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The Correlation of Human Capital on Costs of Air Force Acquisition Programs

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THESIS

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Abstract

Previous studies have linked human capital with performance. The studies have shown performance, measured as output, of a firm can be increased by adding more personnel and/or increasing education levels. This research uses the Cobb-Douglas Production function to build upon that relationship of inputs to outputs. The output in this study is the average cost overrun of Aeronautical Systems Center research, development, test, and evaluation contracts managed from 1994 to 2008. The inputs are the numbers of military/government employee financial managers, program managers, engineers, rated personnel, and military/government employees in those career fields possessing a graduate degree or higher. A time series regression was conducted using those inputs to outputs while controlling for other factors such as budgetary fluctuations, inflation, and individuals doing defense related work in the private sector as a proxy for contractors working in program offices. The results indicate a negatively correlated relationship exists between human capital and cost overruns.

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This work is dedicated to my wife who is also my best friend. Without her support and encouragement, this effort would not have been possible.

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THE CORRELATION OF HUMAN CAPITAL ON COSTS OF AIR FORCE ACQUISITION PROGRAMS

I. Introduction

Purpose

The purpose of this research was to determine if there is a relationship between the number of program office personnel and their corresponding education levels on cost variances for contracts managed by the Aeronautical Systems Center (ASC) located at Wright Patterson Air Force Base, Ohio (WPAFB). This research focused on civilian and military personnel assigned to the cost, program management, and engineering career fields as well as rated officers assigned to acquisition positions within the Air Force Materiel Command (AFMC) at WPAFB. Rated officers are military personnel that possess an aeronautical rating.

Previous Research

The Department of Defense (DoD) routinely experiences difficulty in fielding major weapon systems within allotted budgets. The Air Force is no exception and has historically struggled with cost overruns. Multiple studies have been completed with little success in finding a policy lever to implement to overcome cost overruns. The next few sections of this chapter briefly cover studies completed on overruns, acquisition reform, the private sector, the current Air Force labor force and the research objective.

Overrun Studies

Historical studies on cost overruns indicate they have ranged from an underrun of 1% to an overrun of 68% (Christensen & Gordon, 1998; Drezner, Jarvaise, Hess, Norton, & Hough, 1993; Rusnock, 2008). The results from those studies varied with respect to the causes of the cost overruns. Drezner et al. (1993) found there was no “silver bullet” strategy in bringing cost overruns under control. Their study quantified the magnitude of weapon system cost growth along a number of dimensions but they could not definitively account for the observed cost growth patterns (Drezner et al., 1993). Christensen et al. (1998) identified estimation error as the causal factor in cost overruns. Rusnock (2008) discovered cost overruns vary significantly by commodity type. She found cost overruns in space systems varied significantly from those in aircraft and missiles and ascertained certain predictor variables have a causal relationship with overruns in space systems. She found communications missions, ground equipment, firm-fixed price contracts, and increased program manager tenure are all predictive of lower cost growth for military space systems (Rusnock, 2008). Regardless of the cause of the overrun, the increased costs result in additional funds being directed to the program thus creating instability in the planning, programming, budgeting, and execution (PPBE) system currently used by the DoD. The perpetual drain on investment accounts as a result of instability was what led Dr. Paul G. Kaminksi, a former Under Secretary of Defense for Acquisition, to adopt program stability as his number one acquisition reform initiative (Czelusniak, 1997). In extreme cases, overruns led to program cancellations like the Navy’s A-12 program and the Tri-Service Standoff Attack Missile (TSSAM) for the Air Force (FAS, 2009). Both programs experienced significant cost growth leading to the DoD cancelling them (FAS, 2009).

Acquisition Reform

Some historical studies reviewed specifically acquisition reform and whether or not the initiatives set forth by the government had any effect on cost overruns. The results of those studies are mixed. For example, Christensen et al. (1999) examined 269 defense programs from 1988 through 1995 and found the Packard Commission recommendations did not reduce average cost overruns at all. During that time period, the cost performance on those contracts actually worsened significantly (Christensen et al., 1999). The Packard Commission was initiated in 1985 by President Reagan and was focused on broad organizational changes within the DoD and would become the Reagan Administration's most recognized acquisition reform movement (Holbrook, 2003). Drezner et al. (1993) found similar results of the ineffectiveness of reform initiatives in reviewing 197 acquisition programs from 1960 through 1990. Holbrook (2003) also found parallel results. There was no statistically significant difference in the overruns percentages on pre-reform contracts and post-reform contracts (Holbrook, 2003). Smirnoff (2006) however found the Packard Commission, the Nunn-McCurdy Act of 1982 and the Federal Acquisition Streamlining Act (FASA) of 1994 all led to significant cost savings. The Nunn-McCurdy Act requires the DoD to notify Congress when cost growth exceeds 15% of the original estimate and calls for programs to be cancelled if growth is over 25% of the original estimate unless the DoD submits justification for the program to continue. FASA's intent was to overhaul the cumbersome and complex procurement system of the federal government and more importantly the DoD (Holbrook, 2003).

Private Sector Studies

The previous studies attempted to identify causes of overruns and effectiveness of government wide reform initiatives. Some private sector studies go even further by scrutinizing individual workers to determine the effects of individual efforts on overall firm productivity. The studies are not specific to DoD cost estimating but the same outcome is generalizable to any organization because the studies measured individual efforts without regard to specific career fields. The two types of studies are those relating to the number of personnel (Aral, Brynjolfsson & Van Alstyne, 2007; Li, 2002; Shaw & Weekley, 1985) and those relating to the education level of personnel (Bartel, 1994; Lynch & Black, 1995; Nelson & Phelps, 1966). These studies concluded the number of personnel and their corresponding education level are positively correlated with firm performance. A few of the studies argued for some of the indirect benefits of education for the firm. Two studies found the more educated a firm's employees are, the more likely they are to be innovative and productive (Blundell, Dearden & Meghir, 1996; Lynch & Black, 1995).

Current Air Force Manning and Research Objective

The Air Force has incurred manpower reductions throughout its history and has lost some very talented personnel within its ranks. However, the Air Force realized favorable retention rates following September 11, 2001, and received additional manpower authorizations from Congress due to the global war on terrorism (GWOT) (*Military Personnel End Strength*, n.d.). Those additional authorizations were on a year by year basis. The Air Force anticipated their authorized end strength numbers would decrease over time as the GWOT efforts would hopefully diminish and the entire DoD would begin to downsize once again.

In order to meet their projected end strength numbers, the Air Force instituted force shaping initiatives which allowed and in some cases forced service members to depart the Air Force ahead of their active duty service commitments. This decision is currently a hot topic of debate among Air Force leaders and members alike. The Secretary of Defense, in considering the burdens created by a reduced workforce, did not think force shaping was the right tool at the time to re-size the Air Force so he halted the force shaping initiatives in June of 2008 (Randolph, 2008) shortly after forcing the Secretary of the Air Force Michael Wynne and the Chief of Staff of the Air Force General Michael Moseley to resign.

Force shaping was just one of many initiatives in the history of the Air Force to trim down the ranks. This research is not concerned with the overarching reasoning behind reducing the force but instead tries to establish a relationship between the number and education level of people in the Air Force and cost overruns. The reduction of manpower over the years while at the same time the amount of acquisition work has remained relatively stable or increased in some years is the reason behind this research. The amount of money spent on Air Force RDT&E programs theoretically relates to the amount of manpower required in supporting those programs. In other words, large dollar value RDT&E contracts require many smart and talented personnel to oversee them because there are several parts of that high dollar RDT&E contract to oversee. In Figure 1 on the next page, the Air Force overall end strength representing all career fields has steadily decreased while the Air Force total RDT&E budget has either remained reasonably constant or slightly increased. This study will attempt to determine if adding more people or education will help with better managing those RDT&E programs resulting in fewer overruns.

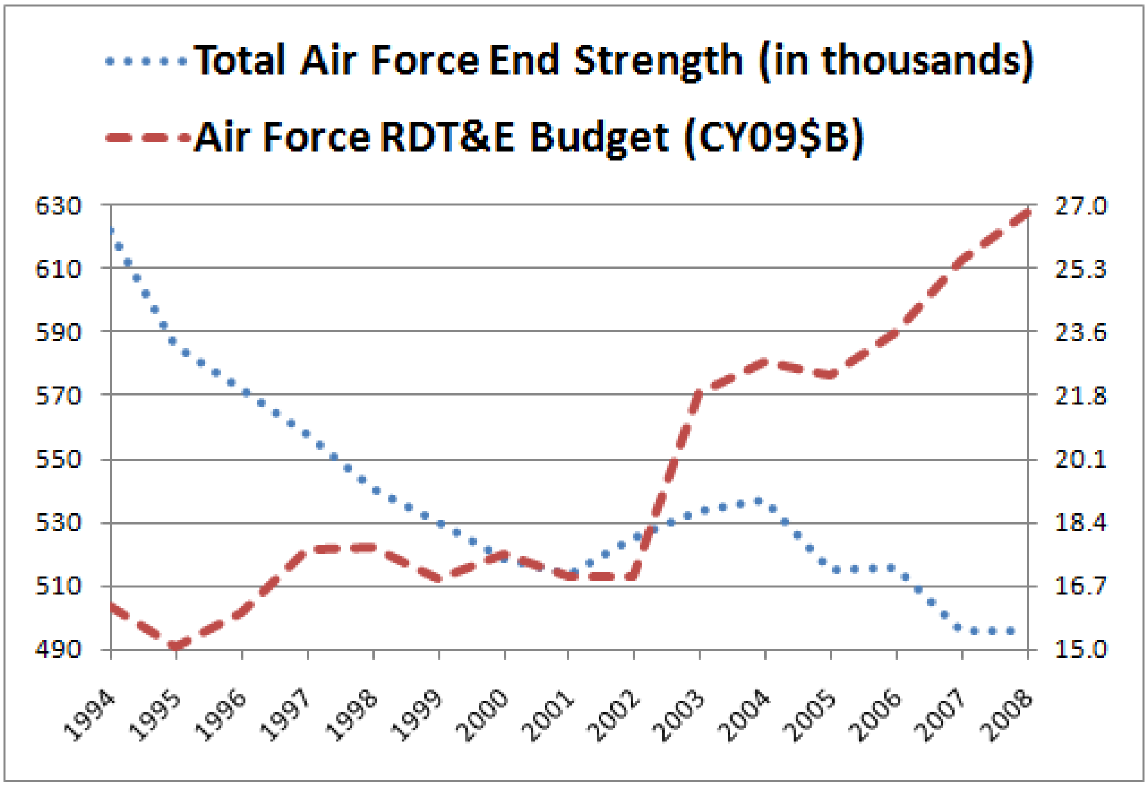

Figure 1 Air Force End Strength-includes both active duty and civil service employees (DoD FY09 Budget Greenbook)

Organization of the Study

This chapter established the incentive for this study and the research objective. Chapter 2 provides a review of the literature related to this research. Chapter 3 details the methodology used to model the relationship between human capital and cost overruns and Chapter 4 provides the results of the analysis with a brief discussion of the significant findings. Lastly, Chapter 5 provides conclusions on the study and recommends future areas of research.

II. Literature Review

This research examines the relationship between cost overruns and human capital. Specifically it examines the education and number of personnel assigned to career fields that make up the bulk of the composition of program offices at WPAFB on the cost variances of contracts managed by ASC. This chapter provides a background on previous literature that has been published on this subject.

Historical Reform in Acquisitions

We expect to achieve greater successes from every person, dollar, and hour we expend to acquire and sustain our current and new weapon systems.
-Darlene Druyun, Principal Deputy Assistant Secretary of the Air Force for Acquisition and Management 1997

There have been multiple studies and audits regarding DoD acquisitions which I will briefly cover in this chapter. Researchers and decision makers are always looking for a policy lever in acquisition reform to try to control costs and schedule. Unfortunately, the results are inconclusive as to what that policy lever might be. This section briefly reviews some historical actions and reforms undertaken by the DoD to control costs. In the early 1990s, senior leaders within the Department of the Air Force recognized the need to streamline acquisitions and become more efficient due to the shrinking DoD industrial base and budget. Some examples of historical studies initiated by the government are the Blue Ribbon Commission on Defense Management (Packard Commission) of 1986 to review the consolidation of the defense industrial base. Resulting reforms include the Federal Acquisition Streamlining Act of 1994 to revise the DoD 5000 series regulations incorporating flexibility into acquisition policies and procedures (Holbrook, 2003). In addition to the above quote by Ms. Druyun and putting aside any irony that would later develop from her statement, she goes on to say the necessary reform direction "…is basically toward creating a partnership with our contractors. They are not our enemy. If we erect a wall between us, then chances are we are going to walk away with a failure" (Kitfield, 1997). There was a huge movement within the Air Force to get contracts under control and to rein in the contractors on performance, costs, and schedule. One initiative that came about during this timeframe was an approach called TSPR (Total System Performance Responsibility). TSPR is an acquisition approach that responds to the government's and industry's recognition of change needed in government procurement (Pandes, 2001). TSPR was a creative contracting method in that it moved several of the functions previously accomplished by the government side to the contractor. TSPR was the response to another Secretary of Defense initiative requiring the use of performance specifications rather than military specifications (Pandes, 2001).

Additionally, there were several reforms in Earned Value Management Systems (EVMS) during the early 1990s. Earned value is a measurement tool used to manage projects. It does this by tracking the performance of work units in the work break down structure, and tracking cost and schedule of work performed against a planning baseline ((Defense Acquisition University, 2008). Earned value programs consisting of 32 stringent criteria have been in place for large, flexibly priced defense contracts since 1967 (Christensen, 1998). Originally, the criteria were established by the Air Force as cost/schedule planning and control specifications (C/SPEC) but they were later adopted by all the military services as cost/schedule control systems criteria (C/SCSC). C/SCSC was then slightly modified and renamed earned value management control systems criteria, all the while maintaining the principles of the 32 original criteria (Christensen, 1998). Over the years, implementation of the criteria consistently across the services or even within the same service, proved to be a cumbersome project. Some studies indicated the criteria was more non-value added activity by contractors and program managers (GAO, 1997). The fundamental use of earned value systems was tainted when the Navy's A-12 program was cancelled. The shortcomings of the system and those who used it were notoriously cited as potential reasons for the downfall of the A-12. When Secretary of Defense Dick Cheney canceled the program in January 1991, he complained that no one could tell him its final cost (Morrison, 1991). Earned value concepts are integral to the management of large, complex acquisition efforts and if used objectively, can facilitate successful project completion.

Reformation of regulations, modification to acquisition processes, and implementation of systems are all active approaches in trying to control contract performance. The quantity and quality of acquisition personnel should also be reviewed as a feasible alternative to managing DoD contracts because the personnel are just as important as the regulations and processes. Military officers that are financial managers routinely seek positions outside of acquisitions because the acquisition corps is sometimes considered a career killer for the finance community and it can be difficult to attain higher rank while remaining assigned to acquisitions (McCrary, 2008). In 2009, the United States House of Representatives approved a 2009 authorization bill with provisions proposing sweeping changes to the way the Pentagon acquires major weapon systems. One of the many changes proposed in the bill is the creation of an acquisition career track within the military, including general officer positions in each service, agency, and combatant command (Bennett, 2008). Many studies have linked acquisition problems to the shrinking acquisition corps among the many other factors discussed previously in this section (Holbrook, 2003; Feuring, 2007).

Cost Variance

There are two types of cost variance measurements (Feuring, 2007). One measure, cost growth, compares a program's beginning budget versus the final budget to see if there was an increase in the overall costs. The other measure, cost overrun, analyzes the cost performance of a program's contract to see if there was a difference in the budgeted cost versus the actual cost at several points throughout the period of performance of the contract. Sipple, White and Greiner (2004) reviewed a myriad of studies on cost overruns and indicated the causes of those overruns are the starting point to identify a model that allows cost variance to be predicted and controlled (Feuring, 2007). Feuring's (2007) focused research on cost overruns indicated they can be reduced by adding more cost analysts or increasing education levels of existing cost analysts. This work expands on Feuring's work and adds program managers, engineers, and rated personnel as having a correlating relationship with cost overruns.

Several studies indicate estimation errors as a common cause of both cost overruns and cost growth. Christensen, Searle, and Vickery (1999) found costs are underestimated initially, specifically Milestone B or the "official start" of an acquisition program, which biases the remaining estimates in many cases. Subsequent estimates use the initial estimate as a baseline so it is difficult to recover from a "bad baseline" in building an accurate final program cost. As a program requires more funds than were originally planned, decision makers have to respond by either reducing the quantity or performance for the system, or they have to reallocate funds from other programs in order to make up for the shortfall (Arena et al., 2006). Reallocating from other programs or cutting requirements from the existing program only exacerbates the problem across the entire resource constrained Air Force (Czelusniak, 1997). These decisions eventually lead to more bad decisions resulting in increased costs. Estimation error not only occurs up front, but can be found throughout the performance of a contract, especially if requirements are constantly changing and the budget is unstable. Pannell (1994) found many of the estimation errors occur during the production periods of acquisition programs. These errors in the estimation of production costs arise because of cost estimating errors, data omissions, schedule slips attributable to technical problems, system weight growth, and inadequately scoped engineering efforts (Pannell, 1994). The Office of the Secretary of Defense Cost Analysis Improvement Group (OSD CAIG, 2001) reviewed several programs trying to uncover the causes of cost variances and they determined two main effects were to blame: mistakes and decisions. Mistakes such as underestimated efforts and decisions such as using too optimistic of a learning curve were specifically mentioned as causes of error.

Decisions and the Role of Systems Engineering

There are obviously more key players in the process than just cost analysts that make poor estimating decisions resulting in cost overruns. A typical program office is manned by several different specialties. This research focuses on a select few from the government side because ultimately, they are the key players in the decision making process. This study specifically examines program managers, engineers, rated officers, and cost analysts assigned to WPAFB working on aircraft development programs. All four areas must work closely together to keep a program on schedule and on cost while maintaining the requirements desired by the end user. The program manager is ultimately responsible for making the decisions, but they must rely heavily upon the team of engineers for technical requirements, the cost analysts for fiscal requirements, and the rated officers for end user performance requirements. In many cases, rated officers are also program managers at WPAFB. The rated officers serving as program managers have dual responsibilities in that they must make sure the performance requirements of the end user are being met while also managing cost and schedule requirements to ensure the program can succeed. The process of managing programs has been studied extensively by the DoD. Numerous research efforts have been completed looking for policy levers in executing successful acquisition management. Regulations have even been written to establish a simplified and flexible management framework for translating mission needs into stable, affordable, and well-managed programs (DoD 5000.2, 2003). The effective integration of the four previous mentioned career fields' contributions are paramount to the success of the overall acquisition system. The acquisition system is an integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective (DAU SE Handbook, 2001). All four key specialties must be well versed in DoD acquisitions and understand how they each play a vital role in the overall system. In 1990, Congress recognized that importance and enacted the Defense Acquisition Workforce Improvement Act (DAWIA, 1990). Congress intended for DAWIA to improve the effectiveness of the personnel who manage and implement defense acquisition programs (Garcia et al., 1997). All personnel assigned to acquisition positions must achieve and maintain certification levels for their field, as required by the

DAWIA. One of the requirements for certification is the completion of Acquisition 101 (ACQ 101), Fundamentals of System Acquisition (DAU, 2008). In ACQ 101, all of the key players in acquisitions are introduced and corresponding roles they play in the acquisition process are explained. A key component explained in ACQ 101 is the concept of systems engineering management. As illustrated by Figure 2, systems engineering management is accomplished by integrating three major activities: development phasing that controls the design process and provides baselines that coordinate design efforts, a systems engineering process that provides a structure for solving design problems and tracking requirements flow through the design effort, and life cycle integration that involves customers in the design process and ensures the system developed is viable throughout its life (DAU SE Handbook, 2001).

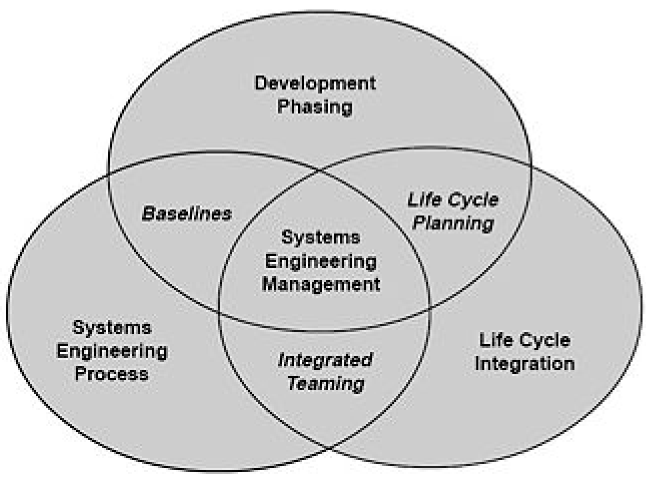

Figure 2 Systems Engineering Activities (DAU SE Handbook, 2001)

Throughout the systems engineering process decisions are made by personnel in all four areas of expertise. Some examples include but are not limited to:

- The cost analyst must decide on ground rules and assumptions in estimating the costs based upon best available data.
- The engineers must decide on acceptable performance parameters and technology readiness levels.
- The rated officers bring expertise and credibility for dealing with end users in communicating the user needs.
- The program manager must decide on schedule baselines and act upon the decisions of the other three key players in the process.

An important distinction to note here is all of the decisions are interrelated. That is, no one particular decision should be made without considering the effects of that decision on the other areas. This concept revolves around effective communication. The foundation of systems engineering is communication and it is imperative to program success that the channels of communication are wide open and clear (DAU SE Handbook, 2001). The concept of systems engineering should not consume the overall efforts of the program. However, key decision makers should be well versed in the concept. An analysis by the International Council on Systems Engineering (INCOSE) Systems Engineering center of excellence (SECOE) indicates that optimal effort spent on Systems Engineering is about 15-20% of the total project effort (Honour, 2002). At the same time, studies have shown that Systems Engineering essentially leads to reduction in costs among other benefits (Honour, 2002).

Aircraft Programs Versus Other Programs

Previous research on cost overruns was at a macro level and has either looked across the entire DoD (Holbrook, 2003) or the entire Air Force (Feuring, 2007). This study takes a more micro approach similar to Rusnock (2008). Rusnock looked at programs managed by the Air Force Space Command (AFSPC) whereas this research looks at programs managed by ASC, primarily aircraft programs. While Rusnock's research focused on cost growth, our research will focus on cost overruns. The Air Force Material Command (AFMC) manages three product centers: ASC, Air Armament Center, and Electronic Systems Center (ESC) (AFMC Factsheet, 2008). While all three product centers manage different types of programs, the results of this research are generalizable to the other centers as well because the acquisition profiles of all three centers are relatively the same. The reasoning behind looking only at ASC managed programs was threefold: First, the ASC data is easily available; second, the close proximity of ASC; and third, the acquisition profile of space is quite different than aircraft.

Military space systems differ from other defense systems in two ways: their operational environment and their acquisition life cycle (Rusnock, 2008). Space vehicles operate in much harsher environments than those of aircraft. Those environments are also very remote, often thousands of miles up in space. Corrections or alterations to the on-orbit system range from extremely expensive at best, to virtually impossible. Space systems are also frequently acquired in small quantities as compared to aircraft and follow on maintenance for launched systems is practically non-existent. Because of these factors, heavy emphasis is placed upon the survivability of the system early on in the acquisition life cycle and few dollars are spent in the production and sustainment phases as compared to the RDT&E phase (Rusnock, 2008) as compared to aircraft programs. As seen in Figure 3, an aircraft system incurs most of its costs in the operating and support phase whereas Figure 4 shows a space system incurs the majority of their costs during the systems acquisition phase. The difference in cost distribution is the result of the significant costs of developing the space vehicle and launching it which is paid with RDT&E funds. In comparison, the O&M costs are relatively minor and represent the resources needed to pay for ground support operations. Our research specifically examines RDT&E cost plus contract cost overruns so it would not be appropriate to include space system acquisitions.

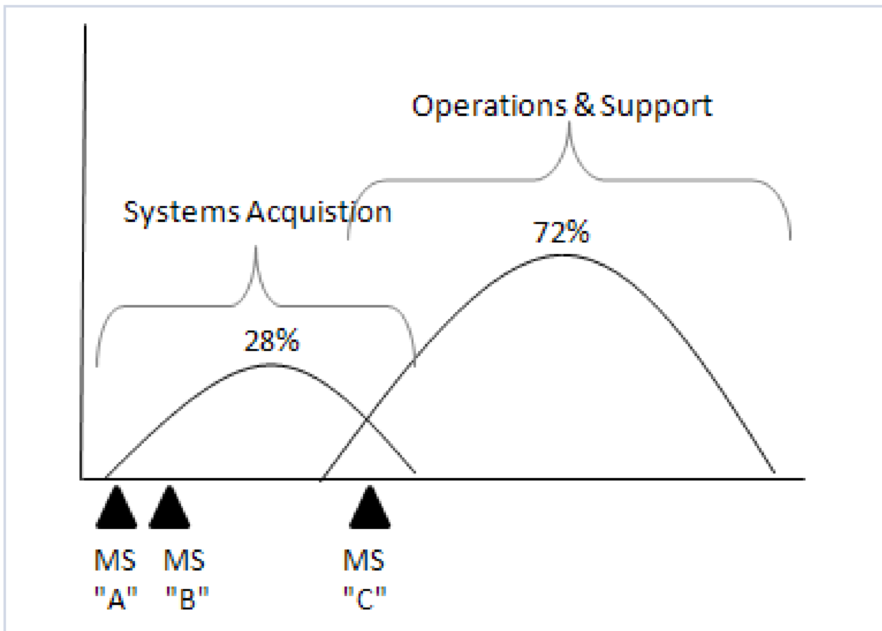

Figure 3 Aircraft System Life Cycle Cost Curve (Rusnock, 2008)

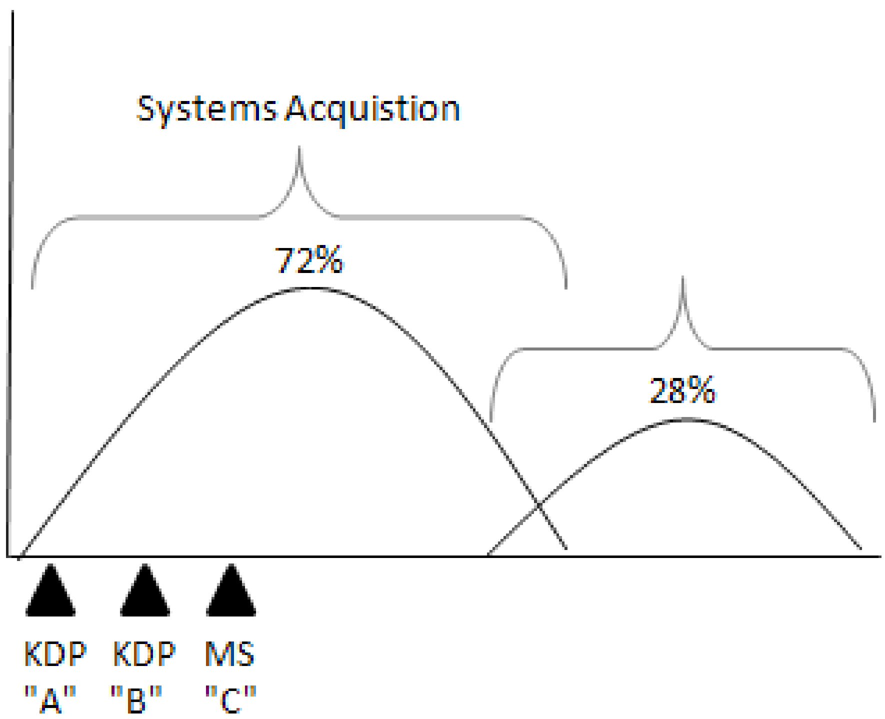

Figure 4 Space System Life Cycle Cost Curve (Rusnock, 2008)

It is worth mentioning software development programs are also quite different from aircraft and space systems which are why we did not include those types of efforts in our research. Software acquisition has steadily increased since the early 1980s where software development comprises a large portion of just about any development effort. Analysts historically determine costs based on the number of Source Lines of Code (SLOC). Estimates differ depending on how many SLOC are commercial off the shelf (COTS) versus originally authored by programmers. The total actual SLOC number, however, will likely be greater as past experience with software estimation has shown the size is typically both underestimated and functionality is added as the development progresses (Pracchia, 2004). That is not to say aircraft program requirements remain stable. Compared to aircraft programs which are approaching 100 years of development, software development is a rapidly changing environment and technology often outpaces development efforts leading to many unknowns in estimating software costs. A software cost estimation model is doing well if it can estimate software development costs within 20% of the actual costs, 70% of the time, and within the class of projects to which it has been calibrated (Boehm, 1984).

Human Capital

The sheer number of people, their corresponding training or education in the field in which they work, and their motivation all affect job performance and efficiency (Bartel, 1994; Lynch & Black, 1995). Feuring (2007) found education of cost analysts to be statistically significant on the amount of cost overruns in the Air Force. There are several differences between education and training but due to data limitations, this research will focus on the education of individuals. Acquisition specific training via the

Defense Acquisition University (DAU) is highly regarded within the acquisition community and is required for professionals assigned to acquisitions (DAWIA, 1990). There are specific Acquisition Professional Development Program (APDP) levels that must be attained at certain points throughout acquisition careers (DAWIA, 1990). Again, due to data limitations, that workforce specific ADPD training data is not available. As a result, this research will focus on post secondary education levels. Previous research supports that more highly educated individuals have a greater probability of receiving both employer-provided training and work-related training (Blundell et al., 1996). Firms that invest in employees' education tend to see returns on those investments either in the form of increased productivity or employee loyalty to the firm (Bartel, 1994). Companies that retain highly skilled workers will normally perform better than those companies that either do not incentivize education or allow their educated employees to walk out the door (Bartel, 1994). The next section will look at previous research on the number of personnel in a firm while the second section deals with education levels of employees.

Number of People

Feuring's (2007) research concluded that increasing the number of cost analysts can have a decreasing effect on cost overruns. Teams usually outperform individuals in just about any task (Hill, 1982). Teams made up of the right skill set and quantity of people will certainly outperform individuals (Bliss & Potter, 2005). Bliss and Potter's (2005) research found that in a sample of over three thousand mutual funds over a twelve year horizon, funds managed by teams outperformed individual managed funds by over 70 basis points per year and had lower expense ratios. Even the fastest and smartest individuals have limits and their performance will start to decline once that saturation point has been reached. For example, a stock analyst's performance begins to decline once the portfolio they are managing exceeds 12-13 stocks (Li, 2002). Another study found an inverted-U shaped relationship exists between multitasking and productivity such that, beyond an optimum, more multitasking is associated with declining project completion rates and revenue generation (Aral et al., 2007). Some research has considered that optimum for two of the variables we are examining. Wheelwright & Clark (1992) explained the following for engineers:

> When an engineer focused on a single project is given a second one, utilization often rises slightly because the engineer no longer has to wait for the activities of others involved in that single project. Instead, the engineer can move back and forth between the two projects. However, if a third, fourth, or even fifth project is added, the percentage of time spent on value-adding tasks drops rapidly, as an increasing fraction of valuable time is spent on non value-adding tasks--coordinating, remembering, or tracking down information, for example. (p. 90)

Feuring (2007) found that as defense employment grew, cost overruns actually increased. As the Air Force gets bigger, we incur more overruns because the Air Force has become too large and has entered into an area of diseconomies of scale (Feuring, 2007). These results could be generalized to a typical program office where complex systems are being managed and critical decisions are made by team members. There are also indirect aspects of being overworked. Workers will begin to resent their jobs and with the increase in anxiety and stress, their performance may begin to falter. In an experimental study, workers in overloaded situations felt more pressure, had less task enjoyment, and felt more depressed (Shaw & Weekley, 1985). If this sort of situation were to be prolonged, one might expect it to have a negative effect on performance (Feuring, 2007).

Education Levels of Employees

Cost overruns cannot be corrected by just adding more people to program offices. Program offices may already have the right number of people but they may not have the right mix of people of the proper number of educated people. So, adding more education to those personnel assigned to program offices may be a part of the solution. Previous research examined education at both the individual and firm level, but this research will focus only on productivity at the firm level. Program offices are teams of people doing acquisition efforts so it would not be appropriate to analyze output at the individual level, but more appropriate at the firm level, or program office level. Program offices typically consist of several people assigned to teams working toward the same goal of acquiring and delivering weapon systems. Bartel (1994) used a Cobb-Douglas production function to estimate the impact of employee training at the firm level because previous research had only focused on the individual level (Feuring, 2007). Organizations that were operating below expected productivity levels increased their performance after training programs were implemented (Bartel, 1994). By using the Cobb-Douglas production again, for every 10% increase in average formal education levels of employees, an 8.5% increase in productivity in manufacturing and 12.7% in non-manufacturing firms results (Lynch & Black, 1995). Human capital in the form of education is an integral component to any organization. This is especially true in the ASC organization where development of new aircraft weapon systems include copious amounts of new technologies. Due to those cutting edge technologies, ASC needs motivated and incredibly smart people.

Highly educated workers have a comparative advantage with respect to the adjustment to and implementation of new technologies (Bartel, 1987). Bartel (1987) also states the relative demand for educated workers declines as the ages of plant and equipment increase, especially in research and development intensive industries. Education enhances one's ability to receive, decode, and understand information (Nelson & Phelps, 1966). Due to the Air Force constantly updating and modernizing their weapon systems, the ability to handle new information is critical.

Summary

This chapter examined previous literature regarding historical reform in acquisitions and the role of human capital in acquisitions. The next chapter will build upon those relationships in constructing a model to test the effectiveness of acquisition personnel and cost overruns.

III. Methodology

This study will link human capital to performance using an objective measure of performance. The objective measure will be the amount of cost overruns realized per year by all programs managed by ASC. The method of analysis for this study is the Cobb-Douglas production function similar to Feuring (2007). This research expands upon Feuring's work and analyzes additional independent variables along with similar variables used in his 2007 thesis. The next section will clarify how the objective yearly cost overruns were quantified.

Objective Measure of Performance

There are multiple measures available for attempting to quantify successful acquisition contract performance. A complete and successful demonstration of the end state system being procured is ultimately the goal but there are key indicators transparent throughout the process to measure whether or not the program is on an executable path. One such measure is the schedule of the project. Are key milestones being met along the way and important deliverables occurring in accordance with the schedule? Many program offices spend immeasurable amounts of efforts in managing schedules and ensuring the acquisition is proceeding as planned. Another factor that receives a lot of scrutiny is cost. There are two methods in measuring cost increases and decreases, specifically cost growth and cost overrun. Cost growth is calculated by subtracting the initial estimate from the final cost, while a cost overrun is computed by subtracting the budgeted cost of work performed from the actual cost of work performed (Christensen, 1998). This cost overrun definition is consistent with the Earned Value Management

System (Defense Acquisition University, 2008). This research is concerned with estimation error, so cost overrun is the more appropriate measure for the context of this research. Factors which are out of the program's control, such as funding instabilities and/or changes in the scope of a requirement, can lead to cost growth but not to cost overruns (Feuring, 2007). The actual cost of work performed versus the budgeted cost of work performed, or the cost overrun calculation, better captures how well a program was estimated. Figure 5 illustrates the cost variance computation which in due course results in cost overruns.

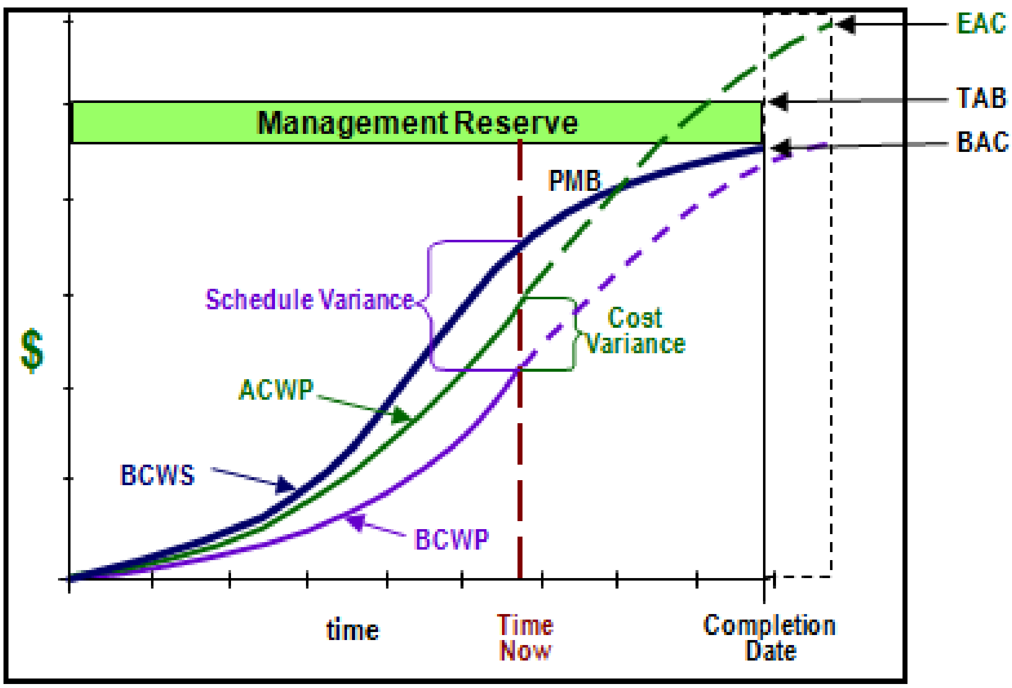

Figure 5 Earned Value Management Gold Card (DAU, 2008)

EAC: Estimate at Completion
TAB: Total Allocated Budget
BAC: Budget at Completion
PMB: Program Management Baseline
ACWP: Actual Cost of Work Performed
BCWS: Budgeted Cost of Work Scheduled
BCWP: Budgeted Cost of Work Performed

The ACWP line or the actual cost of work performed reveals the actual cost of work accomplished. The BCWS line or the budgeted cost for work scheduled reflects the value of work planned to be accomplished. The BCWP line or the budgeted cost for work performed is the value of work actually accomplished or the earned value. The BCWP takes into account changes in the scope of requirements and budget. The cost variance is computed by taking the difference between ACWP and BCWP. The cost variance in essence is the delta between what has been spent and what was planned to be spent for the same amount of work performed. Cost variance is equivalent to a cost overrun because it takes into account the budgeted amount which includes program changes and changes in quantity for example (Feuring, 2007). In contrast, cost growth alternatively is the difference between ACWP and the initial budget. Program changes like quantity reductions or increased scope of the project are updated in the BCWP so to measure the difference in the initial budget and the BCWP or ACWP would not reflect any estimation inaccuracies.

Data and Variables

Dependent Variable

We collected data on the average cost overruns of ASC managed acquisitions per year from 1994 to 2008 using cost performance report (CPR) data from the Defense Acquisition Executive Summary (DAES). The DAES included all programs from the Air Force so to examine ASC specifically the data was sorted by the Department of Defense Activity Address Code (DoDAAC). The DoDAAC is a code that uniquely identifies a unit with authority to requisition and receive materiel. ASC's DoDAAC is F33657 so only contracts with that DoDAAC were included. The amount of overrun for each weapon system was consolidated by fiscal year to give the average overrun for that year in percentage terms.

$$\%\text{Overrun} = \frac{(\text{ACWP-BCWP})}{(\text{BCWP})} * 100 \qquad (1)$$

Independent Variables

We collected the number of individuals working in program offices and their corresponding education levels from the Air Force Personnel Center's Interactive Demographic Analysis System (IDEAS) database. The bulk of ASC program office manning that influences contract decisions, with respect to cost, requirements, and schedules for example, come from eleven specific Air Force occupational specialty codes so this research focused on those respective career fields. The occupational specialty codes and a brief description of their duties are illustrated in figure 6.

Occupational Code	Duties	Area of Expertise
65F	Financial Analyst	Financial Management
65W	Cost Analyst	
501	Financial Management	
63A	Program Manager	Program Management
1101	Program Manager	
62E	Engineer	Engineering
801	General Engineer	
830	Mechanical Engineer	
855	Electrical Engineer	
861	Aerospace Engineer	
Rated	Operators	Rated Personnel

Figure 6 Air Force Occupational Codes

The eleven specific codes were consolidated by area of expertise into four basic groups: financial management, program management, engineering, and rated personnel.

We only considered personnel assigned to WPAFB owned by AFMC in the IDEAS database. It is important to note the database query included personnel assigned to AFMC headquarters and the Air Force Research Laboratory (AFRL). However, personnel assigned to both of those organizations support ASC managed acquisitions. This research attempted to verify Feuring's (2007) thesis which identified a statistically significant relationship between cost analysts and cost overruns. However, due to limitations of the data, our research combines cost analysts and financial analysts into the same independent variable, mainly due to the inclusion of the civilian financial analyst career field. Civilian financial analysts and cost analysts both have the same occupational specialty, 501, so to avoid incorrect statistical inferences with respect to cost analysts versus financial analysts, the two were combined. The rated personnel variable includes both pilots and navigators in the ranks of Lieutenant Colonel and below.

The education level variable is a raw percentage of all the personnel discussed in the previous paragraph having a graduate degree or higher.

Control Variables

We added control variables to the model to account for other plausible causes of cost overruns. We included the historical ASC research and development (R&D) budget per year as a technological proxy. One of the common criticisms of inaccurate estimates is that new weapon systems are becoming more complex requiring more R&D funds and thus are more difficult to estimate (Feuring, 2007). Increased R&D funding could be the result of more programs or just more complex systems so there is a possibility for some error here. We want to account for other plausible causes of cost overruns by tracking the changes in R&D funding but without knowing if the changes resulted from more complex programs or just more programs, we cannot make statistical significant inferences to cost overruns based upon the changes in the R&D budget.

Another variable added to the model is the amount of outsourced work to private contractors at ASC. Over the years, the amount of contractor support in program offices has increased substantially, but trying to quantify that outsourced work is extremely difficult. The type of work that was outsourced is even more difficult to quantify as these contractors support the occupations explored in this research as well as logistics and administration. Following the same method as Feuring's (2007) model, a raw number of people doing defense related work in private industry was added to the model (DoD Greenbook, 2009). This number provides a trend for the amount of work that was outsourced per year by the DoD so the same results could be generalized to ASC.

We added unexpected inflation as another control variable to the model. The budgets executed by ASC over the years represent billions of dollars so even a minor change in the anticipated inflation represents significant cost overruns. Table 5-10 of the OUSD Greenbooks for various fiscal years were utilized to capture the unexpected inflation variable. Table 5-10 contains anticipated inflation as well as the actual inflation for each year. OUSD publishes new inflation rates in January of each year at which time budgets are adjusted to account for anticipated inflation. If the actual inflation is higher than anticipated, then the budget was not sufficient to cover the project and an overrun occurred. The opposite would be true for actual inflation being less than anticipated; the budget would be overfunded resulting in a cost underrun. This research tries to link human capital to overruns so it is important to remove the effects of unexpected inflation.

Model

The basic Cobb-Douglas production function is given by: (Cobb and Douglas, 1928).

$$Q = AK^{\beta}L^{\gamma} \qquad (2)$$

Where Q is a measure of output, A is the technological parameter, K is the capital, L is the labor and the exponents are some proportionate value summing to one of K and L. This model indicates that as more capital or labor is added then more output is achieved. This model was adapted by adding another input variable, education, by Lynch & Black (1995).

$$Q = AK^{\beta}L^{\gamma}E^{\delta} \qquad (3)$$

For this research, Q is the cost overrun, K is the capital of defense industries, L is a vector of the four occupational areas, E is the education level of those individuals and the exponents again are some percentage summing to one. We conducted a log-log transformation on equation (3) to linearize the specification for ease of estimation.

$$\ln Q = \beta \ln K + \gamma \ln LFM + \zeta \ln LEN + \lambda \ln LPM + \eta \ln LRated + \delta \ln E + \alpha X + \varepsilon \qquad (4)$$

We observed negative values in four of the 15 dependent variable observations. This indicates for those 4 years, ASC actually incurred an underrun or programs came in under cost. As such, we are not able to conduct a natural log transformation on those negative values. Therefore, we added the same minimal constant to each of our dependent variables to get positive values for all observations. Now that we have positive values for each year, we are able to log transform our dependent variables. This method introduces some bias in the interpretation of our coefficients which we will address in chapter five. We assumed the capital of defense industries is a good proxy for the capital variable K. Following the model specification used by Feuring (2007), the yearly defense industrial production index published by the Federal Reserve Bank was used because defense contractors utilize their own capital in support of R&D contracts. The use of industrial production data is a standard proxy for capital in the literature (Feuring, 2007). We added the additional X variable to represent the vector of control variables discussed in the previous section. We had zero and negative observations for the unexpected inflation variable so we did not conduct a natural log transformation on unexpected inflation. We will interpret the coefficient as a semi-log if found statistically significant.

We omitted the technological parameter A in the original Cobb-Douglas production function in the final model specification. When the final model is log transformed, the technological parameter A becomes the intercept in the linear equation. Since this study is concerned with the slope of the Cobb-Douglas function or the effects of human capital on cost overruns, the A parameter is given a value of one with no loss of generalizability (Feuring, 2007).

Summary

This chapter covered the model to be used in analyzing the effects of human capital on cost overruns and which variables will be used in the analysis. The method of collection for the dependent and independent variables and why they are important to this study was also covered. The next chapter will present the results of the analysis.

IV. Results

We start by plotting cost overruns over time against the number of engineers, program managers, rated personnel, and cost analysts to get a visual representation of the data. Each of the four career fields are plotted on separate scatter plots to visualize the effects of each career field on cost overruns. Due to limitations of the data, our study ranged from 1994 through 2008, or represents only 15 years worth of data. Our research does not attempt to forecast future relationships. We are only concerned with uncovering historical relationships, if any, between human capital and cost overruns.

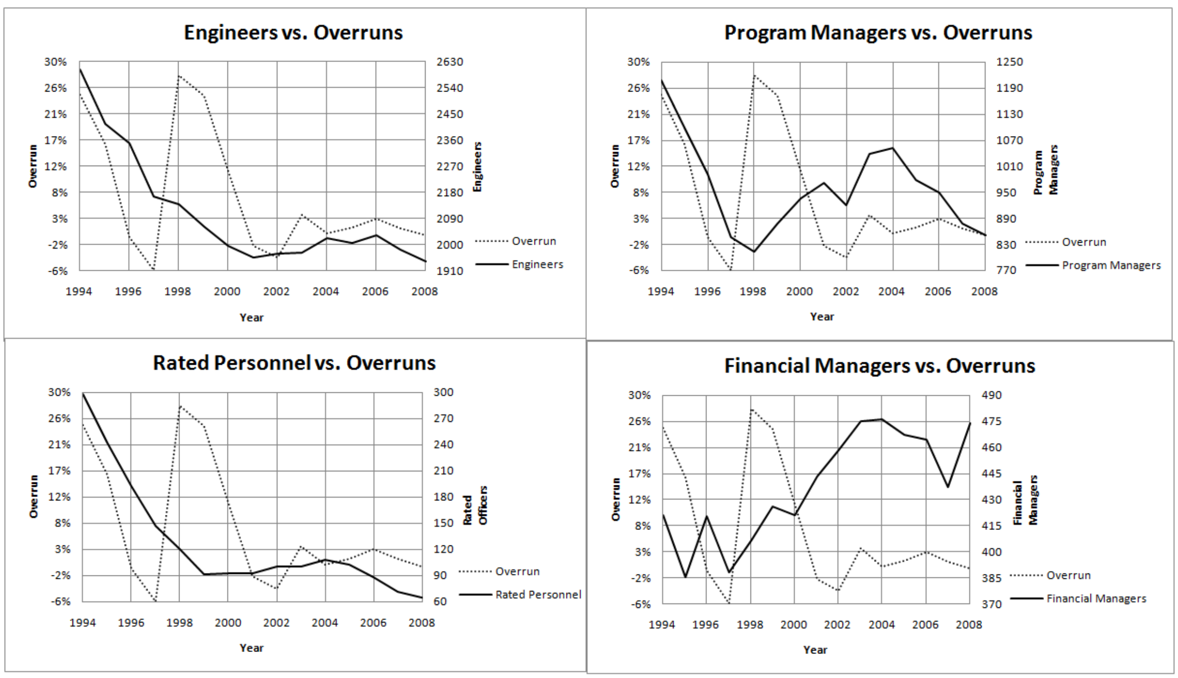

Figure 7 Scatter Plots of Each Career Field on Cost Overruns

There appears to be a relationship between the numbers of personnel in each career field and cost overruns. The scatter plots visually imply that decreasing the number of engineers, program managers, and rated officers will cause the cost overruns to drift toward 0% and in some cases, actually go negative indicating cost underruns. The opposite is true for financial managers. If you increase the number of financial managers, the cost overruns begin to improve as represented visually in Figure 7.

The summary statistics for our database are listed in Table 1 below. The mean cost overrun for our study is 6.78% with a range of -5.89% to 27.69%. The financial managers range from 385 to 476 with a mean of 437. The number of program managers range from 812 to 1208 with a mean of 960. The number of rated personnel range from 65 to 298 with a mean of 128. Lastly, the number of engineers range from 1942 to 2603 with a mean of 2108. Our last variable of interest, education, indicates the percentage of our sample as having a graduate degree or higher averaged 56.57% and ranged from 47.69% to 62.30%. This information is used later in the chapter for interpretation of the significant coefficients.

Table 1 Summary Statistics

Variable	Mean	Maximum	Minimum	Std. Dev.	Observations
OVERRUNS	6.78%	27.69%	-5.89%	11.06%	15
FINANCIAL_MANAGERS	437	476	385	30.97	15
PROGRAM_MANAGERS	960	1208	812	106.84	15
RATED_PERSONNEL	128	298	65	66.33	15
ENGINEERS	2108	2603	1942	197.34	15
EDUCATION	56.57%	62.30%	47.69%	4.01%	15
CAPITAL	106.2	119.4	92.1	7.51	15
RDTE_BUDGET (CY08$M)	3553.76	5151.44	1980.03	930.88	15
DEFENSE_EMPLOYMENT (K)	2828.67	3850.00	2180.00	617.40	15
UNEXPECTED_INFLATION	0.21%	1.50%	-0.60%	0.57%	15

Pre-Estimation Specification Tests

A stationary time series regression model is one whose probability distributions are stable over time. When variables in a time series regression are stationary, conventional statistical measures such as t-statistics and r-squared are the standard indicators used to assess the performance of the hypothesized model. However, if the variables are non-stationary, such usual measures are no longer valid in the interpretation of the model and can lead to faulty conclusions and spurious regression. If two non-stationary variables that do not have a relationship like the height of a tree and Gross Domestic Product (GDP) are regressed, it will appear the height of the tree is affecting GDP (Feuring, 2007). Therefore our dependent and independent variables must be stationary to successfully interpret our time series regression. A common procedure throughout the literature for ensuring stationarity is to test the variables using the Augmented Dickey-Fuller test. The variable is replaced with the change in that variable from one year to the next, called the first difference, if the variable is found to be non-stationary. Using the Augmented Dickey-Fuller test, financial managers, capital, RDT&E budget, and unexpected inflation variables all required a first difference to become stationary. The program managers and education variables required a second difference while the defense employment variable required a third difference to become stationary. The results of our Augmented Dickey-Fuller tests are located in Appendix A.

The next pre-estimation specification test was to determine the appropriate lag lengths of the independent variables. The theory behind lags is the effect of an independent variable may not be felt until later time periods in the dependent variable

(Feuring, 2007). Often, the lag length is dictated by the frequency of the data as well as the sample size and usually one or two lags will suffice for annual data (Wooldridge, 2006). There are several lag length selection criteria available. However, according to Liew's (2004) research, the Akaike information criterion (AIC) is recommended for samples with 60 observations or less so we used the AIC to determine the appropriate lag length of our sample of 15 observations. To determine the appropriate lag length, we regressed up to two lags of each independent variable on the dependent variable and the results of the AIC and adjusted R squared are shown in table 2.

Table 2 Lag Structure Determination

	1st Difference Financial Managers		2nd Difference Program Managers		Rated Personnel	
	AIC	Adjusted R^2	AIC	Adjusted R^2	AIC	Adjusted R^2
No Lag	4.29	0.04	**4.28**	**0.10**	4.38	-0.08
One Lag	4.24	0.14	4.56	-0.09	4.39	-0.06
Two Lags	**4.21**	**0.24**	4.68	-0.07	**4.36**	**0.11**
	Engineers		2nd Difference Education		1st Difference Capital	
	AIC	Adjusted R^2	AIC	Adjusted R^2	AIC	Adjusted R^2
No Lag	**4.36**	**-0.06**	**4.47**	**-0.10**	**4.41**	**-0.08**
One Lag	4.39	-0.06	4.57	-0.10	4.44	-0.06
Two Lags	4.38	0.00	4.68	-0.10	4.51	-0.03
	1st Difference RDT&E		3rd Difference Defense Employment		1st Difference Unexpected Inflation	
	AIC	Adjusted R^2	AIC	Adjusted R^2	AIC	Adjusted R^2
No Lag	**4.28**	0.06	**4.36**	0.03	**4.40**	**-0.07**
One Lag	4.43	-0.04	4.57	**-0.10**	4.48	0.00
Two Lags	4.55	**-0.07**	4.57	0.01	4.43	0.05

In seven of the nine variables, the AIC was minimized when the adjusted R squared was maximized. The RDT&E and defense employment variables were the other two variables where the minimized AIC and maximized adjusted R squared were different so they were defaulted to a no year lag. Financial managers and rated personnel were maximized at lags of two and all of the other variables, either by default or by maximization, were at no lags. The financial managers and rated personnel two year lag is reasonable because both of those career fields rotate in and out of the acquisition field. Often, these personnel are assigned to complex acquisition programs so it can take a few years for them to become proficient in their new acquisition jobs. As such, it is sensible to assume their contributions may not be felt for up to two years, hence the two year lag.

Post-Estimation Specification Tests

Diagnostic checks were then completed to ensure the model specification did not violate any regression assumptions. Tests for multi-collinearity, heteroskedasticity, auto-correlation, cointegration, and normality were conducted.

The Variance Inflation Factor (VIF) was calculated to test for multi-collinearity. The results of those calculations are found in Appendix B. The VIF value should be below 10 to ensure no collinearity between the independent variables. The mean VIF for our model was 6.78 so our model does not exhibit the presence of multi-collinearity.

We empirically tested for heteroskedasticity using the Breusch-Pagan-Godfrey test. The results of that test yielded a p value of .2338 which indicates we cannot reject the null hypothesis of homoskedasticity.

We tested for auto correlation using the Durbin-Watson test statistic which was 2.0067. A table of 5% significance for Durbin-Watson test statistics using 15 observations and 9 variables resulted in a lower bound of .175 and an upper bound of 3.216 in order to not be auto-correlated. As such, our 2.0067 score is well within that range so we do not have auto-correlation.

Due to the presence of unit roots and lagging some of our variables, the next post-estimation specification test was to ensure there was no cointegration of the error terms. For cointegration, a pair of integrated, or smooth series, must have the property that a linear combination of them is stationary (Granger, 2003). The Augmented-Dickey Fuller test was conducted on the residuals to ensure they are stationary. The results of the test are located at the end of Appendix A. The result was a test statistic of -3.74 giving a p-value of .0016 indicating the residuals are stationary.

The last test was to check for normality in our model specification. We tested for normality using the Jarque-Bera test statistic. The Jarque-Bera test indicated a p-value of .8781, not enough to reject the null hypothesis of a normal distribution.

Results

The results, with the required specification changes based upon the aforementioned diagnostic tests, are displayed in table 3 below.

Table 3 Time Series Regression Results

			Number of Observations	15
			R-Squared	0.61
ln (Overruns)	Coefficients	Standard Errors	t values	Probability
1st Difference ln (Financial Managers (Lag 2))**	**-13.602**	**4.737**	**-2.872**	**0.046**
2nd Difference ln (Program Managers)	-0.230	2.283	-0.101	0.926
ln (Rated Personnel (Lag 2))*	**-4.570**	**2.036**	**-2.244**	**0.065**
ln (Engineers)	2.925	2.537	1.153	0.333
2nd Difference ln (Education)*	**-2.586**	**1.280**	**-2.021**	**0.093**
1st Difference ln (Capital)	3.530	4.248	0.831	0.467
1st Difference ln (RDT&E)	0.989	0.905	1.092	0.375
3rd Difference ln (Defense Employment)	-1.768	2.442	-0.724	0.522
1st Difference Unexpected Inflation	-1.281	22.673	-0.056	0.959
constant	-8.791	6.683	-1.315	0.280

***Significant to the 10% level**
****Significant to the 5% level**

The time series regression results illustrate financial managers, rated personnel, and education are all significantly correlated with cost overruns. Due to the small sample size of our data, we discuss the statistical inferences in terms of 95% confidence intervals instead of point estimates.

Specifically, the results show that by adding more financial managers, cost overruns will decrease. For every 1% increase in financial managers, the cost overrun percentage may decrease anywhere from between 4.13% to 23.08%. These results are similar to Fuering's (2007) thesis except our research takes into account more control variables and limits our scope of research to only ASC managed programs. The average number of financial managers is 437 so if ASC added 1% more, or approximately 4 more analysts, cost overruns would be expected to decrease by the above mentioned range.

Increasing the number of rated personnel is also correlated with cost overruns. For every 1% change in the number of rated personnel, cost overruns would be expected to decrease between .5% and 8.64%. If rated personnel assigned to ASC were increased by 1%, cost overruns on average would decrease somewhere between .034% and .59% (average cost overrun = 6.78% * .5% or 8.64%). Both .034% and .59% seem like insignificant amounts but when we considered the average total RDT&E budget, .034% and .59% equate to a range of $1.208 million to $20.963 million (average RDTE budget = $3,553 million * .034% or .59%).

The last statistically significant variable, education, also revealed a negatively correlated relationship with our dependent variable. If we increase the percentage of graduate degrees or higher by 1%, cost overruns should decrease by a range of approximately .03% to 5.15%.

There were no other statistically significant variables found in our regression. Unfortunately due to the small sample size of only 15 years worth of data, we are not able to make statistically significant inferences regarding these marginally significant variables but it is interesting to note the sign on the coefficient of those variables. For example, the sign on the coefficients of program managers and defense employment indicate that increasing these variables may lead to reductions in cost overruns. Conversely, increasing engineers, capital and RDT&E may actually lead to more overruns. More program managers and individuals doing defense related work should cause overruns to decrease because those individuals could better support complex acquisition programs. However, the results of increasing the number of engineers seem counterintuitive. Maybe ASC has reached a point of diseconomies of scale with respect to engineers and adding more engineers to program offices actually would make those program offices less efficient. It is reasonable to assume increasing capital and RDT&E without corresponding respective human capital increases could possibly lead to poorer contract performance with regards to cost overruns.

V. Discussion of Results and Recommendations

In chapter four, our results yielded one independent variable statistically significant at the .05 level and two independent variables statistically significant at the .10 level. Also in the previous chapter, we briefly discussed the signs on the coefficients of the other independent variables as well. Recognizing we had a very small sample size, and the fact that we added a constant to our dependent variable (discussed in chapter three), we felt it is important to discuss the implications and limitations of our findings.

First, remember from chapter three that we added a minimal amount to our dependent variable so we could log transform it keeping it consistent with the Cobb-Douglas production function. This added constant introduces some bias to our specification. Specifically, we added .059 to each observation of our dependent variable. Due to this constant being a very small amount, the resulting bias is almost non-existent because the sum of the actual percentage and our added constant are then log transformed. However, this bias, coupled with our small sample size obligates us to discuss the findings in terms of ranges versus point estimates.

Second, should the Air Force now adopt policy changes based upon this analysis alone? Probably not, but the results should definitely be considered. We discussed our results in terms of confidence intervals of the effects on the cost overrun variable. We used 95% confidence intervals in our interpretations. This is where policy makers need to reflect on the cost versus benefit ratios of hiring additional personnel. Our results show by increasing the financial manager, rated officer, and education level variables the cost overruns will decrease by some range. However due to the small sample size of our data, should the policy makers consider those results as being exact and factual? We prefer to look at in the following manner.

The policy makers should believe the hiring of additional people will equate to less cost overruns based upon our analysis, albeit arguable in some cases, or they can assume status quo and hope the overruns will decrease. More research needs to be conducted in this area. Specifically, we needed more ASC data to have a larger sample size increasing the statistical power of the analysis. Perhaps, this research could be expanded to include the other AFMC centers or the Air Force as a whole. Additionally, the research could be extended across the entire DoD to see if similar results are found, or more importantly, so the sample size is increased thereby improving the credibility of the results.

The effect of program executive officers (PEOs) and program directors is an area that needs further study. Most, if not all, program offices at ASC are managed by personnel above the grade of lieutenant colonel or equivalent and we assume that logic holds true across the other AFMC centers and services as well. Our research was limited to personnel in the grades of lieutenant colonel and below or equivalent. Unfortunately, the data for those higher ranked personnel was not easily available so we could not attempt to capture the effects. We do feel it is important to mention that in Rusnock's (2008) thesis, she found the tenure of PEO's to be statistically significant and negatively correlated on the amount of cost growth in space acquisitions. It would be interesting to see if the same effect would hold true for cost overruns or within ASC.

Another area that needs further study is the delineation between education and training. We would have preferred to model APDP levels versus graduate degrees or higher as our education variable. However, APDP levels for Air Force personnel are not centrally managed and easily available. Acknowledging an individual with a graduate degree or higher will more than likely have greater analytical skills, DoD acquisition is a unique place which is why acquisition reform initiatives require specialty training in each field. Additionally, the personnel modeled in our research could have held graduate degrees not remotely related to their career field. For example, a financial analyst may have a graduate degree in history. Several studies done on reform initiatives yielded mixed results but we could not find any research that looked specifically at the effects of APDP levels and cost overruns. The education variable could be substituted with a percentage of personnel with the appropriate APDP level for each career field, indicating they had completed the required prerequisites for the function they were performing.

Further study needs to be completed on the effects of the DoD procurement holiday that occurred in the early to mid 1990s. The DoD as a whole went through times of shrinking budgets and personnel. Unfortunately, due to the data available, our research starts in 1994 which is right in the midst of the aforesaid holiday. Further studies need to be accomplished several years out into the future to eliminate the effects of the drawdown in terms of resources, including both dollars and people. Also, the global war on terror (GWOT) began during the period of our research. However, we feel we adjusted for GWOT by only including the RDT&E budget in our control variables. Most of the increased spending that occurred during GWOT took place in other fund types like procurement and operating and maintenance accounts. Unfortunately, the DoD may be on the path to another period of reduced spending (“Fox News,” 2009) so further research needs to be conducted on the effects of the ebbs and flows of defense spending on major acquisition programs.

Last, more research needs to be done on the effects of contractors doing cost analysis, program management and engineering duties in program offices. We used individuals doing defense related work in the private sector as a proxy for contractors. More detailed analysis needs to be done with regard to contractors doing what used to be accomplished by military and government employees. ASC needs to better capture the type and amount of work that has been outsourced to contractors to ascertain their effect. In the future, someone could add contractor workers as a variable to mathematically determine if their efforts are more or less productive than military/government employees.

In conclusion, our research identified a relationship between human capital and cost overruns. In previous literature, links between performance levels and human capital have been established. Using the lessons learned from previous studies and the theoretical relationship of inputs and outputs of the Cobb-Douglas production function, we presented analysis supporting a relationship exists between financial managers, rated personnel, education, and cost overruns. By weighing the costs associated with acquiring more personnel and funding more education versus the potential savings associated with fewer cost overruns, ASC could potentially save significant amounts of money.

Appendix A Augmented Dickey-Fuller Test Results

To ensure stationarity among our variables, EViews6 student version was used to run the Augmented Dickey-Fuller tests for unit roots. We selected the trend and intercept toggle button and chose the Akaike Info Criterion (AIC) for lag length for each of our variables. We log transformed all of our variables with the exception of the unexpected inflation variable due to the presence of negative values. The results of the EViews output for each of our variables, including residuals, are presented here.

Unit Root Tests

Null Hypothesis: **LOG(OVERRUNS)** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic based on AIC, MAXLAG=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-11.31515	0.0001
Test critical values:	1% level	-5.124875	
	5% level	-3.933364	
	10% level	-3.420030	

Null Hypothesis: **D(LOG(FINANCIAL_MANAGERS))** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on AIC, MAXLAG=3)

		t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		- 6.662998	0.000
Test critical values:	1% level	- 4.886426	
	5% level	3.828975	
	10% level	3.362984	

Null Hypothesis: **D(LOG(PROGRAM_MANAGERS),2)** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on AIC, MAXLAG=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.080343	0.0107
Test critical values:	1% level	-4.121990	
	5% level	-3.144920	
	10% level	-2.713751	

Null Hypothesis: **LOG(RATED_PERSONNEL)** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 4 (Automatic based on AIC, MAXLAG=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.540773	0.0009
Test critical values:	1% level	-5.295384	
	5% level	-4.008157	
	10% level	-3.460791	

Null Hypothesis: **LOG(ENGINEERS)** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on AIC, MAXLAG=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.380208	0.0051
Test critical values:	1% level	-4.004425	
	5% level	-3.098896	
	10% level	-2.690439	

Null Hypothesis: **D(LOG(EDUCATION),2)** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic based on AIC, MAXLAG=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.973134	0.0032
Test critical values:	1% level	-4.200056	
	5% level	-3.175352	
	10% level	-2.728985	

Null Hypothesis: **D(LOG(CAPITAL))** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on AIC, MAXLAG=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.485077	0.0042
Test critical values:	1% level	-4.886426	
	5% level	-3.828975	
	10% level	-3.362984	

Null Hypothesis: **D(LOG(RDTE_BUDGET))** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on AIC, MAXLAG=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.128962	0.0017
Test critical values:	1% level	-4.057910	
	5% level	-3.119910	
	10% level	-2.701103	

Null Hypothesis: **D(LOG(DEFENSE_EMPLOYMENT),3)** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on AIC, MAXLAG=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.805065	0.0040
Test critical values:	1% level	-4.200056	
	5% level	-3.175352	
	10% level	-2.728985	

Null Hypothesis: **D(UNEXPECTED_INFLATION)** has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic based on AIC, MAXLAG=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.481932	0.0023
Test critical values:	1% level	-2.771926	
	5% level	-1.974028	
	10% level	-1.602922	

Null Hypothesis: **RESIDUALS** has a unit root
Exogenous: None
Lag Length: 0 (Automatic based on AIC, MAXLAG=2)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.736327	0.0016
Test critical values:	1% level	-2.792154	
	5% level	-1.977738	
	10% level	-1.602074	

Appendix B Variance Inflation Factors

To check for multi-collinearity among our independent variables, we computed the Variance Inflation Factor (VIF) for each of our independent variables. We did this by running an ordinary least squares regression that has each independent variable as a function of all the other explanatory variables. We took the resulting r-squared values and calculated the VIF for each variable using the following equation.

$$VIF(\beta_i) = \frac{1}{1-R_i^2} \quad (5)$$

Next we averaged all of the VIFs to arrive at the mean VIF for the variables in the model.

Variable	VIF
Financial Managers	3.56
Program Managers	4.35
Rated Personnel	10.99
Engineers	10.63
Education	4.09
Capital	6.71
RDT&E Budget	12.90
Defense Employment	4.75
Unexpected Inflation	3.08
Mean VIF	6.78

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Vita

Capt Stephen Gray graduated from George West High School in George West Texas in 1991 and enlisted in the United States Air Force in 1993. After graduation from Basic Military and Technical School Training, he entered the financial management career field and was stationed at Davis-Monthan AFB. After two years, Capt Gray was re-assigned to Kunsan Air Base, South Korea, for one year and then completed a two year follow-on assignment at Travis AFB. While assigned to Travis AFB, he deployed to Tbilisi, Republic of Georgia, and Tel Aviv, Israel, as a paying agent. Capt Gray was then re-assigned to Sheppard AFB for three years as a technical school instructor for the financial management career field. While at Sheppard, he completed his Bachelor's degree and was accepted for Officer Training School graduating in 2001. From there, Capt Gray re-entered the financial management community and was assigned to the 31st Comptroller Squadron at Aviano Air Base. While at Aviano, he worked as the Deputy Financial Services Officer, Financial Services Officer, Deputy Disbursing Officer, Deputy Financial Analysis Officer, and Budget Officer. In 2005, Capt Gray was re-assigned to Wright-Patterson AFB, doing cost analysis work on the F-35, Joint Strike Fighter, in the 640th Aeronautical Systems Squadron (AESS). While assigned to the 640th AESS, he deployed in 2006 to Kabul, Afghanistan, in support of OPERATION ENDURING FREEDOM working for the Combined Security Transition Command as a budget analyst for the Afghan National Army. Capt Gray was accepted into the graduate cost analysis program at the Air Force Institute of Technology in 2007. After graduation, he will be assigned to the Electronic Systems Center, Hanscom AFB, Massachusetts.

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14. ABSTRACT
Previous studies have linked human capital with performance. The studies have shown performance, measured as output, of a firm can be increased by adding more personnel and/or increasing education levels. This research uses the Cobb-Douglas Production function to build upon that relationship of inputs to outputs. The output in this study is the average cost overrun of Aeronautical Systems Center research, development, test, and evaluation contracts managed from 1994 to 2008. The inputs are the numbers of military/government employee financial managers, program managers, engineers, rated personnel, and military/government employees in those career fields possessing a graduate degree or higher. A time series regression was conducted using those inputs to outputs while controlling for other factors such as budgetary fluctuations, inflation, and individuals doing defense related work in the private sector as a proxy for contractors working in program offices. The results indicate a negatively correlated relationship exists between human capital and cost overruns.

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