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PREFACE

This paper supports work performed by the Institute for Defense Analyses (IDA) in partial fulfillment of the task entitled "Systems Engineering in the New Acquisition Environment." The work was sponsored by the Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics), Office of Enterprise Development in the Office of Systems Engineering (SE).

This paper responds to the specific task to conduct case studies of defense and commercial organizations implementing practices that would enhance the application of systems engineering in the new defense acquisition environment, and to convey lessons learned and success stories. It is the product of a summer intern project.

The authors wish to thank Dr. Karen Tyson of IDA for reviewing this document.

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SUMMARY

The United Sates military is the best-equipped in the world. Its prowess is owing to many factors, not least of which are the advanced systems that are developed and deployed around the world. While these weapons are some of the most advanced, system acquisition programs often, and repeatedly, suffer the same recurring problems: shortfalls in expected performance, budget overruns, and schedule slips.

These problems are not new, and their causes are many and varied. Taken as a whole, one area that has received considerable attention as being a potential contributor is systems engineering and program management, two of the primary processes that are employed to help cope with the increasing technical and organizational complexity found in the system acquisition process.

A. FINDINGS

The success of systems engineering and program management processes is closely linked to other aspects of the system acquisition process—system design, systems engineering and program management process implementation, and the acquisition environment. The inter-relationship between these three elements creates "problems behind the problems" in system acquisition programs that must be addressed by successful acquisition reform efforts.

We have avoided identifying causal relationships between shortfalls in technical performance, budget overruns and schedule slips, and individual events in this report; instead, we have focused our efforts on identifying and understanding risk factors whose presence indicates an increased probability of negative program performance.

Our examination of case studies, including comparisons among commercial programs and DoD programs and comparisons among DoD programs, combined with an understanding of the emphasis of past acquisition reform efforts, suggests that there are common risk factors across programs and that institutional realities greatly affect the success of systems engineering and program management processes. Crafting processes without considering these larger institutional issues is an incomplete work.

Various strategies exist for crafting processes that may increase program performance. An alternative strategy to current DoD acquisition processes is to explicitly account for institutional realities in the system design. For example, new systems

engineering processes could be emplaced that would limit the negative impact that funding instabilities have on technical performance, budget overruns, and schedule slips.

B. ANALYSIS

In determining if systems engineering or program management is a contributing reason for technical, budgetary, or scheduling challenges, a better understanding of how both processes and tools fit within the system acquisition process is necessary. To facilitate this understanding, we compiled information from three activities: a review of the literature, gathering various examples, and in-depth analyses of case studies. Our objectives were to:

- identify risk factors associated with technical, budget, and scheduling shortfalls
- understand the basic sources or manifestations of risk factors: are they inherent in the systems or are they merely bad practices
- understand how risk factors relate to one another and to the system acquisition process, and
- illustrate the effect risk factors have on one another and on the program.

To accomplish these objectives, information from the following six areas was compiled.

1. A review of the system acquisition process, the systems engineering process, and program management
2. A review of key stakeholders involved in the system acquisition process
3. A review of previous system acquisition case studies, including both programs perceived as being successful and those that were not
4. A review of previous studies and reform efforts aimed at improving the system acquisition process
5. A comparison between DoD system acquisition programs and commercial acquisition programs
6. Comparisons among DoD system acquisition programs.

C. IDENTIFYING RISK FACTORS

Based on the information we gathered from these six areas, we created a list of risk factors that may negatively affect a system program's technical, budgetary, or schedule performance. Identified risk factors are conditions, activities, or events that increase the probability of a negative outcome. Definitive causes for negative performance often are difficult to determine due to the complexity of system programs, so instead we identified risk factors that appear in multiple programs suffering from performance, budgetary, or scheduling shortfalls. In doing so, four major categories became apparent, and we list these in Table S-1.

Table S-1. Major Risk Factor Categories

Risk Factor Categories	Description
Category I – Design Risk Factors	Risk factors stemming from system design choices and design philosophy.
Category II – Systems Engineering and Program Management Process Risk Factors	Risk factors stemming from following systems engineering and program management processes, as defined in DoD 5000.2.
Category III – Systems Engineering and Program Management Implementation Risk Factors	Risk factors stemming from the implementation of defined systems engineering and program management processes.
Category IV – Institutional Risk Factors	Risk factors stemming from the structure of the acquisition environment, external to the other three categories. The structure of the acquisition environment includes organizational, cultural, political, financial, and incentive issues.

We designed these four risk factor categories to provide a thorough look at issues related to systems engineering and program management; hence, the systems engineering-related focus of Categories II and III. In identifying the risk factors, we found that many of them affected systems engineering or program management, but were not related directly to those processes or to the implementation of these processes. We also found that many previously low success attempts at reform in systems acquisition focused on one main area, such as systems engineering or program management, without addressing how these areas fit into the larger picture. Our inclusion of Category I, Design Risk Factors, and Category IV, Institutional Risk Factors, is an attempt to illustrate how systems engineering and program management-related issues encompass more than just the systems engineering and program management processes.

D. REFORM STRATEGIES

From the identified risk factors, we created a broad set of reform strategies to illustrate different possible approaches to addressing persistent technical, budget, and scheduling challenges. As there have been a great many specific reforms generated in the past, with varying degrees of success, we avoided the design of *specific* reforms in this report. Instead, a *reform space* was designed, comprising general types of approaches to reforms. We envision that this—or a similar type of reform space, if generated—could prove a useful tool in creating specific reforms designed at addressing specific challenges. We provide a reform space summary in Table S-2.

Table S-2. Reform Space Summary

Types of Reform	Areas for Reform			
	Category I: Design Risk Factors	Category II: Systems Engineering and Program Management Process Risk Factors	Category III: Systems Engineering and Program Management Implementation Risk Factors	Category IV: Institutional Risk Factors
Focused Reforms	Change design emphasis or philosophy	Change systems engineering or management processes	Change systems engineering or management implementation	Change institutional characteristics
Adaptation / Accommodation Reforms	Create flexible designs and processes that can adapt to changing technical or institutional requirements		Manage for flexibility in programs to identify and adapt to changing conditions	Adapt program to institutional characteristics

We identified two major types of reforms that have particular merit: focused reforms and adaptation reforms. Focused reforms are traditional types of reforms that have as their objective the design and implementation of solutions that solve identified problems. Adaptation reforms are designed with a different philosophy. Design and management decisions are made up front to create a system acquisition process that is flexible enough to accommodate technical and institutional changes. The goal is to recognize the existence of various risk factors and to create a program that can accommodate or adapt to the existence of risk factors without suffering serious technical, budget, or scheduling setbacks.

E. FUTURE WORK

Our report provides a broad-based look at risk factors and reform strategies applicable to systems engineering and program management in system acquisitions. Additional work of a more detailed nature could include, but not be limited to:

- efforts to identify a more complete list of systems engineering and systems program management risk factors;
- efforts to determine the magnitude of risk posed from the presence of different risk factors or combinations of risk factors to technical, budget, and scheduling goals;
- design of specific reforms or efforts to address general or specific risk factors.

I. STUDY OVERVIEW

Our work involved reviewing the literature, developing case studies, and assembling system acquisition program histories to use as examples. In conducting the literature review, we focused on understanding (1) the systems acquisition environment, (2) previously identified problems affecting system acquisition programs, and (3) the institutional nature of the acquisition environment. We developed case studies to help identify risk factors in acquisition programs, to observe commonalities, and to understand how risk factors interacted with one another and affected the program over time. We looked at other systems (in less detail) to develop a representation of a wider range of programs and to identify additional risk factors and risk factor interactions. We then integrated this composite information to arrive at our conclusions.

A. SCOPE

We limited the scope of this report to providing a high-level understanding of risk factors affecting system acquisition programs and the role that systems engineering and program management processes have relative to these risk factors. We steered clear of an exhaustive examination of any one topic in favor of a broad overview and an integration of several areas of study. The areas studied include:

- individual system acquisition programs
- comparison of DoD acquisition programs to commercial programs
- comparison of DoD programs to one another
- the history of acquisition reforms
- analysis of stakeholders involved with system acquisition programs.

B. ACQUISITION PROGRAM CASE STUDIES

We made extensive use of DoD and commercial system acquisition programs as examples to aid in illustrating various points throughout the report; these are:

<u>DoD Programs</u>:

- F/A-22 Fighter Plane
- Global Hawk Unmanned Aerial Vehicle
- F-15 Fighter Plane
- C-17 Cargo Plane
- Arsenal Ship
- Crusader Artillery Vehicle
- Comanche Helicopter
- Joint Direct Attack Munitions.

Commercial Programs:

- Boeing 777
- Bombardier BRJ-X Regional Jet
- Caterpillar 797 Heavy Mining Truck.

C. REPORT STRUCTURE

Our report is structured around identifying, understanding, and presenting the risk factors that appear in system acquisition programs. In Chapter II, we present an overview of our findings, drawing together and summarizing information found in greater detail in the subsequent chapters, which report on:

- Identified risk factors, along with commentary on each. Where appropriate, examples of weapon system programs are presented, along with interactions among risk factors (Chapter III)
- Acquisition, systems engineering, and program management processes and stakeholders in the acquisition environment (Chapter IV)
- Detailed case studies of the F/A-22, Global Hawk, and F-15 acquisition programs (Chapter V)
- A history of reform efforts in system acquisitions (Chapter VI)
- A comparison between commercial and DoD programs (Chapter VII)
- A comparison of DoD programs (Chapter VIII)
- Reform strategies (Chapter IX).

Overall conclusions and suggestions for future work complete the report.

D. ACKNOWLEDGEMENTS

Portions of this report drew heavily on information or ideas from selected references, specifically, Battershell in Chapter VII, Ingols in Chapter VIII, and Weigel in Chapter IX.

II. OVERVIEW OF FINDINGS

Systems engineering and program management processes have an impact on the success of system acquisition programs; at the same time, many other aspects of acquisition programs and the larger acquisition environment appear to have as great an impact. The effect that these processes have on acquisition programs is closely linked with other aspects of the acquisition process and environment. This report provides a discussion of the interrelationship between systems engineering and program management processes and the larger acquisition environment, and attempts to look at the "problems behind the problems." It is necessary that we understand the problems behind the problems if future efforts at reforming the systems engineering and program management processes are to be successful.

A. IDENTIFYING RISK FACTORS

There are several aspects of the acquisition process and its environment that can contribute to budget overruns, scheduling slips, and performance shortfalls. Determining a causal relationship between observed problems and the many events that can occur within the acquisition process can be very difficult. Typically, when programs experience negative impacts, several risk factors are present. Conversely, a single risk factor can affect technical performance, budget, or schedule, or a combination of these.

Determining the magnitude of effects or how combinations of events impact a program is even more difficult. To avoid the problem of determining exact causality and quantifying the magnitude of the effect, we present a series of risk factors and forward the hypothesis that the presence of these conditions, elements, or activities can have a negative impact on a system acquisition program.

We can identify risk factors by looking across programs with a variety of attributes, which can include the sponsoring military Service, the system, the program size, and time. We found that several risk factors are shared across programs, some risk factors appear in certain types of programs, and some appear unique to individual programs. In our report, we are emphasizing the common risk factors, as it is apparent that they cause many of the negative impacts in programs.

B. RISK FACTOR CLASSIFICATION AND INTERACTION

We organized identified risk factors into four main categories: system design and design philosophy; the systems engineering and program management processes; implementation of the systems engineering and program management processes; and the institutional aspects of the acquisition process. These four types of risk factors are not independent; they interact and exacerbate one another. For example, design factors, such as those that are found in large, complex systems, can increase the probability that systems engineering risk factors and institutional risk factors will be present. Examples of risk factors that fall into these categories and are subsequently influenced by the size and complexity of the system include an increase in the number of requirements generated for a program and a decrease in flexibility to perform trade-offs, and an increase in the probability of budget instability over the life of the program.

C. PREVIOUS ACTIONS REGARDING RISK FACTORS

Many of the risk factors we identified are know within the DoD system acquisition community, and we found evidence suggesting that DoD has repeatedly addressed these concerns, with various degrees of success. One reason for this varied success is that people tend to place emphasis on addressing the identified risk factor in isolation. Interactions with and interdependencies on other risk factors have not been adequately addressed; people tend to focused only on the problem at hand. This then leads to an often unrealistic expectation that these focused reforms ─ such as adopting commercial best practices ─ will adequately address the identified risk factors without taking into account the various pressures, goals, incentives, and norms associated with the larger acquisition environment.

D. "PROBLEMS BEHIND THE PROBLEMS"

To deal with these risk factors, the problems behind the problems need to be identified and addressed. These are the issues that result from interaction among systems engineering and program management processes, design attributes, implementation of processes, and larger institutional realities. Institutional realities include organizational structure, organizational behavior, organizational culture, rules, and incentives. But we realize that crafting reforms in this manner is a challenge and is sometimes beyond the scope or mandate of organizations.

E. ALTERNATIVE REFORM STRATEGIES

Without addressing the problems behind the problems, focused reforms often take "two steps forward and one step back." And while progress has been made on improving compliance with budgetary and scheduling constraints, it is slower and more haphazard than desired.

Alternative types of reform that look to be compatible with DoD's current evolutionary acquisition process and open systems strategy may be possible. Such alternative reforms are geared towards providing flexibility in acquisition programs to explicitly take into account risk factors stemming from the larger acquisition environment. For example, open system design allows for the flexibility to adopt new technologies as they become available, without the need for major redesign efforts. Similarly, systems can be designed with flexibility that allows the design to adapt to institutional realities, such as budget instabilities, without incurring major redesign work, technical performance shortfalls, and schedule slips.

III. RISK FACTORS

Creating new acquisition reforms often is in response to the negative program performance of an earlier system. The goal of course is to identify the cause of the negative performance, craft an improved process, and implement the new process to prevent future negative performance. But finding the cause for negative program performance can be very difficult.[1] There are inherent technical and institutional complexities and many different, but inter-related, factors. The effect and magnitude that any one factor exerts - independent of other factors - are uncertain, although the presence of these factors does raise the risk that a program will be negatively impacted.

We borrow the concept of risk factors as used in this report from the medical field of epidemiology (the study of disease). In epidemiology, risk factors are statistically associated with a certain disease, but are not necessarily causally related to the disease. And it is often difficult to determine causality with absolute certainty because a great number of factors affect the biological system and interact in unknown ways with the system, with one another, and with the larger environment.

Acquisition programs, like biological systems, are also complex. Understanding how a great number of factors interact with the acquisition program, with one another, and with the larger environment is not always possible, which makes it difficult to precisely determine cause and effect, forcing the use of risk factors as a concept.

When a risk factor *is* identified, it is often the product of still deeper issues, often the result of technical, process, management, and institutional factors. Many process reforms are ineffective when implemented because they do not adequately take into account technical and institutional realities, or the problems behind the problems. Identifying and addressing only one aspect of risk factors appearing in programs - such as systems engineering and program management - without placing these risk factors in context makes it difficult to craft solutions that will have a positive impact when implemented.

The benefit of using risk factors is that it more realistically describes the situation occurring in acquisition programs, when compared to trying to identify mono-causal

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1 Drezner, Jeffery and Richard Krop, "The Use of Baselining in Acquisition Program Management," National Defense Research Institute, Washington DC, June 1997.

problems, single effects caused by these problems, and single, "silver bullet" solutions to fix these problems. Looking for single mono-causal problems and attempting to find their effect is seductive, but often results in reforms that do not have the desired effect because they are focused to target only the observed risk factor, without taking into account how the reform will affect the entire program and even larger institutional issues. The use of risk factors forces the acknowledgement that several factors will affect a program, often in ways that are not fully understood and that differ from program to program, which then forces a more holistic approach to addressing shortcomings in a program's success.

In order to fully understand and solve problems that affect acquisition programs, knowledge and tools from a range of disciplines will need to be employed. Systems engineering and program management are common ways that engineers cope with complex systems and complex problems, but these tools and processes need to be augmented with tools and processes in domains such as organizational behavior, stakeholder analysis, policy analysis and political economy. Again, broadening the set of tools will allow reforms to be crafted in a more holistic manner.

A. DEFINITION OF RISK FACTORS AND PROGRAM SUCCESS

Risk factors are any condition, element, or activity that tends to adversely affect the success of a program. They are associated with problems observed in the system, but may or may not be the cause of the problems.

Program performance is primarily measured as the ability to complete the program with technical performance, cost, and schedule as close to original forecasts as possible. Other aspects of program success also can be measured, such as the avoidance of bad publicity.

B. RISK FACTOR CATEGORIZATION

From our literature review, we have identified and categorized an array of risk factors that negatively impact systems acquisition, and we have grouped them into four broad categories, as presented in Table III-1.

Table III-1. Major Risk Factor Categories

Risk Factor Categories	Description
Category I – Design Risk Factors	Risk factors stemming from system design choices, design characteristics and design philosophy
Category II – Systems Engineering and Program Management Process Risk Factors	Risk factors stemming from following systems engineering and program management processes, as defined in DoD 5000.2
Category III – Systems Engineering and Program Management Implementation Risk Factors	Risk factors stemming from the implementation of defined systems engineering and program management processes
Category IV – Institutional Risk Factors	Risk factors stemming from the structure and behavior of the acquisition environment, external to the other three categories. This includes organizational, cultural, political, financial, and incentive issues.

Organizing these risk factors into four categories focuses our attention on the specific aspect of the systems engineering and program management processes that produce negative effects, which in turn allows future efforts at crafting corrective action to focus on the appropriate process. But this categorization has it limits: because of the complexity involved throughout the intertwined network comprising weapons systems, the acquisition process, and the defense community, risk factors spill over categories and very often have multiple causes and multiple effects. But for the purposes of this report, we have placed them in single categories.

C. RISK FACTOR IDENTIFICATION AND DISCUSSION

The set of risk factors we present in Table III-2 is not meant to be exhaustive, but rather to illustrate their scope and to highlight inter-relationships. We then discuss each in turn, and use illustrative examples where appropriate.

Table III-2. Summary of Identified Risk Factors

Category I: Design	Category II: Systems Engineering and Program Management Process	Category III: Systems Engineering and Program Management Implementation	Category IV: Institutional Risk
Technological Maturity and Cutting Edge Technology	Number of Requirements	Lack of Program Manager Authority	Lack of Reform Institutionalization and High-Level Support
Over-Constrained and Over-Specified System Requirements	Requirement Instability	Simultaneous Phasing	Requirement Generation Misaligned with Resources
Upgrades and Obsolescence	Contractor Capability to Meet Requirements	Lack of Systems Engineering Funding	Misaligned Stakeholder Goals
	Requirements Set Before Systems Engineering	Lack of Program Status Information	Lack of "Silver Bullet" Solution
	Change of Requirements without Change in Resources	Lack of Ability and Willingness to Make Trade-offs	Lack of Trust in Reform Efforts
	Contractual Uncertainty	Testing Shortfall	

1. Category I: Design Risk Factors

Some design choices and design philosophies inherently lead to more risk than others, which translates into higher risk for the overall acquisition program. Design attributes such as complexity or the inclusion of cutting-edge technology can act to increase the risk that program performance will fall short. Large, complex, highly integrated systems using cutting-edge technology inherently pose greater challenges to meeting performance, budget, and schedule goals than do smaller, simpler systems using familiar technologies. Developing and assessing technical realism in programs has been found to be a critical part of containing program cost growth and schedule slips.[2] Together, design risk factors and institutional risk factors are the "problems behind the problems" associated with systems engineering and program management risk factors.

[2] Tyson, Karen, Bruce Harmon and Daniel Utech, "Understanding Cost and Schedule Growth in Acquisition Programs," IDA Paper P-2967, Institute for Defense Analyses, Alexandria, VA, July 1994.

a. Technological Maturity and Cutting Edge Technology

Since World War II, the culture associated with systems acquisition has been one of using cutting-edge technology. While there are many advantages and reasons for using such cutting-edge technology, it comes with higher risk. Associated unknowns have a higher probability of exceeding budget and schedule constraints than do systems using more mature technology. Programs that underestimate technical difficulty often experience slips in the development schedule.[3]

In addition to individual technology maturity, the integration and application of technologies in new ways pose a risk to budgets and schedules. For example, the C-17 was conceptualized as a low-risk cargo plane using only mature technologies. However, several of the technologies had never been integrated in the manner needed to achieve mission goals. The C-17 design called for a quadruple redundant fly-by-wire system, but the quadruple redundancy created complex computer integration problems that were difficult to resolve.[4]

b. Over-Constrained and Over-Specified System Requirements

Depending on the program context, certain trade-offs must be made to ensure efficiency and a satisfactory program result. In cases where the system requirements are highly constrained in number or in specificity, the contractor's trade-off options can be severely limited, preventing trade-off decisions that would result in significant budget and/or schedule benefit. A willingness to make trade-offs is a key factor in maintaining the development budget.[5]

c. Upgrades and Obsolescence

Historically, upgrading a system to extend its useful life or to satisfy a new need is more cost effective than acquiring a new system. The inability to upgrade a system, or the ability to do so only at great expense, are both risk factors when the cost-effective upgrade option is eliminated. Tailoring designs toward a specific military need and the high-technology, military-specific nature of the system contributes to the frequency with which this risk factor appears. To some degree, tailoring the design is unavoidable; however, future upgrade capability should be accounted for when possible. In recent

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3 Ibid.

4 Battershell, A. Lee, "The DOD C-17 vs the Boeing 777: A Comparison of Acquisition and Development," National Defense University, 1999.

5 Tyson, Harmon and Utech, IDA P-2967, op. cit.

years, DoD has placed emphasis on "upgradeability" at the systems engineering level with evolutionary design principles, the spiral development process, and open systems.[6]

2. Category II: Systems Engineering and Program Management Process Risk Factors

Systems engineering and program management processes are designed to reduce system-level risks and problems by increasing system knowledge and integration. These processes are crafted to link the technical design issues and performance goals to programmatic issues, such as budgets, schedules, and program management structures.

a. Number of Requirements

Large numbers of requirements act to over-constrain system design, reducing the possibilities for trade-offs and increasing overall system complexity. Reducing the number of requirements to only a few key requirements is a systems engineering goal. Traditional acquisition processes in DoD have tended toward setting a multitude of performance requirements, and attempts at reducing these have only been partially successful. For example, the U.S. Army Crusader Artillery Vehicle program attempted to reduce the number of requirements to only five key requirements (called key performance parameters) in areas such as range, speed, and rate of fire. However, after systems engineering was completed, these five parameters were found to be dependant on over 500 other performance parameters that were set before contractor systems engineering was begun.[7]

b. Requirements Instability

Of course, changing requirements late in the design cycle causes all kinds of budget and schedule slips; engineers have to rework design issues or even change manufacturing lines. Requirements instability is common in DoD programs, and it occurs at all phases in the design process. For example, the underlying mission for the F/A-22 was changed multiple times, from a ground attack plane, to a multipurpose ground and air attack plane, to an air superiority fighter, and back to a multipurpose fighter.[8] The C-17 experienced requirements changes all the way through initial Low Rate Initial

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6 GAO Report, "Defense Acquisitions: DOD's Revised Policy Emphasizes Best Practices, but More Controls are Needed," General Accounting Office, Washington DC, November 2003.

7 GAO Report, "Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes," General Accounting Office, Washington DC, GAO-01-288, March 2001.

8 Aronstein, David et. al., "Advanced Tactical Fighter to F-22 Raptor: Origins of the 21st Century Air Dominance Fighter," AIAA Press, 1998.

Production, causing the first six planes to have six different configurations.[9] The F/A-18 is another example of a system experiencing requirement changes late in the program. In that program, there was a production cost growth of 42%, which was attributed in part to the late technical changes.[10]

And then there are "outside" influences. For example, while the F/A-22 experienced repeated requirements changes, this was only part of the reason for production cost overruns. The F/A-22 and C-130J cargo plane shared the same production facilities. When the C-130J experienced lower orders than expected, the share of the overhead costs fell more heavily on the F/A-22 program, increasing production costs.[11]

A primary reason for requirements instability is the highly politicized acquisition environment. To move a design into the acquisition process and avoid it being killed, a coalition of supporters has to be developed. Because of the long times involved in system development (often, decades), the coalition will change and/or new pressure from stakeholders will emerge. These changes and new pressures often force a change in requirements that results in the modification of the system to address whatever new concerns are raised. For example, C-17 requirements were changed from a tactical cargo plane to a cargo plane that was used for both tactical and strategic missions when the Tactical Air Command was merged with the Strategic Military Airlift Command.[12]

Another reason for requirements instability is changes in program management. While changes in commercial management teams are made with care taken to preserve the continuity of program support, management changes in DoD often result in changes in requirements and shifts in mission focus. As the average tenure for program management in DoD is only 18 months and programs can last for decades, this creates the potential for many shifts in requirements.

c. Contractor Capability to Meet Requirements

In some cases, contractor capabilities are not well matched with the program, which can lead to delays in key design areas and in design deficiencies; the persistence of such shortcomings often results in budget and schedule overruns. In Global Hawk, the

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9 Battershell, op. cit.

10 Tyson, Harmon and Utech, IDA P-2967, op. cit.

11 GAO Report, "F-22 Aircraft: Development Cost Goal Achievable if Major Problems are Avoided," General Accounting Office, Washington DC, GAO/NSIAD-00-68, March 2000.

12 Battershell, op. cit.

primary contractor lacked expertise in system integration and software design. A short delay in recognizing this led to some mild negative impacts.

d. Requirements Set Before Systems Engineering

The acquisition process itself creates problems with performing adequate systems engineering early enough; to enter into the acquisition process, requirements must be created - but funding for systems engineering comes only *after* the fact. And often, comprehensive understanding of how performance requirements will affect budget and schedule constraints is not gained until later in the process. We can illustrate this with the Crusader artillery system. Requirements were developed over a number of years, but it was not until two years after the systems engineering contract was awarded that it was discovered that costs to develop the liquid propellant - a critical technology called for in the requirements - would not be feasible within budget constraints. Instead, the change to a lower performing solid propellant ended up forcing changes in many major components of the system.[13]

e. Change of Requirements Without Change In Resources

When resources, such as funding, are reduced, changing system requirements is one way of adjusting the program to cope with the new set of available resources. A change in requirements that calls for an increase in system performance or a decrease in schedule often may require resources to be adjusted upwards if a reasonable chance of program success is to be expected. In most cases, increasing expectations without a corresponding increase in resources only increases the risk of failure.

f. Contractual Uncertainty

Systems engineering is critical, and it must be performed either by the prime contractor or by DoD. However, because DoD frequently changes its acquisition policy, there can be uncertainty as to who has responsibility to fulfill all aspects of the systems engineering function. As a consequence, the necessary systems engineering may not be completed on time.

3. Category III: System Engineering and Program Management Implementation Risk Factors

Risk factors associated with systems engineering and program management processes often stem from the inability to or inexperience in implementing standard and

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[13] GAO-01-288, op. cit.

innovative processes designed to reduce programmatic risk, and these issues often are exacerbated by institutional realities.

a. Lack of Program Manager Authority

DoD program managers do not enjoy the same decision-making authority that program managers in industry enjoy. Design decisions, trade-offs, scheduling shifts, and budget issues all require the approval of several “organizations” before changes can be made in a program. Conversely, the process is designed so that any one organization can kill proposed changes, but rarely can only one organization give approval. This makes changes to the program - such as performance trades or rescheduling - difficult to make, especially if quick reaction times are desired. DoD program managers are often “worked around,” as users can bypass program managers and go directly to contractors.

b. Simultaneous Phasing

The acquisition process is divided into a number of phases, including Engineering, Manufacturing and Development (EMD) and Low Rate Initial Production (LRIP); between each phase is a milestone review, the purpose of which is to assess the current status of the program and decide whether or not to proceed, based on progress to date. When a program is still immature relative to the phase goals and is approved to progress to the next phase, additional risks are assumed in meeting budget and scheduling constraints. For example, the Milestone C review commits DoD to LRIP if the program is approved. To gain that approval, program maturity is judged in several categories, such as the number of design drawings approved for production. When system maturity is lower than required but is still approved to progress to the next stage, additional challenges have a higher probability of occurring.

As a further example: when an immature design is approved to enter LRIP, known design problems and issues are probably being built into the production system, and these issues that will have to be corrected after production has begun. The F/A-22 illustrates this risk factor. While experiencing known problems with avionics and fin buffeting, the F/A-22 was approved for LRIP with the intention that these problems would be worked out. But re-tooling a production line after manufacturing has begun increases the risk that budget and scheduling constraints will not be met, for a number of reasons.

For one, there are multiple forces acting on the Milestone Decision Authority (MDA). Beyond technical maturity and the previous performance of the program, a host of other concerns appear. As an example, involved persons do not want to kill a program, even if it is going over budget and is behind schedule, so there is an incentive to push the program along because, obviously, there is a lower probability that it will be terminated as more resources are devoted to it. And there are other reasons to push a program forward. It is known that early entry into the next acquisition phase has the potential to cause budget overruns and schedule slips, but delaying entry also can cause penalties to be levied on the program. For example, DoD stated that delaying entry into LRIP for the F/A-22 would cost more in paying penalties laid out in their contract with Lockheed Martin, the prime contractor, than in forging ahead.[14]

c. Lack of Systems Engineering Funding

The benefits of systems engineering are often poorly understood. When a program is proceeding well, there can be little incentive to perform systems engineering tasks because they are difficult to observe and to quantify the value added. But when a program is progressing poorly, due to technical reasons, and there is the danger of losing funding or becoming under funded, often there is a desire to push additional funding into the areas experiencing the difficulty, and to starve the areas that don't seem as critical at the moment, such as systems engineering.[15]

d. Lack of Program Status Information

Of course, not knowing the current status of a program makes it difficult to identify and respond to problems effectively and quickly. Information needed to access the status of the program is often required to be collected throughout the program's lifecycle, but often these data are not collected. For example, the F/A-22 has experienced technical problems related to production, but statistical production data haven't been collected since 2000.

e. Lack of Ability or Willingness to Make Trade-Offs

System-wide trade-offs among performance requirements are important to maintain budget and schedule constraints. But often in DoD systems acquisition programs, there is an unwillingness to make trade-offs that will decrease system performance, even when such trade-offs will result in lower budgets and shorter system

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14 GAO Report, "Tactical Aircraft: DOD Should Reconsider Decision to Increase F/A-22 Production Rates While Development Risks Continue," General Accounting Office, Washington DC, GAO-03-431, March 2003.

15 Testimony of Michael Wynne, Hearing of the National Security, Emerging Threats and International Relations Subcommittee of the House Government Reform Committee, Washington DC, April 11, 2003.

delivery time. For example, the U.S. Army Comanche helicopter was originally designed to be produced in eight years for $3.5 billion. To meet Comanche mission requirements in the lightweight, stealthy, maneuverable, all weather, attack, and reconnaissance roles, advanced technology was needed in integrated avionics, advanced infrared night vision, and targeting sensors. When it became apparent that these cutting-edge technologies could not be developed within budget and schedule constraints, the Army was unwilling to accept trade-offs that would lower the Comanche's performance. Instead, they consistently accepted budget and schedule slips that resulted in new program estimates of $8.3 billion and 18 years of development time.[16]

There are several reasons why trade-offs that affect performance are difficult to make. First, there is pressure to produce a system that is substantially different than previous systems. Demonstrating this difference is done in part by employing different technologies to improve performance. For example, the C-17 cargo plane program came under attack when differences between it and its predecessor, the C-5, became indistinguishable. Fear of losing program support if performance drops off often keeps trade-offs from being made among performance, budget, and schedule units.[17]

Once a program has been approved with a certain set of performance requirements, it is also more difficult to make drastic changes to the requirements because of the lengthy process involved. In contrast, in the commercial sector, firms have greater configuration management control. Changes that alter, improve, or abandon products at will and without notice are much easier to enact.[18]

Also affecting the desire to make trade-offs is the environment in which performance requirements are initially crafted. This process of creating requirements is often a multi-year effort, sometimes taking over ten years, as in the case of the F/A-22 program. During this period, coalitions of stakeholders are formed to help ensure that the program can be initiated and sustained. To elicit support, capabilities are added to the systems to make them more appealing to individual stakeholder's needs, and making trade-offs in requirements that result in lower performance can reduce or eliminate the capabilities that are important to critical stakeholders, making it difficult to maintain support for the entire program. The result is requirements that promise high capability

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16 GAO-01-288, op. cit.

17 Battershell, op. cit.

18 Tyson, Karen, John Hiller, David Hunter, J. Richard Nelson, James Woolsey, "Assessing Cost-Reduction Initiatives in a Changing Defense Acquisition Environment: A Handbook," IDA Paper P-3376, Institute for Defense Analyses, Alexandria, VA, January 1998.

and/or many varied capabilities for the same system. An example of this is the C-17 cargo plane, which was supposed to perform airdrops of personnel, equipment, and cargo all in the same mission. Another example is the Crusader Artillery Vehicle program, whose draft requirements were submitted to around 30 organizations, which in turn submitted 943 comments. From these 943 comments, 702 were incorporated into the program for a net effect of adding to requirements, rather than trading off among requirements.[19]

And there is the belief that it is better to wait for a higher performance system than make trade-offs that lower system performance. Because major acquisition programs are infrequent, there is the desire to get as much performance as possible now, rather than wait, possibly decades, for a replacement.

f. Testing Shortfall

It is not uncommon for a weapons system to enter production before adequate testing is done to warrant production. Shortfalls in testing can appear, particularly when a budget and/or schedule overrun exists. Budgetary and scheduling pressures, along with the need for a program to defend its existence to survive, applies a disincentive to identify flaws and problems early in the design process.

Testing shortfalls also can occur as a result of external forces. An example of this is the effect of the DarkStar testing failures on Global Hawk. Specifically, these failures led to a more risk-averse attitude among Global Hawk stakeholders, which, when setting the testing schedule, slowed testing activities. However, this does not mean that the caution was unwarranted. World events took another turn, however, that accelerated the progress of that program.

4. Category IV: Institutional Risk Factors

The institutional environment creates risk factors that interact and exacerbate other risk factors. Organizational structure, organizational behavior, culture, personnel incentives, politics, and competing goals all lead to a different set of priorities for all stakeholders involved, and these can affect the entire acquisition process, from the manner in which missions are defined and requirements are set, all the way to how the program is sustained with support and funding.

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[19] GAO-01-288, op. cit.

Together, institutional risk factors and design risk factors are the "problems behind the problems" associated with systems engineering and program management risk factors.

a. Lack of Reform Institutionalization/High-Level Support

In order for reforms to be effective, they must be embraced and implemented by the people within institutions. It is not unusual for reforms to find a paucity of support, resulting in a lack of effectiveness. Many reasons exist for why some reforms are not embraced by institutions. Reforms that disrupt the current way of doing business are difficult to implement, because existing skill sets are made obsolete and people have to be retrained. Having already mastered old ways of doing business, people do not welcome drastic change. Many new reforms also cause an increase in workload. For example, some new commercial best practices, such as understanding the market before a program can be formed, add additional work to acquisition staff workloads. Or new reforms for collecting commercial cost data for use in making trade-offs and decisions shift work from commercial contractors to DoD officials. If people charged with implementing reforms do not buy into them, they often are able to kill the reforms through inaction. As program managers and political appointees have on average a much shorter tenure than do career acquisition officials, champions of reforms will often leave before those reforms are institutionalized.

The lack of reform institutionalization can occur at high organizational levels. If a reform runs against the perceived needs of an organization, high-level support for working around the reform often can be obtained. Take the Global Hawk UAV program, for example. That program implemented evolutionary acquisition reforms, which allowed an initial UAV capability to be quickly deployed, while later, planned versions of the Global Hawk promised to boast greater technical capabilities. While this was agreed to jointly by OSD and the Air Force, the Air Force later came back wanting a change in requirements that would introduce greater capabilities into the Global Hawk earlier in the program. This effectively would have circumvented the evolutionary acquisition aspect of the program, reverting to a more traditional systems acquisition program, had it not been for high-level intervention in OSD. The reasons for lack of high-level buy-in to reforms are often a perceived conflict between organizational needs and the aim of the reform. In the Global Hawk example, there was a lack of trust emanating from within the Air Force that future increments of evolutionary acquisition would deliver a higher performance UAV. Under the current acquisition environment, it is desirable to design a system with as high a performance as possible, because of the uncertainty over when the next replacement will come along.

b. Requirements Generation Misaligned With Resources

Requirements are generated before a program is approved and before a contractor is determined. The process of approving a program necessitates that requirements be crafted that have support from a coalition and that define system capabilities that are substantially different than previous systems. Meeting these needs often causes generated requirements to be misaligned with available resources; cost and budget estimates are often given based on available funding. These budget and schedule estimates have to be made far in advance of program approval and are often made optimistically to help improve the chances of getting approval. As requirements also are determined before the formal selection of a contractor, they are not matched to contractor capabilities. Contractors often have to rework early requirements, and budget and schedule estimates are constantly revised. This causes reorganizations within the program, or the need for technology maturity programs.[20]

c. Misaligned Stakeholder Goals

The system acquisition process comprises a variety of stakeholders: the user community, program management, Congress, and commercial contractors. Each has their own set of organizational goals and constraints that shape their approach toward system acquisition programs. Often, these goals are not aligned. The result is a set of priorities and incentives that can produce actions that do not support completing system acquisition programs within budget and schedule constraints. For example, program managers have perverse incentives to spend extra funding on programs rather than risk losing unused funding in future years. There also is the incentive to hide potential future problems, avoiding negative scrutiny, especially if those problems will not come to light until after the program manager's usually short tenure is complete. This is similar to many commercial contracts that reduce incentives for contractors to identify and implement cost-saving measures, when the award is based on total program size. These types of perverse incentives prevent actions to implement cost-saving measures, a misalignment of the goals to achieve budget and schedule constraints set by DoD and Congress.

And other actions are taken in acquisition programs that misalign goals. For example, during the F/A-22 program, Congress ordered the Air Force to investigate lower

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20 Ibid.

cost alternatives, specifically, variants on the F-15 and F-16. One reason was that the F/A-22 was exceeding schedule and budget constraint estimates. The derivative planes called for using the same engine that was under development for the F/A-22. To slow studies and support in Congress for the variants, engine development funding was reduced, making it difficult to complete studies on the derivatives. This also slowed engine development for the F/A-22, a program already under fire for scheduling delays. This in turn helped in eroding support for the derivatives.[21] This example shows a misalignment in goals when slowing the development of a program that is under fire for exceeding schedule and budget estimates results in actually helping to maintain the program.

d. The "Silver Bullet" Solution

Many previous reforms associated with systems acquisition have concentrated on process changes where managers tended to favor "silver bullet" process changes that worked for one program and then could be applied uniformly to all programs. But often missing in these process changes was examining how existing organizational structure, behavior, and culture could affect implementation and sustainment of the new processes.

Resistance from organizations down to individuals can result in process reforms not being adopted. For example, in the USN Arsenal Ship program, acquisition reforms were enacted to place increased design authority with commercial contractors. While it appeared that these reforms were producing positive results, when the commercial contractors needed access to major subsystems that previously had been developed in the Navy, the USN participating managers (PARMs) were resistant. Traditionally, the PARMs do not answer to contractors and supply much of the design work themselves. The new reforms threatened to "demote" the PARMs' activities to those of support, which were perceived as being of lower importance. The result was a lack of cooperation, which led to programmatic difficulties, and eventually was a factor in the Arsenal Ship program being cancelled.[22] This is an example of trying to create reforms that solve a specific problem, and neglecting to take into account the institutional context within which the reform must be implemented.

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21 Aronstein, op. cit.

22 Leonard, Robert, Jeffrey Drezner and Geoffrey Sommer, "The Arsenal Ship Acquisition Process Experience: Contrasting and Common Impressions from the Contractor Teams and Joint Program Office," RAND Corporation, Santa Monica, CA, 1999.

e. Lack of Trust in Reform Efforts

Performing trade-offs or engaging in evolutionary acquisition is more difficult when there is an absence of trust that future systems will deliver additional performance. Because of the multiple acquisition reforms in the last couple of decades, civilian and military personnel involved with day-to-day activities become wary of these changes and try to maintain the status quo until the desire for the "current" set of changes recedes. One example of this can be illustrated in the Global Hawk program. The evolutionary acquisition process was to produce a baseline system with increased performance at a later date. It was threatened when the USAF wanted to change performance requirements of early systems to make them more capable. This would have circumvented evolutionary acquisition, making the Global Hawk program more traditional and higher risk. In the end, OSD intervened and kept the evolutionary aspect of the program intact.

IV. OVERVIEW OF SYSTEM ACQUISITION PROCESS, SYSTEMS ENGINEERING AND PROGRAM MANAGEMENT PROCESSES, AND ACQUISITION PROCESS STAKEHOLDERS

The Defense Acquisition Process, as outlined in DoD regulations, repeatedly has been reformed. Every few years a new set of reforms is enacted—with particular regularity when a new administration takes office. As such, no two programs, including those illustrated in this study, have operated under the exact same sets of acquisition rules, and often the life of these programs have spanned many sets of reforms. To further confuse matters, programs often deviate from the official procedures and processes by which they are governed. This presents problems when trying to evaluate the effectiveness of particular reform efforts.

Nonetheless, we review the current status so as to understand the acquisition process and the problems that can arise. In this section, we review the overall acquisition management policies that are currently in place; we then present a summary of the formal acquisition process, with commentary on major stakeholders and systems engineering processes, where appropriate. The acquisition process description in this chapter makes heavy use of the Defense Acquisition University's acquisition process tutorial.[23]

A. ACQUISITION PROCESS DRIVERS

In recent years, DoD has developed overarching policies focusing on flexibility, responsiveness, innovation, discipline, and streamlined, effective management. These policies largely shape the Defense Acquisition Process as it is currently defined.

A primary influence on the acquisition process is the recognition that no single acquisition strategy is appropriate for all systems. As such, defense acquisition regulations seek to lay out an adaptable process, where the direction of the program can be tailored to the situation. A consequence of this flexibility is that situation-specific decisions must be made at key points, known as milestones, and can only be adequately resolved based on knowledge of key aspects of the program. Hence, a knowledge-based decision-making structure is emphasized.

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[23] "DoD 5000 – Defense Acquisition Process Tutorial," http://DoD5000.dau.mil/TUTORIAL/index.htm, January 2004.

Other influences, such as excessive program schedule lengths, have led to the desire to shorten system acquisition time and to maximize system utility when the system is finally deployed. To shorted acquisition time, DoD encourages an evolutionary acquisition strategy that seeks to deliver capability in increments, as technology, need, and resources dictate. Spiral development, the preferred process by which evolutionary acquisition is implemented, places various capabilities on the "arms of the spiral," where the desired capabilities can be pursued in parallel as needed. To maximize system utility, system interoperability, open systems, and system deployment sooner rather than later are emphasized.

Finally, the desire continues to acquire the most advanced systems at the lowest cost. Using competition and performance-based specifications where specific military standards are avoided so as not to hamper contractor creativity seeks to capitalize on innovation. Systems engineering approaches and leveraging commercial resources are then looked to in order to optimize system performance and minimize total ownership costs.

This very brief overview of drivers in acquisition policy provides a context within which the acquisition process structure can be understood and evaluated.

B. THE ACQUISITION PROCESS

The current acquisition process is outlined in DoD 5000.2. The Defense Acquisition Management Framework (Figure 1) illustrates the structure of the acquisition process: it is meant to be more flexible than previous DoD acquisition processes, and it is meant to act more as a guide than as a hard schedule. For example, this flexibility allows a program to skip components of the process, depending on the nature and maturity of the program and the ruling of decision-making bodies.

The structure of the process consists of activities, phases, and efforts. At the highest level, the acquisition process is divided into activities: Pre-Systems Acquisition, Systems Acquisition, and Sustainment. These are governed, respectively, by the Initial Capabilities Document (ICD), the Capability Development Document (CDD), and the Capability Production Document (CPD). Phases break the process down in greater detail into the Concept Refinement, Technology Development, System Development and Demonstration, Production and Deployment, and Operations and Support. Within phases, various efforts can be undertaken, including System Integration, System Demonstration, Low-Rate Initial Production (LRIP), Full-Rate Production (FRP) and Deployment, Sustainment, and Disposal. Passing from one phase to the next is determined at

Milestones, labeled Milestone A, Milestone B, and Milestone C, by a Milestone Decision Authority (MDA).

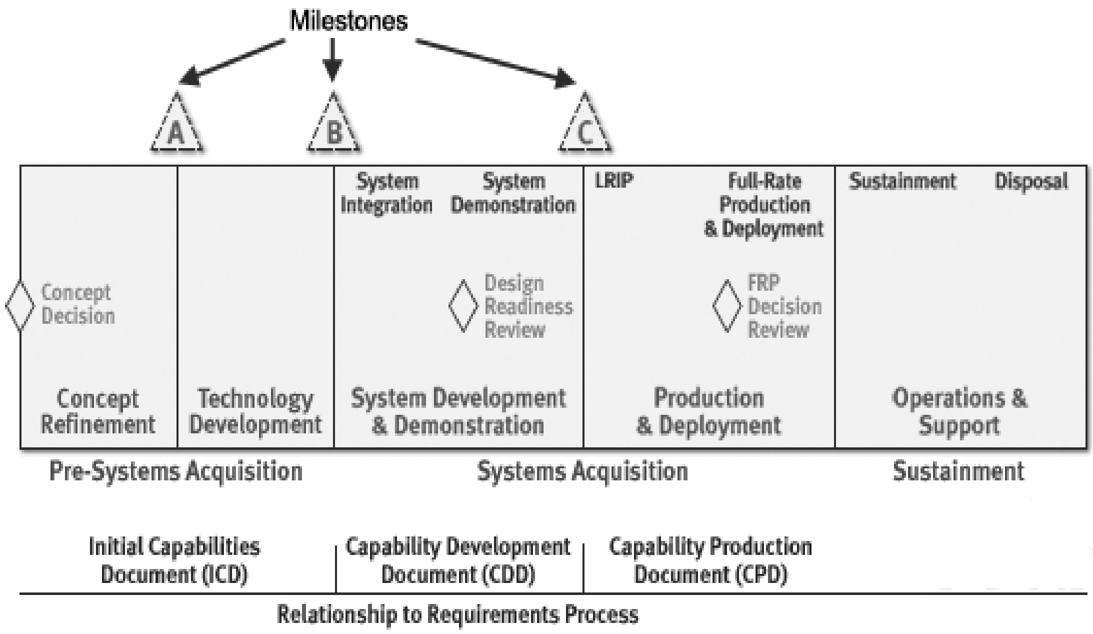

Figure IV-1. Diagram of the Defense Acquisition Management Framework

1. Before Pre-Systems Acquisition

The precursor to Pre-Systems Acquisition activities is actual program initiation, and typically it originates from the identification of a need or a potential new capability. A need-driven initiation starts, of course, with the recognition of that need, followed by a determination of the desired capabilities and requirements to fill the need, from which an ICD is created, and the program enters Pre-Systems Acquisition.

Alternatively, a technology may be identified that offers a potentially useful capability. Often this route originates in government or academic labs, or from commercial sources. From this, a program can enter Pre-Systems Acquisition through three methods: Advanced Technology Demonstrations (ATD), Advanced Concept Technology Demonstrations (ACTD), or Joint Warfighting Experiments. Following these activities, an ICD is created and Pre-Systems Acquisition is entered.

2. Pre-Systems Acquisition

The first step in Pre-Systems Acquisition is a Concept Review. Here, the MDA approves the ICD and the needed items for conducting the Concept Refinement phase. In Concept Refinement, an Analysis of Alternatives (AoA) is conducted, wherein a wide range of potential solutions are considered and judged, based on a number of criteria. The results of the AoA are used to prepare a Technology Development Strategy (TDS) that will help guide activities in the next phase. Milestone A is then reached, where the results of the AoA are approved and the next phase is set up (approval of the TDS and Technology Development phase exit strategy).

After passing Milestone A, the program enters the Technology Development phase. This phase is governed by the TDS in addition to the higher-level ICD. In this phase, there is an effort to reduce technology risk: the technology must be shown to be "…affordable, militarily useful, and mature," appropriate for the intended environment, and preferably able to be developed and produced in a short time. Ultimately, the appropriate technology is selected. Also during this phase, a CDD to govern the Systems Acquisition activities is developed, and the acquisition strategy is completed.

At this point, Milestone B is reached, where functionality for meeting the Federal Government and DoD's primary objectives must be demonstrated. Additionally, it must be shown that DoD is the channel through which the capability should be developed. Here, the MDA approves the acquisition strategy and sets up the next phase (determines the need for Design Readiness Review, approves System Development and Demonstration exit criteria, and approves LRIP quantities). Because successful passage through Milestone B will initiate formal acquisition, the MDA is supposed to consider the many factors affecting the usefulness of the system, the risk involved, and affordability and schedule considerations. In general, the use or modification of existing hardware tends to be more cost effective; as a result, the inability to do so is often a criterion for justifying a new acquisition program.

3. Acquisition

In the first phase of this activity, the CDD governs System Development & Demonstrations, the goal of which is to "…demonstrate an affordable, supportable, interoperable, and producible system in its intended environment." Approval to enter into this phase is based on technical maturity, requirements, and funding. Note that while this phase can be entered into following an approved Milestone B decision, it need not be. Programs can enter directly from virtually any point in Pre-Systems Acquisition at the discretion of the MDA. A program may enter this phase at either a System Integration or System Demonstration effort.

The goal of the System Integration effort is to demonstrate, either by prototype or Engineering Demonstration Model (EDM), a working system. This effort is entered when subsystem integration is needed, system design is incomplete, and/or system-level risk needs reduction. Following System Integration, a Design Readiness Review is typically held to approve entrance into the System Demonstration effort. The criteria used for this decision are flexible in content, as determined by the MDA, to accommodate specifics of the program. The review addresses system-level concerns; adequacy in a number of factors, including environment, safety, logistics, must be demonstrated.

The System Demonstration is entered when a working prototype or EDM has already been demonstrated. This effort seeks to show that the system operates in a useful way. When the system is demonstrated in its intended environment, meets CDD requirements, and can be produced with reasonable industrial capabilities, the effort is completed.

Following System Demonstrations, Milestone C must be passed. Here, the MDA makes the final decision to commit to the weapons system program, or end the effort. As with Milestone B, many factors, including performance in previous phases up to this point and those factors that were less certain earlier in the program, are taken into account by the MDA. Passage through Milestone C results in the MDA's approval of the CPD to govern the next phase, an updating of the acquisition strategy, arrangement of the next phase (authorization of LRIP, exit criteria for limited deployment/LRIP), and DoD's commitment to system production.

The last phase in Systems Acquisition activities is the Production & Development phase. This phase seeks to "…achieve an operational capability that satisfies mission needs…" and is guided by the CPD. As with the previous phase, this phase is divided into two efforts: the LRIP effort and the FRP and Deployment effort. Completing the manufacturing development, establishing the initial production base, and planning for an orderly increase in production rate are the aims of the LRIP effort. Any remaining or newly discovered deficiencies must be remedied in this effort, and any changes to the quantities set at Milestone B will be adjusted by the MDA.

Transitioning from LRIP to FRP and Deployment requires passage through a FRP Decision Review. As with Milestone C, the MDA again considers a wide array of factors (cost/economic analysis, manpower, full-operational testing results, interoperability, etc.) pertinent to the acquisition of the system. Ultimately, the decision review will lead to approval of the acquisition strategy and provisions for the post-deployment performance evaluation, followed by FRP & Deployment efforts.

4. Sustainment and Disposal

The final acquisition activity—sustainment—typically overlaps the latter part of the FRP & Development phase, beginning with deployment of the first systems into the field. The primary objective of this activity is to provide life-cycle support and sustainment of systems in the most cost-effective manner possible.

The sustainment activity consists of the Sustainment and Disposal efforts. The former maintains all aspects of readiness and operational capability of the deployed system, including but not limited to issues concerning supply, maintenance, transportation, manpower, training, survivability, safety, sustaining engineering, data management and information technology (IT) supportability, interoperability, and the environment. Ultimately, this effort must ensure completion of the acquisition strategy, and continually work to address and improve affordability, performance, and readiness. The Disposal effort handles the demilitarization and disposal of the system at the end of its useful life, including aspects of safety, security, and environmental impact.

C. STAKEHOLDERS

The key stakeholders in the acquisition process can be divided into three major categories: program developers, government oversight personnel, and end users. Personnel from all three categories interact on an ongoing basis to reach consensus on the finished product. Many of the risk factors identified in the earlier chapter are due to the large number of stakeholders and their complex interaction. This section describes who the stakeholders are and what their responsibilities are, and highlights the key areas of conflict and how they affect the overall acquisition process.

1. Program Developers

Program developers include the program management office, all of its support staff and offices, and all of the outside contractors. These people are involved in the project full-time after the initial military need and preliminary concept have been established. Major stakeholders within the program office are the program manager, the contracting officer, and the specialist advisors. The program manager theoretically has the day-to-day control of the budget, schedule, and system trade-offs of the program; but in reality he has very little control and ends up bowing to the needs of various other stakeholders, such as mandates from Congress, end user requests, and DoD initiatives. The contracting officers are, by law, the only stakeholders authorized to execute contracts with industrial firms; in effect the contracting officers are the buyers or customers. They act as a liaison between the program office and the outside world. Usually they are heavily involved on the contractors' side of the work to ascertain that technical needs are met, along with any schedule and cost issues.

The specialist advisors support all program offices with such activities as preparing specifications, conducting analysis, creating work statements, and writing contracts that are compatible with the acquisition laws of DoD. These specialists help ensure that program managers take into account special military requirements at the beginning of the design phase so they do not incur extra cost at the end. In reality, this can cause several problems when the PM is forced to oblige with very minute details of the system, details that may not be critical to the overall success of the program but that can cause large cost increases.

2. Government Oversight Personnel

The second major category of stakeholders is associated with government oversight, which includes the Office of the Secretary of Defense (OSD), Congress, and the presidential administration. The current key stakeholders in the OSD that oversee the entire acquisition process are the Defense Acquisition Board (DAB), the Component Acquisition Executive (CAE), and the program executive office. The program executive office was established by the Packard Commission in 1986; it oversees a group of similar acquisition programs to ensure that each of the PMs in their group share similar visions, resources, and knowledge. The component acquisition executive is the chief reviewer for any non-major program milestone decisions. They are the main link between the OSD and the PMs on all minor program decisions and milestone approvals. This frees up time for the DAB to focus on major DoD acquisition programs. Both of these boards serve as the gatekeepers for the milestones as outlined in the acquisition 5000 documents. By adding the new component acquisition executive, the DAB can completely focus on the largest acquisition programs that usually get the most scrutiny from Congress and the president (although the president usually does not get directly involved with any acquisition program). It is the job of the Office of Management and Budget (OMB) to interact directly with DoD managers to formulate budget plans for each of the programs. This budget is then scrutinized by Congress.

While Congress does have the final authority on the budget and spending of any governmental department, including DoD, there are several myths about the degree to which Congress affects the acquisition process. For example, contrary to popular belief, there are relatively few programs that are approved simply because they provide jobs and money to a Congressman's home district. Usually, the greatest effect Congress can have on the physical location of the acquisition program is by pushing for the subcontracts be spread out to as many different locations as possible. While this is much better than keeping or starting acquisition programs strictly for the purpose of creating jobs for their constituents, it creates an additional risk factor for PMs of overspreading resources and losing control.

In recent decades, Congress has developed a habit of micromanaging specific acquisition programs instead of steering the overall direction and scope of the process. Several factors have contributed to this. First, DoD has become much larger and more complex in the last 40 to 50 years, making it more difficult for Congress to fully understand and analyze all programs. Second, the sheer size of DoD also means that any large policy change will face many internal and external resistances and most likely will not only take up much more of a Congressman's time and effort, but also will have few tangible results in the immediate timeframe. With those two facts in place, the typical Congressman resorts to micromanagement of individual defense programs that they or their constituents have a strong feeling towards. Usually, by concentrating their efforts on a few programs, they can achieve more tangible results that can be easily trumpeted in the next election, such as increased jobs for their constituents or uncovering and rectifying an instance of government waste.

Because of this micromanaging environment, Congressmen and their staffs, although generally well intentioned, often leave new and equally serious problems in their wake as they attempt to reform individual management processes. One undesirable effect has been the diffusion of accountability. Instead of laying the groundwork for greater accountability in decision makers, Congress has resorted to additional checks, balances, and layers of review that eventually force decisions to be a consequence of the system rather than the responsibility of an individual. Further, it has made defense managers more focused on the process instead of results. The effect has been the creation of an environment where PMs have little incentive or freedom to exercise critical thinking and judgment; rather, personnel are safer by showing that they have complied with all mandated processes.

3. End Users

The final group of stakeholders is the individual military Services who are the end-users of all the acquisition programs. Most acquisition programs originate from the Services when they identify specific threats or operational missions that require new military systems. Because of the internal competition between the various branches of the Services and a general norm for planning for worst possible contingencies, each Service branch often provides a picture of the threat environment or creates a set of requirements that result in a slight budget increase. This often leads to detailed performance requirements being set too early to give an impression of strategic need and to build consensus within their Service and DoD as a whole.

Furthermore, because the program manager for the acquisition program usually comes from within the Service, it causes a strong misalignment of incentives and goals, which can be seen in several ways. Normally a program manager is judged upon his or her ability to manage the acquisition program to its completion within the required schedule, budget, and technical criteria. In this case, the PM has to do all this and please the Service branch, which usually means keeping the program from getting killed. This leads the PM to become an advocate for the program, instead of a critical manager. Also, instead of forwarding bad developments within the program quickly up the chain of command, "bad news" usually is not revealed in a timely manner, lest it affect the overall funding of the program or the career of the PM.

V. CASE STUDIES

This chapter explores system engineering practices, past reform efforts, stakeholder interactions, and risk factors in three large acquisition programs: the F/A-22, F-15, and Global Hawk programs, each selected based on their similarities and the availability of public information. All three programs involve aerial vehicles that were state-of-the-art; all three were highly visible acquisition programs that tried to utilize varying but similar acquisition reforms to lower cost and improve delivery schedule and technical performance. Even though the reform emphasis was similar, the three programs achieved varying degrees of success. The F-15 was the most successful, followed by Global Hawk. The F/A-22 encountered the most problems, leading to higher costs and long delays.

The F-15 program began in the late 1960s as a conceptual design for an air superiority fighter plane that was to be faster and more maneuverable than the Soviet MIGs of the era. To this date, the program's acquisition process is the gold standard that all other large acquisition programs try to attain. Global Hawk is an unmanned, high-altitude, long-distance, day or night, wide-area observation and reconnaissance system. We will begin with the F/A-22 Raptor, formerly the F-22 Advanced Tactical Fighter (ATF), a next-generation air superiority/ground attack fighter plane that was designed to replace the F-15 Eagle.

A. F/A-22

The F/A-22 Raptor is considered the most advanced and capable fighter plane in the world, integrating several new technologies. Its foremost capabilities include a low observable radar signature (stealth), sustainable supersonic speeds without the use of an afterburner, a highly maneuverable airframe, and an integrated avionics suite that provides greater situational awareness for the pilot.

The ATF program was begun in the early 1970s, entered the acquisition process in 1981, and was approved for Low Rate Initial Production in mid-2001. The number of F/A-22s planned for procurement has shifted continuously throughout the program, from a high of 750 to a current low of fewer than 300 aircraft. From early 1992 to late 2002, unit costs had grown 117.7% to $253.5 million; the program schedule had slipped by 27 months.[24,25]

1. Program History

The ATF was to replace a variety of fighter planes then being used by the Air Force for the ground attack role, including the F-4, F-105, and F-111, aircraft that had been developed in the 1950s and 1960s. [26] To help determine what capabilities the new ATF would have, a variety of requirement documents, design studies, technology studies, and mission analyses were conducted in support of the ground attack mission.[27]

By the late 1970s, threat assessments of Soviet air superiority aircraft began to change. New intelligence suggested that the Soviets were developing a fighter with the same performance as the then-new F-15 Eagle. As U.S. military strategy offset larger Soviet and Warsaw Pact numbers with superior technology, it was felt that a new air-to-air fighter would be necessary to maintain a technological advantage. The ATF was considered for both the air- and ground-attack mission during this time. However, it was undecided whether it should be a multipurpose fighter, to save money, or if the ground and air roles should be separated into different fighter platforms.[28] Prior experience with multipurpose aircraft requirements had not been successful. As originally designed, the F-111 was to be multipurpose, but difficulties during development led to an overweight aircraft capable only of fulfilling the ground attack role.

From 1980 to 1982, several developments shifted the emphasis on the ATF to air superiority. For one, air-to-air capabilities were and continue to be seen as design drivers for fighter planes; historically, air superiority fighters can be modified to accomplish the ground attack role, but not the reverse. New aircraft developments from the Soviet Union also pointed to a shortfall in U.S. air superiority capabilities that were more critical than ground-attack capabilities. Improvements in existing ground-attack fighters, such as the F-111A variant, made the need for a new ground-attack fighter less critical. Also, the recent availability of new technology made an air superiority mission more appealing.[29]

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[24] GAO Report, "Defense Acquisitions: Assessments of Major Weapon Systems," General Accounting Office, Washington DC, GAO-03-476, May 2003.

[25] GAO Report, "Best Practices: Better Acquisition Outcomes are Possible if DoD can Apply Lessons from F/A-22 Program," General Accounting Office, Washington DC, GAO-03-645T, April 2003.

[26] Aronstein, op. cit.

[27] Ibid.

[28] Ibid.

[29] Ibid.

The USAF, in an attempt to keep the industrial base mobilized and to avoid technology development problems that had appeared in past aircraft programs, had been funding several cutting-edge technologies for a number of years. Several of these technologies appeared ready for inclusion in a program and the desire to use these technologies made the air mission appear more attractive.[30]

In November 1981, the ATF officially entered into the acquisition process at the Concept Exploration phase by gaining Milestone 0 approval, after almost 10 years of continuous studies and changes in requirements. The requirements for the ATF were developed to support an air superiority mission and were borne out of a Tactical Air Command (TAC) study completed in the late 1960s and 1970s with lessons learned from Vietnam. In that study, it was found that there was an increased threat to aircraft from networked air defenses and surface-to-air missiles. The study called for increased survivability of aircraft, to include high speed, high maneuverability, electronic countermeasures, and situational awareness.[31]

With these requirements, the ATF program released a Request for Information (RFI) to industry to solicit conceptual designs. Nine areas of interest were declared to the contractors to help focus their efforts; these covered a variety of technical issues, and also included guidance for contractors to address up-front issues relating to quantity versus quality and performance trade-offs. At this time, the ATF was still considering both the air- and ground-attack roles; no guidance was given to the contractors on the question of whether the ATF should be a multipurpose fighter or two separate fighters.[32]

During the Concept Exploration phase, the original requirements released to contractors through the RFI were changed. The new requirements completely dropped the need for the ground attack role; the new emphasis on the air role evolved because the F-15 was now 10 years older than it was when the AFT was first considered and the air superiority mission was now seen as more critical. The contractors returned with several concepts, ranging from fielding large quantities of fighters smaller than the F-16, to large "battle cruiser" designs based on the SR-71 Blackbird. From these early design concepts, new requirements were developed by the ATF program office.[33]

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30 Twigg, J.L., "To Fly and Fight: Norms, Institutions and Fighter Aircraft Procurement in the United States, Russia and Japan," Massachusetts Institute of Technology PhD Dissertation, 1994.

31 Aronstein, op. cit.

32 Ibid.

33 Ibid.

Many of these new requirements were strongly criticized as being too specific (such as specifying number of missiles and cannon caliber, with the numbers apparently being taken from contractor designs submitted in Concept Exploration); additionally, many of the specified performance ranges did not take into account systems engineering issues, such as how these performance requirements would affect cost and weight. (Later in-house systems engineering studies performed for TAC caught many of these issues and modified the requirements before being reissued to the contractors for further work.[34])

In May 1983, a Request for Proposals (RFP) was released for the Concept Development phase. The requirements given to the contractors were modified and much softer: instead of hard performance requirements, specified performance ranges were given; contractors were allowed to make trade-offs within these ranges and could even design outside the ranges if justification was supplied. The emphasis of these requirements was the same as given in the previous RFI - maneuverability and supersonic cruise.

But again, after the RFP had been released, a change in requirements was presented to the contractors, this time with an emphasis on low observability. Up to this point, the ATF program was not aware of the progress being made on stealth aircraft in the F-117 and B-2 Bomber programs. With a change in requirements that added an emphasis on low-observable technology, contractors were briefed on the (then) current developments in stealth technology.[35]

From the outset, it was desired that the ATF be affordable, both in terms of production costs and life-cycle maintenance costs. As production costs are correlated to aircraft weight, the ATF was to be designed as a low-weight aircraft, with a target around 50,000 pounds. Achieving this weight within the rest of the performance requirements proved to be difficult and had a ripple effect on the technology needed. For example, to minimize weight, the ATF would only carry one pilot; this created problems in the avionics systems. As the amount of information available to pilots had been growing with each generation of fighters, presenting the information in a form usable by only one pilot created new demands on the avionics and information technology. A highly integrated avionics system was needed to fuse all the information together into a form usable by the pilot. Previous avionics systems were federated, with each sensor and instrument being

34 Ibid.

35 Ibid.

mounted separately, and their output being presented individually. Integrating hardware and software in this new manner during the mid-1980s pushed the state of the art of computer and software design.[36]

On the program management side, the AFT System Program Office (SPO) made a concerted effort to learn from past aircraft programs. PMs and other key personnel from the F-15 program were brought in to discuss earlier problems. Best practices from the F-15 program also were implemented in the ATF program.[37]

At this point, initial estimates for ATF production were being made: total procurement was set at 750 aircraft, with an annual buy of 72 once full production was reached. This annual rate of 72 was questioned as being unrealistic; the F-15, a simpler aircraft, had never exceed production rates of 42 per year. The high total procurement and high annual production rates, however, helped make the unit cost of the aircraft appear low.[38]

By May 1984, Concept Development studies were completed, with many of the submitted contractor designs looking similar to the ones previously submitted in the Concept Exploration phase. The original plan in the ATF program was to select 3 or 4 contractors to compete in the Demonstration and Validation phase; this phase originally was to emphasize technology development and individually to individually validate key subsystems.

Before the ATF could release an RFP for this phase, a number of concerns were raised by stakeholders. The Air Force had just completed a deal with the Army for providing close air support. As budgets were tight and a separate ground-support aircraft was deemed infeasible, the ATF SPO was directed by the Secretary of the Air Force to show how the ATF would support the ground-support mission (a mission previously rejected for the fighter). The Congressional Budget Office (CBO) also voiced several concerns with the cost estimates. Official estimates for the ATF were for a 50,000 lb, $40 million aircraft. This weight and cost were at the extreme low end of contractor estimates, and the CBO found them unrealistic. Congress also was concerned about the pace of the technology development that was to be integrated into the ATF. And the Office of Secretary of Defense was worried whether sufficient attention was being paid to design supportability. Congress also was being lobbied by contractors involved in the ATF

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36 Ibid.

37 Ibid.

38 Ibid.

acquisition program to purchase F-15 and F-16 derivatives as cheaper alternatives to the F-22.[39]

Several of these concerns arose from conflicting information. For example, while the official estimate was a unit cost of $40 million, the CBO was being given unofficial estimates as low as $30 million from contractors. The result was that the ATF SPO was charged with reducing the estimated $10 billion budget for the next phase to a figure as low as $8 billion. To accommodate the budget shortfall, the SPO recommended a number of changes, such as delaying initial operational capability, eliminating conservatism from models, and accepting higher program risk.[40]

By October 1985, the ATF SPO released the RFP for Demonstration and Validation. Shortly thereafter, Congress threatened to cut funding for the ATF for a number of reasons, including a late release of the RFP, a desire to move the ATF program forward at a slower pace, and uncertainty over what had been traded off in the SPO's cost reduction plan. At the same time, Congress was interested in combining the ATF with the U.S. Navy's Advanced Tactical Aircraft (ATA) program, which was proposed as a long-range, low-observable, high-payload, medium attack fighter. Earlier in 1984, a joint USAF and USN panel concluded that this was not feasible, based on desired technical performance. However, the ATF SPO was directed to find commonality with the USN ATA program, especially in the avionics systems. Later, this study was expanded to include finding avionics commonality with the Army's Light Helicopter Experiment program.[41]

At the same time, new leadership within DoD caused another change in the requirements. Previous requirements had called for low-observability characteristics in all sections of the aircraft, but loosened these restrictions in the aft section; new requirements called for a tightening of low-observability characteristics in the aft section. The original requirements had been in place because low-observable supersonic engine exhaust nozzles had never been developed. While it was felt that developing these nozzles could be done, it would negatively impact other aspects of the ATF's performance. The contractors felt that it could be done, the tightened requirements were added to the RFP, and the due date was pushed back several months to accommodate the change.

39 Ibid.

40 Ibid.

41 Ibid.

Up to this time, the ATF had been managed as a traditional acquisition program. Starting in 1985, acquisition reforms suggested by the just-completed Packard Commission began to be applied to the ATF program. Included in these was the "fly-before-buy" reform, which forced a change in the type of prototyping that was planned in the Demonstration and Validation phase. Instead of emphasizing subsystem prototyping, flight prototypes would be built. Opponents argued that following this reform would de-emphasize prototyping of critical subsystems, such as integrated avionics. Instead, the flight prototype would emphasize flight characteristics such as supersonic flight and low-observable airframe geometry, which were relatively well understood; the inclusion of high-risk systems such as integrated avionics would not appear on the flight test aircraft. However, the use of flight prototypes was embraced for several reasons. One was that there was only enough money in the budget to fund two competing contractor teams for flight prototypes and there were only two excellent designs submitted in response to the RFP. This made for a good fit between submitted designs and available funding. Proponents of flight testing argued that this would be a good opportunity to test integration issues.[42] The Air Force also embraced these reforms in part for political reasons. They felt that implementing the Packard Commission reforms on such a large program would help stave off later Congressional criticism, and that the creation of a highly visible flight test prototype craft would be better for public relations than would laboratory testing of subsystems, making it harder to kill the ATF program after successful flight tests were completed.[43]

In October 1986, Demonstration and Validation contracts were awarded to teams led by Lockheed and Grumman. By this time, the defense environment had changed, with fewer major contracts being available. This in turn caused the major defense firms to form teams even before the announcement of the Demonstration and Validation awards. Lockheed teamed with Boeing and General Dynamics in an equal, three-way partnership. While this had the benefit of spreading risks over a larger group, such as sharing Demonstration and Validation costs,[44] it also created additional difficulties, such as blending the engineering and management activities from each company.[45]

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42 Ibid.

43 Twigg, op. cit.

44 Cosden, Sean, "The Design of the F-22 Raptor: A Case Study of Teaming Agreements in the Aerospace Industry," University of Alaska Fairbanks, Fall 2002.

45 Aronstein, op. cit.

The Demonstration and Validation phases were to focus more on risk reduction and technology development than on developing a single point design. As more was learned about the systems and requirements, several modifications and performance compromises were made in an attempt to meet weight, lower risk, and cost goals. For example, the inclusion of a cannon on the ATF prompted debate on whether to use an existing gun or a new gun from the Advanced Gun Technologies (AGT) program. Eventually, the M61A2 was selected, which was a modification of an existing gun. Performance was compromised for risk and cost concerns.[46]

Toward the end of the 1980s, several tactics used by Congress and the Air Force to contain costs backfired. There are several examples of this. In 1990, over concern with technical and budget problems, Congress threatened to completely cut the ATF budget. While this proved to be only a ploy to force decreases in costs, the opposite happened: contractors reduced their own funding commitment to ATF to lower corporate risk. Another example is the delay of engine development. To contain costs, the USAF was mandated to look at derivatives of the F-15 and F-16, which would be lower-cost replacements for the ATF. As these replacements would have utilized the same engine as the ATF, the Air Force delayed testing the engine, which delayed testing on the derivatives, and eventually contributed to a discontinuation of the derivative programs. And this delayed testing on the ATF.[47]

In 1991, after a fly-off competition, the Lockheed-led team was selected to progress into the Engineering, Manufacturing, and Development phase. The ATF program was renamed the F-22 (and later designated the Raptor). Funding shortfalls and technical difficulties forced a number of program reorganizations, re-phasing higher risk technologies to later in the program, to give more time to development. However, to maintain scheduling goals for production, this meant that some of these technologies would not be fully tested before Low Rate Initial Production (LRIP) was to begin.[48]

Rising cost estimates also led to falling production goals. In 1991, 648 F-22s were planned; by 1994, this had dropped to 442. The continually falling production numbers negatively impacted unit costs. To be ready for production, Lockheed needed enough lead time to ensure that production facilities capable of supporting the estimated annual

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46 Ibid.

47 Twigg, J.L., “To Fly and Fight: Norms, Institutions and Fighter Aircraft Procurement in the United States, Russia and Japan”, Massachusetts Institute of Technology PhD Dissertation, 1994.

48 Ibid.

production rates would be available. To do this, they immediately began construction of production facilities after the award of the EMD contract in 1991. As production numbers fell in later years, the production facilities under construction were oversized, resulting in greater unit costs.[49]

In 1994, to maintain support for the F-22 program, the ground attack role was again added, making it a multipurpose fighter.

After a series of reviews, reorganizations and program re-phasings, the now F/A-22 program entered into LRIP in 2001, with a planned procurement size between 295 and 339 approved and EMD costs increased from $10.91 billion to $18.6 billion.[50]

2. Program Characteristics

a. Integrated Product Design and Integrated Product Teams

The F/A-22 program utilized a series of systems engineering and program management techniques starting in the early 1980s, when it formally entered into the acquisition process. In order to provide early systems engineering and integrate a variety of stakeholders in the design, the F/A-22 SPO and contractors were organized into Integrated Product Teams (IPT) to facilitate integrated product development (IPD) design activities. To further the program management of activities between contractors and the SPO, Integrated Master Plan (IMP) and Integrated Master Schedule (IMS) tools were used. These tools were designed to coordinate the various types of management information being collected by the SPO to ensure that design activities, schedule, and budget were all coordinated.[51] The IPT organization worked well during the competitive portion of the F/A-22 contract, when DoD personnel felt well-integrated in the respective competing contractor teams. But, when the competition ended, the government/contractor relationship reverted to a more traditional, arm's length oversight interaction. *The ability to successfully use various systems engineering and program management tools, such as IPT and IPD, is dependant on the contractual relationship between DoD and contractors.*

The F/A-22 use of IPD was the first time that integrated design had been used by the Air Force, having been adapted from commercial practices. Employing IPD helped generate a set of requirements that included a larger set of stakeholders than had

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49 Aronstein, op. cit.

50 Global Security.org F-22 Raptor website. http://www.globalsecurity.org/military/systems/aircraft/f-22.htm, as of January 2004.

51 Williams, Michael, "Acquisition for the 21st Century: The F-22 Development Program," National Defense University Press, 1999.

previously been included in requirement-generation activities. Notably, the inclusion of maintenance personnel early in the design process was an explicit attempt at creating a design that would have lower life-cycle maintenance costs than did previous fighter planes. *Early inclusion of multiple stakeholders helps identify and address systems engineering and life-cycle concerns in the system design, reducing future uncertainty with early increases in system knowledge.*

The application of IPD initially ran into several problems. First, as IPD was new to the Air Force, it required buy-in from a number of organizations: high-level support from DoD and the contractors was obtained and special efforts were made to ensure that functional organizations were bought into the integrated design paradigm. And there was no ready base of knowledge and experience for implementing integrated design activities, nor was there any formal training. Instead, Air Force personnel learned about IPD through trial and error, information training sessions, and work experience.[52] *The use of new processes involves overcoming resistance from various organizations inside and outside of DoD. To effectively adopt new processes requires early training, support, and buy-in from stakeholders.*

A downside to the use of IPD as enacted in the F/A-22 programs was a lack of integration across teams. While each team was found to create integrated designs, there was a lack of system integration for the entire aircraft; instead, each team optimized their own subsystem in isolation—it was said that the "I" in IPD was for independent instead of integrated. To overcome this, a new layer of integration was added by the SPO: Critical Analysis and Integration teams were created to provide systems integration for the overall aircraft.[53] *The use of new systems engineering and program management tools is not a guarantee that systems engineering and integration activities will be adequately conducted.*

Another difficulty with IPD as enacted in the F/A-22 program was the blending of contracting and finance responsibilities into each IPT. While each IPT was responsible for its own financial and contracting work, there were not enough personnel trained in these activities. A matrix structure was created to help manage the workload, with finance and contracting personnel assigned to both functional organizations and IPTs; as a result, finance and contracting personnel often were not able to fully participate in all

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52 Wagner, Gary and Randall White, "F-22 Program Integrated Product Development Teams: How One Major Aircraft Program Developed Integrated vs Independent Product Teams," Program Manager, July-August 1995.

53 Ibid.

aspects of the IPD decision making.[54] *Additional effort is needed to ensure that cost and schedule impacts are accounted for in system design.*

b. Requirements Generation

Requirements are one of the single largest drivers of design cost and schedule. The F/A-22 program made several efforts at the start of the acquisition process to create requirements that would help facilitate reasonable production and life-cycle costs. The identification of affordability was accepted early in the requirement generation process.

To facilitate the creation of requirements that would lead to an affordable design, the F/A-22 SPO initiated several activities. In generating requirements and in an attempt to understand development, production, and life-cycle costs early, several stakeholders were involved, including users, designers, and maintenance personnel. To help make decisions among these costs, several studies were conducted, which traded-off performance against costs. Performance requirements, as opposed to "how to's," were released to contractors to allow them to use their judgment in balancing performance and cost. *The consistent use of performance requirements over "how to's" is critical for contractors to maintain design flexibility and achieve budget and schedule requirements.*

Throughout EMD, the F/A-22 program suffered from requirement instability. In general, we can see this in the flux in the F/A-22's core mission, which evolved from the early 1970s to the mid-1990s, starting as a ground-attack fighter, having an air superiority mission added, dropping the ground-attack capabilities, and then adding these back in. This requirements instability appeared in other aspects of the design as well. Examples include the shift in requirements during the Concept Demonstration phase to focus on low observability, the tightening of low-observability requirements in the aft section of the aircraft, and various capabilities-related to the integrated avionics system.[55] *Requirements instability causes ripple effects in highly integrated, complex systems, by impacting many systems, making substantial redesign work necessary at additional budgetary and schedule increases.*

Requirements also were loosened when design and budget consequences were deemed undesirable. For example, to maintain weight limits, and therefore cost ceilings, the Infrared Search and Track (IRST) system was completely removed and ejection seat capabilities were reduced. These changes were the consequence of studies done within

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[54] Ibid.

[55] Aronstein, op. cit.

DoD and by contractors as more was learned about system requirements.[56] *Flexibility to perform and implement trade-offs is critical to meet performance, cost, and schedule goals and constraints.*

c. Personnel Shifts

Shifts in experienced personnel away from the F/A-22 program is attributed to some of the problems and schedule slips experienced. Major personnel shifts occurred at Lockheed after they were awarded the EMD contract. After that phase began, Lockheed's F/A-22 headquarters was moved from Burbank, California to Marietta, Georgia. It was expected that 70% of the personnel would make the location transition, but Lockheed was able to keep only 30% of its F/A-22 personnel after the move.[57] Problems with the integrated avionics systems also coincided with a migration of software personnel into the internet software industry during the Dot Com boom of the mid to late 1990s. These major shifts in personnel created a sharp drop in an available, experienced workforce.[58] Other circumstances, such as Congressional budget shortfalls, also caused a personnel shift out of programs. *Stability in personnel is important in maintaining experience and knowledge associated with programs.*

d. Design Reviews

The F/A-22 program was consistently late in achieving design maturity during design reviews. At the time of the Critical Design Review in 1995, only 26% of the engineering drawings were released for production; it was not until 1998 that around 90% of the engineering drawings were released.[59] By this time, two development aircraft had already been produced and were being tested. *Timely design knowledge is important for making system decisions and for correcting problems before beginning production.*

e. Project Phasing

Restructurings were designed to allow more time during EMD to understand and develop technologies and to better match future funding profiles.[60] The F/A-22 project was restructured several times in an effort to contain costs and maintain schedule, but as a

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56 Ibid.

57 Ibid.

58 Tirpak, John, "The F-22 On the Line," Air Force: Journal of the Air Force Association, September 2002.

59 GAO-03-476, op. cit.

60 Center for Defense Information, "Air Force to Proceed with F-22 Procurement Despite Lack of Testing," April 9, 1998.

consequence, the flight testing plan became delayed. This had a ripple effect on the flight test program: flight testing was delayed due to funding shortfalls, late delivery of the test aircraft, unexpected modifications needed on test aircraft, and lower flight efficiency.[61]

As a result, the flight testing schedule was also restructured. Originally, 1400 hours of flight testing was planned for the F/A-22; after restructuring, total flight hours were reduced to 183.[62] To help keep the overall program on schedule, production contracts were awarded when only 4% of the flight testing had been completed.[63,64] This in turn resulted in production beginning when there were still serious design issues with several aspects of the aircraft, including instability in the integrated avionics system, vertical fin buffeting, and excess heating in the aft section.[65] *Testing is necessary to generate design knowledge and confidence before proceeding to production.*

B. GLOBAL HAWK

The High Altitude Endurance (HAE) Unmanned Aerial Vehicle (UAV) Tier II+ - Global Hawk - is the most recent program for UAV platform development. Global Hawk is planned to provide an unmanned, high-altitude, long-distance, day-or-night, wide-area observation and reconnaissance system. Global Hawk has seen increasing success, particularly since the terrorist attacks in 2001 and operations in Afghanistan and Iraq.[66,67,68]

Begun officially in FY94 as an ACTD, the program took advantage of a great many reforms, mostly directed at the perceived causes of problems with previous UAV programs. The ACTD officially ended on March 6, 2001,[69] at which point the program

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61 GAO/NSIAD-00-68, op. cit.

62 Taxpayers for Common Sense, "Taxpayer Group Commends F-22 Cuts," July 22, 1999.

63 Program on Government Oversight, "A Chance to Prevent the F-22 Raptor Aircraft from Turning into a Financial Monster," June 18, 1998.

64 GAO Report, "F-22 Aircraft: Progress of the Engineering and Manufacturing Development Program," General Accounting Office, Washington DC, GAO/T-NSIAD-98-137, March 1998.

65 GAO Report, "Tactical Aircraft: Status of the F/A-22 Program," General Accounting Office, Washington DC, GAO-03-603T, April 2003.

66 Bierstine, Leigh Anne, "Global Hawk Development on Track at Edwards", January 25, 2002, http://www.af.mil/news/Jan2002/n20020125_0131.asp .

67 "Global Hawk Fact Sheet," U.S. Air Force Fact Sheet, April 2003, http://www.af.mil/factsheets/factsheet.asp?fsID=175 .

68 Baker, Sue, "First Production Global Hawk Rolls Out," August 8, 2003, http://www.afmc.wpafb.af.mil/HQ-AFMC/PA/news/archive/2003/Aug/0808-03.htm .

69 Baker, Sue, "Global Hawk Program Enters Initial Acquisition," March 22, 2001, http://www.af.mil/news/Mar2001/n20010322_0402.asp .

was under budget by 2.1% and over schedule by 14 months. One must note that the scope of the program, however, was reduced. By some estimates, the program would have gone over budget by 122% had the original scope been adhered to. The most current cost estimates predict a $16 million to $20 million Unit Flyaway Price (UFP). The program is now entering production[70].

1. Program History

Prior to Global Hawk, U.S. development of UAVs had been plagued with cost overruns and schedule slips. UAV programs began with their limited use in Vietnam. These Remotely Piloted Vehicles, as they were called at the time, demonstrated poor survivability, but displaced otherwise manned surveillance activity, saving lives, and they were fairly effective.[71]

Following Vietnam, a variety of UAV programs were started and ended, including the Compass Arrow and Compass Cope. We can attribute this flux to changing relations with China, towards which these programs were initially targeted. Then, during the 1980s, the Israeli success with their Scout UAV led to U.S. purchase of the system, renamed Pioneer. Throughout the 1980s, programs were created to improve the UAV capabilities. These programs, most notably Lockheed's Aquila, were notorious for budget and schedule overruns, and produced little success.[72]

In FY88, Congress consolidated the non-lethal UAV programs being pursued, and in January 1990, established the need for a "Long Endurance Reconnaissance, Surveillance, and Target Acquisition Capability." Four UAV programs were established to acquire close-range, short-range, medium-range, and endurance UAVs. In 1993, the close- and short-range programs were merged into the Joint Tactical Program, and the medium-range program was cancelled. For the endurance capability, a three-tiered approach was adopted: Tier I – Quick Reaction Capability; Tier II – Medium Altitude Endurance; Tier III – Full Satisfaction of Endurance Capability. Tiers I and II produced Gnat 750 and Predator UAVs, respectively. A July 1993 study criticizing the Tier III program led to its being divided into two parallel programs: the conventional Tier II+

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70 Drezner, Jeffery and Robert S. Leonard, "Global Hawk and DarkStar: Their Advanced Concept Technology Demonstration Program Experience," Rand Corporation, Report MR-1473-AF, Santa Monica, CA, 2002.

71 Sommer, Geoffrey, Giles K. Smith, John L. Birkler, and James R. Chiesa, "Global Hawk Unmanned Aerial Vehicle Acquisition Process: A Summary of Phase I Experience," Rand Corporation, Report MR-809-DARPA, Santa Monica, CA, 1997.

72 Ibid.

(Global Hawk) and the low-observable Tier III (DarkStar). In an attempt to remedy what were thought of as the causes of past acquisition failures, both programs made broad use of innovative acquisition reforms.[73]

DarkStar initially progressed well, leading to a test flight ahead of schedule, but the second test flight crashed and further delayed testing for 26 months. Unsatisfactory flight performance contributed to quickly rising costs, including contractor cost share. Following several additional test flights, the Air Force cancelled DarkStar.[74]

Global Hawk was designated as an ACTD and was overseen by DARPA until October 1998, when oversight was transferred to the Air Force.[75] Unlike DarkStar, Global Hawk eventually evolved into an operations weapons system. This difference, and the lack of low-observable requirements, differentiated the two programs' goals. Teledyne-Ryan Aeronautical (now part of Northrop-Grumman) was selected as the primary contractor, and the program officially completed the ACTD on March 6, 2001[76] and entered formal acquisition as an EMD program. During EMD, Global Hawk was deployed to Australia[77,78,79] and Germany[80,81] for demonstration and testing, and played roles in combating terrorism in Afghanistan and in the War in Iraq.[82] The first unit was rolled out on August 1, 2003; and the final of the 51 units the Air Force intends to buy are scheduled for delivery in 2013.

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73 Ibid.

74 Drezner and Leonard, op cit.

75 "Global Hawk Fact Sheet," U.S. Air Force Fact Sheet, April 2003, http://www.af.mil/factsheets/factsheet.asp?fsID=175, op. cit.

76 Baker, Sue, "Global Hawk Program Enters Initial Acquisition," March 22, 2001, http://www.af.mil/news/Mar2001/n20010322_0402.asp, op. cit.

77 Ibid.

78 "Global Hawk Returns from 'Down Under,' " Air Force News Archive, June 8, 2001, http://www.af.mil/news/Jun2001/n20010608_0778.asp

79 "Global Hawk Fact Sheet," U.S. Air Force Fact Sheet, April 2003, http://www.af.mil/factsheets/factsheet.asp?fsID=175

80 Baker, Sue, "Global Hawk Completes Test Flight", October 21, 2003, http://www.af.mil/stories/story.asp?storyID=123005848 .

81 Baker, Sue, "Global Hawk Returns from Germany", November 10, 2003, http://www.globalsecurity.org/military/library/news/2003/11/mil-031110-afpn01.htm .

82 Baker, Sue, "First Production Global Hawk Rolls Out", August 8, 2003, http://www.afmc.wpafb.af.mil/HQ-AFMC/PA/news/archive/2003/Aug/0808-03.htm , op.cit.

2. Program Structure

The current Global Hawk was to demonstrate "military utility." An ACTD-type arrangement was chosen due to its streamlined management structure. In addition, provisions from Section 845, Other Transactions Authority (OTA), were used to further streamline the management structure, allowing for a "blanket waiving" of additional management and oversight requirements.[83]

During implementation, the Global Hawk ACTD differed from a typical ACTD in a number of key ways. First, requirements were cost-driven, as opposed to performance-driven, the aim of which was to control cost overruns. Instead, performance objectives were stated as goals, not requirements. Second, the Joint Program Office (JPO) was kept small and significant management responsibility and authority was left to the contractor so as to encourage efficient management and innovation. Third, emphasis in the design was placed on trading-off performance to reduce risk of failure. Fourth, extensive and effective use of Integrated Product Teams occurred to the benefit of the program. And finally, user involvement was encouraged early on so as to demonstrate military utility as quickly as possible, well before production commitments were made.[84,85,86]

Formal systems acquisition began in March of 2001, when Global Hawk entered EMD under the oversight of the Air Force. The EMD utilizes an evolutionary spiral development approach, where different capabilities can be accelerated as funding becomes available and necessity presents itself. Six "spirals" were laid out. The first increment included developing worldwide operations functionality in Global Air Navigations, Global Air Traffic Management, and Traffic Collision Avoidance, and the creation of technical orders and training curricula. Spiral 2 sought to improve the air vehicle's structural and power systems, including improved wing design and fuselage changes to increase payload. Spirals 3 and 4 looked to integrate additional sensing capabilities and add improved communications functionality. Last, Spiral 5 and 6 will

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83 Drezner and Leonard, op. cit.

84 Ibid.

85 Drezner, Jeffrey, Geoffrey Sommer, and Robert S. Leonard, "Innovative Management in the DARPA High Altitude Endurance Unmanned Aerial Vehicle Program: Phase II Experience," Rand Corporation, Report MR-1054-DARPA, Santa Monica, CA, 1999.

86 Sommer, et. al., op. cit.

incorporate more performance and reliability improvements and allow for future additions.[87]

3. Requirements

Historically, acquisition tends to be performance driven. A part of the acquisition reforms incorporated into the Global Hawk program was a change to a price-driven set of requirements. The only hard requirement provided by the JPO was a UFP of $10 million: all performance-related specifications were given as goals rather than requirements, and could be traded-off.[88]

Even so, the UFP at the end of the ACTD was expected to overrun by $2 million to $3 million, but the contractor was reluctant to trade-off performance for two primary reasons. First, the purpose of the ACTD was to demonstrate "military utility," a term which was not well-defined; failure to do so would mean an end to future contracts, so it was in the contractor's best interest to maintain performance. Second, there was a perception on the part of the contractor that the JPO was discouraging performance trade-offs. Regardless, it is felt that, throughout the ACTD, the UFP requirement had a significant effect on cost control.[89]

4. Risk Factors

Several risk factors were identified in the program. This section provides an overview of the most important, along with a short description of how each affected the program.

a. Weakened Incentives for Contractor Efficiency

The contractor selection for Global Hawk was designed such that competition among bidders was intended to act as a cost-saving mechanism. Soon after the ACTD began, Congress limited program funding. Instead of making this up by reducing system maturity requirements, it was decided that contractor down-selection would occur earlier, effectively removing the cost-saving mechanism prematurely. Because this situation had not been anticipated, the ACTD did not contain alternative mechanisms for government intervention on this issue.[90]

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87 Baker, Sue, "UAV Provide Warfighters a View," December 10, 2002, http://www.globalsecurity.org/intell/library/news/2002/intell-021210-usaf03.htm .

88 Drezner and Leonard, op. cit.

89 Ibid.

90 Drezner, Sommer and Leonard, op. cit.

b. Inadequate Contractor Management

The reduced management and oversight of the government was left in large part to the contractor, but little incentive existed for the contractor to adequately "fill the management void." Coupled with contractor inexperience with large programs and a lack of expertise in systems integration and software development, records were poorly kept (or kept not at all) during the initial phase of the ACTD, and problems propagated.[91,92]

c. Slow Problem Identification

Both the JPO and the contractor underestimated the difficulties of system integration and software development. This, coupled with reduced oversight and the contractor's inattention and lack of experience in these areas, recognizing and dealing with the situation was delayed.[93]

d. Overburdened JPO

A small, streamlined JPO encourages efficiency and contractor responsibility, but with a multiple-source competitive structure, this JPO was not well equipped to manage the program. To exacerbate the problem, the same JPO was managing DarkStar. With down-selection to a single contractor, the burden on the JPO was lessened significantly.[94]

e. Unclear Government and Contractor Responsibility

The lack of clarity in government and contractor responsibility arose largely as a result of a lack of detail in the ACTD. The most notable example concerned the strength of the wing design. The JPO felt that wing strengthening was necessary; the contractor did not. After some debate, the contractor requested reimbursement for the expense of the work, and the government refused. Obviously, a situation such as this can cause significant friction between the contractor and government, at the expense of the program.[95]

f. Contractor Incentives Drove Trade-Off Choices

Most of the management authority for making trade-offs was left with the contractor; the contractor's desire to demonstrate military utility, and ultimately acquire production orders, led to their reluctance to trade performance to meet the cost

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91 Drezner and Leonard, op. cit.

92 Drezner, Sommer and Leonard, op. cit.

93 Drezner and Leonard, op. cit.

94 Ibid.

95 Drezner, Sommer and Leonard, op. cit.

requirement. This, coupled with the perception that Global Hawk was competing with DarkStar for funding, provided a strong incentive largely at odds with the UFP cost cap. While this incentive conflict did not appear to hurt the progress of the program, a different mix of incentives, some of which might have been unanticipated, could have led to very different decisions by the contractor that may have been undesirable.[96]

g. Lack of Provisions for Government Intervention

In the ACTD, development costs for each phase were to be shared by the contractor and the government, up to a limit; additional costs beyond this limit were the sole responsibility of the contractor. During the second phase of the ACTD, the contractor was facing non-recurring costs that would have put it beyond the cost-sharing cap. Instead, using their authority for trade-offs, they were able to shift the non-recurring costs to the third phase, effectively transferring half of the cost back to the government. This move was recognized for what it was, but the lack of provisions for government intervention in the ACTD left the government with no recourse.[97]

h. Cross-Program Influences

The events and progress of the DarkStar program significantly influenced decisions made in the Global Hawk program; particularly, the general sense of competition between the two programs influenced the decisions made by the contractor concerning trade-offs. The crash of the second DarkStar test flight led to more risk-adverse decisions in Global Hawk, and some testing delays.[98]

5. Testing

Before the terrorist attacks, flight test hours accumulated slowly. The crash on takeoff of the second DarkStar test flight led to greater caution in testing Global Hawk.[99] But the terrorist attacks and subsequent military operations in Afghanistan and Iraq has greatly accelerated the testing process.

Additional testing in Australia and in Germany provided increased testing information and publicity for the program. On April 22-23, 2001, a Global Hawk unit flew 7,500 miles and 22+ hours non-stop over the Pacific Ocean to Australia. Once there, the unit participated in a six-week international Joint forces operation - “Tandem Thrust”

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[96] Drezner and Leonard, op. cit.

[97] Ibid.

[98] Ibid.

[99] Ibid.

- to "demonstrate its military utility in concert with other airborne, land-based, and ocean-going forces." After its return on June 8, 2001, 11 sorties had accumulated 238.3 flight hours.[100,101,102] Global Hawk was flown to Germany on October 15, 2003. Six sorties, totaling 29 flight hours, demonstrated interoperability with German systems, and an additional 21.6 trans-Atlantic flight hours were accumulated.[103,104]

6. Terrorism, Afghanistan, and the War in Iraq

The events of September 11, 2001, coupled with its successful use in Afghanistan[105,106] and Iraq,[107] had a profound effect on the Global Hawk program. Media attention contributed to public awareness of the program and increased political and military interest in Global Hawk's capability. Following the terrorist attacks, the program staff, formerly focused on acquisition and development, began additional efforts to produce an operational system for use in Operation Enduring Freedom (OEF).[108] The wartime urgency greatly accelerated the testing schedule and minimized delays when failures occurred – the December 30, 2001 crash of a Global Hawk unit supporting OEF had little effect on the testing schedule.[109] The opportunities to test under real conditions were of great value, and minimized "…the required sorties necessary to complete the test process… ."[110]

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100 Baker, Sue, "Global Hawk Program Enters Initial Acquisition", March 22, 2001, http://www.af.mil/news/Mar2001/n20010322_0402.asp , op. cit.

101 "Global Hawk Returns from 'Down Under'", Air Force News Archive, June 8, 2001, http://www.af.mil/news/Jun2001/n20010608_0778.asp, op. cit.

102 "Global Hawk Fact Sheet", U.S. Air Force Fact Sheet, April 2003, http://www.af.mil/factsheets/factsheet.asp?fsID=175, op. cit.

103 Baker, Sue, "Global Hawk Completes Test Flight", October 21, 2003, http://www.af.mil/stories/story.asp?storyID=123005848, op. cit.

104 Baker, Sue, "Global Hawk Returns from Germany", November 10, 2003, http://www.globalsecurity.org/military/library/news/2003/11/mil-031110-afpn01.htm , op. cit.

105 Bierstine, Leigh Anne, "Global Hawk Development on Track at Edwards", January 25, 2002, http://www.af.mil/news/Jan2002/n20020125_0131.asp, op. cit.

106 "Global Hawk Fact Sheet", U.S. Air Force Fact Sheet, April 2003, http://www.af.mil/factsheets/factsheet.asp?fsID=175, op. cit.

107 Baker, Sue, "First Production Global Hawk Rolls Out", August 8, 2003, http://www.afmc.wpafb.af.mil/HQ-AFMC/PA/news/archive/2003/Aug/0808-03.htm, op. cit..

108 Baker, Sue, "UAV Provide Warfighters a View", December 10, 2002, http://www.globalsecurity.org/intell/library/news/2002/intell-021210-usaf03.htm, op. cit.

109 "RQ-4A Accident Report Released", Air Force Media Center, Press Release and Media Advisories, July 3, 2002, http://www.af.mil/mediacenter/archive.asp?startDate=7/1/2002&endDate=9/30/2002 .

110 Bierstine, Leigh Anne, "Global Hawk Development on Track at Edwards", January 25, 2002, http://www.af.mil/news/Jan2002/n20020125_0131.asp , op. cit.

C. F-15 EAGLE

The F-15 program began in the early 1960s under then-new DoD acquisition policies that looked to counter cost growth and schedule delays and compromised technical performance. Although the F-15 was and still is a huge program with many acquisition "problems," it is looked upon today as an example against which all other large, complex system acquisitions are held.

1. Program History

Following the Vietnam conflict, the Air Force sought to develop and procure a new, dedicated air superiority fighter to outmatch the Soviet-built MiG21.[111] Originally known as Fighter Experimental (FX), F-15 requirements were for a fighter with unparalleled maneuverability and state-of-the-art avionics and weaponry. From 1967 to 1969, conceptual design competitions were held among the major contractors at the time: McDonnell Douglas, North American Rockwell, and Fairchild Republic.

Uniquely, DoD asked NASA to respond to the F-15 RFP in a manner similar to industry contractors. The thinking within DoD was that NASA's designs would embody the latest advanced technology concepts and would serve as the upper limit of technology for industry proposals.[112] DoD also wanted to use NASA's problem-solving expertise to minimize risks and problems that would occur later in the development program.

Industry design teams visited Langley frequently during their design process and studied in detail each of the four design concepts that NASA had laid out for the F-15. In fact, McDonnell Douglas embraced the fundamental layout of one of NASA's designs (LFAX-8) and eventually won the competition on December 23, 1969, using that basic design concept with several modifications.

As full-scale development began on January 1, 1970, the F-15 SPO was charged by Deputy Secretary of Defense David Packard to develop the fighter aircraft in a manner that would restore the faith of Congress and the public in the ability of DoD to manage large weapons systems.[113] In fact, due to the program's success, Packard used the F-15 as a model for much of his acquisition directive known as the 5000.1: "Acquisition of Major Defense Systems."

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[111] Information on F-15 Eagle, as found on http://www.globalsecurity.org/military/systems/aircraft/f-15-history.htm, as of March 17, 2004.

[112] Ibid.

[113] Guarino, Gilbert, Relva Lilly and James Lindenfelser, "Faith Restored – The F-15 Program," Air University Review, January-February 1976.

2. F-15 Acquisition and Management Techniques

a. Personnel

One of the most important keys to the success of the F-15 acquisition process was the selection of its System Program Director – Major General Benjamin N. Bellis.[114] At the time, Bellis had considerable experience both in terms of understanding systems acquisition and in managing large programs. He was given full responsibility and authority for the direction of the F-15 program and was allowed to operate under the "Blueline Management Concept," which streamlined the chain of command and gave him immediate access to top USAF and OSD decision makers.

The selection of key subordinate personnel also contributed greatly to the success of the program. Not only were each of the personnel handpicked by the F-15 program office based on their past performance, but also they were signed to a period of five years to guarantee continuity. Thus, it was extremely rare when a manager transferred at an inopportune time. And experts were brought into the program during the conceptual and validation phases, which allowed them to be involved in testing, production, and logistics as well as other functional disciplines during basic program planning. This was a major change from past management techniques where key members were not brought on board until the development or production phases.[115]

b. Organization

The F-15 organization was a unique integration of the traditional two types of organization: project and functional.[116] A project manager was picked for each of the major development areas, including airframe, engine, avionics, armament, TEWS, AGE, training, and support. At the same time, a project directorate was picked for each functional area: engineering, configuration, test and deployment, integrated logistics, production, and procurement. Each project directorate had full responsibility for his or her area and reported across all project areas.

This organizational layout provided two key levels of interface: between the Program Director and each of the program managers, and between the program managers and the functional directorates. Both interfaces facilitated early problem identification and resolution before permanent impacts could occur.

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114 Ibid.

115 Ibid.

116 Ibid.

c. Planning

The F-15 program office placed heavy emphasis on early and concrete planning to stabilize and control costs, schedule, and performance,[117] the objective of which was to solidify system definition and design requirements early on to allow timely corrective actions, minimize misunderstandings between the SPO and contractors, and optimize cost of ownership. And although these actions contributed the overall success of the F-15 program by stabilizing program objectives and cost requirements and facilitating detailed planning throughout the program (including secondary support for training, spares, technical data, and facility requirements), it did not prevent some gold-platting. Several recent studies have shown that the requirement of mach 2.5 was unnecessary and extremely costly. Most studies aver that reducing the top speed requirement from mach 2.5 to 1.5 would not have been detrimental to the overall air superiority of the aircraft, and would have saved the program $20 billion dollars.[118]

d. Testing

Another major success factor in the F-15 program was its emphasis on early and complete subsystem and system ground testing well in advance of flight testing. The F-15 program utilized the "test-before-fly" and "fly-before-buy" concepts to the fullest extent. This philosophy, coupled with the extensive planning efforts, minimized the possibility of surprise during the flight test program and subsequent costly and time-consuming system modifications.

During the validation phase, two prototype development contracts were awarded for three of the most critical subsystems: engine, fire control radar, and the advanced 25-mm gun.[119] The competitive development of all three systems reduced the degree of risk before full-scale development was undertaken by a single source. In the case of the engine, the contract was split between the competing contractors Pratt & Whitney and GE. The decision was not made on the basis of cost savings - a single contract to either firm would have saved over one billion dollars; rather it was to protect against a possible catastrophic failure to the entire fleet due to a faulty engine design by either firm.

In addition and whenever possible, extensive laboratory testing that simulated real-world situations were utilized. Wind-tunnel testing and subsystem prototype testing

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117 Ibid.

118 McNaugher, Thomas L., "New Weapons, Old Politics," The Brookings Institute, Washington DC, 1989.

119 Guarino, Lilly and Lindenfelser, op. cit.

and analysis were performed at a much higher rate than past programs and were instrumental in reducing developmental risk and improving overall safety record.

e. Contracting Methodology

F-15 program managers initiated many of the most innovative and successful management and contracting methodologies. The Total System Performance Responsibility (TSPR) clause charged the prime contractor with responsibility for total system integration, performance, and support responsibilities. It covered all components of the F-15, whether built by the TSPR contractor, subcontracted by him, or provided to him through government-furnished equipment. This clause shifted a great portion of the overall system responsibility from the government to the lead contractor. Throughout development, this forced the lead contractor - McDonnell Douglas, in this case - to be responsible for more of the everyday management and system integration, and they were far more experienced at this than was the government.

The Limitation of Government Obligation (LOGO) required the contractor to identify any changes in negotiated fiscal year funding 17 months prior to the start of the fiscal year. Any additional funding not so identified would be the responsibility of the contractor until the next billing cycle, and the government would not be responsible for any lost interest or loans. This gave extra incentive to the contractors to provide sound and accurate funding requests that matched the government's normal budget request cycle. The innovative part of this clause was that it forced the contractor to be more accurate in its bidding and, by default, it forced the program to hold to its budget plan before Congress each year. If the program had to ask for more future years' monies, it was guaranteed that it would hit the budget for the current year – a big bragging right that is usually not achieved by any program, much less a large defense acquisition system.

The third innovative clause, Correction of Deficiency (COD), defined the contractor's responsibility for correcting defective equipment even after the government has accepted it. This reduced the risk of long-range defects that might not be visible at the time of contract expiration.

Besides these important management clauses, the F-15 program also had a successful interface between the program office and the main contractors. The management engagement philosophy meant that F-15 managers were totally involved in the day-to-day problems facing the prime and secondary contractors. Early program office involvement ensured timely contractor action and minimized the risk of serious impacts to program cost, schedule, and technical objectives.

f. Production and Quality Assurance

Preparation of F-15 production and quality plans always involved the program office, the contractor, and the government plan representative, a joint effort that ensured mutual understanding and provided a forum for disagreements to be aired and compromises to be reached quickly and effectively.

Configuration management was another key cornerstone to success. To avoid haphazard design changes, which are always expensive and time consuming, the F-15 program office established stringent criteria for the evaluation of any changes. All proposed changes were thoroughly reviewed by the program managers, the contractors, and any necessary supporting commands. Passing review, the proposed change was submitted to the Configuration Control Board, comprising members from each major stakeholder; the Board would recommend approval or disapproval. If change was determined essential, all negotiations including cost, schedule, and technical modifications would have to be completed before final authorization; this ensured that no member of the team was ever surprised by any development, and that all were working toward the same goal.

3. Program Analysis

This case study illustrates a successful DoD acquisition program. While there was not any one single reason for this success, there were many initiatives and unique events that either eliminated or greatly reduced many of the risk factors.

The F-15 program did a very good job of eliminating contractual uncertainty. The TSPR and LOGO clauses were huge steps in the right direction in clearly stating the responsibility of each of the contractors and in giving full responsibility for full system integration to the main contractor. These new policies enhanced the performance of the contractors and improved communications, as now it was essential for the contractors to know exactly what was expected of them.

The majority of the improvements were made in the systems engineering and program management implementation category. Out of the six original risk factors identified for this section, we found that the F-15 program improved on five. First, the project manager was given a much bigger role and responsibility in this project. He had previous management experience, he was given full responsibility and authority for the direction of the F-15 program, and he was allowed to operate under the “Blueline Management Concept,” which streamlined the chain of command and gave him immediate access to top USAF and OSD decision makers. Next, the F-15 program placed heavy emphasis on the system engineering process. Unlike other projects where the SE process was underfunded and undermanned, the F-15 project placed heavy emphasis on early and concrete planning and system design to stabilize and control costs, schedule, and performance. Thirdly, the F-15 program implemented a new management hierarchy, allowing the smooth flow of information between levels and up and down the program level, which ensured that the program status was known at all levels of management. Finally, the program took steps to reduce both the phasing and lack of testing program by placing heavy emphasis on the "test-before-fly" and "fly-before-buy" concept. This greatly reduced the time, effort, and cost at each development stage due to heavy modifications or even re-development owing to faulty products from the previous development stage.

At the institutional level, the F-15 program reduced several risk factors by showing strong support for the reforms initiated and gaining trust in the reforms. These improvements came about not from direct efforts but rather as indirect benefits from the nature of the program. Because this program was designated by Mr. Packard at the time as the acquisition reform poster-child to regain the trust of the Congress and the American people, the F-15 development was heavily and actively managed from the very top of DoD all the way to the bottom of the management ladder. This consistent and dedicated effort throughout DoD greatly contributed to the success of all the reform initiatives. Everyone within DoD wanted to make sure this program was a success and that each reform was carried out to its fullest. While it is nearly impossible to value the total impact of this indirect benefit, it surely was a leading contributor to the overall success of the program.

Even with all its improvements, there were still risk factors to be considered throughout the program. The two biggest ones were a high-tech design risk and an unwillingness to make trade-offs. It is almost impossible to avoid the high-tech design risk. As this was another state-of-the-art acquisition program, R&D was again involved in development. We credit management for recognizing this and for trying to minimize its effects by incorporating the expertise of NASA in developing high-tech products. The second risk factor was a much greater problem and in some experts' estimates, cost the program $20 billion. The lack of willingness to make the tradeoff for lower performance, in particular the top mach level of 2.5, greatly increased development time, R&D, and overall risk. It was thought that the high mach level was crucial for air superiority when compared against the MIG, but later studies proved otherwise.[120]

D. CONCLUSION

Detailed studies of these three programs reveal the complexity and uncertain nature of the acquisition system. Even though all three programs were similar and even shared many of the same risk factors and acquisition processes, it is impossible to pinpoint one or even two events or reforms that made the difference between a successful and a less successful program. We believe this is illustrative of the entire defense acquisition process and the difficulties that arise when reformers try to find the "silver bullet" solution and ignore design and institutional realities.

[120] Farrell, Theo, "Weapons Without a Cause," Macmillan Press LTD, 1997.

VI. A HISTORY OF ACQUISITION REFORM EFFORTS

A. THE EARLY YEARS: 1940s AND 1950s

The military has always relied on private industry to supply the materials and equipment needed for war and peace.[121] Although the government manufactured some war materials, at no time have our forces been completely independent of the private sector in the acquisition process. Prior to World War II, the defense industry can be compared to a typical manufacturing industry, with emphasis on simplicity, reliability, and producibility. During the war, the procurement process worked well because wartime urgency required the relaxation of traditional regulations, such as large amounts of paperwork, signature and review cycles, and other routine regulations characteristic of the government process. The defense industry was focused on the quick and efficient production of new weapons systems for the war effort and, even though there was a lack of bureaucratic accountability, each person was focused on delivering the right result. This made the system extremely lean and efficient. Following the war, the focus of the acquisition system evolved toward increased research and development spending and production of the most advanced technological systems.

In 1947, the Department of Defense was established, but the Secretary of Defense (SecDef) had little authority beyond providing general direction. Formal DoD acquisition policy was limited to the Armed Services Procurement Regulation (ASPR), written in 1947 and approximately 125 pages in length (compared to the current acquisition regulations, which total over 1400 pages).[122] Monies were authorized to develop almost any new defense system that appeared capable of giving the United States any performance advantage over adversaries. Ideas and phrases such as “should-cost,” “design-to-cost,” and “life-cycle cost” where not yet conceptualized. Production costs seldom posed a major constraint on engineering design. The defense budget itself totaled 5% of the federal budget in 1950, although it grew to almost 10% by the late 1950s.

In the late 1950s, the DoD Reorganization Act was chartered to give the SecDef authorization in assigning development, production, and use of the weapons systems to

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121 Doane, Donna and Susan Spencer, “Cultural Analysis Case Study: Implementation of Acquisition Reform within the Department of Defense,” Massachusetts Institute of Technology Masters Thesis, Cambridge, MA, May 16, 1997.

122 Ibid.

the three military Services. This Act provided the groundwork for the leadership role of the Defense Secretary and paved the way for OSD to write the strong acquisition reforms of the 1960s.

B. THE McNAMARA ERA: 1960s

By the start of the 1960s, several national trends began to focus a more critical look at the acquisition process and its burgeoning costs to the nation. These included increasing constraints on available resources (both in terms of budget and personnel), escalating enemy threat (Cold War, Vietnam), spiraling production costs, and longer systems life cycles.[123] During this crucial era, Robert McNamara was appointed Secretary of Defense; he was a "take charge" manager, he brought a business school mentality to the office, and he had a core philosophy and a goal of centralizing planning and authority at the OSD level, including the acquisition process.

McNamara's staff stressed systems analysis as an aid in decision-making on weapons systems development and on many other budget issues. The secretary believed that the United States could afford any amount needed for national security, but that "this ability does not excuse us from applying strict standards of effectiveness and efficiency to the way we spend our defense dollars . . . . You have to make a judgment on how much is enough." Acting on these principles, McNamara and his team developed and implemented a number of initiatives. The planning, programming, and budgeting system (PPBS) provided the Secretary of Defense and the President with an organized approach to major program decisions and to the allocation of resources within DoD. He created the Office of Systems Analysis to perform cost-effectiveness studies on all of the acquisition programs. And he created the total package procurement (TPP), which required simultaneous bidding, on a fixed-price basis, for both development and production stages of the acquisition process. This was a significant change from previous cost-plus-fixed-fee contracts and limited competition at the production stage of a contract, and although it was a good idea in theory, it did not see any success in practice for two key reasons: there was a shallow knowledge-base and a lack of willingness on part of the junior managers in the acquisition process; and there were a large number of loopholes in the actual implementation of the program. Any incentives for cost control and accountability for cost growth were nullified by the numerous changes adopted in the program by different acquisition projects and managers. Furthermore, DoD found it difficult to enforce fixed-

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[123] Fox, J. Ronald, "Defense Management Challenge," Harvard Business School Press, 1988.

priced contracts. The Services often forced programs to forego the concept; they did not want to incur delays by either changing contractors or designs midway through a project.

Other initiatives developed by the Secretary's office included:[124]

- The integration of supply and maintenance considerations and planning into the systems engineering and design process
- Standard procedures for proposal evaluation and source selection
- Standard procedures for improved quality assurance
- Information systems for planning and control of schedules and costs
- Programs for value engineering and to eliminate and modify unessential equipment features and to minimize costs
- Standard procedures for collecting and storing technical data for different contracts
- The work breakdown structure framework (WBS) – a systems engineering method of dividing work into logical subcomponents such as hardware, software, etc.

All these initiatives were aimed at a centralized and systematic method of analyzing and procuring new weapons systems at a reduced cost to the government, while maintaining a high standard of technical advancement. Unfortunately, the Services were not motivated to follow these protocols, and the lack of managerial training for acquisition managers thwarted DoD's ability to correctly implement many of these practices.[125] So, without backing from the leadership of OSD, along with continued cost overruns, Congress began to move in and assist in the acquisition process, further complicating the entire system. But one of the worst fallouts was the loss of the true function of the program manager. Instead of properly managing the project, the program manager became overwhelmed by the new initiatives set forth by the Secretary and spent most of his time marketing and defending his program in various committee and review meetings.

C. REFORM IN THE 1970s AND 1980s: PACKARD COMMISSION YEARS

Acquisition reforms in the 1970s and early 1980s were mainly short-lived and/or poorly implemented. Bureaucratic constraints and lack of coordination rendered most of the initiatives ineffective. For example, the 1969-70 President's blue ribbon defense panel study stressed the urgent need for an independent weapons testing office. Despite the support of both the Defense Secretary and the Deputy Secretary, a bureaucratic war of

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124 Doane and Spencer, op. cit.

125 Fox, op. cit.

attrition within the Pentagon gradually devoured the initiative, until Congress legislated it into existence some thirteen years later. It took another two years before the Secretary of Defense appointed someone to head it.

Some of the more worthwhile reforms in this early era were developed by then-Deputy Secretary of Defense David Packard, who published his famous Packard Commission reports and reforms in the late 1980s (spoken of in Chapter V). To review: he established the DSARC to advise him of the status of each major defense system and to allow for careful evaluation before proceeding from one program phase to the next. He formed the independent Cost Analysis Improvement Group (CAIG) to provide unbiased cost estimates for OSD managers and DoD as a whole. And he issued a memorandum that described what he viewed as the necessary components of a successful acquisition system: competent people, rational priorities, and clearly defined responsibilities. This referendum later served as the basis for DoD 5000.1: “Acquisition of Major Defense Systems” (the first of a number of publications in the 5000 series).

By the mid-Reagan era, defense costs had again become such a national issue that Reagan commissioned Packard to perform a comprehensive review of the overall defense acquisition system. In early 1986, the Packard Commission recommended creation of a single top-level Defense Acquisition Executive responsible for the defense acquisition process - the Under Secretary of Defense (Acquisition, Technology and Logistics) (USD(AT&L)) - and the establishment of a streamlined reporting chain from program managers of major defense acquisition programs to top-level executives. Reagan approved the Commission’s recommendations and directed their implementation in National Security Decision Directive 219 on April 1, 1986. The Commission also renamed the McNamara “phases” of development to what are known today as milestones.[126] Under the new system, Packard attempted to develop a method of measurement, via these milestones, that would allow top OSD leaders to block programs from moving on to the next phase if there were major technical or financial problems appearing in the program. In practice, this theory did not perform up to its expectations as the lack of options often resulted in the request for, and ultimately the granting of, blanket approval to proceed even when major flaws were still present. Other regulations implemented in the late 1980s include the Federal Acquisition Regulation (FAR) and the Defense Acquisition Regulation (DAR). Both were enacted as successors to the ASPR from the mid-1940s.

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126 Doane and Spencer, op. cit.

D. REFORM IN THE 1990s

By the 1990s, the new defense environment brought about another round of acquisition reforms. Coinciding with the ending of the Cold War was the development of high-tech R&D in the commercial world. The dramatic increase in private funding for technology research and growth meant that the government and DoD were no longer the only ones developing next-generation state-of-the-art technology. To further reduce cost and take advantage of this development, the next round of acquisition reforms focused on using commercially available technology, developing dual-use systems, focusing on more conventional warfare weaponry, and a more concerted effort to develop weapons systems that could be used by multiple Service branches. These cultural shifts in the acquisition process are set forth in Table VI-1.

Table VI-1. Comparison of Acquisition System Characteristics [127]

Goals of Past Acquisition Systems	Today's Acquisition Emphasis
• Many new systems	• Fewer new systems; modified legacy systems
• Focus on nuclear warfare	• Conventional warfare
• Technology driven systems	• Affordability driven systems
• Service-specific programs	• Joint programs
• Military-unique technology	• Commercial and dual-use technology
• Technology development	• Technology insertion

Recognizing the need for real and lasting changes in the acquisition process, a new position was created, Deputy Under Secretary of Defense for Acquisition Reform (DUSD(AR)). Then Secretary of Defense William Perry issued a memorandum outlining the needed methods and initiatives for reform. These included: [128]

- Adapting the best practices of world-class customers and suppliers
- Continuously improving the acquisition process to ensure flexibility, agility, and, to the maximum extent possible, based on best practices
- Providing incentives for acquisition personnel to innovate and manage risk, rather than avoid it
- Taking maximum advantage of emerging technologies that enable business process reengineering and enterprise integration.

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127 "Introduction to Defense Acquisition Management," Defense Acquisition University Press, Fort Belvoir, VA, January 5, 2001.

128 Ibid.

The major legislative reforms that followed these initiatives included:

- *Federal Acquisition Streamlining Act* (FASA) (1994). FASA repealed or substantially modified over 225 provisions of law primarily dealing with contracting and procurement matters. Notable features of this legislation include emphasis on the use of commercial versus military specifications, encouragement of electronic commerce, and requirements to use past performance when evaluating contractor proposals.
- *Federal Acquisition Reform Act* (FARA) (1996). A follow-up to FASA, FARA covered issues ranging from exceptions for commercial item acquisitions, to the Truth in Negotiations Act, and Cost Accounting Standards.
- *Information Technology Management Reform* Act (ITMRA) (1996). This act required greater accountability for system improvements achieved through information technology. It also addressed the issue of rapidly changing technology by requiring modular contracting, with increments delivered within 18 months of contract award.
- *The 1997 rewrite of the 5000 series of acquisition regulations* (1997). A dramatically shorter document that streamlined the regulations surrounding the acquisition process.
- *National Defense Authorization Act* (1998). This act, along with the 1993's Defense Acquisition Workforce Improvement Act, were the DoD's attempt to improve the workforce of those concerned both with the acquisition process and with DoD. This was in recognition that, at the end of the day, good acquisition reform only happen with the right people at the right places.

E. REFORMS IN THE 2000s

Acquisition reforms in the 2000s have focused on incorporating flexibility, commercial best practices, and shortened acquisition program timelines into the acquisition process to better meet technical, budget, and schedule goals. Investments in new systems from 2003 to 2009, expected to top $1 trillion, have provided greater motivation for increasing the efficiency of the acquisition process, and are meant to provide a transformation between current legacy forces and future forces that will be capable of conducting information age warfare.

New reforms are designed to move system acquisition toward a more evolutionary development process. Trying to achieve all technology advances at once with a "big bang" approach of system acquisition often has resulted in program delays and overruns to allow for adequate resources to be invested in technology development, testing, and integration. The evolutionary acquisition model emphasizes developing and fielding a system in phases, with limited functionality systems being fielded first and then progressing up to the ultimate functionality over time. While the initial set of fielded systems may not have the ultimate capability, evolutionary acquisition is meant to allow systems with some capability to be fielded in a much compressed timeline when compared to past acquisition efforts.

When combined with other acquisition strategies such as spiral development and open systems concept, evolutionary acquisition is meant to decrease the time in which systems are fielded and help rein in program costs and increase the ability to make rapid, incremental changes in the technology and capabilities of systems. By moving away from big-bang systems to a phased development, the flexibility to incorporate new technologies and the time to build a knowledge base of high-risk, cutting-edge technologies will be achieved.

Table VI-2 presents a summary of major milestones in the acquisition process.

Table VI-2. Overview of Defense Acquisition Process and Reforms

Era	Characteristics of the Defense Acquisition Process	Important Acts or Regulations Concerning the Acquisition Process
1940s (WWII)	• Defense industry similar to a manufacturing industry • Almost no bureaucratic accountability system	• Establishment of DoD in 1947 • Armed Services Procurement Regulation (ASPR) in 1947. First rules associated with defense purchases, 125 pages
1950s	• Trend towards high tech and advanced weapons systems • Cost was not an issue • Limited DoD wide control on the acquisition process due to lack of leadership from the OSD office	• Department of Defense Reorganization Act. Provided ground work for the lines of authority between the Secretary of Defense and the armed forces

Table VI-2. Overview of Defense Acquisition Process and Reforms, continued

Era	Characteristics of the Defense Acquisition Process	Important Acts or Regulations Concerning the Acquisition Process
1960s	• McNamara era of stronger OSD leadership and reliance on systems engineering principals • Streamlining of the systems acquisition process was mainly thwarted by the lack of incentive and education necessary on the part of lower-level managers involved in the everyday process. No incentives for the service branches to follow orders either • Congress began to move in, question, and assist in the acquisition process, resulting in further complications and slow downs	• Planning, Programming and Budgeting System (PPBS). First organized approach to major program decisions and to the allocation of resources within DoD • Office of Systems Analysis. For unbiased cost and technical analysis • Total Package Procurement. Fixed-price bidding instead of cost + fixed fee; simultaneous bidding on development and production stages • Other smaller initiatives including: - The integration of supply and maintenance considerations and planning into the systems engineering and design process - Standard procedures for proposal evaluation and source selection - Standard procedures for improved quality assurance - Information systems for planning and control of schedules and costs - Program for value engineering and to eliminate or modify unessential equipment features and minimize costs - Standard procedure for collecting and storing technical data for different contracts - Work breakdown structure (WBS) framework
1970s	• Era of little change in the acquisition process • Deputy Secretary of Defense David Packard returned some autonomy to the individual Services but maintained OSD involvement in program decisions	• Establishment of the DSARC-Defense Systems Acquisition Reform Council • Formation of Cost Analysis Improvement Group (CAIG) • Memorandum on ways in which the acquisition process can be better streamlined. Later served as the basis for the DoD 5000.1 document

Table VI-2. Overview of Defense Acquisition Process and Reforms, continued

Era	Characteristics of the Defense Acquisition Process	Important Acts or Regulations Concerning the Acquisition Process
1980s	• Further public demand for changes in the acquisition process • Reagan appoints Packard Commission for comprehensive overview of the acquisition system and to provide recommendations for change	• Formalization of the milestones • Creation of the Undersecretary of Defense for Acquisition • Streamlining of reporting within the acquisition process • Federal Acquisition Regulations (FAR) • Defense Acquisition Regulations (DAR)
1990s	• Changing economic (tighter budgets) and political environments (end of Cold War) lead to drastic changes in acquisition goals: Fewer new systems Conventional instead of nuclear warfare Cost driven acquisition Joint program instead of single Service programs Increasing reliance on commercial and dual-use technology Technology insertion, not development	• New acquisition initiatives as outlined by Secretary Perry: - Adapting the best practices of world-class customers and suppliers - Continuously improving the acquisition process to ensure it remains flexible, agile, and, to the maximum extent possible, based on best practices - Providing incentives for acquisition personnel to innovate and manage risk rather than avoid it - Taking maximum advantage of emerging technologies that enables business process reengineering and enterprise integration • Federal Acquisition Streamlining Act (FASA) (1994) • The Federal Acquisition Reform Act (FARA) (1996) • Information Technology Management Reform Act (ITMRA) (1996) • The 1997 rewrite of the 5000 series of acquisition regulations (1997)

Table VI-2. Overview of Defense Acquisition Process and Reforms, concluded

Era	Characteristics of the Defense Acquisition Process	Important Acts or Regulations Concerning the Acquisition Process
2000s	• Evolutionary acquisition to field systems with limited functionality in compressed time scale, while ultimate functionality will occur in future system generations • Spiral development to increase system flexibility and allow rapid adoption of incremental advances, for combined effect of transformational forces • Open systems concept meant to anticipate future technology advance in systems, designing in ability up front to make future changes with reduced effort	

F. SUMMARY OF ACQUISITION REFORMS

DoD has tried a variety of methods to reform its acquisition process. Some success has been achieved, but the system remains problematic: it still is not uncommon to have major acquisition programs that are over budget and behind schedule. Much of this can be attributed to the fact that most of the acquisition reforms have been looking for a "silver bullet," which has caused DoD to go after the "low hanging fruit" solutions while ignoring the "problems behind the problems."

In general, DoD reforms did not consider all the risk factors as a whole but looked instead for single, causal relationships to fix. In the 1960s, McNamara looked to fix the problems associated with system engineering and program management process without addressing their implementation or the institutional constraints. He tried to limit cost by implementing management policies for simultaneous contracting bids, but it failed owing to a paucity of education, an unwillingness on the part of the junior managers, and too many loopholes. He was not able to address implementation and institutional issues. This led to a lack of incentives on the part of the Services and a lack of managerial training for acquisition managers, thwarting DoD's ability to correctly implement many of these practices. Furthermore, without solidifying the leadership of the OSD, along with the continued cost overruns, Congress began to move in and assist in the acquisition process—further complicating the entire system.

During the Packard years, reforms were again generally geared towards the basic system engineering and program management process, with a bit more concern for its implementation. But again DoD mainly looked for single causal solutions, and other risk factors foiled most of the reforms. And example is the policy for more testing without specific institutional changes to make this possible.

While the jury is still out on the effectiveness of reforms in place, our analysis shows that it embodies many of the traits that caused earlier reforms to fail. However, in the latest round of reforms, changes were made in almost all four categories of risk factors: using more commercially available products to reduce high-tech design risk; adopting commercial best practices selectively to reduce risk factors through better contracting procedures; fewer requirements; and greater PM authority and a greater willingness to make trade-offs. Institutional issues also are being considered, through better education to ensure commitment at all levels is needed to build trust and communication among all stakeholders.

VII. COMPARISON OF COMMERCIAL AND DOD ACQUISITION PROGRAMS

Transplanting the best of the commercial practices into the DoD acquisition environment is seen as a way to address system performance shortfalls, budget overruns, and schedule slips. Understanding the similarities and differences between government and commercial programs, however, is necessary before applying commercial best practices to DoD programs. Differences ranging from missions to institutions affect the success of applying best practices. To help in this understanding, we have developed case studies for the Boeing 777 and DoD C-17 cargo plane, and we go on to discuss the applicability of commercial best practices to DoD programs. Much of our material on the C-17 and 777 programs is drawn heavily from Battershell.[129]

A. DOD C-17 CARGO PLANE

1. Technical Description and History

The C-17 was conceived in the early 1970s as an Advanced Medium Short Range Take Off and Landing (AMST) cargo plane - an affordable, technologically mature aircraft capable of carrying outsized tactical cargo into and out of austere airfields; requirements were later modified to include strategic cargo-carrying objectives as well. The plane was to augment the existing cargo-carrying capabilities held primarily by the C-5A.

It was the first cargo plane to use fly-by-wire; it included an upgraded avionics suite that contained a heads-up display and the capability to airdrop cargo and personnel into and out of small, austere airfields, owing to significant improvements in its ground maneuverability over other cargo planes.

By the mid-1970s a reorganization within DoD caused a change in the primary requirements for the AMST. When TAC (the organization originally advocating the AMST) was combined with the Strategic Military Airlift Command, the result was a compromise between the Army’s need for improved tactical airlift capabilities with the Air Force’s need for additional strategic capability. With the new requirements, the AMST was renamed the C-X.

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[129] Battershell, op. cit.

The C-X met with delays from Congress, as the new requirements were similar to the existing C-5A's mission statement. Lobbying from Lockheed resulted in Congressional funding delays. And because of previous overstatements of performance, the Air Force was not able to convince Congress that the C-X could outperform the C-5A. By 1980, Congressional funding had been obtained. But throughout the 1980s and into the 1990s, support from Congress and DoD for the C-X, now renamed the C-17, was erratic. At least seven major studies were conducted over a 12 year period to reassess the need for the C-17, causing instability in requirements and production numbers needed, with variations from 40 to 210. In 1995, after 24 years, the first C-17 was delivered at a total program cost estimated to be $7.3 billion.

2. Challenges

a. Integration Issues with Mature Technologies

At the outset, the goal of the C-17 program was to develop and produce a cargo plane that was technically mature, as "undue complexity or technical risk will be regarded as poor design."[130] This led to the desire to use technically mature components; however, while many of the components were mature, the manner in which they were used or integrated was new. This new integration of mostly mature technology caused the system design to be newer and riskier than planned. For example, avionics systems were designed to reduce the crew to a total of three, two pilots and a load master, which was a radical departure from previous cargo plane crew sizes: the C-5A needed seven crew members. *Immature technologies and new ways of integrating mature technologies create technical design risk.*

The change in mission need also contributed to applying proven technologies in new ways. For example, the STOL technologies needed to allow the C-17 to operate from austere airfields was deemed as mature, but these technologies originally had been envisioned for the AMST tactical airlift cargo plane. When these same technologies were applied to the C-17 - which had a requirement to be able to carry as much as five times the amount of cargo of the AMST - the technologies seen as mature presented several challenges. *Instability of mission needs creates different states of technology maturity as the operational context changes.*

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130 Charles Johnson II, "Acquisition of the C-17 Aircraft," Air Command and Staff College Thesis, Maxwell Air Force Base, AL, 1986.

b. Change in Requirements

Changes in requirements, e.g., payload weight, range, and loading requirements, especially once the program had entered design and production, resulted in expensive, time consuming reworks. Many of these requirements changes were the result of studies being conducted by many different sources, each analyzing the problem and drawing their own solutions based on current threat status, technology status, and political considerations. The result, when combined with concurrent design and production, was the creation of six different configurations in the first six planes produced. For logistical and maintenance reasons, the USAF required that these six configurations be modified to produce one configuration, or two at the most. *Requirements instability creates the risk of exceeding budget and schedule constraints. Concurrent design and production increases the risk of creating multiple configurations that cannot be supported or that require costly rework to fix technical problems.*

c. Use of Cutting-Edge Technology

While most of the technology used in the C-17 was relatively mature, some cutting-edge technology was used: the aircraft used new materials to reduce airframe weight so as to meet both the requirements of operating out of austere airfields and carrying cargos five times greater than originally required with the AMST. While holding promise, the Aluminum-Lithium alloy used eventually resulted in structural defects on the first several C-17s produced, all of which had to be reworked after production was complete.

d. Managerial and Organizational Restructuring

During the course of the C-17 development, several program and management restructurings occurred at DoD and McDonald-Douglas. At DoD, organizational restructurings often involved a re-examination of program need, resulting in new or modified requirements. From 1981 through program completion in 1995, the C-17 had seven major restructurings within DoD alone. At MacDonald-Douglas in the same time period, multiple restructurings and three major labor turnovers occurred. Some restructurings were internally driven while others were DoD mandated. Some of the labor fluctuations involved were caused by instability in Congressional funding, causing McDonald-Douglas to shift experienced personnel off the C-17 program. *Continuous organizational restructuring increases the risk of creating a discontinuity in management knowledge, personnel experience, and mission goals.*

e. Lack of Organizational Integration

Several technical problems arose that could be traced back to a lack of organizational integration. For example, in the avionics subsystem, MacDonald-Douglas did not require that subcontractors use any particular programming languages. As a result, the C-17 "evolved with software in almost every computer language known at the time."[131] Within DoD, direct conflict between organizations also helped cause instability in Congressional funding. While the Mobility Air Command was trying to sell Congress on the C-X concept, the USAF Systems Command was still trying to push through funding for the original AMST.

f. Difficulty in DoD-Contractor Relationship

The constant changes in the requirements and production orders also affected the working relationship between DoD and MacDonald-Douglas. Constant shifts in production numbers, mostly downward, resulted in a strained relationship that led to MacDonald-Douglas slowing C-17 production and threatening lawsuits.

B. BOEING 777

1. Technical Description and History

The Boeing 777 was envisioned as a long-distance, twin-engine plane, inexpensive in design and production; a major driver in its development was the desire to send a flawless design to the production floor. The 777 was the first entirely new Boeing design in almost a decade and explicitly had as an objective the integration of customers' needs into the design and requirement process to better meet their needs.

The 777 embodies several notable technical characteristics, including an advanced avionics suite, fly-by-wire, advanced liquid crystal flat panel displays, and a two-way digital data bus. It also has a new, more aerodynamically efficient airfoil wing and makes use of several new composite materials. Perhaps most significant is that it is designed entirely electronically with the use of computer-aided design and manufacturing tools (CAD/CAM), which was to help envision the three-dimensional layout of the plane before production started, reducing the need for expensive mockups and equipment integration changes during production. In 1995, the first aircraft was delivered and in service with United Airlines, with a total program cost of almost $6.0 billion.

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131 Battershell, op. cit.

2. Challenges

At the outset, it was determined to not use any cutting-edge technology in the aircraft, in an effort to keep cost down. While the design did incorporate several technical firsts for Boeing, such as the use of fly-by-wire, these were all felt to be technically mature enough to not cause any major problems. The only major technical challenge that was predicted, and encountered, was difficulty in making the transition to a pure computer-designed plane. This reliance on CAD/CAM capabilities to replace mock-ups and eliminate changes resulted in technical challenges and cultural challenges: the Boeing development teams had to make the equipment work and learn how to effectively use it. *Use of mature technology reduces programmatic risks.*

Because of the technical difficulties that were predicted with the use of CAD/CAM, Boeing program management sought and gained approval for extra time and resources. In the end, over a year of additional time was added onto the traditional Boeing development and production cycles to account for the learning curves associated with the CAD/CAM equipment. Upper management was informed of this need prior to program initiation and approved both the time and resources required. *Early identification of high-risk aspects in the program and the dedication of resources and continuous management support are essential for the increasing probability of meeting budget and schedule constraints.*

During the course of the program, multiple changes occurred in both program and corporate management. At the program manager level, three different PMs held tenure during the five-year design and production cycle. Corporate management also had a major change during this time, with the initial 777 program manager becoming President of Boeing.

But even with these changes, there was constancy within the program. Managers from within were promoted to become new program managers, which helped reduce the learning curve. Corporate management's support also remained unwavering, even with the changes. This continual support did not cause the 777 program to have to resell itself to corporate management each time, and suffer a loss of funding or resources. *Constant program support during changes in program and corporate management is essential to reduce programmatic risks such as redefining mission needs and funding instability. Promotion of program managers with direct prior experience in the program reduces risk of discontinuity in program.*

C. GENERAL DIFFERENCES BETWEEN COMMERCIAL AND DOD PROGRAMS AND INSTITUTIONS

Expanding on the case study comparison of the C-17 and the Boeing 777, differences in the system engineering-related aspects of how the DoD and commercial organizations pursue acquisition can be identified, differences that can be seen in design, systems engineering and management processes, implementation of those processes, and the institutional environment. These differences are identified below with a corresponding discussion of how they can evolve into risk factors that affect program performance in the areas of technical performance, budget, and scheduling. Additional case study examples from both DoD and industry are used throughout this section to help illustrate these points.

1. Design Emphasis and Trade Offs in Setting Requirements

One of the key differences between DoD systems and commercial platforms is the importance placed on various aspects of the design. Commercial designs emphasize affordability and low risk; DoD systems historically have emphasized high performance. This different set of priorities greatly influences many factors throughout design and production. The first appears in setting requirements. Commercial programs often refuse to include requirements that will force the use of immature and risky components to achieve mission needs. Commercial firms are more likely to delay including cutting-edge technology into programs until the new component has been more fully developed;[132] a more incremental approach is preferred. And when requirements generated from customers appear to require the use of new technology or designs to achieve needed performance, commercial firms are more likely to work with customers to change the requirements, often through trade-offs

In contrast, DoD programs often emphasize performance so high that cutting-edge technology is needed to get there. Requirements usually are generated in long-term trade studies from the user community and are passed down to developers. Often, there is neither the ability nor the desire to perform trade-offs later in the process when the budgetary and scheduling impacts are better understood. While select sub-system complexity and performance may be comparable between military and commercial

[132] GAO-01-288, op. cit.

programs, total system complexity and performance for military systems is often much greater than for commercial systems.[133]

Examples from the commercial world that follow these principles of setting low-risk requirements span a range of industries. The Caterpillar 797 heavy mining truck is an example of how requirements were crafted to delay the use of immature technology and design. In the initial set of market surveys, Caterpillar determined that customers would want a new, larger mining truck that would be capable of working with the new, larger shoveling loads that were being used in mining operations. To attract customers, Caterpillar wanted a design that would have lower operating costs. To get there, a single engine was proposed to power the truck; however, the size of the engine needed to power such a large truck entailed the design of an entirely new engine. It was determined that while the engine could be developed, it could not be reliably developed in the 18 months that had been allotted for design and production. Given the choice of meeting the original 18 month schedule or letting the schedule potentially slip to include the higher-performing single engine, Caterpillar management chose to stay with the original schedule. In place of the single engine, a dual engine design was used instead, even though it would have a lower performance than the single engine design.[134]

The Bombardier BRJ-X regional jet is an example of working with customers to understand and trade-off requirements. In developing the new regional jet, Bombardier worked with customers to develop requirements to help ensure future sales. The requirements generated from potential customers called for cruising speeds to reach 0.81 Mach. However, after studying these requirements, Bombardier realized that to achieve 0.81 Mach, a new engine design would be necessary, and development of the new engine likely would exceed the 36 month schedule allocated for design and production. If customers would accept a speed of 0.78 Mach, off-the-shelf technology could be used. After meeting with customers to discuss the trade-offs, requirements were changed and the 0.78 Mach engine was selected.[135]

In comparison, DoD often generates requirements that require cutting-edge technology and is unwilling to make trade-offs between performance, budget, and schedule. The Army's Comanche helicopter program illustrates this. Initially the Comanche was to be a reconnaissance helicopter, with operations and maintenance costs

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133 Tyson, Hiller, Hunter, Nelson and Woolsey, op. cit.

134 GAO-01-288, op. cit.

135 Ibid.

50% lower than the Vietnam-era Cobra and Kiowa Warrior helicopters it was replacing, with performance as high as could be obtained within low unit cost limits. As the performance requirements evolved, the Comanche's performance was such to allow it to perform an attack role while still being lightweight, stealthy, highly maneuverable, and all weather. Fulfilling this set of requirements within budget and schedule limits was judged as highly risky by the developer, but trade-offs between performance, budget, and schedule were not allowed. When budget and schedule began to slip, the Army elected to keep performance requirements intact and to allow the slips. The result is that, as of 2001, the Comanche program was estimated to take $8.3 billion and 18 years to complete, as opposed to the original $3.6 billion and eight years initially allotted. This compares to the Bombardier regional jet which, in 2001, was on target for both cost and schedule and the Caterpillar mining truck, which met its 18 month development time and was only 5% over its initial budget.[136]

The reasoning behind the differences in technical requirements between DoD and industry are based largely on institutional, cultural, and mission differences. In the commercial world, new designs often have as their only goal making a profit for the company. To do this under competitive conditions, commercial firms want to ensure that their designs meet customer needs and can be developed as quickly as possible for as low a price as possible. To do this, commercial designs are very risk-adverse, preferring proven technologies and designs that have a high degree of probability of working within the budget and schedule estimates. Often, as in the case of the Boeing 777, the investment in the new design will bet the company's future on the success of the design. The survival pressures from competition forces low-risk designs and for companies to work with customers in meeting their needs. The result is a strong emphasis on schedule and budget over technical performance when making trade-offs. New technology is developed and matured off-line and included in later design efforts.

In DoD, programs also face competitive pressures for their survival, but the pressures are different and the effect this has on mission requirements differs from that of the commercial world.[137] The first pressures that DoD programs face are cost/benefit hurdles. When crafting new requirements, the proposed design must show that it is substantially different than other competing designs and from existing system

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136 Ibid.

137 Heberling, Michael and Mary Kinsella, "Complicating Issues in Adopting Commercial Contracting Practices in Defense Acquisition," Defense Acquisition University, January 1998.

capabilities. This is most effectively done by utilizing new, cutting-edge technologies.[138] Also, as there are many competing designs all vying for limited resources, a necessary step in the process is to form a coalition, all of whom will support the proposed design. To do this, the requirements have to be crafted to appeal to many different groups, each with their own objectives. This forces compromises to the design, usually in the form of additional missions and capabilities.[139] Since as many as 30 different organizations are involved in these compromises,[140] once made, it is difficult to make later trade-offs and still maintain the coalition. Recent examples of this include the Comanche helicopter expanding its mission from reconnaissance to include attack, the F/A-22 to include ground attack in its original air superiority mission, and the C-17 to include carrying both tactical and strategic cargos. The result of these pressures drives systems to promise high performance.

Cost and schedule estimates also have to be on the optimistic side;[141] both estimates cover the initial requirements, months before a complete systems engineering analysis has been performed.[142] Later slips in budget and schedule historically have been met with additional funding, after considerable resources have already been expended; thus, there is seldom a need or a desire to trade performance for budget or schedule reductions. This is reinforced by the infrequency of major system programs: major programs only present themselves every few decades, so there is a desire to get all the performance that is possible out of a design. This is evidenced by the Comanche helicopter replacing Vietnam-era helicopters.

Another key difference between commercial and DoD programs in crafting requirements is in the environment that each design is expected to operate within. In an effort to control costs, commercial programs often strive to narrow the performance margin as much as possible. Crafting requirements for mass producing a product that is designed to operate within relatively strict environmental and operational parameters is much easier than when the product has to be robust enough to handle a wider range of environments and operations. DoD requirements are crafted to produce designs that can operate over a greater performance range, as the exact environment and operations will

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[138] GAO/NSIAD-98-56, op. cit.

[139] Wilson, James Q., "Bureaucracy, Basic Book," 1989.

[140] GAO-01-288, op. cit.

[141] GAO/NSIAD-98-56, op. cit.

[142] Schinasi, Katherine, et al. "Applying Best Practices to Weapon Systems Takes the Right Environment," Program Manager, February 2000.

largely depend on the mission. This more stringent set of requirements often precludes the use of commercial off-the-shelf products (COTS), as these products are not designed to produce the kinds of performance that DoD programs require. Commercial products use a greater percentage of cheaper COTS products than do DoD programs.

The result of all these pressures is that, while the commercial world emphasizes budget and schedule over performance, DoD programs do exactly the opposite. Even programs that have, as their initial goal, low unit, operational, and maintenance costs end up having high performance requirements.

The lack of flexibility and desire to make trade-offs between high performance requirements and budget and schedule constraints is a risk factor affecting DoD programs to a greater extent than commercial programs.

The need for DoD programs to stand out through the use of cutting-edge technology and optimistic budget and schedule estimates is a risk factor for completing the program within budget and schedule constraints.

2. Requirements Fluctuation

Changing requirements while in the design or production phases of a program can result in budget and schedule slips. Commercial programs often manage to set requirements early in the program and then adjust them throughout the life of the program. When requirements change during the course of the program, requirement management and configuration control in commercial programs continues to be risk-adverse. For example, in the Boeing 777, an initial requirement was the inclusion of folding wing tips to allow the plane to fit into its hangers. To accommodate this early requirement, Boeing included an additional bulkhead in the wing. During the course of the program, the customer’s need for folding wingtips changed and the requirement to include them was removed. As Boeing had included the bulkhead only to accommodate the folding wingtip design, the company could have changed the design and removed the bulkheads. However, as analysis showed that multiple other subsystems would be impacted by such a decision, they elected to avoid the additional risk associated with removing the bulkheads and maintain their budget and schedule.

DoD programs often experience multiple and major requirement changes, ranging from shifts in capability to expansion of the original mission. Performance requirements often are set early by the user community, before a complete system engineering analysis is conducted.[143] When developers complete the systems analysis, requirements may be found to be infeasible or risky within budget and schedule constraints. As an example, the Army's Crusader artillery vehicle was to have an improved firing range over existing artillery. To achieve the firing range requirements, a liquid propellant was needed; based on this, additional operational and logistic requirements for the Crusader and its re-supply vehicle were crafted. Two years of systems engineering performed by the developer determined that using the required liquid propellant was infeasible within the cost and budget constraints. An estimated $500 million was needed to develop the liquid propellant, so the requirements were changed, allowing a solid propellant to be used. However, the absence of systems engineering at the outset caused a ripple effect on other requirements in the Crusader and its supply vehicle.[144]

The Comanche is an example of additional mission capabilities being added to a program. Originally conceived of as a reconnaissance helicopter, an attack function was added later. The attack role increased the weight of the helicopter, because additional armaments had to be added. This conflicted with an initial goal of providing a low-weight helicopter. Unwilling to make performance trade-offs in the new attack role and the original reconnaissance role forced the Comanche program to pass over mature technologies that could have been used for the avionics and tracking system. Instead, new lighter weight and higher risk systems had to be developed to satisfy the requirements.[145]

Program length is one of the key reasons behind the difference in requirement fluctuation between DoD and the commercial world. DoD programs run 18 years on average; commercial programs, usually between 18 months and five years.[146] The Boeing 777 took five years;[147] the Bombardier regional jet was a 36-month program, and the Caterpillar mining truck was initiated and delivered in 18 months.[148] The longer time spans that DoD programs operate under are a cause and effect of requirements changes. More time allows for more requirements change, while more requirements change increases program length. The change in program requirements is often the result of re-

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143 GAO Report, "Defense Acquisitions: DoD Faces Challenges in Implementing Best Practices," General Accounting Report, Washington DC, GAO-02-469T, February 2002.

144 GAO-01-288, op. cit.

145 Ibid.

146 Mounts, William E., "Commercial Acquisition and Practices in the Department of Defense," Second Annual Federal Procurement Institute, Vol. 1, Tab 16, American Bar Association: Section of Public Contract Law, 1996.

147 Battershell, op. cit.

148 GAO-01-288, op. cit.

organizations within the program and DoD. On average, management tenure in the program and within DoD is only around 18 months.[149] It is not uncommon for new management to be the result of an organizational change within DoD, where new management also brings new priorities. Shifts in organizational goals, management, the threat environment, the support of the original coalition, or political goals all act to produce organizational and management changes that affect program requirements. Program and corporate management changes in the commercial world often do not affect program requirements.

The lack of a set of fixed and feasible program requirements throughout the program life-cycle is a risk factor that affects DoD programs to a greater extent than it affects commercial programs.

The lack of early systems engineering studies is a risk factor for being able to produce a set of performance requirements that are feasible within budget and scheduling constraints.

The volatility in management and especially in management support are risk factors that affect DoD programs to a greater extent than commercial programs.

3. Institutional Constraints and Differences in Defining Goals

A key difference between commercial and government institutions is in defining goals. Commercial organizations have a much more straightforward set of goals than do government agencies, including DoD. As a general rule, businesses have profit as their primary goal. When a company makes a decision on whether to start a program, it must determine whether the program has a good probability of adding to the company's profit margin. The current and future state of the market is analyzed and requirements are designed to minimize the chance that the program will negatively affect profits. This is especially important when companies pursue large projects where they are betting the entire company's future on success or failure. Such pressure helps maintain focus on lowering risk and crafting performance requirements that are feasible within budget and schedule constraints.

As a government agency, the goals that DoD must pursue are not as straightforward as in the commercial world. DoD has as its primary mission providing for the national defense. However, how best to provide this goal is not always clear.

[149] Ibid.

Translating this goal into program requirements is often difficult and a matter of opinion. Added to this difficulty are additional government-wide goals. While commercial projects ultimately are judged on whether they help or hurt the company's bottom line, government programs are judged on a much more complex set of criteria. Government agencies often are instructed to administer their programs to follow a broad set of legislative mandates and accomplish various policy goals. These mandates can include such things as favoring domestic companies over foreign companies, favoring small companies over large ones, ensuring that a specific percentage of business goes to companies owned by historically disadvantaged peoples, ensuring fairness in awarding contracts, protecting the environment, rehabilitating prisoners, demonstrating that public monies are being used efficiently and equitably, providing accountability, and a host of other social goals. Each social goal has been crafted to try to spend government resources in a way that meets the broad agenda of the electorate. For DoD programs, this includes providing for the national defense, and doing so in a manner that meets other government social goals as well. While the individual merits of each of these social goals can be debated, taken in whole they can severely constrain the choices available within a program.[150,151]

In addition to numerous social goals, DoD programs also must conform to several agency-specific policies and directives that often were created in response to circumstances that had previously caused problems. To satisfy department, Congressional, administration, and media critics, new policies designed to deal with these problems or guard against them have been enacted. Again, while many of these policies are individually beneficial, when take in whole, they pose severe constraints on program flexibility.

Additionally, DoD, as a government agency, is constrained by long-standing policies for standard operating procedures. For example, unlike the commercial industry, DoD civilians and military personnel have built-in career protections; also, key decision makers change frequently.[152] This often limits flexibility in selecting the appropriate set of personnel and providing program stability.

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[150] Wilson, op. cit.

[151] Heberling and Kinsella, op. cit.

[152] Tyson, Hiller, Hunter, Nelson and Woolsey, op. cit.

To ensure that a program is approved and maintains support, political goals are another driving factor. Keeping lawmakers and their constituents happy further constrains programs.

In all, these social, agency, and political goals act as another set of requirements that the program must conform to. However, while requirements such as firing range or flight speed are written down and easily measured, these other goals are implicit and much more volatile. Even though these other "requirements" do not appear on paper, they are as important if not more important to the survival of the program, and a considerable amount of resources is spent in their pursuit. For example, it is estimated that program managers spend an estimated 30 to 50 percent of their time advocating for their program within DoD and Congress, instead of managing the program.

Trying to conform to various policies and avoid the consequences of not doing so also produces a very risk-adverse culture within DoD. Incentives are crafted to reward conformity with regulation rather than program result.[153]

Often, even when it appears that program-level goals in technical performance, budget, and schedule are being met, these other goals can actively work against a program. For example, the Navy's Arsenal Ship was a pilot program in acquisition reform. It was to produce a ship that had a revolutionary performance capability in firepower and reduced crew usage, while delivering this performance on a relatively low budget and tight schedule. While it appeared that the program was meeting its objectives, it faced severe Congressional opposition, in part because it threatened to undermine the mission need of existing weapons systems, such as the B-2 Bomber. To protect constituents in states that played a large part in manufacturing and basing the bombers from a loss in jobs, Senators from those states actively led a successful fight to cancel the Arsenal Ship program. In this case, political goals were more important than the successful achievement of program requirements.[154]

The presence of so many "extra" requirements makes it much more difficult to satisfy the performance, budgetary, and scheduling requirements that programs are judged against. These extra requirements are not present in commercial programs. Even more importantly, when trying to understand the failure of government programs to offer

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153 Heberling and Kinsella, op. cit.

154 Leonard, Drezner and Sommer, op. cit.

the same type of budgetary and scheduling discipline as occurs in commercial programs, these extra requirements are not counted in the overall equation.

It is important to understand the institutional differences when adapting commercial best practices for use in a government setting.[155] In several GAO reports, commercial best practices are suggested as potential solutions for DoD acquisition problems. In some of these reports, the GAO recognizes the need for change in the DoD organizational environment to take place before commercial best practices can be effectively adopted; however, it is rarely mentioned that there is a fundamental difference in commercial and government institutions that goes beyond organizational and cultural differences. The presence of multiple goals is a major source of these differences and can cause difficulties in the adoption of commercial best practices to DoD.

The presence of multiple goals, such as social, political, and agency, is a risk factor that affects DoD programs to a greater extent than it affects commercial programs.

Adopting commercial best practices for DoD programs without adequately understanding institutional differences is a risk factor in crafting best practices that are workable in the DoD environment.

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155 Tyson, Karen, Hiller, Hunter, Nelson and Woolsey, op. cit.

VIII. COMPARISON OF DOD PROGRAMS

A great many reforms have been made to the acquisition and systems engineering and program management processes over the last several decades; many have been implemented in a number of pilot system acquisition programs to demonstrate their value. The outcomes of these programs have met with varying degrees of success. It is important to understand whether that success (or failure) is because of the reform, or because of something else that is intrinsic to the program or to the implementation of the new processes.

This chapter compares reforms that were applied to two programs; the Joint Direct Attack Munition (JDAM) and the F/A-22 Raptor. These programs are similar in that both were initiated as programs that would demonstrate reform effectiveness. However, program success is varied.

A. JDAM TECHNICAL AND PROGRAMMATIC DESCRIPTION

The JDAM is a strap-on guidance kit that turns free-fall munitions into smart munitions, i.e., dumb bombs into smart bombs. The strap-on kit comprises three major subsystems: an inertial guidance system that interfaces with the Global Positioning System (GPS) to update current JDAM position; moving tail fins that allow changes in course; and side strips that increase lift, giving the JDAM additional time to enact cross-range course corrections. The JDAM kit can be used with 500, 1000, and 2000 pound munitions.[156]

JDAM was born of a need (in 1991, shortly after Desert Storm) to overcome many of the problems encountered with other smart munitions, including high unit costs, poor performance in adverse weather, and a narrow range of aircraft that could deploy the munitions. Separate but similar USAF and USN programs were combined into the JDAM program late in 1991.[157]

Initially, the JDAM Systems Program Office (SPO) was aligned with the traditional DoD organization and processes. Initial requirements and systems analysis

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[156] Thompson, Loren, “What Works? VIII. The Joint Direct Attack Munition: Making Acquisition Reforms a Reality,” Lexington Institute Report, Arlington, VA, November, 1999.

[157] Myers, Dominique, “Acquisition Reform – Inside the Silver Bullet: A Comparative Analysis – JDAM versus F-22,” Acquisition Review Quarterly, Fall 2002.

determined that the program's technical difficulty was relatively low and a cost cap of $68,000 was set for each kit (later reduced to a unit cost of $40,000). While the technical design was not challenging, meeting the new cost cap, which was given high priority, was deemed a major challenge. The SPO determined that a reorganization of the JDAM program along more commercial lines was the only way to do this.[158]

Coincidentally, as part of new acquisition reform legislation, the Federal Acquisition Streamlining Act (FASA) of 1994 called for the creation of a new set of reform pilot programs. With the Defense Acquisition Pilot Programs (DAPP), several programs were newly christened as programs to demonstrate reforms, including JDAM.[159,160] The purpose of the DAPP was to demonstrate use of more commercial-like practices in the acquisition process.[161]

Just prior to the re-organization in the JDAM program, the Engineering, Manufacturing and Development Phase I (EMD-I) contracts were awarded to Martin Marietta (later part of Lockheed Martin) and McDonald Douglas. The purpose of EMD-I was to focus on reducing manufacturing risk and affordability. At the conclusion of EMD-I, the two companies would be downselected to a single company. The criteria for the down-selection would be based on affordability and contractor performance first; then by technical performance.[162]

The competition between the firms was useful in helping bring down the cost estimates of the JDAM unit, as the new cost goal was $20,000 per unit. As the JDAM program was taking place during severe drawdowns in the defense industry, getting the award was seen as vital for both firms. This helped maintain focus on creating a low-cost design.[163]

In managing the EMD-I phase, the JDAM SPO took a non-traditional approach to interacting with the contractors. Instead of maintaining an arms-length, oversight approach, a more partnered approach was taken. The SPO office was divided into sub-teams that were assigned to each contractor, with the goal of providing aid. The focus was on implementing commercial best practices, such as using a limited number of

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158 Ibid.

159 Ibid.

160 Thompson, op. cit.

161 Ingols, Cynthia and Lisa Brem, "Implementing Acquisition Reform: A Case Study on Joint Direct Attack Munitions," Defense Systems Management College, July 1998.

162 Myers, op. cit.

163 Ingols and Brem, op. cit.

performance-based requirements, emphasizing performance/price trade-offs, and relying on the use of commercial products whenever possible, among others.[164]

At the end of EMD-I, McDonald Douglas was awarded the contract. With the absence of competition, a more conventional government–industry relationship developed, but there were still considerable changes in the way the program was run. Integrated Product Teams (IPTs) were used to cope with the new, tighter cost caps: the goal was to reduce the possibility of creating a design that met the performance requirements but were too difficult to manufacture or maintain for the cost goal.[165]

To try and gain oversight of the contracts without relying on regulations, a series of incentives and disincentives were designed into the program. If the program was proceeding well, contractors had a broad degree of authority and autonomy: exemption from submitting cost data to justify technical or price proposals; complete control over the technical configuration of the system as long as it continued to meet performance requirements; no obligation to pass savings onto the government; guaranteed sole source for production, maintenance, and repair contracts; and the award of an additional bonus if technical performance exceeded requirements. Disincentives were essentially the opposite of these incentives.[166]

The results shown by the program were impressive. On the programmatic side, the development schedule was shortened by 33% of estimate, and a 42% and a 50% reduction were achieved in the development and production costs, respectively.[167] On the performance side, technical performance was improved by obtaining a 95% reliability rate and by increasing target accuracy from the required 13 meters to 9.6 meters.[168]

The success of the JDAM program can be largely attributed to working outside the standard DoD acquisition system. As part of the DAPP, the JDAM program was allowed many waivers; over its course, it had 28 waivers from Federal Acquisition Regulations, 27 waivers to Defense Federal Acquisition Regulation Supplements, and almost a complete waiver from the DoD 5000 series. Additionally, the JDAM SPO had the authority to renegotiate in EMD to make it more flexible and commercial; was able to streamline milestone review processes; and had flexibility with the "color of money" –

164 Myers, op. cit.
165 Ibid.
166 Thompson, op. cit.
167 Myers, op. cit.
168 Thompson, op. cit.

savings obtained during EMD were applied to increase production, which helped reduce unit costs. Throughout the program, JDAM also received continued support from the DoD, the USAF, and the USN.[169]

The JDAM contractors also were vested with authority, which they used. For example, a contractor design called for the use of injection-molded plastic fins. The Navy objected to the use of the plastic-based material (they had a prior negative experience with a component made of the same base material, although it was laminated rather than injection molded). The Navy advocated for a metal fin instead, but it was twice as expensive as the plastic fin, and because of tight cost controls, the contractor did not want to use it. To assuage the Navy, the contractor demonstrated the adequacy of the plastic fin but the Navy persisted in wanting a design changes. With the configuration control that had been granted, the contractor refused and proceeded with the original plastic fin design.[170]

B. F/A-22 TECHNICAL AND PROGRAMMATIC DESCRIPTION

The F/A-22 Raptor ATF was designed to provide the next-generation in air superiority while also providing ground-attack capabilities. The F/A-22 contains several cutting-edge technologies, such as low observability, integrated avionics to improve pilot awareness, a highly maneuverable airframe, and an engine capable of sustained supersonic flight without the use of afterburners. The requirements for the F/A-22 also stress creating a design with improved reliability, maintainability, and supportability in an effort to decrease total lifecycle costs.

The F/A-22 program entered the acquisition process in the early 1980s. During that time, a growing public awareness of defense system overruns garnered a lot of publicity and culminated in a series of studies and reports suggesting reforms, most notably from the Packard Commission. Almost from the outset, the F/A-22 program was to implement a number of reforms recommended by the Packard Commission, which dealt with implementing commercial best practices in defense programs.

Initially, the F/A-22 was run as a competitive program in the Concept and Technology Development stages between Lockheed and Grumman. Similar to the JDAM program, the F/A-22 SPO was divided into sub-groups that worked with the contractors to help implement more performance-based specifications. To facilitate communication

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169 Myers, op. cit.

170 Ingols and Brem, op. cit.

and cooperation with the contractors in implementing reforms and obtaining desired performance within cost constraints, the SPO was reorganized to facilitate the use of IPTs. Another innovative aspect was sharing R&D costs between government and the contractors to help keep costs down by encouraging contractor investment.

The results were good. Grumman and Lockheed both developed flight demonstrators in four years, a noticeable reduction from the eight years that it took to develop the B-2 Bomber flight demonstrator aircraft, the last stealthy aircraft developed before the F/A-22. The cost also was significantly lower, coming in at $5.9 billion, of which $3.9 billion and $2 billion were government- and contractor-financed, respectively. This compared with the $33.2 billion at a comparable stage in the B-2 program. Note also that the F/A-22 was able to make use of a considerable knowledge base dealing with design and manufacturing processes learned from the B-2 program, so an comparison in schedules and costs would not be accurate. However, it still appears that the F/A-22 program operating under new commercial reforms achieved substantial results.[171]

At the end of the Concept and Demonstration phase, the contractors were downselected, with Lockheed winning the contract. At the start of EMD, the nature of the program changed from competitive to one more aligned with the traditional acquisition framework. During the course of the EMD phase, the F/A-22 program was restructured five times, due to continuous technical problems, cost overruns, schedule slips, and funding shortfalls. The testing schedule was markedly reworked, decreasing the number of testing hours from a planned 1400 to 183.[172] Delays in fabricating the test aircraft, due to technical problems and funding shortfalls, resulted in only 4% of testing being completed by the time production contracts were awarded.[173] Increases in reporting and oversight requirements were also substantially increased.

C. DIFFERENCES BETWEEN JDAM AND F/A-22

Both the JDAM and F/A-22 program emphasized cost affordability and the use of commercial best practices, but the results obtained are very different. While the JDAM was able to exceed technical performance requirements, budget, and scheduling constraints, the F/A-22 program continues to experience technical difficulty, budget

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171 Myers, op. cit.

172 Taxpayers for Common Sense, “Taxpayer Group Commends F-22 Cuts,” July 22, 1999.

173 GAO/T-NSIAD-98-137, op. cit.

overruns, and schedule slips. The commercial best practices utilized in both programs were similar; competition was used through the EMD-I phase in the JDAM program and through Concept and Technology Development in the F/A-22 program; management and organizational techniques such as IPTs were used to increase cooperation and coordination between government and industry; and a low number of performance based requirements were used for each program. Despite these similarities, the outcomes of both programs differ.

While differences in technical skills or management capabilities could be a cause for the disparity, it seems more likely that the reason lies in the type of system program and the institutional environment. The JDAM program was relatively small compared to the F/A-22 program; less than $20,000 per system[174] compared to more than $253.5 million per system.[175] This cost difference means several things. *Larger programs have a higher probability of encountering problems than do smaller programs, due to an increased number of components, subsystems, and integration issues.*

The F/A-22 is a much larger and more complex system, which forces differences in program management. Being a smaller program, JDAM was able to sustain a competitive environment between contractors all the way through EMD-I, which the F/A-2 program could not do. Competition has repeatedly been shown to be one of the best ways to contain cost growth. However, competition also can be expensive, and the size and complexity of the F/A-22 made extensive competition infeasible. The F/A-22 program had to move to a sole-source contract much earlier than did the JDAM program, losing out on the additional benefits of competition.

Aside from the shear size difference increasing the possibility of problems arising during all phases, the mission also creates additional demands. While the JDAM was able to use almost all commercially available technologies and processes in the design,[176] this was not true with the F/A-22. Many of the F/A-22's defining characteristics - stealth, high maneuverability, increased speed and improved avionics - necessitated the use of non-commercial components and systems. *Lack of maturity in technology and manufacturing processes in a program is a risk factor that can cause budget overruns and schedule slips.*

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174 Ingols and Brem, op. cit.

175 GAO-03-476, op. cit.

176 Myers, op. cit.

A key aspect to keeping costs low was the type and amount of technology used in each design. Approximately 85% of JDAM is composed of commercially available technology, which helped reduce the development costs of new, program-specific technologies. Related, many of the manufacturing processes needed for the JDAM were also commercial dual use, meaning production costs could be spread to commercial projects as well.[177] *The use of commercial best practices, such as competition, commercial off-the-shelf parts, and commercial manufacturing processes, are easier to implement and sustain in smaller programs, due to budget constraints and system design needs.*

The number of units needed for each system played a significant role in final cost. With total planned procurement of over 40,000 JDAM kits, the per unit cost was substantially lower than the 278 F/A-22s planned for procurement, just due to economies of scale.

Similarly, multi-year contracts can be used as a means to limit risk to contractors, facilitating increased investment of funds from private industry. It has been shown that awarding multi-year contracts incentivizes industry to make greater fixed-cost investments than would be possible with year-to-year contracts. The result is lower total program costs. Previous studies have found that programs with multi-year contracts that run longer than three years had an average cost growth of 24%, compared to a 69% growth for programs with year-to-year contracts.[178] *Small production lots and short-term contracts force system unit costs higher, lose economies of scale, and provide a disincentive for commercial firms to invest their own money in a limited production line.*

When the programs employed competition to keep cost growth in check, both enjoyed success. Once the competition ended, both programs suffered setback, though the F/A-22 did so to a greater extent. One reason for this was the continued use of innovative incentives and the high degree of autonomy and authority vested in the JDAM SPO. This authority was used to remove many of the traditional government regulations and oversight requirements from the contractors. While this worked for the JDAM program, it is questionable if something similar could be applied to a program of the size of the F/A-22. As the Air Force's largest acquisition program, it is unlikely that even under perfect conditions could the F/A-22 avoid continuous oversight. By exempting contractors and

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177 Ibid.

178 Tyson, Karen, David Hunter and Daria Rendon, "Acquisition Initiatives in the New Environment: Multi-Year Procurement Update," IDA Document D-2185, Institute for Defense Analyses, Alexandria, VA, December 1998.

the JDAM SPO from many regulations, OSD, the Services, and Congress willingly gave up substantial control. It is unlikely that the same degree of autonomy would be granted to such a large program like the F/A-22. Furthermore, being a smaller and simpler system, the JDAM program had this level of control for only about four years. The time necessary to complete a larger program of course would be much longer. *Larger programs have more oversight requirements, more publicity, and a lower degree of autonomy afforded to program management. Meeting oversight requirements and having to constantly defend the program take resources away from program management activities and increase the risk that funding levels and performance requirements will be changed.*

Tied to the time required for completion is the level of support and funding received for both programs. JDAM enjoyed continual support and funding from OSD, the USAF, and the USN, so problems such as reorganizations to account for funding shortfalls and requirements changes did not occur.[179] This is in stark contrast to the F/A-22 program. During the close-to 20 years that the F/A-22 program has been in existence, it has repeatedly experienced shifts in support and funding, which has caused a number of reorganizations and requirement changes. *Larger programs take longer to complete than smaller programs, making it more difficult to maintain consistent levels of management and funding support over the longer time period.*

From these two programs, we see that the adoption of commercial best practices are not uniformly effective. Program characteristics, such as size, affect program success to a degree at least equal to the process used. *The presence of specific program traits or design characteristics, such as size, is a risk factor that affects the probability of program success.*

D. RISK FACTOR INTERACTION

Risk factor interaction played a large role in each program's ability to meet performance, budget, and scheduling goals. The F/A-22 is a large and complex system, using cutting-edge technology, all of which are risk factors. Because the F/A-22 was such a large acquisition program, this introduced additional risk factors, such as increased oversight requirements and the potential for funding instability. This in turn produced additional interaction with systems engineering and program management-related risk

179 Myers, op. cit.

factors. For example, the F/A-22 SPO had much less autonomy than did the JDAM SPO in implementing commercial best practices and managing the program.

Systems engineering and program management processes, like the use of performance requirements and integrated product teams, do not produce consistent results in all programs. It appears that a uniform set of processes is not what is needed - the ability to adopt or effectively implement process reforms depends to a great extent on attributes of the program itself and the institutional environment. Rather, a more tailored set of processes are needed for different types of programs, or even individual programs, which take into account differences in the program and institutional reaction to the program.

IX. REFORM STRATEGIES

A. TRADITIONAL REFORMS

From our study, it appears that a substantial number of risk factors affecting program success are owing to factors that may not be addressable via traditional focused process reforms, i.e., reforms that are aimed only at changing a specific process without taking into account the larger acquisition environment have a lower probability of meeting with success. Institutional issues related to organizational structure, organizational behavior, culture and norms, incentives, goals, and pressures affecting personnel and programs should be acknowledged when crafting reforms.

Additionally, as major weapons programs run for an average of 18 years, the acquisition environment is dynamic. Ideally, reforms should take into account this type of dynamic environment as well. Currently, DoD acquisition programs have begun to move toward an open system philosophy that is designed to allow systems to adapt to and incorporate changes in the technological environment.

B. ALTERNATIVE REFORM STRATEGIES

One possible set of reform strategies would be to design systems to adapt to changes in the acquisition as well as the technical environment. The idea behind the flexible system design would be to understand potential changes in the acquisition environment that commonly affect systems negatively, such as budget shortfalls, and prepare for these possibilities early, during requirement definition. The goal would be the design of a system that can better respond to institutional changes. An example is offered below, which illustrates how the design of a constellation of satellites could be modified when anticipating future budget shortfalls. (More on this example can be found in Weigel.[180])

During the design of a satellite constellation, a few of the many parameters under consideration include the number of satellites, orbital parameters, and constellation cost. None of these parameters is independent from one another and changes in one will affect the others; the decision to add or subtract a satellite from the constellation, for example,

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180 Weigel, Annalisa, "Bringing Policy into Space System Conceptual Design: Qualitative and Quantitative Methods," Massachusetts Institute of Technology PhD Dissertation, 2002.

will affect price and will change the orbital parameters needed to provide certain coverage. Some of these parameters can be changed midway through the acquisition process, such as number of satellites; others cannot be changed so easily, such as drastic changes in orbital parameters. For needed coverage, an optimal number of satellites and orbital parameters can be found, with an associated price. Conversely, a maximum price can be set, from which satellite numbers and orbital parameters can then be derived.

In either eventuality, a great many combinations of satellites, orbital parameters, and prices can be created, resulting in different constellation designs. Some will provide better performance for a given cost than others. Traditional design in the acquisition process attempts to maximize performance for a given budget. Unfortunately, as with many optimization exercises, changes in the assumptions can knock a system off the optimal point. In the case of the constellation, budget shortfalls midway through the acquisition process could result in funding only being available for a fraction of the satellites, instead of all of them. The loss of even a few satellites often can severely affect constellation performance, especially when performance has been optimized. The result may necessitate either a redesign of the satellites or the acceptance of substantial performance degradation of the constellation.

If, however, a potential instability to funding had been anticipated as being a high probability, a different set of design decisions could have been made. From the complete space of constellations that could have been designed, it is possible to find those whose performance will only slightly change given a change to environmental parameters, such as budget shortfalls. While the performance may not be quite as high as if no budgetary change had occurred, the constellation performance does not degrade as quickly as it does under a loss of funding. The design is not flexible enough to adapt to changes in the larger acquisition environment without requiring a drastic design change to minimize performance degradation.

In other words, there is a choice between two types of designs. The traditional choice is the optimal design that maximizes performance for estimated resources, but results in substantial performance loss when resources are changed. The alternative choice is a constellation design which, under initial conditions, gives a lower performance, but whose performance suffers much less with a drop in resources than does the optimal constellation design. This results in a design that adapts to changes in the acquisition environment, which in this example was represented as budget shortfalls.

This type of flexibility takes into account the larger acquisition environment and the dynamic nature of the environment when designing a system. Systems engineering studies of a larger scope would be needed to understand this interaction between the technical performance of the system and the larger acquisition environment. The systems engineering process could be reformed to explicitly account for the acquisition environment when appropriate, and managers could be trained to think about design decisions in a new way.

Added flexibility to allow systems to adapt to the acquisition environment may not be appropriate for all systems. However, this is just one example of alternative processes that could be used to help reform the acquisition, systems engineering, and program management processes.

Other alternative reforms include changing the nature of the relationship between the defense community and private industry, and the increased use of dual-use technology. Commercial-military integration has been forwarded as a potential method for lowering program costs by designing military systems that increase the content of commercial products and processes, with the goal of achieving prices comparable to those found in the commercial sector. Dual-use technologies are used in a similar manner, to increase the commonality between military and commercial systems, effectively lowering military system costs by leveraging commercial investment by sharing the development and production costs.[181] The challenge in both strategies is finding the proper mix of military and commercial integration and commonality.

Table IX-1 summarizes the reforms.

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[181] White, Richard and An-Jen Tai, "The Economics of Commercial – Military Integration and Dual Use Technology Investments", IDA Paper P-2995, Institute for Defense Analyses, Alexandria, VA, June 1995.

Table IX-1. Reform Space Summary

Types of Reform	Areas for Reform			
	Category I: Design Risk Factors	Category II: Systems Engineering and Program Management Process Risk Factors	Category III: Systems Engineering and Program Management Implementation Risk Factors	Category IV: Institutional Risk Factors
Focused Reforms	Change design emphasis or philosophy	Change systems engineering or management processes	Change systems engineering or management implementation	Change institutional characteristics
Adaptation / Accommodation Reforms	Create flexible designs and processes that can adapt to changing technical or institutional requirements		Manage for flexibility in programs to identify and adapt to changing conditions	Adapt program to institutional characteristics

X. CONCLUSIONS

Our report concludes that if systems engineering and program management issues in system acquisition programs are to be adequately addressed, the “problems behind the problems” must be identified, understood, and addressed. Previous reform efforts have focused on introducing improved systems engineering and program management processes into the acquisition process; less effort has been made to ensure that these reforms “fit” into the overall acquisition environment. The result is that process reforms have met with varied success. Overall, it appears that progress has been made, although major weapons systems still experience undesirable outcomes and it is difficult to predict the success of programs based on the implemented process reforms.

In this study, we found:

- Systems engineering and program management processes and implementation risk factors are linked to other risk factors, such as design and institutional attributes.
- Not enough is known about the complex interaction between risk factors and their effect on programs to determine causality between negative program performance and the presence of risk factors.
- The presence of risk factors is not a definitive indication that negative program performance will result, but it does increase the probability of negative outcomes.
- Many individual risk factors previously have been identified and associated with negative program performance.
- Many identified risk factors are common across programs.
- Risk factors can be grouped into four main categories: design, systems engineering and program management processes, systems engineering and program management process implementation, and institutional. Consideration of all categories must be made to understand the impact of systems engineering and program management process risk factors on program performance.
- Focused process reforms that target individual risk factors have been the primary means of combating negative program performance in the past.
- Not enough emphasis has been placed on creating reforms that take into account institutional and design realities, even though this is highly challenging.
- Alternative reform strategies exist that create system designs capable of adapting to changes in the institutional environment.

XI. FUTURE WORK

Additional work would expand upon the information presented in this report. Three major areas warrant additional investigation.

A. UNDERSTANDING RISK FACTORS

This report makes no attempt to provide an exhaustive list of risk factors or a complete, in-depth understanding of any one risk factor. Additional risk factors could be identified by increasing the range of programs considered; specifically, increasing the number of acquisition program studied. A wider range of program types also could be investigated and compared. Several areas of interest would include comparing programs from each of the Service branches, comparing DoD acquisition programs with acquisition programs supported by other countries, and comparing DoD acquisition programs to other U.S. government acquisition programs.

Additional work aimed at understanding individual risk factors and their interaction with other risk factors also would be useful.

B. UNDERSTANDING RISK FACTOR CRITICALITY

This report made no attempt at determining the criticality of risk factors in affecting program performance. Future work could focus on quantifying the programmatic impacts that each risk factor presented, if any. A combination of a regression analysis and the creation of a probability distribution correlating each risk factor with performance shortfalls, budget overruns, or schedule slips would create a database of risk factors that could be listed according to criticality. Such a database would help identify areas where reforms are needed the most.

C. RISK FACTOR REFORMS

Reforms that address identified risk factors are needed. As forwarded in this report, reforms should be crafted to address the "problems behind the problems." This is a non-trivial goal, with additional work needed to create reform strategies that address risk factors, are implementable and sustainable, and that take into account the institutional environment within which acquisition programs operate.

Appendix
ACRONYMS

ACRONYMS

ACTD	Advanced Concept Technology Demonstrations
AGT	Advanced Gun Technologies Program
AoA	Analysis of Alternatives
ASC	Aeronautical Systems Center
AMST	Advanced Medium Short Range Take Off and Landing Cargo Plane
ASPR	Armed Services Procurement Regulation
ATA	Advanced Tactical Aircraft
ATD	Advanced Technology Demonstrations
ATF	Advanced Tactical Fighter
CAD	Computer Aided Design
CAIG	Cost Analysis Improvement Group
CAM	Computer Aided Manufacturing
CBO	Congressional Budget Office
CCB	Configuration Control Board
CDD	Capability Development Document
CDR	Critical Design Review
COD	Correction of Deficiency
CPD	Capability Production Document
DAPP	Defense Acquisition Pilot Programs
DAR	Defense Acquisition Regulation
DFARS	Defense Federal Acquisition Regulation Supplement
DoD	Department of Defense
DSARC	Defense Systems Acquisition Review Council
DUSD(AR)	Deputy Under Secretary of Defense for Acquisition Reform

EDM	Engineering Demonstration Model
EMD	Engineering, Manufacturing and Development
FAR	Federal Acquisition Regulation
FARA	Federal Acquisition Reform Act
FASA	Federal Acquisition Streamlining Act
FRP	Full-Rate Production
FX	Fighter Experimental Program
FY	Financial Year
GAO	General Accounting Office
GPS	Global Positioning System
HAE	High Altitude Endurance
ICD	Initial Capabilities Document
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IPD	Integrated Product Design
IPT	Integrated Product Team
IT	Information Technology
ITMRA	Information Technology Management Reform Act
JDAM	Joint Direct Attack Munition
JPO	Joint Program Office
LOGO	Limitation of Government Obligation
LRIP	Low-Rate Initial Production
MDA	Milestone Decision Authority
NASA	National Aeronautical and Space Administration
OEF	Operation Enduring Freedom
OSD	Office of the Secretary of Defense
OTA	Other Transactions Authority

PARM	Participating Manager
PM	Program Manager
PPBS	Planning, Programming and Budgeting System
RFI	Request for Information
RFP	Request for Proposal
SAM	Surface to Air Missile
SPO	Systems Program Office
TAC	Tactical Air Command
TDS	Technology Development Strategy
TPP	Total Package Procurement
TRA	Teledyne-Ryan Aeronautical
TSPR	Total System Performance Responsibility
UAV	Unmanned Aerial Vehicle
UFP	Unit Flyaway Price
USA	United States Army
USAF	United States Air Force
USD(AT&L)	Under Secretary of Defense (Acquisition, Technology and Logistics)
USN	United States Navy
WBS	Work Breakdown Structure

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14. ABSTRACT

This paper examines case studies of system development programs in defense and commercial industry and, combined with an understanding of the emphasis of past acquisition reform efforts, suggests that there are common risk factors across DoD systems acquisition programs. The paper illustrates how institutional realities greatly affect the success of systems engineering and program management processes.

15. SUBJECT TERMS

Systems engineering, program management, systems acquisition, systems development

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