AN ANALYSIS OF THE RELATIONSHIP BETWEEN
RISK ALIGNMENT AND COST PERFORMANCE

THESIS

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To Heidi, with all my love. Christopher M. Wegner

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Abstract

This study investigates the relationship between risk alignment and cost performance in DoD procurement. Both the government and the contractor conduct independent assessments of the perceived risk in a contract. The results of inaccurate risk assessments are undesirable consequences, one of which is the inability to achieve cost targets. If both the contractor's and the government's perceptions of risk are in alignment with the actual risk involved in a contract, then we would expect minimal impact. If, however, either or both parties fail to accurately assess the actual risk, then we would expect consequences, such as cost overrun/underrun. The level of cost overrun/underrun can be determined by examining the level of alignment between the actual risk and each party's perception of the risk.

Results indicate a significant potential for cost growth when both the government and the contractor underestimate the actual risk. In this context, the level of cost growth experienced on a contract is a reflection of the adequacy of the parties' risk assessments. Failure to accurately assess risk could result in a lack of sufficient "safeguards" necessary to help mitigate the damaging effects of risk inherent in a contract.

AN ANALYSIS OF THE RELATIONSHIP BETWEEN RISK ALIGNMENT AND COST PERFORMANCE

I. Introduction

GENERAL PURPOSE

The concept of risk pervades every action of daily life. Life requires choices and choices involve risks. Every day we subject ourselves to the risk of death by getting in our cars and driving down the road. While we cannot avoid risks completely, we can minimize the risks we face.

Although everyone makes daily decisions involving risks, not everyone makes daily decisions resulting in risks associated with thousands of dollars or thousands of lives. Political leaders and managers of large business firms, however, are faced with such decisions with regularity. In addition, they are ultimately responsible for the consequences of the decisions they make. How important, then, is it for organizational leaders to understand the elements of risk associated with their decisions? I would consider it critical. To ignore potential risks and make decisions with a laissez-faire attitude is not management; it is gambling. Since risk management recognizes the potential impact (damage) of risky decisions, it can take proactive actions (safeguards) to reduce risk.

For business and government leaders, the effect of not recognizing and planning for risk is to subject themselves to uncontrollable consequences. Risk is associated with future events and, as such, contains elements beyond our control. The proper use of risk analysis and risk management techniques, however, can work to mitigate those risks to the point where the outcomes are within acceptable limits.

The underlying premise is that decisions involve risks. We can choose to either ignore those risks and accept the consequences, or we can take proactive steps toward understanding the risks associated with our decisions and developing ways to mitigate those risks, thereby maintaining acceptable results.

One of the most damaging results of poor risk management within the DoD is the issue of cost growth. The average cost overrun on defense contracts has been estimated at 40 percent (Gansler, 1989: 4). Considering the enormity of acquisition expenditures within the DoD, this estimate could result in dollar overruns of $37B per year.

Extensive research has been conducted to determine the cause of cost growth in Federal acquisition programs (Drezner, 1995;Pletcher & Young, 1994;Singleton, 1991). No one, however, has developed a single definitive explanation for cost overruns. A 1993 Rand study set out to identify factors affecting cost growth (Drezner, et.al, 1995: xi). They examined aspects ranging from program length, size, and maturity to management, budget, and political decisions. Their overall observation: "the problem of cost growth does not have a 'silver bullet' policy response" (Drezner, et.al, 1995: xiii). In other words, many factors affect the problem of cost overruns, yet no one factor can individually be labeled as the defining, overarching precedent to cost growth.

Although much research has been accomplished to investigate the causes of cost growth, little has been conducted to address how poor risk assessment affects cost growth. The intent of this study is to investigate the effect of inaccurate risk assessment on the government's ability to achieve cost targets.

BACKGROUND

Each party to the contract, the government and the contractor, conducts an independent assessment of the risks associated with a contract. This risk assessment is a reflection of their perception of the level of risk faced. Poor risk assessments can lead to consequences, most of which are damaging in nature. Poor risk assessments can also lead to consequences which, on the surface, appear to be beneficial. For instance, an assessment of risk which is higher than the actual risk could result in an overall cost underrun. While this initially appears to be a desirable outcome, it in fact means funds were under-utilized, possibly to the detriment of other programs.

One way to investigate the impact of risk assessment on cost performance is by analyzing the alignment between each party's (government and contractor) perception of risk and the actual risk involved in a contract. If both the contractor's and the government's perceptions of risk are in alignment with the actual risk involved in a contract, then we would expect minimal impact. If, however, either or both parties fail to accurately assess the actual risk, then we would expect consequences, such as cost overrun/underrun. Consequently, it may be argued that cost overrun/underrun is, in part, a function of the alignment between the actual risk and each party's perceptions of the risk. In instances where risk is underestimated, the expectation is that the contract will experience a cost overrun, because the parties have failed to adequately provide "safeguards" to help minimize the consequences of the actual risk level. Conversely, if risk is overestimated, the expectation is that managers have under-utilized their funds and the contract will experience a cost underrun.

RESEARCH DESIGN

The Defense Acquisition Executive Summary (DAES) database contains historical information on completed and ongoing Department of Defense (DoD) contracts. The data is summarized in the form of Cost Performance Reports (CPRs) and submitted to the Office of the Under Secretary of Defense for Acquisition & Technology (OUSD(A&T)) on a quarterly basis (DoD, 1991). The database contains contracts from all three military services and covers a wide variety of contract types and end-items.

The dependent variable of interest for this study is the final cost variance of contracts in the DAES database. At contract completion, the overrun or underrun is the difference between the total budget for all the work on contract, termed the "Budget at Completion" (BAC), and final actual cost of the work performed (ACWP) (Christensen, 1993: 44).

The independent variables of interest are the measures of each party's perceptions of risk and the actual risk involved in the contract. The measure of actual risk chosen for this study was the phase of procurement reported in the DAES database. Contracts pertaining to the R&D phase of development were coded as high risk, while contracts used during production were coded as low risk. The reported contract type was used as the government's perception of risk. Fixed-price type contracts were used to indicate a low level of perceived risk, while cost-reimbursable type contracts reflected a high level of risk perception. Finally, the contractor's perception of risk was determined by the initial percentage of management reserve (MR) budget reported in the DAES database. High risk was viewed as an initial MR > 7.5%, while MR < 7.5% was considered low risk.

The individual perceptions of risk and the actual risk were then organized into alignment combinations. Two combinations were investigated in this study. The first was the scenario in which both the government and the contractor overestimated the actual risk. It was believed that this combination would result in the highest degree of cost underrun. The second combination was the scenario in which both the government and the contractor underestimated the actual risk, thereby resulting in the highest degree of cost overrun.

The procedure used to analyze the difference in cost performance for the two combinations was the Analysis of Variance (ANOVA) technique. The ANOVA was used to compute the mean overrun/underrun values for each combination and then compare the means for statistically significant differences at the p-value=.05 level.

FINDINGS

Analysis of the statistical results indicated that the alignment of risk had a significant, but inconclusive effect on the contract cost performance. In the instance where both the government and the contractor underestimated the risk, the mean cost performance was a 22% overrun. Conversely, an overestimation of risk by both parties resulted an mean underrun of approximately 1.4%.

The findings indicate that inaccurate alignments of risk can lead to undesirable cost performance. The implications for DoD contract managers is that proper risk management is a critical element in the effort to achieve cost targets. One part of proper risk management is the ability to accurately analyze the actual risk in a contract and then take the necessary steps to develop "safeguards" capable of mitigating the damaging consequences of that inherent risk. Failure to adequately align the perceptions of risk with the actual risk has been shown by this study to create a tendency towards poor cost performance.

ORGANIZATION OF THE STUDY

Chapter II establishes the theoretical foundation for the study. The general concept of risk and risk management from the government and the contractor perspective is discussed. The chapter concludes with the development of two hypotheses used to test the relationship between risk alignment and cost performance. Chapter III details the methodology and research design of the study. The validity and measurement techniques for the dependent and independent variables are established. The analytical model used to test the hypotheses is presented. Chapter IV reports the results of the statistical analysis. The study concludes with a discussion of the implications of the results and recommendations for future studies in Chapter V.

II. Literature Review

OVERVIEW

Each party to a contract, the contractor and the government, conducts an independent assessment of the risks involved in a program. The accuracy of those assessments is reflected in the resulting consequences, one of which is cost performance. The degree to which either or both parties calculates risk accurately can be seen by examining the level of cost underrun/overrun experienced on a particular contract.

This chapter will present the concept of risk as it applies to Department of Defense (DoD) acquisition. Following a general discussion of risk, descriptions of the government's and contractor's risk management processes are provided. The chapter concludes with two hypotheses established to investigate the link between risk alignment and cost growth.

THE GENERAL CONCEPT OF RISK

The purpose of this section is to investigate the issue of risk and determine the role risk management plays in the formulation of business strategy. This section begins with conceptual definitions of risk and then follows with a discussion of risk management and risk analysis. The section concludes with two examples of the business-related outcomes associated with various forms of risk.

Definitions of Risk

Webster defines risk as exposure to possible loss or injury. This definition of risk contains three key elements-exposure, possibility, and loss. First, for an event or decision to involve risk, there must be some potential loss to the decision maker. Second, the element of possibility requires that there be some form of "chance" associated with the outcome. A situation involving complete certainty of loss is not a risk. Finally, the definition refers to the concept of exposure. The exposure element of the definition reflects the notion that the decision maker has the ability to take actions which may increase or decrease the severity of the loss (MacCrimmon & Wehrung, 1986: 9).

Thus, according to this definition of risk, there are three components--the degree of loss, the chance a loss will occur, and the willingness or decision to expose oneself to loss. Efforts to diminish the risk of any decision or behavior must then focus on reducing one of these elements. The *degree* of risk associated with an action can be thought of as being directly proportional to the magnitude of the loss, the probability (or chance) loss will occur, and the amount of exposure to loss (MacCrimmon & Wehrung, 1986: 10).

The preceding definition of risk focuses primarily on the negative impacts of "risky" decisions. In his book, *The Business of Risk*, Peter Moore reminds us that risk also involves the hope of some benefit or gain (Moore, 1986: 3). Moore points to a quote from Shakespeare's *Merchant of Venice*: "Men that hazard all do it in hope of fair advantages." Using hazard synonymously with risk, Moore points out that engaging in risky ventures involves the potential for favorable outcomes. Indeed, from the business perspective, this would seem intuitive. If taking risks involved no potential for gain, then sound business judgment would require us to avoid risky endeavors in favor of the status quo.

Conceptually, risk can be defined as a function of uncertainty and damage, as shown below (Kerzner, 1995: 879).

$$\textbf{Risk} = f(\textbf{uncertainty, damage})$$

In order to understand this definition, a distinction must be made between risk and uncertainty. Risk, in this instance, refers to an outcome which is subject to an uncontrollable random event derived from a *known* probability distribution. Conversely, uncertainty involves outcomes in which the probability distribution is *unknown*. For example, the toss of a die yields the probability that each side will turn up one-sixth of the time. Each surface has an equal chance of occurring, so the laws of nature, over time, dictate a known likelihood of any particular side landing face-up. Consider now a loaded die, the precise weighting of which was unknown. Without conducting experiments, we would be uncertain of the exact probability of any particular face landing upturned (L'Heureux & Grant, 1996: 18-3). Consequently, a gambler would be taking a calculated *risk* when competing with a fair die. Any bets placed on loaded die, however, would result in outcomes which were *uncertain*.

Similar to *Webster's* definition of risk, the conceptual definition presented above involves some degree of damage associated with the outcome. For example, two projects, Project A and Project B, may have identical probabilities of failure. However, if the consequences of not completing Project A are greater than those for not completing Project B, then Project A would be considered the more "risky" situation. In general, as either uncertainty or damage increases, so does risk. Furthermore, since risk actually constitutes a lack of knowledge concerning future events, risk analysis must account for the cumulative effect of the outcomes associated with the risk-taker's decisions.

Another element of the conceptual definition is the cause of risk. The source of danger which induces risky situations is referred to by Kerzner as the hazard (Kerzner, 1995: 879). This leads to the second conceptual equation:

$$\textbf{Risk} = f(\textbf{hazard, safeguard}).$$

The safeguard refers to preventative actions which may be taken to overcome the hazard. An example is a large pothole in the road. The pothole is the hazard which creates the risk of damaging a vehicle. A safeguard to this risk is illustrated by the driver who is familiar with the road.

The familiar driver would slow down and go around the hole, in order to reduce the risk of damage. As we can see then, hazards are directly related to risks, while safeguards have an inverse relationship with risk. That is, increased hazards will increase risk while increases in safeguards (preventative actions) tend to reduce overall risk.

In the business context, the most direct way to illustrate the concept of risk is through the use of *decision tree* analysis. Consider, for example, a company considering the production of a new line of merchandise. The decision tree might look like the one shown in Figure 2-1.

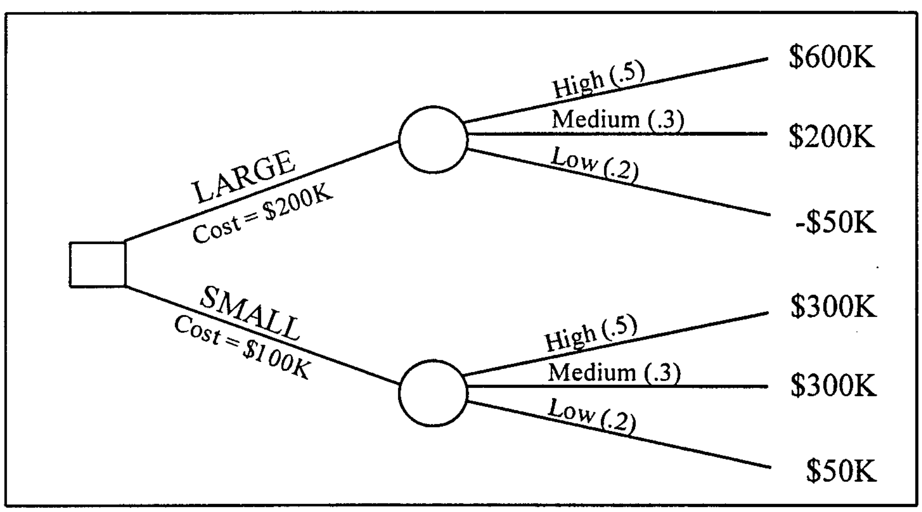

Figure 2-1: Decision Tree

Inspection of the decision tree shows there are two types of nodes on the tree. The square *decision node* represents a point in time where a choice must be made between alternative courses of action. In this instance, the company may decided to either build a large plant, at a cost of $200,000, or build a smaller plant, at a cost of $100,000. The circular nodes represent *states of nature*, where the outcomes are not entirely within the control of the company.

Through market research, the company may have determined that each possible outcome (demand rate) has a certain respective probability of occurrence. In this example, there is a 0.5 probability of high demand, a 0.3 probability of medium demand, and a 0.2 probability of low demand, regardless of which plant is built. The monetary values listed to the far right of the decision tree are the net values of sales over the life of the plant, relative to each demand rate. They are computed based on net sales minus capital expenditures, where net sales for each demand rate are given as $800K for high demand, $400K for medium demand, and $150K for low demand. In decision tree analysis, they are often referred to as the *payoff* for the given combination of decisions and states of nature. For example, the *payoff* for the large plant, high demand combination is:

$$\text{Net Sales} - \text{Capital Expenditures}$$

$$= \$800K - \$200K = \$600K.$$

Notice for the small plant decision, the *payoff* for the high and medium demand rates are identical, because the small plant cannot produce enough to meet the higher demand and sales are therefore limited to the medium demand rate.

Now, in order to make a business decision on which plant to build, the *expected value* of each decision must be calculated by summing the products of *payoff* X *probability* for each of the two possible decisions. For the large plant decision, the *expected value* (EV) is given as:

$$EV_L = (\$600K)(.5) + (\$200K)(.3) + (\$-50K)(.2) = \underline{\$350K}.$$

Likewise, for the small plant decision:

$$EV_S = (\$300K)(.5) + (\$300K)(.3) + (\$50K)(.2) = \underline{\$250K}.$$

We can see, based on the predictions given in this scenario, the decision to build the larger plant would result in a higher *expected value* over the life of the plant. Therefore, the optimal business strategy in this example would be to build the large plant.

The preceding example illustrates several of the elements of our conceptual definitions of risk. First, there is uncertainty involved in the estimates of demand rates and in the estimated net sales over the life of the plants. On a more fundamental level, a real-world problem would involve uncertainty in a myriad of elements, such as production costs, salaries, changes in technology, etc. Second, there is a potential for damage associated with the decision. There is a 20% probability that, having chosen to build the large plant, the company would lose $50K over the life of the project. Third, there exist hazards which may affect the risk of the decisions. Another company may decide to market a similar consumable, thereby reducing the anticipated demand. Finally, there are potential safeguards the company may use to lower the risk associated with the hazards, such as aggressive advertising and early entry into the market.

Risk Management

According to MacCrimmon & Wehrung, all risky situations inherently contain three identifiable determinants: lack of control, lack of information, and lack of time (MacCrimmon &

Wehrung, 1986: 14). If we had complete control of the situation, we could always determine the best possible outcome, and there would be no risk. Similarly, if we had perfect information, there would be complete certainty in all of our actions. Again, risk would not exist because of a lack of the uncertainty associated with unknown probabilities. If we had no time constraints, we could wait until the outcome of any uncertain event was resolved. Proper risk management, then, involves understanding these three determinants and seeking ways to reduce their undesirable effects on outcomes.

From the business perspective, risk management is an organized means of identifying and measuring risk and developing, selecting, and managing options for handling these risks. It involves understanding the danger signals that may indicate a project is off track and prioritizing corrective actions as necessary. Risk management is not a separate office activity, but rather is one aspect of sound technical management. Proper risk management implies control of possible future events, and is proactive rather than reactive. Proper risk management will reduce not only the likelihood of an unfavorable event occurring, but also the magnitude of its impact (Kerzner, 1995: 880).

The recurring premise is that the best way to handle risky situations is to <u>manage</u> them. By this, I mean taking an active stance in identifying potential problem areas and then preparing a necessary course of action to alleviate the damage associated with risky decisions. This leads to the topic of the next section--risk analysis. In order to effectively manage risk, we must first ascertain what risks exist and what tools are available to alleviate risk.

Risk Analysis

The ultimate purpose of risk analysis is to identify and mitigate the inherent risks to the point where they are manageable. Accomplishing risk mitigation requires an understanding of the risks involved and the impact they may have on meeting desired objectives. Kerzner describes the impact of risk with the following mathematical illustration (Kerzner, 1995: 890):

Impact of Risk=(likelihood of risk)x(consequence of risk).

This relates directly back to the conceptual definition of risk. Earlier, we had defined risk to be a function of both the uncertainty of the situation and the potential damage. The illustration presented here shows the compounding effect these two elements have on the overall impact of risk. Reducing the impact through risk analysis would then involve modeling the likelihood of event occurring and understanding the consequences of that event occurring.

Many tools have been developed to assist in the analytical process of modeling risk. Some of them are described below (DSMC, 1989: 5-28 - 5-58).

Network Charts - a graphical display representing the individual activities necessary for the completion of a project, the time required for each activity, and the inter-relationships between activities.

Life-cycle cost analysis - Computerized models used to predict the effect a change will have over the full spectrum of development, production, operations, and support costs.

Probability analysis - Statistical modeling of the uncertainty associated with a decision or event.

Decision analysis - Probabilistic model of the expected monetary value of a decision.

Work Breakdown Structure (WBS) - A process which develops individual probability distributions for each "work package" and then aggregates the individual estimates into one total program cost risk distribution.

Consequences of Poor Risk Management: 2 DoD Examples

In the early 1980's the U.S. Army was developing the Sergeant York air defense gun, formerly known as the Division Air Defense gun, to fill a perceived void in the air defense of forward battle areas. Sergeant York's primary mission was to engage enemy helicopters and fixed-wing aircraft involved in close-air-support activities. It was to have a three member crew and an armament of twin 40-mm. radar-directed computer controlled guns, and a 7.62-mm. machine gun. The Army had a planned procurement of 618 production units at a total acquisition cost of $4.2 billion (GAO, 1983: 1).

On August 27, 1985, the Secretary of Defense announced he was canceling the Sergeant York program. Out of the 618 planned production units, the contractor, Ford Aerospace, had delivered only 64 systems at the time of the Secretary's decision (GAO, 1986: 1). The Secretary's decision was primarily based on the results of the latest operational tests which showed the Sergeant York achieved only marginal improvement over other available systems in the Army's inventory.

The Army had chosen an accelerated acquisition strategy for the procurement of the Sergeant York. The intention of the Army was to field the weapon system as quickly as possible with substantial cost savings. The Army recognized the accelerated strategy carried higher than usual cost and technical risks. First, the decision to schedule less testing prior to production increased the possibility of producing a weapon system with unproven technical capabilities. Secondly, the accelerated strategy increased the likelihood of cost growth due to lack of slack time in the schedule. The Army sought to minimize the cost risks by providing safeguards, such as a requirement for the contractors to use proven, mature subsystems and by including more extensive than usual warranty provisions (GAO, 1986: 3).

Up to the point of termination, the Army had apparently succeeded in controlling costs (GAO, 1986: 4).

However, the desired schedule was not maintained and the technical performance was deficient in several key areas. The decision to use mature components had contributed to the lack of cost growth. Unfortunately, this decision also contributed to the significant technical difficulties which arose during attempts to integrate the subsystems into a workable unit. The end results of such difficulties were delays in testing and the production of prototypes with less-than mature technological capabilities.

The use of an accelerated strategy was not, in itself, the cause of the Sergeant York's demise. The program's cancellation was a result of the Army's decision to not allow additional time to resolve technical problems in the system's targeting subsystem. When technology did not mature fast enough to maintain schedule, the Army chose to exercise fixed-price production options for the sake of cost control and disregarded the risks the weapon system's technical difficulties posed (GAO, 1986: 6-7). When the technical shortcomings were finally revealed during live-fire tests in mid-1985, the Secretary of Defense was left with little choice but to cancel the program. Sergeant York had demonstrated less than adequate performance and was due for the first major production contract in January 1986, only five months away from the cancellation decision.

Although the Army most likely understood the "uncertainty" surrounding the unproven technology in the Sergeant York, I don't believe they understood the "damage" that could, and did, result from the system's inability to meet the specified level of performance. Additionally, the Army did not develop adequate "safeguards", such as slack time in the schedule, to help mitigate the consequences of risk.

Like the Army's Sergeant York, the Air Force's Advanced Medium-Range Air-to-Air Missile (AMRAAM) program was a technically risky venture with a compressed acquisition schedule. The AMRAAM program arose from an Air Force and Navy need for a high-speed missile capable of beyond-visual-range (BVR) interception of enemy aircraft (Mayer, 1993: 15). This "launch and leave" capability would involve an active guidance and control system that would allow the missile to track and destroy targets on its own, without assistance from the pilot in the launch aircraft. Through the use of advancing technologies, the AMRAAM was envisioned as having significant performance improvements over its predecessor, the AIM-7, while maintaining lower life-cycle costs.

From very early in the program, AMRAAM was exposed to a high level of external demands. In fact, congressional pressure to shorten the acquisition cycle and maximize competition was a key factor in how the Air Force structured the program (Mayer, 1993: 53). Additionally, in an effort to compete with a proposed decision to upgrade the Sparrow (AIM-7) missile, AMRAAM program officials oversold the program in terms of the cost and schedule requirements for development and production (Mayer, 1993: 52).

To a great degree, the technical risks associated with the development of the AMRAAM were known and understood. The technology was still evolving, but was predictable enough to develop realistic specifications and timetables. Problems arose when forces external to the program imposed "hazards" for which the Air Force had not prepared adequate "safeguards". Congressional mandates to utilize a compressed schedule and to second-source production options were not consistent with the degree of technical risk associated with the program (Mayer, 1993: 53). To the Air Force's credit, the end result was a fully capable weapon system. But the results of poor risk management are demonstrated by an initial operating capability (IOC) slip of over five years and a final unit cost of 4 to 6 times greater than initial estimates (Mayer, 1993: 18,52).

HOW THE FEDERAL GOVERNMENT MANAGES RISK

As mentioned earlier, risk is primarily a function of the uncertainty of an event occurring and the possible consequences associated with that uncertainty. These two elements, uncertainty and consequence, are the cornerstones of risk management.

Within the DoD, there are five facets of risk associated with every project--technical, supportability, programmatic, cost, and schedule (DSMC, 1989: 3-3). The first three facets--technical, supportability, and programmatic--are related to the uncertainty of the project. The final two--cost and schedule--reflect the possible consequences associated with the failure to meet established goals.

Technical risks are those risks associated with evolving a new design to achieve a higher level of performance, or to maintain a constant level of performance under new constraints (DSMC, 1989: 3-3). Many of the systems procured by the DoD are expected to achieve a high level of performance. Often, the technical requirements necessary to achieve high levels of performance involve projections about the future state of technology. The level of uncertainty associated with the future projections of technology in turn determines the level of risk associated with the program.

Programmatic risks are the risks associated with acquisition and utilization of resources which may be beyond the control of the program manager (DSMC, 1989: 3-5). They are often a function of the business environment and generally are not directly related to improving state-of-the-art. The most common form of programmatic risk in DoD acquisition is the uncertainty of political decisions made at levels of authority above the program manager.

Supportability risks are associated with the fielding and maintenance of the developed systems (DSMC, 1989: 3-6). The technical complexity of today's systems places a heavy burden on the maintenance and logistics requirements to support those systems. Additionally, the multitude of physical environments in which the systems must operate pose a great challenge for those who must design a usable and maintainable product.

Table 2-1: Sources of Risk (DSMC, 1989: 3-4)

TYPICAL TECHNICAL RISK SOURCES	TYPICAL PROGRAMMATIC RISK SOURCES	TYPICAL SUPPORTABILITY RISK SOURCES	TYPICAL COST RISK SOURCES	TYPICAL SCHEDULE RISK SOURCES
Physical Properties	Material Availability	Reliability	Sensitivity to Technical Risk	Sensitivity to Technical Risk
Material Properties	Personnel Availability	Maintainability	Sensitivity to Programmatic Risk	Sensitivity to Programmatic Risk
Radiation Properties	Personnel Skills	Training	Sensitivity to Supportability Risk	Sensitivity to Supportability Risk
Testing/Modeling	Safety	Operations and Support Equipment	Sensitivity to Schedule Risk	Sensitivity to Cost Risk
Integration/Interface	Security	Manpower Considerations	Overhead/G&A Rates	Degree of Concurrency
Software Design	Environmental Impact	Facility Considerations	Estimating Error	Number of Critical Path Items
Safety	Communication Problems	Interoperability Considerations		Estimating Error
Requirements Change	Labor Strikes	Transportability		Slack Time
Fault Detection	Requirement Changes	System Safety		
Operating Environment	Political Advocacy	Technical Data		
Proven/Unproven Technology	Contractor Stability			
System Complexity	Funding Profile			
Unique/Special Resources	Regulatory Changes			

The final two facets of risk--cost and schedule--can be seen as a reflection of how well DoD managers have dealt with the uncertainties associated with technical, programmatic and supportability risks. Failure to adequately account for these uncertainties is often reflected as cost overruns and schedule extensions. There is a long history of cost and schedule growth in federal acquisition. In an era of limited DoD budgets, the impacts associated with cost overruns and schedule extensions are particularly disconcerting (see Sergeant York and AMRAAM examples above).

For DoD acquisition managers, risk involves three steps-- risk assessment, risk analysis, and risk handling (DSMC, 1989: 4-2). Risk assessment is the process of identifying and describing the sources of risk within the program. Risk analysis is the process of developing tools to assist in determining the uncertainties and consequences associated with each source of risk. The third step, risk handling, is the process of developing "safeguards" to account for the sources of risk.

As mentioned at the beginning of this section, the risk elements of uncertainty and damage are the foundation of risk management within the federal government. Through the use of risk assessment and risk analysis techniques, the government identifies sources of risk within a program and then determines the uncertainty and damage associated with the occurrence of "risky" events. Then, safeguards are developed to minimize the risk of damaging consequences like cost growth.

HOW THE GOVERNMENT CONTRACTOR MANAGES RISK

Government contractors often face difficult choices when deciding how to position themselves with regard to risk in a program. In a competitive situation, the contractor must often bid aggressively in hopes of winning a contract (Mayer, 1993: 8). If a company is too optimistic about its chances of meeting a cost target, however, it may expose itself to significant financial risk.

Like the government, effective risk management for the contractor begins with an independent assessment of the technical and financial risks associated with a program. Based on the Government's proposed requirements, the contractor will assess the degree of technical risk associated with performance or design criteria, as well as the schedule risk associated with maintaining the desired timeline of events. In the risk assessment process, the contractor is making determinations about the "uncertainty" involved in their ability to achieve the requirements of the program.

In addition to assessing the technical risks associated with each program, the contractor must also assess the level of "programmatic" risk. Not unlike the government, the primary influence to programmatic risk for the contractor is political in nature. Instead of responding to congressional inquiries and inputs, however, the contractor must answer to stockholders and lien-holders. As a business institution, the contractor must focus on achieving an acceptable rate of return on their investment in order to build capital and remain solvent (Mayer, 1993: 9). In doing so, the contractor must influence the stakeholders of the corporation that the level of risk taken in bidding on a program is worthwhile in comparison to the possible rewards associated with success. This form of risk assessment is similar to conducting a cost-benefit analysis of alternatives.

Even though the contractor is concerned with the "uncertainty" involved in risky behavior, there is evidence to support their primary concern being the impact associated with the failure or success emanating from risky decisions. A recent study on the managerial perspective of taking risks found that over 95% of the executives surveyed primarily associated the concept of risk with detrimental outcomes (Shapira, 1995: 45). The executives tended to downplay or ignore the probability of risk, instead focusing on the impact of their decisions. One executive pointed out that the uncertainty associated with two *good* outcomes is not risky at all (Shapira, 1995: 44). Others indicated their decisions involving risk depended on the estimates of the worst possible outcome. "Only if the negative outcome was tolerable did they consider the alternative and eventually looked at the possible opportunities involved in making the decision" (Shapira, 1995: 46). While these managers were totally aware of the positive sides to taking risks and the expected value approach of classical decision theory, they were clearly more influenced by the impact associated with their decisions.

At some point, the prospect of encountering risky decisions is inevitable. In order to alleviate the possible impacts, the contractors, like the government, develop "safeguards" to reduce risk. One "safeguard" the contractor uses to avoid financial risk is through the creation of a reserve budget. This budget is an amount of money set aside by management to help provide additional funding in the result of poor initial estimates. The reserve budget is not unlike a personal savings one would have available for use in the event of an unexpected repair bill to their car or home. The amount of personal savings held, in this case, would be subject to an individual assessment of the likelihood of needing to make repairs (uncertainty) and the possible costs associated with the repairs (impact). Similarly, the amount of budget created by the defense contractor is a reflection of the uncertainty and impact contained in their risk assessment (Gould, 1995).

In summary, the contractor makes an independent judgment of the risks involved in defense programs. To assist in decision making, the contractor assesses the uncertainty of meeting technical, schedule, and cost parameters and the impact which may result from a failure to meet those parameters. Then, with an understanding of the uncertainties and their impacts, the contractor develops safeguards in order to minimize the overall risk of the decision.

SETTING UP TESTABLE RELATIONSHIPS

The elements of risk--uncertainty, consequence, safeguard--are constants in DoD acquisition. We have seen how a proactive stance towards risk management helps to minimize the consequences inherent in risky decisions. One of the keys to effective risk management has been shown to involve an accurate assessment of the actual risks involved. Failure to accurately assess the risk leads to consequences which, most often, are damaging in nature.

One of the most damaging results of poor risk management within the DoD is the issue of cost growth. The average cost overrun on defense contracts has been estimated at 40 percent (Gansler, 1989: 4). Considering the enormity of acquisition expenditures within the DoD, this estimate could result in dollar overruns of $37B per year.

Extensive research has been conducted to determine the cause of cost growth in Federal acquisition programs (Drezner, 1995;Pletcher & Young, 1994;Singleton, 1991). No one, however, has developed a single definitive explanation for cost overruns. A 1993 Rand study set out to identify factors affecting cost growth (Drezner, et.al, 1995: xi). They examined aspects ranging from program length, size, and maturity to management, budget, and political decisions. Their overall observation: "the problem of cost growth does not have a 'silver bullet' policy response" (Drezner, et.al, 1995: xiii). In other words, many factors affect the problem of cost overruns, yet no one factor can individually be labeled as the defining, overarching precedent to cost growth.

In an effort to find better methods of controlling and predicting acquisition costs, the DoD implemented a set of criteria known as the Cost/Schedule Control Systems Criteria (C/SCSC). DoD instruction 5000.2 requires the use of C/SCSC for research, development, test and evaluation contracts of $60 million or more or procurement contracts valued at $250 million or more (DoD, 1991: 11B2). As outlined in DoDI 5000.2, "the purpose of cost/schedule control systems criteria is to provide contractor and the Government program managers with accurate data to monitor execution of their program" (DoD, 1991: 11B1). The intention is to standardize evaluation and reporting procedures so that accurate and prompt management decisions can be made regarding the achievement of cost, schedule and technical elements of the program.

Despite the detailed efforts to monitor and control costs, Drezner indicates a lack of substantial improvement in average cost growth over the past 30 years (Drezner, et.al, 1995: xiii). In a report on weapon systems cost trends, James Wiggins of the General Accounting Office stated "the practice of making unrealistically low initial cost estimates has been the major contributor to weapon systems cost growth" (Wiggins, 1988: 16). Similarly, a 1993 study by Dr. David Christensen confirms that poor initial estimates are a major cause of cost overruns and that "recoveries from cost overruns on defense contracts are highly improbable" (Christensen, 1993: 47). Poor estimates alone, however, do not account for the enormity of cost overruns experienced in today's acquisition community.

Cost estimating is, however, one of the steps used by the DoD when conducting risk assessment. Although much research has been accomplished to investigate the causes of cost growth, little has been conducted to address how poor risk assessment affects cost growth. The intent of this study is to investigate the effect of inaccurate risk assessment on the government's ability to achieve cost targets.

Each party to the contract, the government and the contractor, conducts an independent assessment of the risks associated with a contract. This risk assessment is a reflection of their perception of the level of risk faced. Poor risk assessments can lead to consequences, most of which are damaging in nature. Poor risk assessments can also lead to consequences which, on the surface, appear to be beneficial. For instance, an assessment of risk which is higher than the actual risk could result in an overall cost underrun. While this initially appears to be a desirable outcome, it in fact means funds were under-utilized, possibly to the detriment of other programs.

Hypotheses

Inaccurate risk assessments can lead to undesirable consequences. One of these consequences is the aforementioned inability to achieve cost targets. If both the contractor's and the government's perceptions of risk are in alignment with the actual risk involved in a contract, then we would expect minimal impact. If, however, either or both parties fail to accurately assess the actual risk, then we would expect consequences, such as cost overrun/underrun. Consequently, it may be argued that cost overrun/underrun is, in part, a function of the alignment between the actual risk and each parties perceptions of the risk. In instances were risk is underestimated, the expectation is that the contract will experience a cost overrun, because the parties have failed to adequately provide "safeguards" to help minimize the consequences of the actual risk level. Conversely, if risk is overestimated, the expectation is that managers have under-utilized their funds and the contract will experience a cost underrun.

Hypothesis (1) - Cost underruns will be highest, if both the government and the contractor perceptions of risk are higher than the actual risk.

Hypothesis (2) - Cost overruns will be highest, if both the government and the contractor perceptions of risk are lower than the actual risk.

III. Methodology

OVERVIEW

The purpose of this chapter is to describe the methodology used to examine the relationship between risk alignment and cost growth in DoD acquisition. The chapter begins with a description of the population of interest and the subset of data taken from that population to be used as the sample for this study. The validity and measurement techniques for the dependent variable (cost overrun/underrun) and independent variables (contract type, contractor management reserve, and acquisition phase) are then established. The chapter concludes with the development of the analytical procedure (ANOVA) and model used to investigate the hypotheses presented in Chapter II.

POPULATION OF INTEREST AND THE SAMPLE

The population of interest was all acquisition contracts within the Federal Government. Cost performance data of a subset of that population is reported in the Defense Acquisition Executive Summary (DAES) database. The DAES database contains data on completed and on-going DoD contracts since 1977 (Christensen, 1993: 45). The data is summarized in the form of Cost Performance Reports (CPRs) and submitted to the Office of the Under Secretary of Defense for Acquisition & Technology (OUSD(A&T)) on a quarterly basis (DoD, 1991). The database contains contracts from all three military services and covers a wide variety of contract types and end-items.

The sample consisted of all contracts in the database that are complete or nearly completed and that contain the information necessary to define the variables of interest. For the purposes of this study, nearly complete was defined as contracts that were past the 85% completion point. It has been shown that once a contract reaches the 85% completion point, over 95% of the total costs will have been incurred (Wilson, 1992: 38). Percent complete (PC) is a function of the Budgeted Cost of Work Performed (BCWP) and the Budget at Completion (BAC) and was defined as follows:

PC = BCWP/BAC.

MEASUREMENT OF THE DEPENDENT VARIABLE

The dependent variable of interest for this study was the final cost variance of contracts in the DAES database.

At contract completion, the overrun or underrun was the difference between the total budget for all the work on contract, termed the "Budget at Completion" (BAC), and final actual cost of the work performed (ACWP) (Christensen, 1993: 44). In the case of an overrun, the money actually paid to contractor for completion of the work (ACWP) was greater than the monies budgeted for that work (BAC). Conversely, an underrun exists if the ACWP was lower than the final BAC. For the purposes of this study, a numerical rating of cost performance was assigned through the following formula:

Final Cost Overrun/Underrun (FCO/U) = ACWP/BAC.

By this definition, contracts exhibiting an FCO/U greater than one experienced a cost overrun, while those contracts with an FCO/U less than one resulted in a cost underrun. A relative indication of cost overrun/underrun was thus established by the degree to which the FCO/U for each contract was above or below unity.

MEASUREMENT OF THE INDEPENDENT VARIABLES

Three independent variables were necessary to investigate the relationship between risk alignment and the dependent variable--cost performance. The variables needed were: a measure of the actual risk, a measure of the government's perception of risk, and a measure of the contractor's perception of risk.

Actual Risk

A measure of the actual risk encountered in a contract was exhibited by the phase of development of the system. During the research and development (R&D) phase of a system, the requirements are not fully refined and the desired level of technology has not fully matured. For these and other reasons, the uncertainty associated with the state of the final design tends to create a higher level of risk in meeting objectives. Ideally, once a program transitions into the production phase, the system has a stable design. At this point, the manufacturing and production processes have been validated and the system produced has demonstrated the ability to meet contractual specifications and satisfy minimum operational performance requirements (Przemieniecki, 1993: 27). The lower level of uncertainty during production tends to indicate a shift in the actual risk of meeting objectives.

The contracts in the DAES database were, therefore, separated into low and high risk categories based on the phase of development. Contracts pertaining to the R&D phase of development were coded as high risk, while contracts used during production were coded as low risk.

The Government's Perception of Risk

The government's perception of cost risk was reflected in the selection of contract type. The government chooses a contract type it believes accurately reflects the certainty or uncertainty of achieving cost targets. If the government believes there is a high certainty that the contractor can achieve program goals and still maintain adequate cost control, then they tend to select a fixed-price type contract. By doing so, the government is relieving itself of most of the burden of cost overruns by requiring the contractor to complete the contract for a fixed price. Conversely, by selecting a cost reimbursable type of contract, the government is suggesting that there is high uncertainty in the contract, and, therefore the risk of cost escalation is also high. In this instance, the government assumes the risk of cost overruns by agreeing to reimburse the contractor, within set limits, for the work associated with completing the contract.

Similarly, the type of contract selected will coincide with the certainty or uncertainty associated with the technical risks in the contract. A well defined system with complete specifications will usually lend itself to be procured most effectively with a fixed-price arrangement due to the increased certainty of the contractor's ability to meet the requirements. Conversely, if the technical requirements are not so well defined, there is a high degree of uncertainty in the contractor's ability to achieve the specified level of performance and still meet program objectives. In this instance, the government assumes the burden of overrun risk through the selection of a cost-reimbursable-type contract.

Summarily, we can see how the government's perception of the level of risk is captured through the selection of a particular contract type. The variable pertaining to the government's perception of risk was, therefore, the contract type shown in the DAES database. Fixed-price type contracts indicated a low level of perceived risk, while cost-reimbursable type contracts reflected a high level of risk.

The Contractor's Perception of Risk

An indication of the contractor's perception of risk was the level of reserve budget, or management reserve (MR), allocated to the contract. Management reserve (MR) is part of the 10th criterion of the Cost Schedule Control Systems Criteria (C/SCSC) (DoD, 1987) The C/SCSC allow the contractor, after contract award, to budget a management reserve into the program. This MR budget is held in reserve by the contractor program manager and is intended to be used for management control purposes.

> In most major acquisition contracts, particularly in the development phase, there is *considerable uncertainty* regarding the timing, contractor work breakdown structure (CWBS) elements involved, or magnitude of difficulties. The C/SCSC permit the use of a management reserve provided that adequate identification and controls are maintained. (DoD, 1987: 3-10, emphasis added)

A 1995 thesis by Kevin Gould set out to provide a field expert evaluation of the purpose and development of management reserve (Gould, 1995). According to Gould's investigation of former studies, a primary use of the contractor's management reserve is "to provide an adequate budget for in-scope, unanticipated performance requirements that will impact the future effort" (Gould, 1995: 3). As part of the research effort, Gould developed a series of questions relative to management reserve and then interviewed ten different government and contractor managers with extensive experience in the field.

Overwhelmingly, respondents indicated MR is a reflection of the contractor's assessment of the level of risk associated with the program, in general, and the contract specifically (Gould, 1995: 34-35). Gould's analysis led him to the conclusion that "risks are used to assist in the computation of an appropriate level of management reserve budget" (Gould, 1995: 36).

Another part of Gould's research indicated that the average level of MR was 7.5% of the total budget (Gould, 1995: 9). Using this figure as a crude breaking point, contracts in the database with an initial MR greater than 7.5% were categorized as being high risk, as perceived by the contractor. Conversely, contracts with a reported initial MR of less than 7.5% were categorized as low risk.

DESIGN OF THE MODEL

The hypotheses presented in Chapter II were tested by examining the final cost overrun/underrun (FCO/U) for each of the possible alignments of the variables described above. The possible combinations are presented in Table 3-1.

Table 3-1: Risk Alignment Combinations

Combination Number	1	2	3	4	5	6	7	8
Actual Risk	H	H	H	H	L	L	L	L
Government's Risk Perception	L	L	H	H	L	L	H	H
Contractor's Risk Perception	L	H	L	H	L	H	L	H

Combination #1 above represents the alignment described in Hypothesis (2), whereby an underestimation of risk by both parties should result in the highest level of cost overrun. Likewise, combination #8 above represents the alignment of Hypothesis (1). The overestimation of risk by both parties should result in the highest levels of cost underrun. Combinations #4 and #5 above reflect an accurate risk assessment by both parties. These two combinations represent an ideal scenario, whereby the level of cost overrun/underrun should be minimal.

The Analytical Model

An Analysis of Variance (ANOVA) technique was utilized to determine if the variance in FCO/U was significant between the alignment combinations shown in Table 3-1. Using the *Statistix* software package, a one-way ANOVA provided results on the between-groups effect and the equality of within-group variances (Analytical Software, 1994: 130). Additionally, the ANOVA allowed for a comparison of means option, which was used to compare the mean values of FCO/U for each of the eight risk alignment combinations. All tests were conducted at the p-value=.05 significance level. The ANOVA technique was selected for use in this study because of its ability to quickly analyze multiple levels of combinations. Also, the ANOVA process did not pose the restriction of equal sample sizes within the combination levels.

IV. Results

OVERVIEW

The purpose of this chapter is to present the results of the statistical analysis described in Chapter III. Descriptive statistics and variable correlations of the sample are followed by the ANOVA results and comparison of mean values of the risk alignment combinations. The risk alignment combinations and their associated combination references are presented again in Table 4-1.

Table 4-1: Risk Alignment Combinations

Combination Number	1	2	3	4	5	6	7	8
Actual Risk	H	H	H	H	L	L	L	L
Government's Risk Perception	L	L	H	H	L	L	H	H
Contractor's Risk Perception	L	H	L	H	L	H	L	H

DESCRIPTIVE STATISTICS OF THE SAMPLE

Contracts in the DAES database were divided into eight combinations in accordance with the risk alignment described in Chapter III. The frequency of each risk alignment combination is shown in Table 4-2 below.

Table 4-2: Frequency Distribution of Combinations

COMBINATION NUMBER	FREQUENCY	FREQUENCY PERCENTAGE
1	17	5.4
2	20	6.4
3	46	14.7
4	19	6.1
5	137	43.9
6	51	16.3
7	19	6.1
8	3	1.0
TOTAL	312	100.0

The combination frequencies exhibit a normal distribution with the bulk of occurrences (50%) at combinations 4 & 5 and a diminishing tendency toward the tails (5.4% for combination 1 and 1% for combination 8).

A *Pearson* correlation table of the dependent and independent variables is shown in Table 4-3.

Table 4-3: Variable Correlations

	CTYPE	FCOU	MR
FCOU	-0.0151		
MR	-0.0615	0.0428	
PHASE	0.5570	-0.1543	0.1284

The correlations appear to be low with the exception of contract type (CTYPE) to procurement phase (PHASE). The value of .557 is a strong correlation, indicating that changes in the phase of procurement tend to be positively accompanied by changes in contract type.

ANOVA RESULTS

A standard analysis of variance table is displayed in Table 4-4.

Table 4-4: ANOVA Statistics

SOURCE	DF	SS	MS	F	P
BETWEEN	7	0.83867	0.11981	3.52	0.0013
WITHIN	304	10.3403	0.03401		
TOTAL	311	11.1790			

The reported p-value of 0.0013 suggests a substantial between-groups effect. This indicates there is reason to believe, at the .05 significance level, that at least two of combination mean values differ from one another.

Comparison of Mean FCO/U Values

A *Bonferroni* pairwise comparison of means was computed as part of the ANOVA procedure. The results are shown in Table 4-5.

Table 4-5: ANOVA Pairwise Comparison of Means

COMBINATION	MEAN FCO/U	1	4	3	5	6	2	8
1	1.2264							
4	1.0863	2.28						
3	1.0587	**3.21***	0.55					
5	1.0268	**4.21***	1.32	1.01				
6	1.0158	**4.08***	1.42	1.14	0.36			
2	1.0040	**3.66***	1.39	1.11	0.52	0.24		
8	0.9866	2.08	0.87	0.66	0.37	0.27	0.15	
7	0.9742	**4.10***	1.87	1.68	1.17	0.84	0.50	0.11
Critical T Value = 3.152 *p value < .05								

The combinations in Table 4-5 are ordered according to the mean value of final cost overrun/underrun (FCO/U), with the highest value appearing first. The numbers in the body of the table are the t-statistics for each combination pair. A t-statistic higher than the critical value of 3.152 indicates that the mean values of FCO/U for that pair are statistically different at the .05 significance level.

Combination pairs exhibiting t-statistics higher than the critical value are indicated by the bold text.

The results indicate that the highest FCO/U value occurred at combination number one, while the lowest FCO/U value occurred at combination number seven. Note, however, the reported mean value of combination number eight was less than 1.0 and that the mean values for combinations seven and eight were not statistically different. Note, also, that combination number one exhibited a statistically different mean value with five other combinations--the only exceptions being combinations four and eight.

One of the assumptions for the comparison of means ANOVA test is that the within-group variances are equal for all combinations. *Bartlett's* test of equal variances tests this assumption. The results are shown in Table 4-6.

Table 4-6: Bartlett's Test of Equal Variances

CHI-SQ	DF	P
77.39	7	0.0000

The reported p-value of 0.0000 indicates that all of the combinations do not exhibit equal variances. The equal variances assumption necessary for this ANOVA is therefore not supported. The violation of equal variances between combinations does not conclusively invalidate the results of the ANOVA comparison of means. It does, however, suggest that the resulting differences in means may be attributable to variance behavior instead of the actual mean FCO/U tendencies.

Because of the ANOVA limitation concerning equal variances among combinations, a two-sample t-test was conducted between combinations one and eight and the other six risk alignment combinations. The results are shown in Table 4-7.

Table 4-7: T-Test Comparison of Means

COMBINATION	MEAN	p- value	
		Comb 1	Comb 8
1	1.2264	-	.0326*
2	1.0863	.0258*	.7237
3	1.0587	.0212*	.1629
4	1.0268	.2505	.5830
5	1.0158	.0001*	.3750
6	1.0040	.0023*	.5196
7	0.9866	.0112*	.7735
8	0.9866	.0326*	-

The reported p-values assume either unequal or equal combination variances, as is appropriate for each individual pair. The p-values shown with an asterisk indicate the mean values of FCO/U for the two combinations are statistically different at the .05 significance level.

The results of the t-test are similar to those reported in the ANOVA comparison of means. The only difference being that the t-test indicates a significant difference between mean FCO/U values for combinations 1 and 8.

CHAPTER SUMMARY

Results of the statistical analysis indicate significant differences exist between several of the mean final cost underrun/overrun (FCO/U) values. The only significant differences, however, were between combination 1 and five of the other risk alignment combinations (see Table 4-5). Because of failed equal variances assumption of the ANOVA procedure, a t-test had to be conducted to confirm the ANOVA results. The results of the ANOVA were supported by the t-test. Additionally, the t-test indicated a statistically significant difference existed between risk alignment combinations one and eight, which represented the difference between an underestimation of risk by both the government and the contractor and an overestimation of risk by both parties.

V. Conclusions

OVERVIEW

Proper risk management is an organized means of identifying and measuring risk and developing, selecting, and managing options for handling these risks. It involves understanding the danger signals that may indicate a project is off track and prioritizing corrective actions as necessary. Risk management is not a separate office activity, but rather is one aspect of sound technical management. Proper risk management implies control of possible future events, and is proactive rather than reactive. Proper risk management will reduce not only the likelihood of an unfavorable event occurring, but also the magnitude of its impact (Kerzner, 1995: 880).

The recurring premise is that the best way to handle risky situations is to <u>manage</u> them. By this, I mean taking an active stance in identifying potential problem areas and then preparing a necessary course of action to alleviate the damage associated with risky decisions.

Cost and schedule performance on a contract can be seen as a reflection of how well DoD managers have dealt with the uncertainties associated with risk. Failure to adequately account for these uncertainties is often reflected as cost overruns and schedule extensions. There is a long history of cost and schedule growth in federal acquisition. In an era of limited DoD budgets, the impacts associated with cost overruns and schedule extensions are particularly disconcerting.

The Sergeant York and AMRAAM examples discussed in Chapter II reflect the possible consequences of poor risk management. In both examples, DoD acquisition managers either failed to adequately understand the "uncertainties" associated with the risk in their programs, or failed to develop the necessary "safeguards" to mitigate the damaging effects of a risky environment. The end results were the cancellation of the Sergeant York program and cost overruns of the AMRAAM by an estimated 4 to 6 times the initial estimates.

As part of the risk management process, each party to the contract, the government and the contractor, conducts an independent assessment of the risks associated with a contract. This risk assessment is a reflection of their perception of the level of risk faced. Poor risk assessments can lead to consequences, most of which are damaging in nature. Poor risk assessments can also lead to consequences which, on the surface, appear to be beneficial. For instance, an assessment of risk which is higher than the actual risk could result in an overall cost underrun. While this initially appears to be a desirable outcome, it in fact means funds were under-utilized, possibly to the detriment of other programs.

This study attempted to investigate the effect of inaccurate risk assessment on the government's ability to achieve cost targets. The organization of the study focused on the alignment, or lack of alignment, between each party's perception of risk and the actual risk encountered. The actual risk was believed to be a function of the phase of procurement (high risk for R&D and low risk for production). The government and contractor perceptions of risk were based on contract type (high risk for cost-type contracts and low risk for fixed-price contracts) and initial percentage of management reserve (MR) (high risk for MR > 7.5% and low risk for MR < 7.5%), respectively. If both the contractor and the government perceptions of risk were in alignment with the actual risk involved in a contract, then the expectation was to experience minimal consequence. If, however, either or both parties failed to accurately assess the actual risk, then the expectation was consequences, such as cost overrun/underrun. Consequently, it was argued that cost overrun/underrun is, in part, a function of the alignment between the actual risk and each parties perceptions of the risk. In order to investigate the relationship between risk alignment and cost performance, two hypotheses were developed and presented in Chapter II.

Results of Hypothesis One

Hypothesis one stated cost underruns would be highest if both the government and the contractor perceptions of risk were higher than the actual risk. In this scenario, it was believed that the overestimation of risk would lead to an under-utilization of funds, resulting in an overall cost underrun. This scenario was indicated by the group of contracts in risk alignment combination number eight, where an actual risk level of low was accompanied by government and contractor high risk perceptions.

Based on the variables selected and the analytical model used, hypothesis one was not supported. Results showed that the mean value of final cost overrun/underrun

(FCO/U) for combination number eight was 0.9866. This indicates that, on the average, contracts in this group exhibited an underrun, as expected, of approximately 1.14%. The mean value for combination number eight, however, was not significantly different from the other combinations when using the ANOVA procedure. This may have been due in part to the small sample size for this combination (3 cases). Results of the t-test conducted, however, did indicate a statistically significant difference between combination number eight and combination number one--represented by an underestimation of risk by both the government and the contractor. While not conclusive in the support of the underrun hypothesis, this does partially support the belief that an overestimation of risk by both parties will result in lower levels of cost growth.

Results of Hypothesis Two

Hypothesis two stated cost overruns would be highest if both the government and the contractors perceptions of risk were lower than the actual risk. In instances where risk was underestimated, the expectation was that the contract would experience a cost overrun, because the parties had failed to adequately provide "safeguards" to help minimize the consequences of the actual risk level. This scenario was indicated by the group of contracts in risk alignment combination number one, where an actual risk level of high was accompanied by government and contractor low risk perceptions.

Based on the variables selected and the analytical model used, hypothesis two was partially supported, however the results were inconclusive. Results showed the mean value of final cost overrun/underrun (FCO/U) for contracts in combination one was 1.2264. This indicates that, on the average, contracts in this group exhibited overruns, as expected, of approximately 22.6%. Additionally, the ANOVA procedure indicated the mean value of FCO/U for combination one was statistically different from five of the other risk alignment combinations. The significance of these findings, however, is limited by the fact that the assumption of equal variances within the combinations was violated.

Because of the ANOVA limitation on equal variances, a two-sample t-test was conducted as an alternative analysis in the hope of validating the ANOVA results. Results from this test indicate that the mean value of FCO/U for combination one is, in fact, significantly different at the .05 level from all but one risk alignment combination. The exception was the difference between combination one and combination number four, where both parties perceptions of high risk were in line with an actual high risk categorization. While not conclusive, this result partially confirms the hypothesis that an underestimation of risk by both parties will create a higher likelihood of experiencing a contract cost overrun.

IMPLICATIONS

The elements of risk--uncertainty, consequence, safeguard--are constants in DoD acquisition. The theory behind risk management discussed in this study suggests a proactive stance towards developing safeguards helps to minimize the consequences inherent in decisions involving uncertainty. One of the keys to proactive risk management involves an accurate assessment of the actual risks involved. Failure to accurately assess the risk leads to consequences which, most often, are damaging in nature--as shown by the Sergeant York and AMRAAM examples presented in Chapter II.

An extension of an accurate risk assessment is an alignment of the actual risk in a contract with the level of risk perceived by both the government and the contractor. A misalignment of risk could result in damaging consequences, such as poor cost performance. As cost performance becomes an increasingly growing concern in DoD acquisition, the need to understand the reasons for poor cost performance also increase. The intent of this study was to determine if the alignment of perceived risk to actual risk provided some insight into cost performance behavior.

The statistical results do not completely confirm the hypotheses presented in this study. They do, however, strongly suggest a relationship exists between the alignment of risk and the cost performance experienced on a contract. The implications for DoD contract managers is that proper risk management is a critical element in the effort to achieve cost targets. One part of proper risk management is the ability to accurately analyze the actual risk in a contract and then take the necessary steps to develop "safeguards" capable of mitigating the damaging consequences of that inherent risk. Failure to adequately align the perceptions of risk with the actual risk has been shown by this study to create a tendency towards poor cost performance. Most significantly, an underestimation of risk by both parties could result in the highest degree of cost growth.

LIMITATIONS

The major limitation in this study was in the development of the independent variables. The proxies used to operationalize the perceptions of risk and actual risk were theoretical in nature and, as such, their effectiveness had not been tested.

One of the indications of less-than-ideal proxy selection was in the reported correlation between contract type and phase of procurement. The strong correlation of .556, however, was not totally unexpected. In fact, the standard practice within DoD procurement is to favor cost-type contracts during development and fixed-price contracts during production. The utilization of contract-type in this manner is accomplished in part because of the government's understanding of the differences in risk between R&D and production phases. While the high correlation tends to weaken the strength of the findings, it does not totally invalidate the results, as would be the case with a perfect correlation of 1.0.

Additionally, while the ANOVA procedure is ideally suited for examining the variances in mean values, its use may not have been totally appropriate for this data set due to the assumptions it imposes. In order to verify the ANOVA results, a t-test had to be conducted. The t-test partially confirmed the validity of the ANOVA results, but it also introduced the possibility of family-wise error associated with multiple t-test comparisons. This, again, tends to weaken the value of the findings.

RECOMMENDATIONS FOR FUTURE RESEARCH

This study was an introductory approach into the investigation of risk alignment and its effect on cost performance. That being the case, there are many areas for future improvement.

The most notable recommendation is the development and usage of more accurate proxies for the variables of interest. While the theory behind the need for proper risk alignment has been established, the variables used to test that theory were very tentative and untested. The development of more suitable proxies for actual risk and government and contractor perceptions of risk may produce more conclusive results. Specifically, proxies which are independent from one another would eliminate the high correlations experienced with contract type and phase of procurement.

Another area of improvement would be to obtain a larger sample of some of the key risk alignment combinations. One of the limiting factors in statistically proving the difference in mean FCO/U values was the small number of contracts in the group representing overestimation of risk by both parties (combination number eight).

The final recommendation would be to investigate the theoretical basis for the behavior of the risk alignment combinations as a continuum. While this study focused on the behavior of the extreme scenarios (combinations one and eight), there may exist the possibility of confirming a sequential relationship among the eight combinations. A greater understanding of the consequences associated with each of the possible risk alignment combinations may provide

DoD acquisition managers with more information to use in reducing poor cost performance.

BIBLIOGRAPHY

Analytical Software. *Statistix v4.1, User's Manual*. Tallahassee FL: Analytical Software, 1994.

Christensen, David S. "An Analysis of Cost Overruns on Defense Acquisition Contracts," *Project Management Journal, 14*: 43-48, (September 1993).

Cibinic, John & Ralph C.Nash, Jr. *Cost Reimbursement Contracting*. Washington DC: Government Contracts Program, George Washington University, 1981.

Cibinic, John & Ralph C.Nash, Jr. *Administration of Government Contracts, Third Edition*. Washington DC: Government Contracts Program, George Washington University, 1995.

Defense Systems Management College (DSMC). *Risk Management: Concepts and Guidance*. Washington DC: U.S. Government Printing Office, 1989.

Department of Defense (DoD). *Armed Services Pricing Manual*. Chicago IL: Commerce Clearing House Inc, 1986.

Department of Defense (DoD). *Cost/Schedule Control Systems Criteria Joint Implementation Guide*. Washington DC: U.S. Government Printing Office, 1987.

Department of Defense (DoD). *Defense Acquisition Management Policies and Procedures*. DoD Instruction 5000.2. Washington DC: U.S. Government Printing Office, 1991.

Department of Defense (DoD). *Federal Acquisition Regulation*. Chicago IL: Commerce Clearing House Inc, 1993.

Drezner, J.A., et.al. *An Analysis of Weapon System Cost Growth*. Santa Monica CA: RAND Corporation, MR-291-AF, 1995.

Gansler, Jacques S. *Affording Defense*. Cambridge MA: The MIT Press, 1989.

General Accounting Office (GAO). *The Army Should Confirm Sergeant York Air Defense Gun's Reliability and Maintainability Before Exercising Next Production Option*. Washington DC: U.S. General Accounting Office, 1983.

General Accounting Office (GAO). *Sergeant York: Concerns About the Army's Accelerated Acquisition Strategy*. Washington DC: U.S. General Accounting Office, 1986.

Gould, Kevin T. *An Analysis of the Purpose and Development of Management Reserve*. MS Thesis, AFIT/GCA/LAS/95S-3. School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1995 (AD-A300504).

Kerzner, Harold. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*. New York NY: International Thomson Publishing Inc, 1995.

L'Heureux, Richard A. and Kevin P. Grant. *Defense Acquisition Strategy: Development and Execution*. Unpublished Textbook for SMGT 647, Air Force Institute of Technology, Wright-Patterson AFB OH, 1996.

MacCrimmon, Kenneth R. and Donald A. Wehrung. *Taking Risks*. New York NY: The Free Press, 1986.

Mayer, Kenneth R. *The Development of the Advanced Medium-Range Air-to-Air Missile: A Case Study of Risk and Reward in Weapon System Acquisition*. Santa Monica CA: RAND Corporation, N-3620-AF, 1993.

Moore, Peter G. *The Business of Risk*. New York NY: Cambridge University Press, 1983.

Pletcher, J.M. & J.C. Young. *An Evaluation of Department of Defense Contractors' Cost Performance*. MS Thesis, AFIT/GCA/LAS/94S-5. School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1994 (AD-A285017).

Przemieniecki, J.R. *Acquisition of Defense Systems*. Washington DC: American Institute of Aeronautics and Astronautics Inc, 1993.

Shapira, Zur. *Risk Taking: A Managerial Perspective*. New York NY: Russell Sage Foundation, 1995.

Singleton, P.J. *Estimating Potential Cost Growth of the Most Probable Cost Estimate*. MS Thesis, AFIT/GCA/LSQ/91S-11. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1991 (AD-A243919).

Wiggins, James F. *What Will Weapons Being Developed Today Cost to Produce Tomorrow--An Analysis of Weapon System Cost Trends*. Washington DC: U.S. General Accounting Office, 1988.

Wilson, Brian D. *An Analysis of Contract Cost Overruns and Their Impacts*. MS Thesis, AFIT/GCA/LSY/92S-8. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1992 (AD-A258422).

Vita

Captain Christopher M. Wegner was born 21 Nov 1968 in Brenham, Texas. In December, 1991, he graduated from the University of Texas at Austin with a Bachelor of Science Degree in Aeronautical Engineering and was commissioned a second lieutenant in the United States Air Force via the Reserve Officer Training Corps (ROTC), Detachment 825. In October 1992, Capt Wegner attended contracting officer's training at Lowry AFB, CO in route to his first assignment at the 16th Special Operations Contracting Office, Hurlburt Field, FL. Capt Wegner was accepted into AFIT in May of 1995 and graduated from the Contracting Management Master's Degree program in September 1996. His follow-on assignment from AFIT was to the Training Systems Product Group, ASC/YWK, Wright-Patterson AFB, OH. He is married to the former Josepha L. Fraboni, Capt, USAF and has a two-year-old daughter, Heidi Noelle.

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13. ABSTRACT ***(Maximum 200 Words)***

This study investigates the relationship between risk alignment and cost performance in DoD procurement. Both the government and the contractor conduct independent assessments of the perceived risk in a contract. The results of inaccurate risk assessments are undesirable consequences, one of which is the inability to achieve cost targets. If both the contractor's and the government's perceptions of risk are in alignment with the actual risk involved in a contract, then we would expect minimal impact. If, however, either or both parties fail to accurately assess the actual risk, then we would expect consequences, such as cost overrun/underrun. The level of cost overrun/underrun can be determined by examining the level of alignment between the actual risk and each party's perception of the risk.

Results indicate a significant potential for cost growth when both the government and the contractor underestimate the actual risk. In this context, the level of cost growth experienced on a contract is a reflection of the adequacy of the parties' risk assessments. Failure to accurately assess risk could result in a lack of sufficient "safeguards" necessary to help mitigate the damaging effects of risk inherent in a contract.

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