uses a proportional model comprised of the expected number of hours to be flown multiplied times a CPFH factor. The product is an estimate for the FH program budget for the subsequent year. The model will be slightly modified based on unique situations, but the basic model follows the structure shown in Figure 4 (SAF/FMC, 2005:18).



**Figure 4: Basic CPFH Model, (SAF/FMC, 2005:18)**

A GAO report highlighted the inaccuracies of using a cost per flying hour model as a predictor of expected cost for a given year (GAO, 2000:1). Additionally, Armstrong found that FH predictive models to have errors as large as 25% of the total flying-hour program budget (Armstrong, 2006:iv). In efforts to improve the program, the Air Force has progressed through multiple iterations of the CPFH methodology. In the late 1990s, the Air Force was repeatedly flying fewer hours than were budgeted (GAO, 2000:2). Flying units were expending the allotted funds before the budgeted (expected) hours were flown. The result necessitated grounding aircraft or soliciting congress for more funds. To increase accuracy in the program, each major command (MAJCOM) initiated a new process that calculated the number of expected flying hours based on the number of pilots needed for the assigned missions and training (Hess, 2009:18). The new method has increased the steady-state (peacetime or baseline) projected flying hours; hours for contingency operations are budgeted separately (SAF/FM, 2011:8). The other major element to the basic model is the CPFH factor.

The CPFH factor, as described by the Air Force Cost Analysis Improvement Group (AFCAIG) for aviation, includes 1) Materiel Support Division (MSD) managed Depot Level Repairables (DLRs) and consumable spares, 2) consumable supplies procured via the General Support Division (GSD) and the Government Purchase Card (GPC), and 3) aviation fuel. Another iteration of the FH program took place in 2008 when the Air Force switched from allowing each MAJCOM to develop the above factors

used in computing a CPFH for a MDS. The factors are now developed by the Centralized Asset Management (CAM) office for each MDS.

The DLR costs include some overhead costs; thus, the CPFH includes some fixed cost and is not a solely variable cost metric. The MSD and GSD items number in the hundreds and thousands respectively. Each item is individually forecasted for demand and expected cost by collecting two years of demand data and dividing it through the number of flying hours over the same period (Hess, 2009:19). The total of all those forecast are compiled at the weapon system level by the CAM office. The Spares Requirement Review Board projects the demand for each item, including adjustments for unique situations such as planned maintenance and warranties. The final demand is multiplied by the projected price of each part; however, the projected price of the parts has been known to fluctuate significantly throughout the year (Kirby, 2010). There are also some savings from bulk purchases that are not reflected in this calculation. The result can (at times) be over or under budgeting the cost of parts needed for the upcoming year. When there is a surplus of money for a specific part, it is redistributed to other parts that may be under budgeted (Kirby, 2010). The fluctuation in part-costs, unexpected maintenance costs, and the interaction of fixed costs with a per-hour measurement create inaccuracies in the FH program (Rose, 1997:8). There is significantly less fluctuation with the consumables factor. Consumables are calculated using three years historical data, then normalized for inflation and total hours flown (Hess, 2009:20). Beyond the basic three elements discussed above, previous literature has proposed numerous alternatives (see Table 1). Some of the factors that could relate to the ICBM mission are discussed in the next section.

**Table 1: Alternative CPFH Factors**

	Hildebrant (1990)	Wallace (2000)	Kiley (2001)	Pyles (2003)	Laubacher (2004)	Hawkes (2005)	Armstrong (2006)	Bryant (2007)	Van Dyk (2008)	Kimbrough (2004)
<b>Dependent Factors</b>										
Operations/Support Costs	X		X							
Number of Parts Replacements		X								
Maintenance Work Hours				X						
Net Flying Costs					X				X	
CPFH Factor						X	X	X		X
<b>Independent Factors</b>										
Flying Hours	X	X	X				X	X	X	
Lagged Cost					X	X				
Aircraft Age	X	X	X	X		X	X		X	
Average Total Operating Hours								X	X	
Flyaway Cost	X		X	X						
IOC Year	X									
Aircraft Type	X			X						
MAJCOM				X		X				
Percent Engine Type						X				
Percent Block						X				
Sorties		X							X	
Average Sortie Duration						X	X	X	X	
Utilization Rate						X		X	X	
Mission Capable Rate								X	X	
Cannibilization Rate									X	
Deployments						X	X	X		
Ground Days		X								
Total Aircraft Inventory	X									
Program Change							X	X		
Base Location						X				
Petroleum Proximity							X	X	X	
Temperature							X	X	X	
Dew Point								X		
Month/Seasonality							X	X	X	
Construct Support										X
Personnel Costs										X

The inaccuracy of the basic CPFH model has been highlighted by historic surges and lulls in flying hours. If the costs per flying hour model were relatively accurate, one

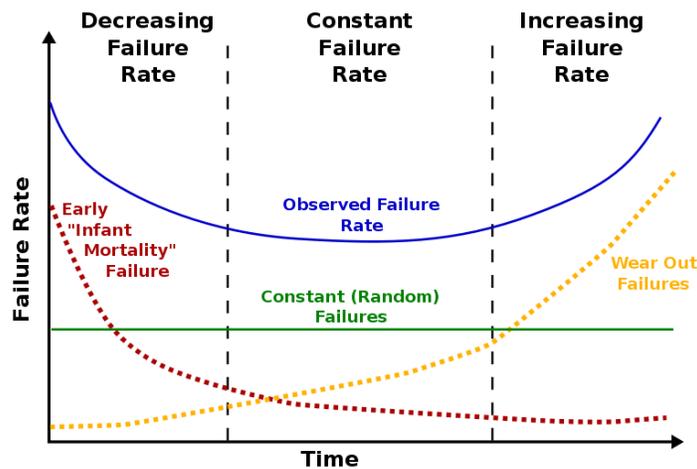
would expect the cost to increase and decrease linearly with the number of hours flown. For example, during contingency operations such as Operation Desert Storm and Kosovo Air Campaign, many of our airframes saw increased flying hours that were not budgeted for in the previous year. Wallace, Houser, and Lee found that when the CPFH model was used to estimate maintenance costs for the increased hours, the C-5Bs had a predicted demand for parts of over 200% of actual parts demanded (Wallace et al, 2000:1-2). Their model was validated with KC-10, F-16C, and C-17 data from Kosovo that over-estimated the cost of increasing the number of hours flown. The reason the costs did not increase linearly has been debated. The researchers proposed a model including three failure modes: dormant, cycle induced, and operations based. They conclude that the most accurate model includes the proportion of time each MDS spends in one of the three identified states (Wallace et al, 2000:2-2). Aircraft experience more failures in relation to takeoff and landing counts than in relation to the hours flown, especially heavier aircraft (Slay and Sherbrooke, 2000:1-1). Therefore, a model that is solely based on flying hours will overestimate the maintenance cost for hours accumulated with longer sorties (Slay and Sherbrooke, 2000, 1-2). One reason the per-hour costs decrease (increase at a lower rate than hours flown) with increased sortie durations (and fewer sorties), relates to the combinations of failure types. Ebeling describes five different methods of inducing a failure (Ebeling, 2009:50)

- Hourly operation time
- Operating cycles
- Clock time
- Failures on demand
- Maintenance-induced failures

For a CPFH model to accurately predict maintenance cost, failures would need to primarily occur from hourly operation time and total clock time. Dawson and Howe looked into the average sortie duration (ASD) in relation to an aircraft's CPFH and found that the longer duration flights serve to decrease CPFH (Dawson, 2006:22). Their observation is that aircraft experience higher rates of failure on demand. Meaning, the aircraft are more likely to fail (experience a scenario where a maintenance action is required and a maintenance cost is incurred) when they go through the sortie process as opposed to increasing the sortie duration. For example, two sorties of one hour each will cost more than one two-hour sortie.

The Air Force has recognized the influence of age on the cost of maintaining our weapon systems (Schwartz, 2011:7). The failure modes identified by Ebeling are critical for ICBMs, because missile maintainers state that LGM-30s are a system with significant effects of aging manifesting (Doyle, 2012). As a system ages, the O&M costs for that system increase exponentially (Unger, 2008:24). In an interview with missile maintainers, they described the maintenance rates of the MM III weapon system components as also experiencing failure upon demand (Doyle, 2012). Together, the components utilized during a maintenance action create an increasing rate of maintenance-induced failures. The maintenance-induced failures do not mean that the maintenance teams are haphazardly breaking components. Rather, a component that is functioning while undisturbed may fail once it is removed to access a deeper component, replaced, and tested. The Air Force has sought to mitigate the increasing maintenance cost of our aging systems through a series of recapitalization and modernization initiatives (Schwartz, 2011). However, in addition the actual costs of the initiatives, the

replaced parts must have a significantly higher reliability to justify replacing the part versus dealing with increasing repair costs (Ebeling, 2009:265). Some components designed as part of modernization efforts actually have experienced lower reliability rates than the original components (Doyle, 2012 and Lorenz, 2011). Certainly, the goal is to have components that meet the stringent reliability thresholds, and many of the ICBM components do achieve the needed reliability rates (Lorenz, 2011). Unfortunately, a single item with a relatively high failure rate can spawn more maintenance visits and increase the likelihood of maintenance induced failures.



**Figure 5: Bathtub Curve (Ebeling, 2009:31)**

A concern with the introduction of new parts is failures from burn-in. A common model for visualizing lifetime failure rates is the bathtub curve as shown in Figure 5 (Ebeling, 2009:31). Many CPFH rates for Air Force MDS follow a bathtub curve (Hawkes and White, 2008:15). Not all MDS have been shown empirically to follow this curve; some systems have linearly increasing failure rates (Hildebrandt and Sze, 1990:23). The burn-in failure rates of new components (either replacement or modifications) can be compounded by the age of the system (Unger, 2008:31). Consider

the conceptual bathtub curve presented in Figure 5. Then, imagine that in addition to the given parameters, new items with burn-in rates are added on the right side after the system already has an increasing failure rate. The added burn-in failures can make the observed failure rate increase exponentially. The failure rates would then be compounded by the end of service life failures, for both a bathtub curve and a linearly increasing failure rate (Hildebrandt and Sze, 1990:21).

### **Related Applications from the Commercial Sector**

The CPFH metric is a per-unit measurement; similar metrics are used throughout the commercial sector (Kaplan and Cooper, 1998:15). The trouble is that a per-unit measurement provides a false sense of costs distributions. For example, if a factory is producing 100 items and the total operating cost is \$1000, the temptation is to believe that it cost \$10 to make one item. However, an Activity Based Costing (ABC) analysis may reveal excess capacity and show that the factory could produce 200 items without a two-fold cost increase. ABC seeks to find out how much it cost to complete a specific activity such as paint widgets, package widgets, etc. Once all the activity costs are totaled, a more accurate picture is obtained about the costs of producing the items. Taking the example further, if sales are slow and they only sell half as many items, the per-unit cost allocation would say that it now cost \$20 to produce the items when the actual cost of producing one item did not significantly change. Additionally, if the factory produces half as many items, not all per-unit costs are recouped (Lambert, 2008:44). Lambert describes the importance of accurately capturing the effect of reducing the number of items produced with what he calls “segment profitability.”

Without the key enablers of segment profitability: data availability, data accuracy, and state of the art system capabilities, a company [or government entity] will not know the implications of a production change (Lambert, 2008:48). For the ICBM community, this means that a cost increase per missile may be the result of cost increases of required activities. The apparent cost increase may also occur because the number of missiles was reduced (with costs staying relatively the same) or a combination of the two situations. Chapter III and IV of this thesis provide an analysis as which scenario seems to be occurring with the LGM-30.

### **ABC examples in the military**

“The ability to forecast accurately starts at the lowest level possible; this is the wing/base level in the USAF” (Armstrong, 2006:2). Furthermore, a true ABC model would start at the root action and determine a cost for that action. A macro example is looking at the many functions or activities performed by the DOD. The cost of National Defense is often equated to the budget of the entire DOD. However, the DOD completes other activities including “nation-building, policing foreign nations, humanitarian missions and ferrying executive and legislative-branch leaders and their attendants around the globe” (Factor, 2011:1). Such activities do not directly contribute to war fighting capabilities; rather they are more a function of our foreign policy. The Marines implemented many ABC initiatives in the late 1990s. One key element they identified was the ability to ensure multiple systems are able to communicate the associated cost of an activity (Chadwick, 2007:3).

Activity Based Costing has been used in the Navy as well. In 1999 and 2000, the Navy spent about \$100,000 and 6 months implementing ABC at the Naval Air Depot in Jacksonville, Florida. The revamped processes revealed that only 51 of 213 activities added value to the repair process. The activities were reduced to 66 activities with an annual savings of \$200 million (Dekker, 2003). Fully implementing ABC requires the organization to be committed to the entire process. An ABC undertaking is beyond the scope of a thesis, however, it is beneficial to see how such a transformation has been used in other military settings and could feasibly be implemented for base-level support to the Minuteman III weapon system.

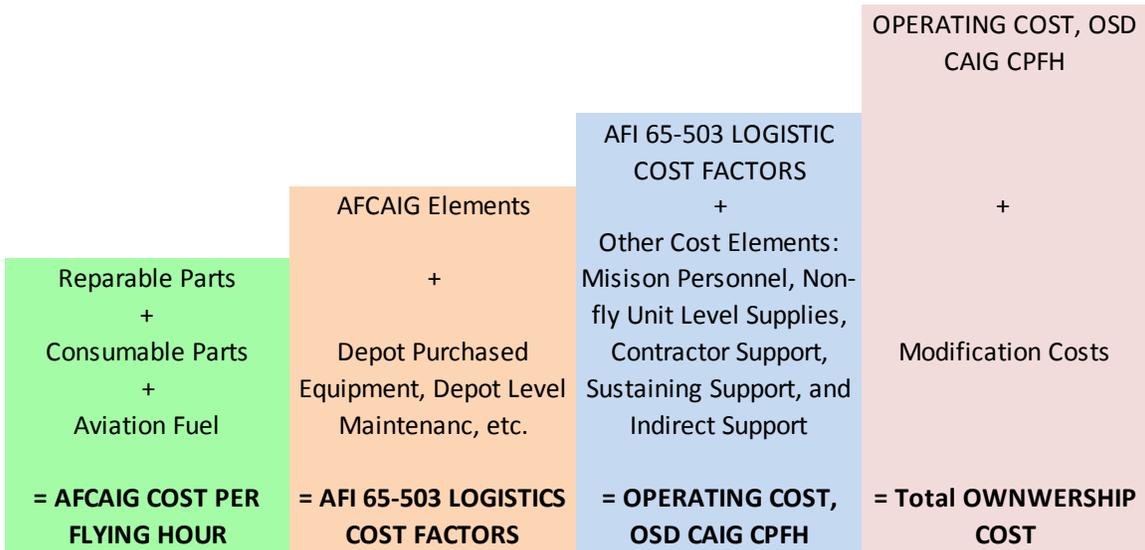
### **Recent CPFH Examples.**

Most CPFH analyses involve efforts to develop more accurate CPFH models (see Table 1). To develop stronger models, the researchers try to identify more accurate predictors or input variables (Armstrong, 2006:12). Dr. David Lee proposed a physics-based model including take-off/landing cycles, ground hours, and flying-hour variables (Wallace, 2000:2-1). Some of the suggested models have outperformed the current models and others have only marginally varied from the current AFCAIG model. Nonetheless, the proposed models have not been widely incorporated into the AFCAIG process (Van Dyk, 2008:4).

Figure 6 shows how the AFCAIG elements used to develop the AFCAIG CPFH model can be considered a subset of the more comprehensive OSD CAIG elements. The ODS CAIG elements changed in 2008 from seven items to the six items shown below (AFTOC, 2012). The new OSD CAIG cost elements are calculated by including the

AFCAIG items, plus AFI 65-503 Logistics Cost Factors, plus other cost elements such as mission personnel, contractor support, sustaining support and indirect support.

1. Unit Personnel
2. Unit Operations
3. Maintenance
4. Sustaining Support
5. Continuing System Improvements
6. Indirect Support



**Figure 6: Increasing Factors Considered in AFCAIG and OSD CAIG CPFH Models (Kirby, 2011)**

The AFTOC tool gathers the data used to compute the models from numerous sources (see Table 2) and allocates the costs based on the AFTOC business rules (Kirby, 2012:2). All the aforementioned factors comprise the weapon system operating costs; modification costs are added to the operating cost to obtain the ownership cost (Kirby, 2012:4).

**Table 2: AFTOC Data Sources**

•Financial	•Supply
–GAFS-R	–SBSS
–ABIDES	–DO35K
–IDECS	–DO43
–TWCF	–AFLMA
•Maintenance	–GCSS-AF
–FAS	•Munitions
–REMIS	–CAS
	–Training Munitions
•Personnel	•Factors
–E300Z	–AFI 65-503

**Non-traditional CPFH Example**

Some weapon systems do not readily conform to the AFCAIG CPFH model and the OSD CAIG Operation and Ownership models (as shown in Figure 4). If the AFCAIG model must be modified, by extension, the OSD CAIG model will be slightly different. For example, a thesis by Kimbrough analyzed the factors that best suit two satellite MDS (2004:6). He looked at costs that comprise the majority of the O&M phase of the Global Positioning System (GPS) and the Military Strategic and Tactical Relay Satellite System (MILSTAR). He focused on manpower variables, given that they comprised about 75% of the O&M costs of the satellites. Where the traditional AFCAIG model uses aviation fuel, DLRs, and consumables, Kimbrough’s model used Critical Space Contract Operations, Critical Space Operations—Direct Support, and DLR—Non-Flying (Kimbrough, 2004:34). The model’s predictive power was primarily found in accounting

for the total manpower costs and expected increases in cost of living allowances, pay increases, and inflation.

### **Elements Specific to the ICBM Mission**

ICBM alert hours are different from aircraft flying hours in three important aspects. The alert hours do not vary from year to year, the variable costs drivers are different, and the weapon system is stationary (granted, it is capable of intercontinental use, but the cost of an alert hour is associated with a stationary system). The goal is to have every missile constantly on alert; the weapon system boasts near 100% mission capable rates (Donley, 2012). However, there is a requirement for scheduled and unscheduled maintenance. When a single missile is taken “off-alert” for maintenance, the costs associated with being on alert are still incurred. The site is still secured, manned and the flight still has all the costs of being on alert (alert costs are explained in further detail in Chapter III). Therefore, the costs measured for an alert hour can actually be greater than an off-alert hour (Harlow, 2011). When a missile is removed from a site, it is called a warm site. Again, due to the increased maintenance demand, the cost of a warm site can actually be higher than a fully functioning site. However, in a study conducted at Malmstrom AFB based on FY11 data, the budget office found that a long-term warm site could be operated at about 27% of the cost of fully functioning site (Steely, 2011:2).

Given that the weapon system is stationary, it incurs costs differently than aircraft. The details will be provided in Chapter III; here though, it is important to note how fixed costs have been analyzed in CPFH literature. Aircraft have costs that accumulate

regardless of any sorties generated. Variables such as temperature, weapon system age, time spent on the ramp, and cannibalization all lead to costs incurred for aircraft while on the ground. Using log-linear least square regression with a non-zero intercept was found to more accurately predicted changes in CPFH (Van Dyk, 2008:80). Many of the above factors affecting aircraft, leading to the validity of a non-zero intercept, are also present for ICBMs.

### **Unique ICBM Funding History**

Neil Sheehan recounts the origins of the ICBM program in a biography of Bernard Schriever. He describes the multifaceted approach Schriever took to accomplish developing the ICBM program in a short amount of time. Many contracts were made with manufacturers, suppliers, construction companies, and engineering divisions. The contracts were all managed in-house by Schriever's team (Sheehan, 2009). Over time, the management of the ICBM program evolved through multiple homes in the DOD including Strategic Air Command, Air Force Space Command, and Air Force Global Strike Command. Until 1997, the Air Force managed the many contracts for the ICBMs. In 1997, Northrup Grumman was selected as the ICBM Prime Integration Contractor (IPIC) on a 15-year contract expiring in FY12. The DOD policy no longer allows integration contractors without explicit approval; therefore, the process will revert to a structure similar to the pre-1997 structure (Harlow, 2011). Insourcing the integration contract will bring opportunities for more direct oversight and potential savings. However, just as in the commercial sector, not all decisions to insource or outsource are based on monetary factors alone (Johnson, Leenders, and Flynn, 2011:129).

## **Out/Insourcing Based on Factors Other Than Just Cost**

The goal of cost models is to better understand how costs are distributed. An increased understanding of cost distributions can allow management to make better financial decisions (Kaplan and Cooper, 1998:107). However, cost is only one element of the decision process. In one ABC study, the Army found childcare facilities on Army installations cost up to twice as much as comparable commercial facilities due to higher worker-child ratios and higher wages. The Army decided (as of the writing of the thesis) to keep the childcare facilities open based on troop morale and convenience (Peters, 1999:1). Similarly, if an aspect of the nuclear enterprise is deemed critical for strategic purposes, then it may be maintained even if there were a more cost effective alternative.

Civilian businesses also face decisions to insource, outsource; or, as Harry Moser presents, they can offshore (Moser, 2012). The factors that affect a company's decision to insource, outsource, or offshore are similar to the factors that led to outsourcing the maintenance contract in 1997. While the production of critical components of the nuclear enterprise is closely monitored, it is beneficial to consider what led (and could lead in the future) to outsourcing the maintenance for the LGM-30. In the commercial sector, the factors leading to major outsourcing decisions are apparent in the decision to move an aspect of the firm overseas, also known as offshoring. Offshoring is a unique form of operating in another country where the company can move in entirety, or it can outsource a portion of its operations to a company in another country (Moser, 2012). Of utmost concern to a commercial enterprise is the profitability of such a move. Moser asserts that many sourcing decisions are based on price alone, resulting in 20-30% miscalculation of actual costs (Moser, 2012). Numerous factors affect the decision to outsource (or

insource a previously outsourced function). Outsourcing may result in increased risks, increased lead times, supply restraints and unexpected fees (Johnson, et al, 2011:128). Dr. Thomas Goldsby states that out of 50 multi-billion dollar companies who decided to outsource overseas, 75% were dissatisfied with their return on investment. He attributed the unexpected meager returns to a lack of assessing all parameters, which lead to unexpected outcomes (Goldsby, 2012). Therefore, it is imperative for a company and government entities to consider all the affected aspects of a situation before making major change in process (Johnson, et al, 2011:129). Similarly, the Air Force has observed that some decisions to outsource did not turn out to save as much as first expected (Harlow, 2011).

### **ICBM CPAH Considerations**

CPAH is not an operationally flexible metric like CPFH. Missile alert hours are not adjusted in the same way that scheduled flying hours are adjusted based on the approved yearly budget. Unger modified a CPFH model and found that the proportional method used to determine CPFH amounts is only accurate when the number of hours flown is relatively close to the number of hours used to develop the CPFH value (Unger, 2008:87). The area of accuracy is narrowed for the LGM-30, given that ICBMs have a constant number of alert hours. The proportional model can lead decision makers to believe that flying one less hour will save the full CPFH amount and that adding one more hour will require a full CPFH amount increase. However, the non-proportional nature of the CPFH [and certainly the CPAH] models make for poor marginal analysis (Hess, 2009:35).

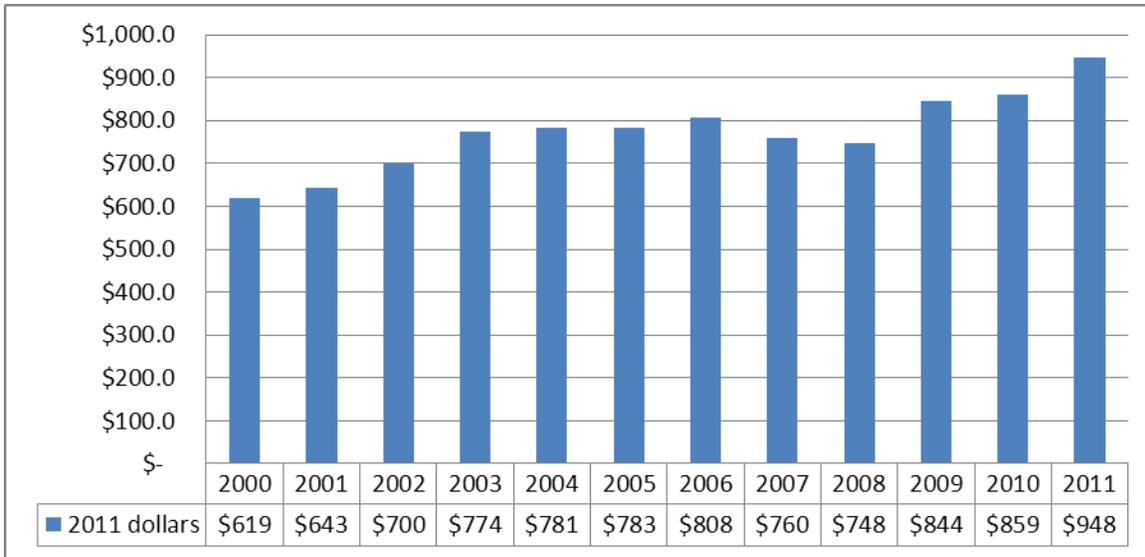
## **564<sup>th</sup> MS Deactivation Case Study**

The 2006 Quadrennial Review directed DOD to “Reduce the number of deployed Minuteman III ballistic missiles from 500 to 450 beginning in Fiscal Year 2007”

(Rumsfeld, 2006:50). The Air Force selected the 564<sup>th</sup> Missile Squadron (MS) of the 341<sup>st</sup> Missile Wing (MW) at Malmstrom Air Force Base (AFB) to be deactivated. The decision was both a strategic and financial decision. Eliminating a squadron from the 341<sup>st</sup> MW would bring all three MWs to an equal 150 missiles each. The 564<sup>th</sup> MS may have been selected because it used missiles built and installed by General Electric while all other MM III missiles were built and installed by Boeing. As a result, the 564<sup>th</sup> MS missiles used different training systems and ground technologies (Woolf, 2006:10).

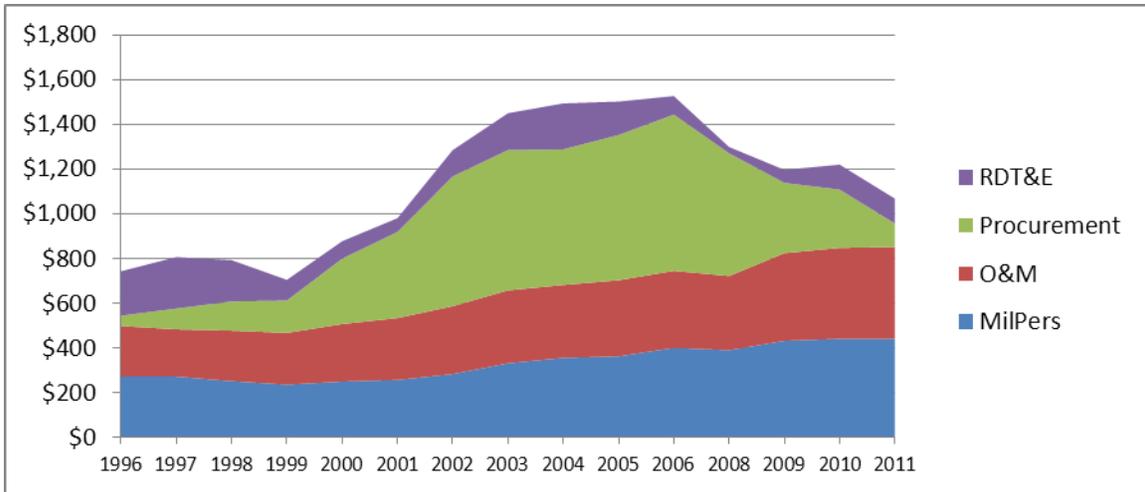
Operating a common system was likely desired as a means to reduce O&M costs.

However, eliminating a missile squadron did not show immediate savings due to the large deactivation costs (Woolf, 2006:11). As shown in Figure 7, overall costs (adjusted from “then year dollars” to FY11 dollars) show only a minor decrease while the squadron was undergoing deactivation, then increased afterwards.



**Figure 7: LGM-30 O&M Costs Over 564th MS Deactivation Period (in millions) (AFTOC, 2012)**

Since 2008, base-level costs have increased, in part, due to increased personnel costs. Additionally, there have been many modernization and modification initiatives (Harlow, 2011). In a memo released by the Secretary of the Air Force, Michael Donley, and Air Force Chief of Staff, General Norton Schwartz, they emphasize the impacts of the 2013 budget. They state that many modernization projects will be deferred to later years or canceled. The LGM-30 modifications are not listed explicitly as being kept or canceled (Donley and Schwartz, 2012). Figure 8 shows the impact that reducing R&D and Procurement has had on the LGM-30's total expenditures in recent years. Figure 8 shows the total appropriated dollars for the LGM-30. There are numerous factors affecting total costs; therefore, it is hard to say directly how significant the impact of deactivating the 564<sup>th</sup> MS was to the total budget.



**Figure 8: LGM-30 Appropriations Summary (in millions) (AFTOC, 2012)**

Malmstrom AFB is located in Great Falls, Montana; the city commissioned a report to assess the total dollar revenue the region around the base would likely lose due to the squadron’s deactivation. Their report included payroll downsizing, reduced utility consumption, decreased local educational enrollments, facilities O&M, and a general category of “other areas” that would be affected. The largest factor was the official estimate reducing the number of manning authorizations by 14.2%. Additionally, the report estimated that the base would lose an additional 143 indirect positions for a total area payroll decrease of about 24.9 million dollars. When added to the other categories, the report estimated the total decrease of revenues (Malmstrom Air Force Base spending) of about 30.2 million dollars (Great Falls, 2008). These dollar figures were not verified by the Air Force, but show how the elimination of a squadron, if the reduced manning authorizations are observed, can provide a significant reduction in costs.

## **Summary**

This literature review first discussed the general mechanics of a cost per flying hour program. Next, applications from the commercial sector were considered as they related to the flying hour program. The chapter expanded the workings of the Air Force's cost per flying hour program by reviewing examples of how the flying hour program has been used recently. An example of a non-traditional cost per flying hour assessment for satellites was considered. Finally, this chapter reviewed elements specific to the ICBM mission, including funding history, force structure, and other aspects of the weapon system relating to operating costs.

### **III. Methodology**

*In finding and achieving efficiencies, a fundamental challenge is cost visibility at the decision-making levels. It's at this point where data – both qualitative and quantitative – can be used to paint an accurate picture of the options for senior leaders. But absent such cost visibility – and good data – we struggle to make the right budget choices.*

The Honorable Erin C. Conaton, Under Secretary of the Air Force

#### **Chapter Overview**

This chapter presents how data are obtained and what analysis methodology is used to answer the four research questions from Chapter 1. The chapter begins by scoping the analysis and explaining the methodology goals of the. Next, the chapter describes the processes and data used to develop an intercontinental ballistic missile (ICBM) Air Force Cost Analysis Improvement Group (AFCAIG) cost per alert hour (CPAH) model. Then, the chapter describes the process and data used for developing an ICBM Office of the Secretary of Defense, Cost Analysis Improvement Group (OSD CAIG) CPAH metric. Finally, the chapter shows how the data can be combined to develop a comprehensive model, accounting for indirect ICBM costs. The results from each model are presented in Chapter 4.

#### **Methodology Overview**

The overall approach is to develop a model for determining ICBM CPAH and to assess the CPAH at different levels of management. The first part of this approach is based on the AFCAIG and OSD CAIG CPFH models. The second aspect of the methodology is similar, though not identical, to how Activity Based Costing (ABC) can highlight administrative costs that are rolled into operating cost at each hierarchical level

of management. For the ICBM enterprise, this thesis assesses costs starting with the single launch facility (LF), then the missile alert facility (MAF) or flight level (10 missiles), squadron level (50 missiles), missile wing (MW) (150 missiles), and the weapon system (WS) (450 missiles). The WS costs are calculated at the command level (AFGSC) and the LGM-30G mission series design (MSD) level. The MSD level is divided by the same number of hours as the command level, but also includes depot costs not included at the command level. Each echelon total is divided by the number of alert hours managed at the given level. In actuality, each level acquires slightly fewer alert hours than the indicated amount. However, the actual amount is less than .01 different than mathematical totals indicated in Table 3. Additionally, given that a non-alert hour will likely have equal or greater costs (due to maintenance and security actions), all calculations are based on the mathematical totals for alert hours shown in Table 3.

**Table 3: Alert Hours by Echelon**

<b>Echelon</b>	<b>Alert Hours Per Year</b>	<b>Alerts Per Year</b>
Launch Facility	8,760	365
Missile Alert Facility	87,600	3650
Missile Squadron	438,000	18,250
Missile Wing	1,314,000	54,750
Command and WS	3,942,000	164,250

### **Data Sources**

The AFCAIG model is derived for the WS, AFGSC, and the wing levels using data from the Air Force Total Ownership Cost (AFTOC) system. The lower levels require personal interviews with subject matter experts (SMEs) to determine the depot, squadron, flight, and missile costs. The wing data is acquired via the AFTOC system and personal interviews with base-level SMEs, providing a comparative value from two

perspectives. The OSD CAIG model includes more elements than the AFCAIG model and requires more data. The data for the ODS CAIG assessments is compiled from numerous legacy systems into the AFTOC tool (see Table 2). The data set is massive and can be cumbersome, but making the task more manageable are standard queries that provide the needed data. However, the standard queries are limited to higher-level reports for the MDS, command, wing, and base levels. Data are not attributed to a specific squadron, flight, or LF in the standard queries. Therefore, the OSD CAIG model is only used for the three top levels of management.

This thesis follows basic ABC principles but is not a full ABC assessment. “AFTOC is not an Activity Based Cost Accounting System, but is the closest thing the Air Force has to one” (McNutt, 2012:6). Developing a traditional cost dictionary for every action in the nuclear enterprise is beyond the scope of a thesis and would be virtually impossible given the magnitude of the enterprise. The data for the weapon system, command, and wing are census data, meaning that they include all the data feeds compiled in AFTOC. The data for the lower levels are samples from one base/wing and squadron. The data for the MAFs and LFs are assumed to be constant across the command. This assumption is valid for depot level reparable (DLRs) and personnel costs, but consumable costs can vary based on the mileage disparity of each MAF and LF. The wing chosen is the 341<sup>st</sup> MW at Malmstrom AFB in Great Falls, Montana. The squadron sampled is the 490<sup>th</sup> MS. Malmstrom is analyzed for three reasons. First, the choice is limited to Malmstrom and F.E. Warren because these locations do not have an active flying wings that could distort the allocation of indirect costs. Secondly, the researcher was stationed at Malmstrom prior to being assigned to the Air Force Institute

of Technology (AFIT) and knew many of the contacts needed to collect the data. Finally, Malmstrom’s sampled costs are very close to the average for the three missile wings (see Table 4).

**Table 4. ICBM Wing OSD CAIG Operating Cost Comparisons**

F.E. Warren	\$164,410,482
Malmstrom	\$153,257,407
Minot	\$142,538,245
Average	\$153,402,045

The personal interviews with SMEs and the AFTOC system provided ample data for each echelon (see Figures 9 and 10). However, the data are not available for all echelons from one source. The AFTOC data does not provide the fidelity to assign cost to a specific squadron, MAF, or LF with the standard reports. The SMEs provided the lower-level data for the AFCAIG elements and two of the OSD CAIG elements.

	LGM-30G	Wing	Squadron	Flight (MAF)	Missile (LF)
DLR	SPO	AFTOC			
CONs	AFMC	AFMC			
Personnel	SPO*	MAFB			

**Figure 9: AFCAIG Data Availability**

	LGM-30G	Wing	Squadron	Flight (MAF)	Missile (LF)
1.0 Unit Personnel	AFTOC		MAFB		
2.0 Unit Operations					
3.0 Maintenance					
4.0 Sustaining Support					
5.0 Continuing Improvements					
6.0 Indirect Support					

## Figure 10: OSD CAIG Data Availability

### AFCAIG CPAH Models

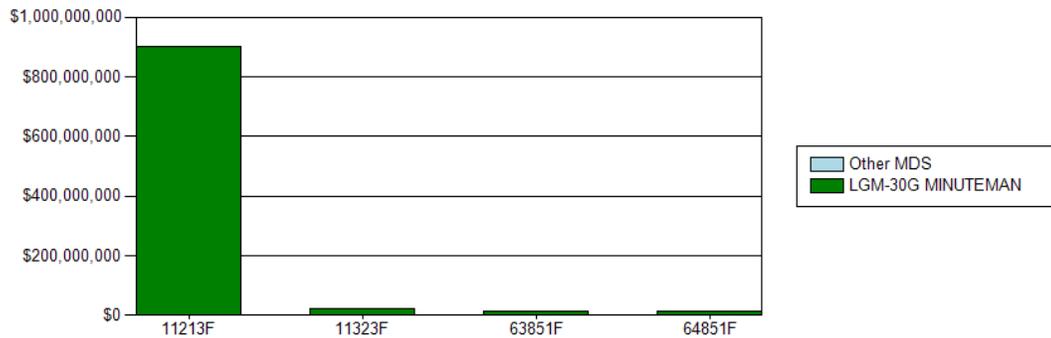
$$\frac{DLRs + Consumables + Personnel}{Alert Hours} = Cost Per Alert Hour$$

### Figure 11: AFCAIG Model

The AFCAIG CPFH model, as it was described in Chapter II for aircraft, uses DLRs, consumables, and aviation fuel as the three cost drivers. The ICBM AFCAIG CPAH model uses DLRs, consumables, and personnel cost as the three cost drivers. DLRs and consumables are defined the same as for aircraft. Personnel costs for this model include both active duty and civilian costs. The AFCAIG model data is obtained from two sources for the wing level. The first is used to develop the AFTOC-AFCAIG model, with data from the AFTOC system for the wing and higher levels. The second version uses the same elements, but the data is obtained from the SMEs from the wing and lower levels. The two versions overlap at the wing level, providing two comparative data points for an AFCAIG based wing CPAH. The AFTOC-AFCAIG model uses actual gross obligations from the AFTOC tool to obtain personnel costs for the WS, command, and wing. The personnel cost in the SME-AFCAIG model are based on personal interviews and localized documentation to determine the number of personnel authorized for the wing, squadron, flight, and LF levels.

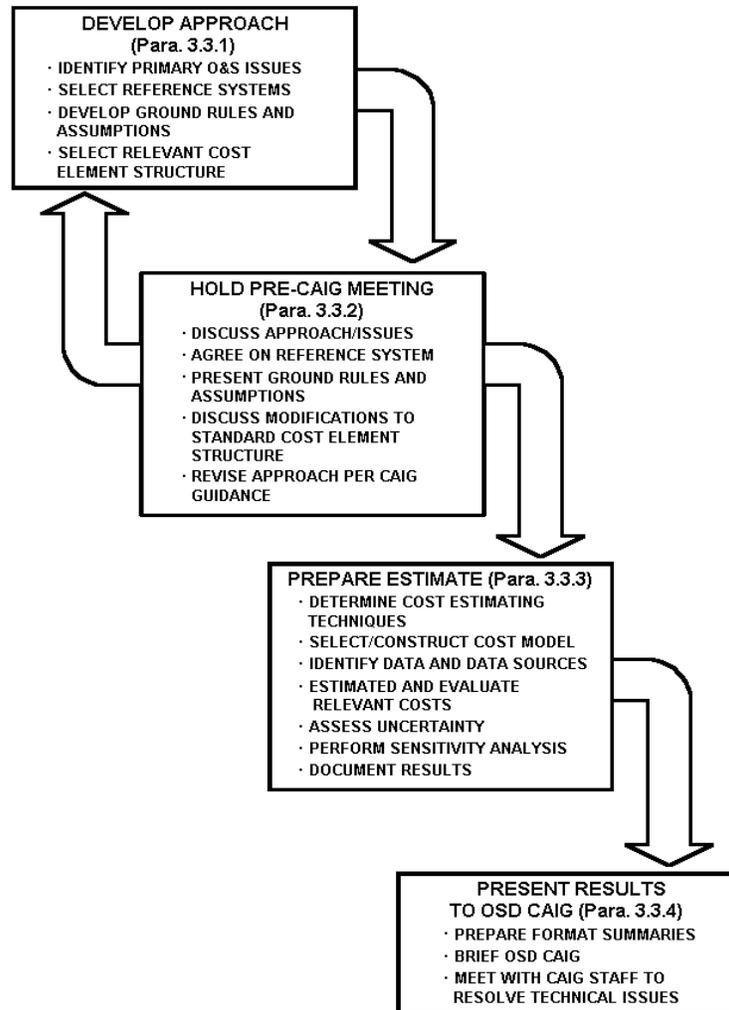
ICBM data are comprised of about a dozen Program Element Codes (PECs) and hundreds of Element of Expense/Investment Code (EEICs) to track costs. For the localized data, PEC 11213F was used (see Appendix E for PEC descriptions). The

AFTOC system combines all the associated PECs and provides a slightly more comprehensive picture. Figure 12 shows that PEC 11213F is by far associated with the largest portion of ICBM costs. Therefore, localized data showing only 11213F does not include every ICBM cost, but is within 2% of the total costs.



**Figure 12: PEC Comparison (AFTOC, 2012).**

The operating costs of a missile squadron, MAF, and LF are largely adapted from a 2011 Malmstrom missile-squadron reduction study. The study looks at variable costs that would likely be eliminated if one squadron were deactivated. A similar study was conducted in 2005; the 2005 *then year dollars* were converted to FY11 values with DOD Inflation Tables. The researcher integrated the local studies with the AFCAIG model to determine a cost per alert hour for a LF, MAF, and squadron. This thesis utilizes the AFCAIG and OSD CAIG basic models; however, it does not, complete the OSD CAIG process as shown in Figure 13. Currently, ICBMs are not part of the OSD CAIG or AFCAIG processes for determining a CPFH (or CPAH) metric.



**Figure 13: CAIG Preparation Process (OSD, 1992).**

### **OSD CAIG CPAH Model**

The OSD CAIG model is more inclusive than the AFCAIG model. Data for the OSD Model are divided into 6 elements listed below.

1. Unit Personnel
2. Unit Operations
3. Maintenance
4. Sustaining Support
5. Continuing System Improvements
6. Indirect Support

$$\frac{\text{OSD CAIG Elements}}{\text{Alert Hours}} = \text{Operating Cost Per Alert Hour}$$

**Figure 14: OSD CAIG Operating Cost Model**

$$\frac{\text{OSD CAIG Elements} + \text{Modification Cost}}{\text{Alert Hours}} = \text{Ownership Cost Per Alert Hour}$$

**Figure 15: OSD CAIG Ownership Cost Model**

Figures 14 and 15 show the OSD CAIG operating and ownership CPAH models. Figure 6 shows what elements are added to each model and how the AFCAIG and OSD CAIG models relate to one another. In addition to the standard reports used to assess costs, Mr. Billy Kirby from the Air Force Materiel Command (AFMC) Central Asset Management (CAM) office accessed in-depth supply costs from the AFTOC system for the weapon system for comparison to the standard reports. The supply data shows charges for what items are purchased and credits for items returned. Each transaction includes the MDS, location (down to the base level) and time period. The AFTOC supply data also contains numerous financial identifiers to narrow the scope of transactions included in the queries. For this comparison, the focus is on Budget Codes 8 and 9 for PEC 11213F. There are more than 20 PECs associated with the installations that house the ICBMs. Many of the PECs are historical and only used to show credit for an item no longer in use. Other PECs identify items purchased for tenant units. The PEC 11213F accounts for 98% of the total cost and is the focus of the lower-level analysis; a

description of the PEC is below. Descriptions of other PECs used are presented in Appendix E.

**Minuteman Squadrons:** This program element supports the operation and maintenance of the Minutemen weapon system. It supports missile modifications to include Guidance Replacement and Propulsion Replacement Programs. The PE includes manpower authorizations, peculiar and support equipment, necessary facilities and the associated costs specifically identified and measurable to the Minuteman weapon system. Includes: wing headquarters, missile squadrons, missile maintenance, munitions maintenance and weapon system security. Excludes: nuclear warhead component costs which are handled by the Department of Energy and dedicated intrasite communications. (AFCAIG, 2010)

The data from the AFTOC system are also compared with data from the ICBM system program office (SPO) for depot related costs. The first appropriation code this analysis considers at the depot is from the FY11 priority buy (PB) Position 3020. When it is added to the O&M cost (3400), it matches the AFTOC figures for DLR costs. However, the cost from Automated Budget Interactive Data Environment System (ABIDES) Position 3600, for research and development (R&D), is not included in the lowest three layers of the OSD CAIG model. It is added last to calculate the total weapon system Ownership Cost (see Figure 15). The R&D costs are significant, totaling \$135,140,000; yet if they are distributed across the weapon system's yearly alert hours, they represent only a \$34.00 increase per alert hour.

### **Comprehensive Model**

The OSD CAIG model is a robust model, giving a good picture of costs incurred by a particular WS. The ability of AFTOC to provide installation indirect costs and the ICBMs' unique structure allows an additional analysis that is more subjective yet could

prove beneficial when trying to understand all costs associated with the weapon system. As described in Chapter I, the LGM-30 is a component of the larger WS-133A/M including airborne launch control centers (ALCC), EC-135s, MILSTAR satellites, etc (see Figure 2). Moreover, the ICBMs are stationary and have a large indirect support footprint covering thousands of square miles. The indirect costs incurred by a WS are harder to quantify than the direct cost captured in the AFTOC system. For example, a satellite that supports the LGM-30 will also support many other weapons systems. Some indirect cost can be divided based on percentage of use, but others are harder to divide. Therefore, this analysis uses the Indirect Costs Summary Report data provided by the AFTOC system for each of the ICBM MWs. The indirect costs include base operating and support items that are assumed to be independent of the weapon system but necessary for a mission to occur at a given location. Some indirect costs include base housing, real property costs, medical costs, and utilities maintenance. For the 90th MW and the 341st MW, where there is only one major weapon system on the installation; the indirect costs for the base can be largely attributed to the LGM-30. Although, there is a likely a slight overlap with some of the tenant units. For the 91st MW at Minot AFB, the indirect costs are divided between other wings on the same installation by the AFTOC system. When the attributed indirect cost are added to the ownership costs of the OSD CAIG model, a comprehensive costs is derived (see Figure 16). The results for each model are discussed in Chapter IV.

$$\frac{\text{OSD CAIG Ownership Cost} + \text{Indirect Base Costs}}{\text{Alert Hours}} = \text{Comprehensive CPAH}$$

**Figure 16: Comprehensive Model**

## **Summary**

This chapter describes the elements used to develop three models for assessing ICBM CPAH factors. The first model is adapted from the AFCAIG model and includes DLRs, consumables, and personnel costs. The second model is based on the OSD CAIG structure and provides ICBM operating cost and ownership cost. The final model is more subjective and incorporates the unique support structure of the ICBMs. The final model can provide a comprehensive cost consideration of the ICBM CPAH.

## IV. Analysis and Results

### Chapter Overview

The data analysis seeks to determine how the Air Force Cost Analysis Improvement Group (AFCAIG) and Office of the Secretary of Defense, Cost Analysis Group (OSD CAIG), and Comprehensive models can be used to determine an LGM-30 cost per alert hour (CPAH). It is not organized to assess the models' power as proportional predictive models. However, given the described structure of the intercontinental ballistic missile (ICBM) force, it is necessary to consider the fixed costs when accurately describing the CPAH. The CPAH appear to follow a step function based on the level of management for each echelon. Table 8 shows how each level of management has distinct changes in CPAH. The presented analysis emphasizes the step function and the relation of fixed costs to prevent any misconceptions about proportionality among model comparisons. A more apt view of the data could be to consider it a *cost per LGM-30 echelon* (flight, squadron, etc.) rather than a CPAH (see Table 8).

### AFCAIG Model Results

First, data for the AFCAIG based model are presented. All costs are compared using fiscal year 2011 (FY11) values. Historical figures have been converted from *then year dollars* to FY11 dollars to account for inflation. The wing-level AFCAIG data is collected from both local interviews with subject matter experts (SMEs) (shown in Table 5) and the Air Force Total Ownership Cost (AFTOC) (shown in Table 6). The data for

the consumables and personnel cost are acquired from the base –level SMEs, while the shaded data is based on data provided by the ICBM system program office (SPO) for DLRs.

**Table 5: AFCAIG, SME CPAH Results**

	<b>Wing</b>	<b>Squadron</b>	<b>Flight (MAF)</b>	<b>Missile (LF)</b>
<b>DLR</b>	\$ 3,636,875	\$ 1,212,292	\$ 242,458	\$ 24,246
<b>CONs</b>	\$ 18,062,296	\$ 5,066,808	\$ 1,983,260	\$ 61,124
<b>Personnel</b>	\$ 154,166,467	\$ 9,902,356	\$ 754,808	\$ 5,737
Total Assessed Cost	\$ 175,865,638	\$16,181,456	\$ 2,980,526	\$ 91,107
Alert Hours	\$ 1,314,000	\$ 438,000	\$ 87,600	\$ 8,760
CPAH	\$ 134	\$ 37	\$ 34	\$ 10

The depot level reparable (DLR) and consumable cost drivers are very close to each other, within 5% each. However, the personnel costs are significantly different, with about 38% difference in the data obtained from AFTOC system and the base-level SMEs. The reason for the personnel cost-disparity is that the lower-level costs are based on authorizations multiplied by the DOD-AF active duty composite rates. The AFTOC personnel values are not solely based on authorizations, but on actual costs incurred. Given that the wings and squadrons are not fully manned, it is expected that costs based on authorizations will be greater than the actual costs incurred (Lara, 2012). The disparity affects the data obtained from the base level for the wing and squadron personnel costs. However, the data for the launch facilities (LFs) and flights or missile alert facilities (MAFs) provides an accurate portrayal of personnel costs because the LF and MAF teams are set sizes and the personnel costs are stable.

**Table 6: AFCAIG, AFTOC CPAH Results**

	<b>LGM-30</b>	<b>AFGSC</b>	<b>Wing</b>
<b>DLR</b>	\$ 10,910,625	\$ 10,437,648	\$ 3,636,875
<b>CONs</b>	\$ 97,601,809	\$ 97,580,167	\$ 12,350,229
<b>Personnel</b>	\$ 459,298,121	\$ 440,878,762	\$ 135,307,896
Total Assessed Cost	\$ 567,810,555	\$ 548,896,577	\$ 151,294,999
Alert Hours	\$ 3,942,000	\$ 3,942,000	\$ 1,314,000
CPAH	<b>\$ 144</b>	<b>\$ 139</b>	<b>\$ 115</b>

As shown in Chapter II, there are many factors that can actually increase costs when a LF is down for maintenance or other reasons. Therefore, the likelihood of saving \$10.40 for every hour that a missile is off-alert is negligible. Rather, the value of the metric is to highlight the smallness of the marginal CPAH per missile. Both sets of data, and results, include the wing level CPAH. Table 5 shows the AFCAIG SME CPAH results for the wing, squadron, MAF and LF, while Table 6 contains the AFCAIG AFTOC CPAH results for AFGSC, the weapon system, and the wing. The CPAH values for the wing level can be contrasted a third time with the OSD CAIG based model shown in Table 7.

### **OSD CAIG Model Results**

The OSD CAIG-based model derives a CPAH for the WS, AFGSC, and wing echelons. All the data for the six elements of the OSD CAIG model comes from the AFTOC system. The modification costs were provided by the ICBM SPO and were verified with the AFTOC values. The figures under the heading *Operating* include all the

OSD items included in Figure 2 and Appendix C. The OSD CAIG total Ownership Cost includes all the items comprising the LGM-30 Operating cost plus modification cost, for a total of \$328.

**Table 7: OSD CAIG CPAH**

OSD CAIG Elements	LGM-30		AFGSC	Wing
	Ownership	Operating	Operating	Operating
1.0 Unit Personnel	\$ 420,509,716	\$ 420,509,716	\$ 403,999,241	\$ 135,307,896
2.0 Unit Operations	\$ 46,368,719	\$ 46,368,719	\$ 59,530,962	\$ 7,797,141
3.0 Maintenance	\$ 306,843,120	\$ 306,843,120	\$ -	\$ 4,553,088
4.0 Sustaining Support	\$ 21,585,028	\$ 21,585,028	\$ 7,971,981	\$ -
5.0 Cont System Improv.	\$ 103,828,658	\$ 103,828,658	\$ 1,850,705	\$ -
6.0 Indirect Support	\$ 49,124,926	\$ 49,124,926	\$ 48,887,526	\$ 11,578,767
Modification Cost	\$ 343,956,000			
Total Assessed Cost	\$ 1,292,216,167	\$ 948,260,167	\$ 522,240,415	\$ 159,236,891
Alert Hours	3,942,000	3,942,000	3,942,000	1,314,000
CPAH	\$ <b>328</b>	\$ <b>241</b>	\$ <b>132</b>	\$ <b>121</b>

### Comprehensive Model Results

The Comprehensive model includes all the costs of the OSD CAIG Ownership Costs plus the indirect costs for the associated installation. The indirect costs almost double the costs at each echelon. A necessary caveat to the Comprehensive model's results is that the indirect costs are not directly attributable to the weapon system. Rather, the indirect costs are associated with the location of the weapon system. The indirect costs for the wing in Table 8 are the indirect cost for Malmstrom AFB. The indirect costs for AFGSC include the indirect cost from Malmstrom AFB, F.E. Warren AFB, and the 91st MW at Minot AFB. The data for Malmstrom AFB and F.E. Warren AFB capture indirect costs that include most base-operating costs including items like facility support and medical operations. However, the figure for the 91st MW is only a percentage of

total installation indirect costs. The percentage varies for each item and is determined by AFTOC. The total 91st MW indirect costs account for about 1% of the total indirect costs at Minot. The majority of the indirect costs for Minot are assigned to the 5th Bomber Wing (BW) by the AFTOC tool. The Comprehensive model costs provide a broader perspective of the total costs DOD incurs each hour to operate the LGM-30. However, it is emphasized that the values reflected in the Comprehensive model reflect many costs that would remain if the ICBM mission were to cease at those installations. For example, a large percentage of the personnel would likely be transferred to other missions and continue to be an expense to the DOD. Appendix C contains tables showing the comparative results of the OSD CAIG Operating and Ownership CPAH results to the Comprehensive CPAH results.

**Table 8: Comprehensive CPAH**

OSD CAIG Elements	LGM-30*	AFGSC	Wing
1.0 Unit Personnel	\$ 680,391,818	\$ 660,697,776	\$ 154,166,467
2.0 Unit Operations	\$ 142,175,907	\$ 155,316,508	\$ 13,209,287
3.0 Maintenance	\$ 308,637,741	\$ 1,794,621	\$ 4,853,010
4.0 Sustaining Support	\$ 23,789,427	\$ 10,176,380	\$ -
5.0 Continuing Sys Improv.	\$ 103,829,958	\$ 1,852,005	\$ -
6.0 Indirect Support	\$ 870,368,190	\$ 866,879,679	\$ 140,485,240
Modification Cost	\$ 343,956,000		
Total Assessed Cost	\$ 2,473,149,042	\$ 1,696,716,969	\$ 312,714,003
Alert Hours	3,942,000	3,942,000	1314000
CPAH	\$ <b>627.38</b>	\$ <b>430.42</b>	\$ <b>237.99</b>

## Investigative Questions Answered

1. Can the AFCAIG and OSD CAIG aircraft CPFH models be used to develop a CPAH model for the LGM-30 weapon system? If so, what are the differences?

This thesis presents two models already in use by the Air Force. The AFCAIG model is used by modifying the cost drivers to fit the unique aspects of the Minuteman III. It incorporates two of the three drivers from the CPFH model: DLRs and consumables, including GPC items. The third CPFH driver, aviation fuel, is replaced with personnel costs to acquire a CPAH metric. The OSD CAIG model is used for the LGM-30 without any manual modification. The modifications occur in the internal workings of the AFTOC system. For example, the AFTOC system includes “range support” in item 6.7 for the aircraft OSD CAIG totals, but includes “cost of supporting live fire of missiles” for missile OSD CAIG item 6.7.

2. Do the cost per alert hour factors change significantly based on the level of management?

The CPAH values of the AFCAIG model do increase disproportionately with each level of management, but not as drastically as the OSD CAIG model or comprehensive models (see Table 9). The AFCAIG model includes fewer cost drivers than the other two models, likely contributing to it monotonically increasing over the echelons.

Additionally, the drivers not part of the AFCAIG model are the most varied costs of the weapon system. The steadiness of the AFCAIG drivers is emphasized in the comparison between the wing, AFGSC, and weapon system AFCAIG CPAH figures (see Table 6). The AFGSC and weapon system CPAH figures only increase by 20% and 3%

respectively from the previous (lower) level of management. Conversely, the OSD CAIG CPAH figures for the weapon system and AFGSC increase by 80% and 46% respectively from the next lower level of management. This results because the three AFCAIG drivers are mainly spent at the base level. However, the OSD CAIG drivers include items (e.g. contractor support) that are spent largely at the higher levels of management. The OSD CAIG and Comprehensive models do not have the needed fidelity to distinguish cost below the wing level, thus a comparison is only presented down to the base level.

**Table 9: Echelon CPAH Comparison**

	LGM-30G	AFGSC	Wing	Squadron	Flight (MAF)	Missile (LF)
AFCAIG CPAH	\$ 144.04	\$ 139.24	\$ 115.14	\$ 36.94	\$ 34.02	\$10.40
OSD CAIG CPAH	\$ 327.81	\$ 132.48	\$ 121.18			
Comprehensive	\$ 627.38	\$ 430.42	\$ 237.99			

3. What cost drivers should be included in developing a comprehensive CPAH model for the LGM-30 weapon system?

The drivers for the AFCAIG model are selected based on their portion of impact on the total weapon system costs. Three elements are desired based on the three elements of the accepted AFCAIG model. Nonetheless, this analysis could have included more or fewer AFCAIG drivers as fitting. The three factors of the AFCAIG CPAH model account for the three largest portions of the available weapon system drivers. The main diversion of the traditional CPFH model is replacing aviation fuel with personnel costs. This change is made because fuel, POL, and electricity account for .5% of the total weapon system cost, while personnel account for 46.5% of the weapon system costs. The

cost drivers for the OSD CAIG model are not modified for this analysis. Appendix B provides an expanded list of the OSD CAIG drivers.

4. What is the expected relationship of costs and alert hours?

The relationship of costs and alert hours is presented in multiple formats to provide readers with the broadest perspective of how a CPAH metric can be utilized. Some applications will benefit from using the AFCAIG model. The AFCAIG model provides the most commonly adapted model for predictive metrics. The OSD CAIG model provides an in-depth analysis from data that is accessible to AFTOC users and regularly updated. The Comprehensive model provides decision makers an analysis of how much money is likely to be affected by decisions that affect an entire level of management. Further recommendations on applications for the models are presented in Chapter V. Finally, this analysis shows how the CPAH metrics are not proportional. One less alert hour will not directly reduce the bottom line proportionally to the CPAH figures from the models. This relationship is observable in the vast differences between a marginal costs of \$10.40 for one missile and a Comprehensive costs (including all the weapon system direct and indirect support) of \$627.38 shown Table 9. The ICBMs are not turned on and off by the hour and the fixed costs associated with operating the weapon system are very large. Thus, if only one ICBM is on alert, the costs will not be the marginal \$10.40 per hour. Considering the fixed costs is imperative for accurate strategic-level decisions.

## **Summary**

Chapter IV includes the results from the three models developed and analyzed. The analysis shows how the models are used to develop multiple perspectives for a CPAH metric. The models are not developed as proportional predictive models. This chapter shows how each level of management generates distinct changes in the CPAH. The model emphasizes the step function and the relation of fixed costs to provide an accurate assessment for decision makers. Finally, each model has strengths and weaknesses for decision makers; Chapter V presents the recommended uses of each model.

## **V. Conclusion and Recommendations**

### **Chapter Overview**

This chapter presents the concluding remarks and recommendations for further research. The analysis presented in this thesis is the result of both census data for the entire weapon system and survey data acquired from the base level. Together, the data provide a wide swath of analysis, but do not go in depth at any one echelon. Much could be gained from looking at only one level in greater detail. A goal of this thesis was to provide the sponsor and other interested parties with a broad overview of ICBM-costs drivers. This broad perspective will allow future analysts, and decision makers, to make informed decisions regarding follow-on studies. Below are recommendations from this researcher based on experience gained during this study.

### **Recommendations for Model Use**

Each model has strengths and weaknesses for given situations. The *best* model is determined by the decision makers' needs and acceptable assumptions. First, the AFCAIG model is weakened by limiting the elements considered. It is based on the cost assessments for flying missions from the 1960s, when less data was readily available. Today, the robust capabilities of the AFTOC system render limiting of considered factors of the AFCAIG model unnecessary. Nonetheless, it is still the most widely accepted model in the Air Force flying community. Therefore, it is best suited for comparisons to the larger Air Force.

The OSD CAIG model requires more data and involves more factors for consideration. The capability of the AFTOC system to synthesize all of the needed elements mitigates what would have been impossibly daunting using only the Air Force's legacy systems. The readily accessible data set in the AFTOC system makes the OSD CAIG model an informative tool for considering the cost directly attributable to the weapon system. Therefore, it is best suited for the decision makers in the ICBM community.

Lastly, the Comprehensive model's main weakness is the assumptions about what happens to the resources if a mission ceases. The Comprehensive model includes the support items for the ICBM installations. If the ICBM mission were to cease at that location, not all the costs would be eliminated. Likely, many of the resources would cross-flow where possible and some may be put into long-term storage. The complex endeavor of deactivating an entire installation would require further analysis beyond the scope of this thesis. However, the Comprehensive model does provide insight about the total costs the ICBM enterprise incurs to operate. This model is most applicable to strategic-level decision makers.

### **Recommendations for Action**

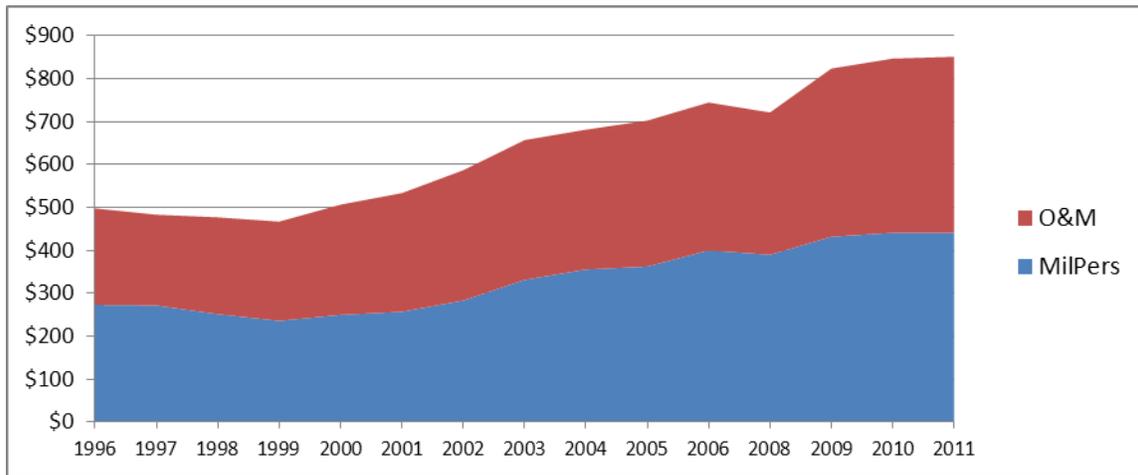
The researcher came across a few items that are worthy of deeper focus in future studies. One such item would be to determine why the 91st MW is only assigned 1% of the indirect costs at Minot. It may be that the MW consumes significantly fewer resources than the 5th BW, but the actual percentage should be verified. Further analysis of other percentages of indirect costs at each base are worthy of more analysis. This

thesis is unclassified, which limits some of the analysis of how future options could affect indirect costs. However, it would be beneficial to determine if there is a plan (and what it is) for directing resources if any echelon of the WS is deactivated. For example, what percentage of personnel would be affected if a LF, MAF, squadron, or wing were eliminated? In addition, would the personnel be reassigned within the enterprise, reassigned to another weapon system, or eliminated? In addition to the personnel driver, assigning indirect costs can also be affected by the intended use of a base if the mission is changed. If an installation receives a new mission in place of the ICBM mission, then the installation-indirect costs will no longer be associated with the WS-133A/M, but will still be a real cost to the DOD.

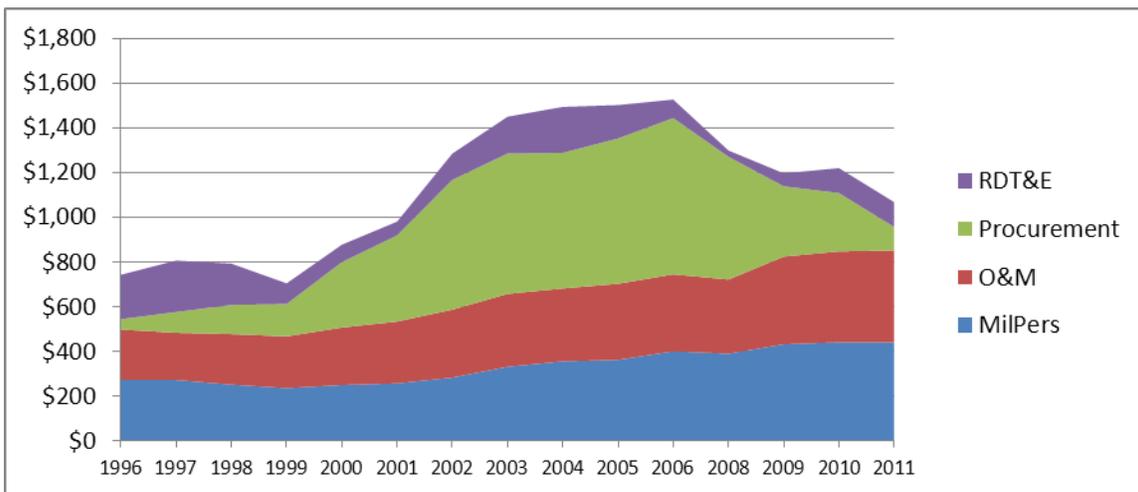
### **Recommendations for Future Research**

Future research can expand this model by developing a predictive model for CPAH. The current analysis is based on FY11 values. This analysis does not identify what the expected CPAH will be in future years. Developing a predictive model is a challenging proposal, but could be very useful to decision makers. In the course of collecting data for this thesis, the researcher was provided a chart similar to Figure 18 below. The figure shows the O&M and active duty personnel appropriated funds for the LGM-30G; the data is from PEC 11213F. All dollar values are adjusted from “then year dollars” to FY11 dollars. The graph shows how the selected cost drivers have been increasing most years. As this thesis shows, there are other cost drivers that may paint a more accurate picture. Figure 19, includes the same cost drivers as Figure 18 along with research, development, testing, and evaluation (RDT&E) and procurement costs. All

four elements together comprise the total appropriated funds for the weapon system. When all the drivers are chosen, a very different trend emerges. Thus, future research would need to analyze carefully which drivers best predict total WS costs for future years.



**Figure 17: LGM-30 O&M and Personnel Appropriations Summary (in millions) (AFTOC, 2012)**



**Figure 18: LGM-30 Appropriations Summary (in millions) (AFTOC, 2012)**

Another element to consider in future research would be a variable accounting for the average age of the ICBM and/or ICBM selected components. As stated in the literature review, systems experience higher failure rates as they age. The accuracy of predicting future CPAHs will be increased if the model is able to account for the expected increase in failures based on age, year over year. Additionally, a predictive model could include the number of maintenance visits per LF as a variable. Many of the cost associated with operating the ICBMs are fixed; however, the largest variable portion is related to maintenance actions.

### **Summary**

This chapter provides the researchers final remarks and recommendations for future analyses. This thesis presents both AF level data and data obtained from interviews with SMEs. The result is a broad analysis across each level of management for the Minuteman III. This wide-ranging perspective prepares the field for future researchers and decision makers to conduct more in-depth follow-on studies. The results of this study, along with future studies, will continue to improve our stewardship of the ICBM nuclear component.

## Appendix A: Abbreviations and Acronyms

ABIDES	Automated Budget Interactive Data Environment System
AF	Air Force
AFB	Air Force Base
AFCIAG	Air Force Cost Improvement Group
AFGSC	Air Force Global Strike Command
AFTOC	Air Force Total Ownership Cost
BW	Bomber Wing
CAPE	Cost Analysis Program Evaluation
CPAH	Cost-per-[missile] alert-hour
CPFH	Cost-per-flying-hour
DLR	Depot Level Repairables
EEIC	Element of Expense/Investment Code
ICBM	Intercontinental Ballistic Missile
IPIC	ICBM Prime Integration Contract
LF	Launch Facility (Single Minuteman III)
LGM-30	Nomenclature for Minuteman III
MAF	Missile Alert Facility (Missile Flight)
MM III	Minuteman III ICBM
MW	Missile Wing
OSD CAIG	Office of Secretary of Defense Cost Analysis Improvement Group
PEC	Program Element Code
WS	Weapon System
WS-133A/M	Nomenclature for entire Minuteman III weapon system and peripheral systems

**Appendix B: AFCAIG (CAPE) Missile**  
**Operating and Support Cost Element Structure**

**1.0 MISSION PERSONNEL**

1.1 OPERATIONS

1.2 MAINTENANCE

1.3 OTHER MISSION PERSONNEL

**2.0 UNIT-LEVEL CONSUMPTION**

2.1 POL/ENERGY CONSUMPTION

2.2 CONSUMABLE MATERIAL/REPAIR PARTS

2.3 DEPOT-LEVEL REPARABLES

2.4 TRAINING MUNITIONS/EXPENDABLE STORES

2.5 OTHER

**3.0 INTERMEDIATE MAINTENANCE (EXTERNAL TO UNIT)**

3.1 MAINTENANCE

3.2 CONSUMABLE MATERIAL/REPAIR PARTS

3.3 OTHER

**4.0 DEPOT MAINTENANCE**

4.1 OVERHAUL/REWORK

4.2 OTHER

**5.0 CONTRACTOR SUPPORT**

5.1 INTERIM CONTRACTOR SUPPORT

5.2 CONTRACTOR LOGISTICS SUPPORT

5.3 OTHER

**6.0 SUSTAINING SUPPORT**

6.1 SUPPORT EQUIPMENT REPLACEMENT

6.2 MODIFICATION KIT PROCUREMENT/INSTALLATION

6.3 OTHER RECURRING INVESTMENT

6.4 SUSTAINING ENGINEERING SUPPORT

6.5 SOFTWARE MAINTENANCE SUPPORT

6.6 SIMULATOR OPERATIONS

6.7 AIR SUPPORT

6.8 OTHER

**7.0 INDIRECT SUPPORT**

7.1 PERSONNEL SUPPORT

7.2 INSTALLATION SUPPORT

### Appendix C: OSD CAIG Based Model Details

		LGM-30				
		Comprehensive	Ownership	Operating	Indirect	
		CPA	15,057	7,867	5,773	7,190
		CPAH	627	328	241	300
		Alert Hours	3,942,000	3,942,000	3,942,000	3,942,000
		<b>Total Assessed Cost</b>	<b>2,473,149,042</b>	<b>1,292,216,167</b>	<b>948,260,167</b>	<b>1,180,932,875</b>
		<b>Modification Cost</b>	<b>343,956,000</b>	<b>343,956,000</b>		
OSD OWNERSHIP COST	OSD OPERATING COST	1.0 Unit Personnel	680,391,818	420,509,716	420,509,716	259,882,102
		2.0 Unit Operations	142,175,907	46,368,719	46,368,719	95,807,188
		3.0 Maintenance	308,637,741	306,843,120	306,843,120	1,794,621
		4.0 Sustaining Support	23,789,427	21,585,028	21,585,028	2,204,399
		5.0 Continuing System Improvements	103,829,958	103,828,658	103,828,658	1,300
		6.0 Indirect Support	870,368,190	49,124,926	49,124,926	821,243,264

		AFGSC			Wing (Malmstrom)			
		Comp.	Operating	Indirect	Comp.	Operating	Indirect	
		CPA	10,330	3,180	7,151	5,712	2,908	2,803
		CPAH	430	132	298	238	121	117
		Alert Hours	3,942,000	3,942,000	3,942,000	1314000	1314000	1314000
		<b>Total Assessed Cost</b>	<b>1,696,716,969</b>	<b>522,240,415</b>	<b>1,174,476,554</b>	<b>312,714,003</b>	<b>159,236,891</b>	<b>153,477,113</b>
		<b>Modification Cost</b>						
OSD OWNERSHIP COST	OSD OPERATING COST	1.0 Unit Personnel	660,697,776	403,999,241	256,698,535	154,166,467	135,307,896	18,858,572
		2.0 Unit Operations	155,316,508	59,530,962	95,785,546	13,209,287	7,797,141	5,412,146
		3.0 Maintenance	1,794,621	0	1,794,621	4,853,010	4,553,088	299,922
		4.0 Sustaining Support	10,176,380	7,971,981	2,204,399	0	0	0
		5.0 Continuing Sys Impmts	1,852,005	1,850,705	1,300	0	0	0
		6.0 Indirect Support	866,879,679	48,887,526	817,992,153	140,485,240	11,578,767	128,906,473

## **Appendix D: Minuteman III Description (USAF, LGM-30 Factsheet)**

### **Mission**

The LGM-30G Minuteman intercontinental ballistic missile, or ICBM, is an element of the nation's strategic deterrent forces under the control of the Air Force Global Strike Command. The "L" in LGM is the Department of Defense designation for silo-launched; "G" means surface attack; and "M" stands for guided missile.

### **Features**

The Minuteman is a strategic weapon system using a ballistic missile of intercontinental range. Missiles are dispersed in hardened silos to protect against attack and connected to an underground launch control center through a system of hardened cables. Launch crews, consisting of two officers, perform around-the-clock alert in the launch control center.

A variety of communication systems provide the president and secretary of defense with highly reliable, virtually instantaneous direct contact with each launch crew. Should command capability be lost between the launch control center and remote missile launch facilities, specially configured E-6B airborne launch control center aircraft automatically assume command and control of the isolated missile or missiles. Fully qualified airborne missile combat crews aboard airborne launch control center aircraft would execute the president's orders.

An extensive life extension program is underway to keep the remaining missiles safe, secure and reliable well into the 21st century. These major programs include: remanufacture of the solid-propellant rocket motors, replacement of standby power

systems, repair of launch facilities, and installation of updated, survivable communications equipment and additional security enhancements.

## **Background**

The Minuteman weapon system was conceived in the late 1950s and Minuteman I was deployed in the early 1960s. Minuteman was a revolutionary concept and an extraordinary technical achievement. Both the missile and basing components incorporated significant advances beyond the relatively slow-reacting, liquid-fueled, remotely-controlled intercontinental ballistic missiles of the previous generation. From the beginning, Minuteman missiles have provided a quick-reacting, inertially guided, highly survivable component to America's strategic deterrent program. Minuteman's maintenance concept capitalizes on high reliability and a "remove and replace" approach to achieve a near 100 percent alert rate.

Through state-of-the-art improvements, the Minuteman system has evolved to meet new challenges and assume new missions. Modernization programs have resulted in new versions of the missile, expanded targeting options, improved accuracy and survivability. Today's Minuteman weapon system is the product of almost 40 years of continuous enhancement.

The current Minuteman force consists of 450 Minuteman III's located at the 90th Missile Wing at F.E. Warren AFB, Wyo.; the 341st Missile Wing at Malmstrom AFB, Mont.; and the 91st Missile at Minot AFB, N.D.

## **General Characteristics**

**Primary Function:** Intercontinental ballistic missile

**Contractor:** Boeing Co.

**Power Plant:** Three solid-propellant rocket motors; first stage - Thiokol; second stage - Aerojet-General; third stage - United Technologies Chemical Systems Division

**Thrust:** First stage, 202,600 pounds

**Length:** 59.9 feet (18 meters)

**Weight:** 79,432 pounds (36,030 kilograms)

**Diameter:** 5.5 feet (1.67 meters)

**Range:** 6,000-plus miles (5,218 nautical miles)

**Speed:** Approximately 15,000 mph (Mach 23 or 24,000 kph) at burnout

**Ceiling:** 700 miles (1,120 kilometers)

**Date deployed:** June 1970, production cessation: December 1978

**Inventory:** Active force, 450; Reserve, 0; ANG, 0

### Appendix E: Program Element Codes Used

<b>PE (AF - 6 Digit)</b>	<b>Title</b>	<b>Description</b>
<b>11198F</b>	Management HQ-Global Strike Command (AFGSC)	Includes manpower authorizations, peculiar and support equipment, necessary facilities and the associated costs specifically identified and measurable to the following: Global Strike Command (GSC); HQ 8th Air Force; Excludes non-management headquarters resources WWMCCS ADP.
<b>11213F</b>	MINUTEMAN Squadrons	Minuteman Squadrons: This program element supports the operation and maintenance of the Minutemen weapon system. It supports missile modifications to include Guidance Replacement and Propulsion Replacement Programs. The PE includes manpower authorizations, peculiar and support equipment, necessary facilities and the associated costs specifically identified and measurable to the Minuteman weapon system. Includes: wing headquarters, missile squadrons, missile maintenance, munitions maintenance and weapon system security. Excludes: nuclear warhead component costs which are handled by the Department of Energy and dedicated intrasite communications.
<b>11215F</b>	PEACEKEEPER Squadrons	Peacekeeper Squadrons: Includes manpower authorizations, peculiar and support equipment, necessary facilities and the associated costs specifically identified and measurable to the Peacekeeper weapon system (Minuteman silos basing mode). Includes Wing Headquarters, Missile Squadrons, Missile Maintenance, Munitions Maintenance, Missile Site Support Aircraft, Weapons System Security, and weapons system acquisition costs. Excludes advanced missile training, nuclear warhead component costs which are borne by Atomic Energy Commission and missile site support.
<b>11235F</b>	ICBM Helicopter Support	ICBM Helicopter Support: Funds operational costs for ICBM helicopter support required by nuclear weapon system safety rules for convoy movements. Provides essential equipment, crew manpower, and flying hours for commanders to run day-to-day maintenance and operation of these MAC operated helicopters in support of SACs ICBM fleet.

<b>11321F</b>	Special Purpose Communications	Special Purpose Communications: Includes manpower authorizations, peculiar and support equipment, necessary facilities and the associated costs specifically identified and measurable to the following: Air Force Low Frequency System (487L) Transmitters Receivers at Northern Area UHF Sites, Minuteman and Titan Missile Sites, Wing Command Posts, and COC Communications Squadrons Excludes resources identified to the airborne command posts (see PACCS elements in this program and Programs 2 and 3).
<b>11323F</b>	MINUTEMAN Communications	Minuteman Communications: Includes the non-DCS procurement, construction, and operations resources required to support the ICBM Minuteman Squadrons (PE 0101213F)and the communications resources required to support the administrative, logistic, and launch/status functions. Additionally, this program element includes the intersite and intrasite communications resources required to support the command control function. Excludes communications resources integral to the weapons system which are designed for and delivered with and as a part of the missile complex, and whose costs are normally included in the cost of the weapons system.
<b>11879F</b>	Facilities Operations - Offensive	Facilities Operations - Offensive: Includes manpower authorizations, peculiar and support equipment, necessary facilities, contracts, and associated costs to plan, manage, and execute these functions: Fire prevention and protection including crash rescue, emergency response, and disaster preparedness, engineering readiness including explosive ordnance disposal, and Prime BEEF forces, utilities to include plant operation and purchase of commodity, refuse collection and disposal to include recycling operations, pavement clearance including snow and ice removal from roads, and airfields, lease costs for installation real property including off-base facilities, grounds maintenance and landscaping, real property special inspections of facilities and master planning, pest control, and custodial services. Excludes sustainment, restoration, and modernization of facilities, other environmental services (such as disposal of hazardous materials), and mission-funded contingency costs which are funded elsewhere. The title of this PE was changed from Real Property Services.

<b>11978F</b>	Facilities Sustainment - Offensive	Facilities Sustainment - Offensive: Facilities Sustainment. Provides resources for maintenance and repair activities necessary to keep facilities in the Departments real property inventory in good working order. It includes regularly scheduled adjustments and inspections, preventive maintenance tasks, and emergency response and service calls for minor repairs. It also includes major repairs or replacement of facility components (usually accomplished by contract) that are expected to occur periodically throughout the life cycle of facilities. This work includes regular roof replacement, refinishing of wall surfaces, repairing and replacement of heating and cooling systems, replacing tile and carpeting, and similar types of work. It does not include certain restoration, modernization, and environmental compliance costs which are funded elsewhere. Other tasks associated with facilities operations (such as custodial services, grass cutting, landscaping, waste disposal, and the provision of central utilities) are also not included. This program supports all facilities reported in the real property inventory for which the Facilities Sustainment Model provides a funding requirement estimate, it excludes unreported facilities or any other facilities for which the Facilities Sustainment Model does not estimate a funding requirement.
<b>18538F</b>	Installation Law Enforcement Operations - SAFs	Installation Law Enforcement Operations - SAFs: Includes manpower authorizations, contracts, peculiar and support equipment, and associated costs specifically identified and measurable to plan, manage, coordinate, and execute functions of Installation Law Enforcement (LE) Operations. Installation LE Operations includes enforcing federal, state and military law, enforcing installation guidance, issuance of citations, detaining suspects, motor vehicle traffic management, traffic investigations, apprehension and restraint of offenders, and crowd control, crime prevention, crime detection, LE patrols, LE liaison, apprehension of persons who commit crimes on the installation, testifying in prosecution cases and temporary detention of offenders. This includes protecting, defending, and deterring against criminal activities, conduct of minor investigations, the development of plans for the employment of law enforcement personnel, emergency response, and management as it relates to law enforcement activities and functions and which includes all processes intended to preserve the principles of law through various strategies. Excluded are the following functional

		categories: Facilities Operations (Real Property Services), Facilities Sustainment, Facilities Restoration and Modernization, and Facilities Demolition/Disposal, which are reported under separate PEs.
<b>18539F</b>	Physical Security Protection Service - SAFs	Physical Security Protection Service - SAFs: Includes manpower authorizations, contracts, peculiar and support equipment, and associated costs specifically identified and measurable to plan, manage, coordinate, and execute functions of Installation Physical Security Protection and Services. This includes personnel, procedures and equipment measures employed or designed to safeguard personnel, facilities and property from loss, destruction, espionage, terrorism, or sabotage on the installation, prevent unauthorized access to facilities/installations/restricted areas, equipment, and materials. This includes regulation of people, material, and vehicles entering or exiting a designated area, mobile and static security activities for the protection of installation or government assets, conduct of physical security inspections/assessments, construction design review, special protection of high value or sensitive property and management of installation security systems, plans and funding. Excluded are the following functional categories: Facilities Operations (Real Property Services), Facilities Sustainment, Facilities Restoration and Modernization, and Facilities Demolition/Disposal, which are reported under separate PEs.
<b>18542F</b>	Transportation Logistics - SAFs	Transportation Logistics - SAFs: Includes manpower authorizations, contracts, peculiar and support equipment, and associated costs specifically identified and measurable to manage and administer the acquisition, dispatch, operation (includes arranging for the movement of passengers, cargo, and personal property), maintenance, and disposal of all non-tactical government owned and controlled vehicles and transportation related equipment used for the day-to-day support of installation operations. This includes, but is not limited to, vehicles (passenger carrying, special purpose and general purpose) and equipment such as railway equipment, portable generators (not supplying facility back-up power), mobile cranes, material-handling equipment, construction equipment, civil engineering support equipment, contractual transportation equipment, such as contractual bus services, vehicle

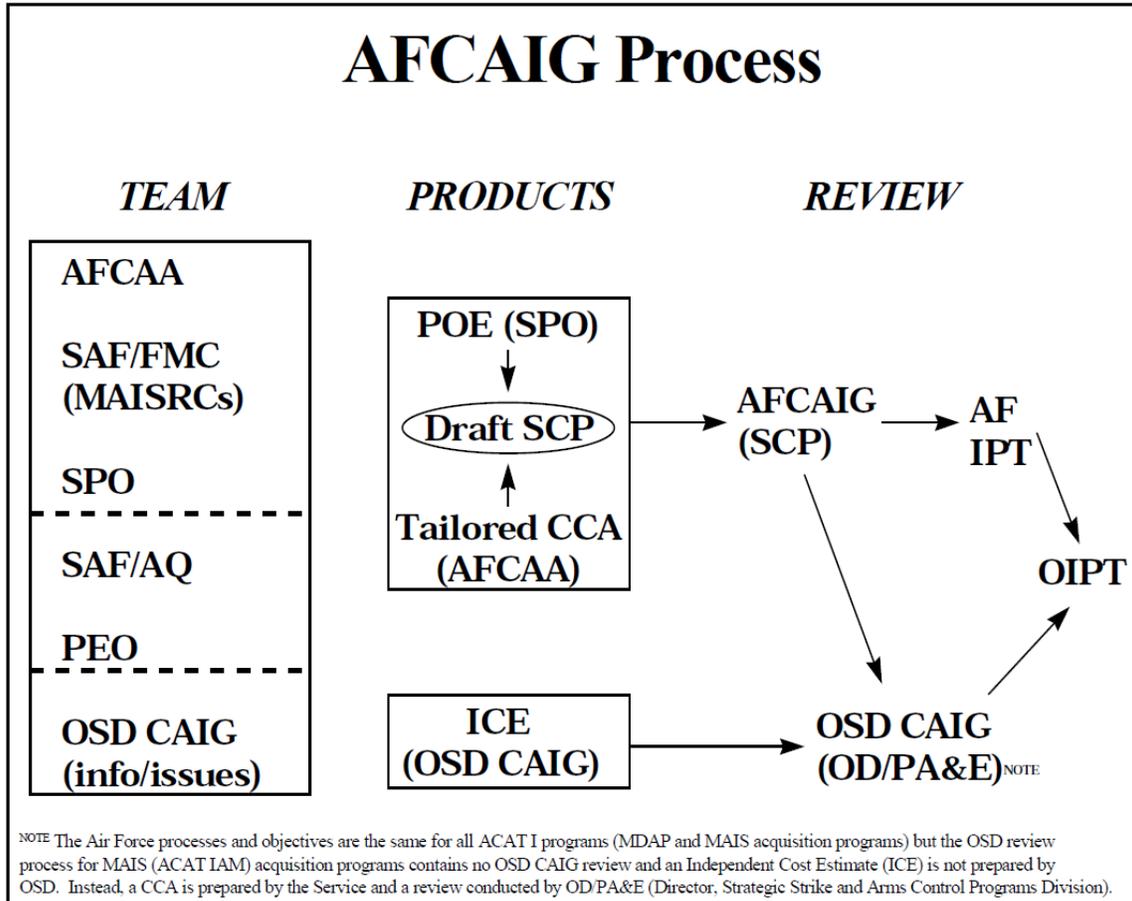
		<p>leasing, and other transportation services. This does not include those vehicles and equipment used in direct connection with or in support of combat or tactical operations. This includes Installation Movement operational activities to include deployment, sustainment (resupply), redeployment, passenger services, passenger terminal and cargo handling operations to include airfield arrival/departure, personal property movement, Privately Owned Vehicles (POVs), mobile homes, and movement of freight. Excluded are the following functional categories: Facilities Operations (Real Property Services), Facilities Sustainment, Facilities Restoration and Modernization, and Facilities Demolition/Disposal, which are reported under separate PEs.</p>
<p><b>18550F</b></p>	<p>IT Services Management - Offensive</p>	<p>IT Services Management - Offensive: Includes manpower authorizations, contracts, peculiar and support equipment, and associated costs specifically identified and measurable to plan, manage, coordinate, and execute Information Technology Services Management (ITSM). Includes the delivery of services consisting of secure and non-secure fixed voice communications, wireless voice, data and video connectivity services, video conferencing services (excludes desktop video teleconferencing (VTC) Collaboration). Provides infrastructure support, including the design, installation, and maintenance of special circuits/systems in support of life safety/security systems and monitoring/control systems. Provides Collaboration and Messaging Services including services and tools for workforce to communicate and share information). Provides Application and Web-hosting including operation and management services required to support web and application hosting. Provides for IT Operations Centers including systems and processes necessary to allow customers to have seamless access to IT applications and solutions. Provides Desktop Management Support including management and support for end-user hardware and software services and tools. Includes Service Desk Support, Continuity of Operations (COOP) and Disaster Recovery support, requirements and training for common-user software applications, Information Assurance, and Multimedia/Visual Information. Provides printing, publication, and duplication services. Excluded are the following functional categories: Facilities Operations (Real Property Services), Facilities Sustainment, Facilities Restoration and Modernization, and Facilities</p>

		Demolition/Disposal, which are reported under separate PEs.
<b>27588F</b>	Air Base Ground Defense	Air Base Ground Defense: This program procures equipment and provides for the sustainment of security forces (CONUS, OCONUS, and in-place mobility) assigned to detect and defeat various threats directed against Air Force resources and personnel during peacetime contingencies and execution of war plans. The personnel and equipment provided by this program contribute to the overall Air Force antiterrorism/force protection program. It enhances security forces ability to provide rapid responses by building more deployable, flexible, and sustainable forces capable of operating from other than main operating bases to support sustained sortie generation and air operations. It directs the procurement of advanced technology force multipliers to include: night vision and thermal imagery equipment, counter sniper/battery capabilities, ground weapons, target acquisition radar, interoperable tactical communications, wheeled tactical armored vehicles, tactical sensors systems and unit/personnel protective field equipment. This program protects and defends personnel and other critical Air Force resources.
<b>87700F</b>	Defense Medical Centers, Station Hospitals & Medical Clinics - CONUS	Defense Medical Centers, Hospitals, Medical Clinics - CONUS - Includes manpower authorizations, peculiar and support equipment, necessary facilities and the associated costs specifically identified and measurable to the following: Resources devoted to the provision of health care in DOD-owned and operated CONUS facilities which are staffed, and equipped to provide inpatient care for both surgical and non-surgical conditions and/or outpatient care for non-hospital type patients. Includes medical centers, station hospitals, medical clinics, subordinate aid stations, resource sharing and resource support agreements, federal sharing agreements, medical center laboratories which are integral to these facilities, alcohol abuse treatment programs conducted at these facilities, clinical investigations activities conducted at these activities, and

		<p>staff support for on-the-job training and education programs conducted at these facilities. Excludes supplemental care costs specifically identified and measurable to health care services received in a non-defense facility as a result of a referral for authorized beneficiaries of the military services. Excludes resources associated with the operation of management headquarters for regional lead agents, dental clinics, tactical medical units (see appropriate elements in Programs 2 and 5) and other health care resources devoted exclusively to teaching (see appropriate elements in this program).</p>
<b>32053F</b>	<p>NMCS-wide Support - Communications</p>	<p>National Military Command System (NMCS)-Wide Support - Communications: Includes manpower authorizations, peculiar and support equipment, necessary facilities and the associated costs specifically identified and measurable to the following: Resources in support of the National Military Command System as defined in DOD Directive 5105.19 necessary for support of the National Military Command System as defined in DOD Directive 5105.19 necessary for support of multiple facilities of the NMCS. This includes leased/government-owned circuitry supporting the NMCS which interconnect multiple facilities of the NMCS. This includes: ARMY: Automatic Message Processing System (AMPS), Secure Data and Visual Communication System (SDVCS), Washington Area High Speed Facsimile Network (WASHFAX), NMCC Message Center (NMCC/MCO), and dedicated leased communications circuits and equipment for the above. AIR FORCE: EMATS, MINUTEMAN, WHEEL HOUSE, WASHINGTON SWITCH, CAOCOMNET, JOTS, JCSAN, and JCCs. NEACP: Resources for leased/government-owned circuitry, personnel, installation, hardware improvement, construction and other activities which interconnect the NEACP with multiple facilities of the NMCS, agencies and command centers via ground entry points. NMCC: Resources for leased circuitry personnel, installations, hardware improvement, construction and other activities which interconnect the NMCC with the ANMCC and with communications networks that in turn provide access to other command centers and the Unified and Specified Commands. NAVY: Resources to include leased/government-owned circuitry supporting the NMCS which interconnect multiple facilities of the NMCS, including digital, video, facsimile teletype or voice related systems. Excludes all NMCS</p>

		resources identified and reported in PEs 0302012A, 0302052F and 03034010.
<b>63851F</b>	Intercontinental Ballistic Missile (ICBM) - Demonstration/Validation	ICBM - DEM/VAL - Includes demonstration and validation development efforts to support Minuteman efforts focused on extending the service life of Minuteman III through 2020, including replacing 1960 vintage electronics in the guidance system and refurbishing propulsion stages to correct age-related degradation and to maintain reliability.

**Appendix F: AFCAIG Process (SAF/FMCC)**





# Minuteman III Cost Per Alert Hour Analysis

# AFIT

Capt Allen R. Miller

Co-Advisor: Dr. William Cunningham

Co-Advisor: Dr. Jeffery Ogden

Department of Operational Sciences (ENS)

Air Force Institute of Technology

### Introduction

This research analyzes the cost associated with the Minuteman III (MM III) weapon system. The research develops three models for determining MM III costs per alert hour (CPAH). The first model is based on the Air Force Cost Analysis Improvement Group cost per flying hour model. The model is modified to include depot level repairables, consumables, and personnel costs. The second model is based on the Office of the Secretary of Defense, Cost Analysis Improvement Group cost per flying hour model and is formulated using service-wide data from the Air Force Total Ownership Cost tool. The third model is a comprehensive model including indirect costs associated the ICBM-supporting installations. Additionally, this research includes a CPAH for each echelon or level of management for the MM III

### Research Questions

- Can the Air Force Cost Analysis Improvement Group (AFCOIG) and Office of the Secretary of Defense, Cost Analysis Improvement Group (OSD CAIG) aircraft cost per flying hour models be used to develop cost per alert hour models for the LGM-30 weapon system? If so, what are the differences?
- Do cost per alert hour factors change significantly based on the level of management?
- What cost drivers should be included in developing a comprehensive CPAH model for the LGM-30 weapon system?
- What is the relationship of costs and alert hours?



### Models and Results

#### AFCOIG CPAH Model

$$DLRs + Consumables + Personnel = \text{Cost Per Alert Hour} \\ \text{Alert Hours}$$

	LGM-30	AFSC	Wing
DLR	\$ 10,310,625	\$ 10,417,444	\$ 3,636,875
COFs	\$ 97,601,609	\$ 97,550,167	\$ 12,350,252
Personnel	\$ 459,286,124	\$ 440,878,763	\$ 135,107,896
Total Assessed Cost	\$ 667,208,358	\$ 648,846,374	\$ 151,294,999
Alert Hours	\$ 3,942,000	\$ 3,942,000	\$ 3,314,000
CPAH	\$ 169.54	\$ 164.65	\$ 45.68

#### OSD CAIG CPAH Model

Based on Office of Secretary of Defense  
Cost Analysis Improvement Group Elements

- Unit Personnel
- Unit Operations
- Maintenance
- Sustaining Support
- Continuing System Improvements
- Indirect Support

$$\text{OSD CAIG Elements} = \text{Operating Cost Per Alert Hour} \\ \text{Alert Hours}$$

$$\text{OSD CAIG Elements} + \text{Modification Cost} = \text{Ownership Cost Per Alert Hour} \\ \text{Alert Hours}$$

	LGM-30	AFSC	Wing
OSD CAIG Elements	\$ 420,500,000	\$ 400,000,000	\$ 120,000,000
OSD Unit Personnel	\$ 46,568,718	\$ 46,568,718	\$ 59,550,965
OSD Unit Operations	\$ 306,843,000	\$ 306,843,000	\$ -
OSD Sustaining Support	\$ 21,588,028	\$ 21,588,028	\$ 7,971,985
OSD Continuing System Improvements	\$ 103,820,000	\$ 103,820,000	\$ 1,800,700
OSD Indirect Support	\$ 49,124,025	\$ 49,124,025	\$ 11,573,703
Modification Cost	\$ 345,000,000	\$ -	\$ -
Total Assessed Cost	\$ 1,222,148,871	\$ 848,260,141	\$ 139,234,893
Alert Hours	\$ 3,942,000	\$ 3,942,000	\$ 3,314,000
CPAH	\$ 310.03	\$ 215.16	\$ 42.01

#### Comprehensive CPAH Model

$$\text{OSD CAIG Ownership Cost} + \text{Indirect Base Costs} = \text{Comprehensive CPAH} \\ \text{Alert Hours}$$

	LGM-30	AFSC	Wing
OSD CAIG Elements	\$ 420,500,000	\$ 400,000,000	\$ 120,000,000
OSD Unit Personnel	\$ 46,568,718	\$ 46,568,718	\$ 59,550,965
OSD Unit Operations	\$ 306,843,000	\$ 306,843,000	\$ -
OSD Sustaining Support	\$ 21,588,028	\$ 21,588,028	\$ 7,971,985
OSD Continuing System Improvements	\$ 103,820,000	\$ 103,820,000	\$ 1,800,700
OSD Indirect Support	\$ 49,124,025	\$ 49,124,025	\$ 11,573,703
Modification Cost	\$ 345,000,000	\$ -	\$ -
Total Assessed Cost	\$ 1,222,148,871	\$ 848,260,141	\$ 139,234,893
Alert Hours	\$ 3,942,000	\$ 3,942,000	\$ 3,314,000
CPAH	\$ 310.03	\$ 215.16	\$ 42.01

### Conclusion

- Squadron CPAH provide single most informative value.
- Analyzed with three sets of data
- All values were within 5%
- First level where savings are actualized
- Most likely echelon to be affected by budget decisions

### Alert Hours

Echelon	Alert Hours Per Year	Alerts Per Year
Launch Facility	8,760	365
Missile Alert Facility	87,600	3650
Missile Squadron	438,000	18,250
Missile Wing	1,314,000	54,750
Command and WS	3,942,000	164,250

### Model Integration

	LGM-30	AFSC	Wing	Squadron	Flight (MAF)	Missile (LF)
AFCOIG CPAH	\$ 169.54	\$ 164.65	\$ 45.68	\$ 36.94	\$ 34.00	\$ 50.40
OSD CAIG CPAH	\$ 310.03	\$ 215.16	\$ 42.01	\$ -	\$ -	\$ -
Comprehensive	\$ 627.38	\$ 480.42	\$ 237.99	\$ -	\$ -	\$ -

Sponsor:  
AFNWC/LG

### Recommendations

- AFCOIG model
  - Data availability makes limitations unnecessary
  - Most commonly accepted model in aviation community, easily communicated
  - Recommended for larger AF comparisons
- OSD CAIG model
  - More factors to consider
  - Readily accessible data set
  - Recommended for ICBM community decision makers
- Comprehensive model
  - Assumption of mission resource termination debatable
  - Provides insight into actual costs of ICBM mission
  - Recommended for strategic-level considerations

Squadron CPAH Metric	
Cost Per Alert Hour	\$ 37
Cost Per Alert	\$ 887
Annual Cost Per LF	\$ 323,629
Annual Cost Per Squadron	\$ 16,181,456

Appendix G: Thesis Storyboard

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