Complexity Within the Air Force Acquisition System
Gaining Insight from a Theory of Collapse

by

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Submitted to the System Design and Management Program
In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering and Management

at the

Massachusetts Institute of Technology
February 2012

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ABSTRACT

Joseph Tainter's theory of societal collapse is applied in an examination of the U.S. Air Force's aircraft acquisition system in order to gain insight into the enterprise's lagging performance. Theories of collapse at both the societal level and the organizational level are reviewed. Tainter's interrelationship between increasing system complexity and diminishing marginal returns is highlighted as especially relevant to the performance of the Air Force aircraft acquisition enterprise.

Using Tainter's theory as a framework, evidence is gathered leading to the conclusions that the Air Force aircraft acquisition enterprise is highly complex and as a result is experiencing diminishing marginal returns. Tainter's framework is then also used to explain why past attempts to reform the enterprise have fallen short of their goals. Previous reform efforts, in the form of reorganizations and senior leader initiatives, have been ineffectual beyond the short term because they fail to reduce the underlying level of complexity within the enterprise. The use of workarounds by stakeholders within the enterprise are shown to be efforts to increase marginal returns and avoid overcomplexity.

The primary implication of viewing the Air Force aircraft acquisition enterprise through the lens of Tainter's theory of collapse is that in order to be effective, any effort undertaken to improve the performance of the enterprise must reduce the overall level of complexity within the system. Additional insights include the use of current workarounds as leading indicators of complexity or overly burdensome processes. Lastly, senior acquisition leaders should be prepared should a collapse of the enterprise occur. A vision of a much less complex enterprise should be advocated.

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ACKNOWLEDGEMENTS

I owe a special thank you to my family who are my most ardent supporters and who have sacrificed the most as I have pursued a policy of never ending curiosity and continuous learning.

I am also especially thankful for the support and friendship provided to me by my colleagues within the System Design and Management Program and the Lean Advancement Initiative, especially Sean Dorey, Shane Scott, Matias Raby, Andrea Ippolito and Chris Berardi.

I am thankful for the support of my thesis advisor, Dr. Ricardo Valerdi who has opened my eyes to an even greater world of learning and opportunity. I also thank Pat Hale for his continued support of the military fellows within the System Design and Management Program.

I am very grateful for the assistance provided by the Aeronautical Systems Center History Office especially for the support provided by Mr. Henry Narducci and Ms. Tasha Hairston. I also thank the staff of the Cambridge Main Library. It is there where I stumbled upon Joseph Tainter's book on collapse during my first week in Cambridge. The book became the foundation for this thesis.

Lastly, I owe a debt of gratitude to the U.S. Air Force for this opportunity to expand my education. I look forward to applying what I have learned within the acquisition enterprise and beyond.

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ACAT	Acquisition Categories
AFMC	Air Force Materiel Command
ASC	Aeronautical Systems Center
ASD	Aeronautical Systems Division
CJCS	Chairman of the Joint Chiefs of Staff
CSAF	Air Force Chief of Staff
DAE	Defense Acquisition Executive
DAU	Defense Acquisition University
DCAA	Defense Contract Audit Agency
DCMA	Defense Contract Management Agency
DEPSECDEF	Deputy Secretary of Defense
DFARS	Defense Federal Acquisition Regulation Supplement
DoD	Department of Defense
EVM	Earned Value Management
FAR	Federal Acquisition Regulation
FYDP	Future Years Defense Program
FDIC	Federal Deposit Insurance Corporation
GAO	U.S. Government Accountability Office
INCOSE	International Council on Systems Engineering
JCIDS	Joint Capabilities Integration and Development System
JDAM	Joint Direct Attack Munition
MAIS	Major Automated Information System
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MFP	Major Force Program
PEO	Program Executive Officer
PPBE	Planning, Programming, Budgeting, and Execution
RCO	Rapid Capabilities Office
RDT&E	Research, Development, Test and Evaluation
SAE	Service Acquisition Executive
SAF/AQ	Assistant Secretary of the Air Force for Acquisition
SOC	Self-Organized Criticality
SECAF	Secretary of the Air Force
USAF	United States Air Force
USD(AT&L)	Office of the Undersecretary of Defense for Acquisition, Technology and Logistics
WPAFB	Wright-Patterson Air Force Base

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Chapter 1 Introduction

1.1 Thesis Motivations

As a member of the Air Force aircraft acquisition enterprise since 1994, I have marveled at the size and complexity of the system. It involves thousands of military members, government employees and contractors. In its entirety, it spans the entire "cradle-to-grave" weapon system lifecycle from research and development to sustainment and eventual retirement.

Over this same time span, I have observed and experienced many attempts, undertaken by senior leaders, to improve the efficiency and cost-effectiveness of the system. While each of these efforts may have generated some improvement, very few would argue that system performance has substantially improved over the long term. Aircraft costs and fielding schedules continue to far exceed initial estimates.

Throughout my 18 years of experience, I have consistently heard fellow professionals within both the Air Force and its supporting contractors predict the "collapse" of the current acquisition system. These statements have sometimes been uttered by leaders as an impetus to change. More often they are uttered by individuals working within the system out of frustration with the difficulty of making progress within the enterprise. While these comments are often flippant in nature and also uttered with emotion, they prompt one to reflect on the concept of collapse and the various theories that seek to explain its occurrence.

In 1988, anthropologist Joseph Tainter, in his book *The Collapse of Complex Societies,* argued that societies become susceptible to collapse as they increase their level of complexity in an effort to solve problems. Tainter further asserted that maintaining all of this complexity requires a significant "energy subsidy" in the form of resources and people. When the value gained is less than the investments necessary to maintain the increased complexity, the society is ripe for collapse to a less complex, more sustainable structure.

Upon reading Tainter's book in 2010, I was struck by how much his theory and examples resonated with my experiences working within the Air Force aircraft acquisition enterprise. The realization that Tainter's theory of collapse had important implications for the Air Force aircraft acquisition enterprise was further bolstered by insights into system behavior gained over the course of completing the System Design and Management Program.

These linkages were the genesis of this thesis, which examines the Air Force aircraft acquisition enterprise from the perspective of Tainter's theory in an effort to understand why past

efforts to improve the enterprise have fallen short of their objectives. **My hypothesis is that these efforts to improve the enterprise fall short of their objectives because they fail to address the underlying level of complexity within the system.**

Additionally, the level of complexity present in the Air Force aircraft acquisition enterprise makes the enterprise increasingly vulnerable to collapse. Viewing the Air Force aircraft acquisition enterprise through the lens of Tainter's theory of collapse provides an understanding of how the enterprise reached its current complex state and why efforts to improve performance fall short of their goals. More importantly, Tainter's theory also provides a way forward to prevent collapse.

1.2 Complexity Defined

In order to fully appreciate Tainter's theory and its implications for the Air Force aircraft acquisition enterprise, it is important to first understand how he defines complexity. Because the word complexity is used in multiple ways across a wide spectrum of disciplines, Tainter takes the time to clarify his definition in his 2012 publication with Patzek. The use of the term complexity here is broad: Complexity emerges from "two elements: the diversity of things to be done, and the coordination required to get them done." (Tainter & Patzek, 2012)

> "These two elements introduce what the development of complexity in human societies has entailed. It has consisted of adding more parts, especially more kinds of parts, and organizing to coordinate those parts." (Tainter & Patzek, 2012)

Simply having a lot of parts (structural differentiation) does not make something complex. "Something must make the parts work together, and that is organization." While organization can take many forms, at its core, organization is a set of constraints which limit the behavior of the parts within a system. In human endeavors, organization is often imposed by institutional rankings and organizational hierarchies which constrain individuals and allow a society to emerge from its many parts (Tainter & Patzek, 2012).

As described by Moore (2009) and Tainter & Patzek (2012), early American anthropologists including Alfred Kroeber, Julian Steward and John Peabody Harrington analyzed cultures by "breaking them down into discrete customs or elements, such as the forms of descent (matrilineal, etc), where a couple resides after marriage, types of houses or tools and various kinds of cultural practices." Later archeologists, including Moore, considered this method of

comparing cultures oversimplified and flawed since it assumes various elements to be of equal significance and neglects to consider distinctions in how similar elements are used differently across cultures (Moore J. D., 2009).

Despite these shortcomings, Tainter points out that Julian Steward "realized that culture element lists were a crude way to begin to compare societies on a dimension of complexity." (Tainter & Patzek, 2012) Tainter's first example of how structural differentiation and organization must both be present in order for complexity to emerge is a military one from World War II compiled by Steward: In order to execute the Allied landings on the North African coast, the U.S. military transported 500,000 parts along with their landing forces. This large number of parts is in contrast to "3,000 to 6,000 cultural elements documented among the native people of western North America..." However, because the supplies were packed haphazardly and mostly ended up uselessly dumped on the beach, Tainter concludes that the parts failed to coalesce into a complex, functional system. "Differentiation, in structure without corresponding organization makes a system complicated, not complex." (Tainter & Patzek, 2012)

Tainter's second example illustrates how "organization alone cannot make a system complex." During the opening ceremony of the 2008 summer Olympics in Beijing, one "display showed a sea of drummers, each dressed identically, all drumming in unison. It was most impressive...But it was not a complex system. Although organization was high, (everyone performed as required), there was no structural differentiation at all." (Tainter & Patzek, 2012)

While Tainter understandably focuses on complexity at the societal level in support of his societal collapse theory, his definition is also applicable at the organizational level. For example, a small entrepreneurial start-up is a much less complex organizational entity than a large corporation or government agency. A start-up will likely only have a few employees; each simultaneously serving in multiple roles. Specificity in roles is limited with each person covering multiple tasks. The amount of hierarchy present in such a firm is also likely to be correspondingly low. In contrast, a multi-national corporation has a very large number of employees, each employed in a very specific role. Employees of a large corporation or government agency also tend to operate within a strict hierarchy that clearly delineates their level of responsibility and authority.

1.3 Empirical Observations Regarding Enterprise Improvement Efforts

Anyone who has worked with or within the Air Force aircraft acquisition enterprise would undoubtedly agree that it is a complex system and that complexity can be an impediment to successful mission accomplishment. Over the past two decades, those working within the Air Force aircraft acquisition enterprise have witnessed many efforts to improve performance of the acquisition system. These efforts have included re-engineering, balanced scorecard, system metrics tracking, Air Force Smart Operations 21 as well as multiple efficiency initiatives and reorganizations driven by the Department of Defense or the Air Force.

Having personally witnessed a number of these efforts fall short of producing the expected level of improvement, I have empirically developed opinions on why they have been less than successful.

Performance is measured in two ways that are often in tension.

The first way performance of the Air Force aircraft acquisition enterprise is measured is how well it does delivering capabilities to the operational Air Force. This is the conventional definition and is measured in terms of cost, schedule and performance with performance denoting meeting or exceeding requirements.

The second way performance of the Air Force aircraft acquisition enterprise is measured deals with how closely the process is in compliance with the laws, regulations and policies governing acquisition. It is in this area where most of the complexity resides. A great deal of the work performed by members of the Air Force aircraft acquisition enterprise is expended to ensure the level of performance in this regard is kept high. Compliance is enforced through functional professionalism and expertise, approval processes and inspections. These activities have a cost, both in terms of resources and time.

The underlying complexity of the Air Force aircraft acquisition enterprise is largely unaffected by top-level changes

Past efforts to improve the system have strived to improve cost, schedule and delivered system performance yet were limited in what they are able to alter in terms of underlying complexity. The laws, regulations and policies are established at higher levels of authority within the defense acquisition system and are not affected by organizational changes accomplished at the local level.

Attempts to solve problems add more complexity

Problem solving within the Air Force aircraft acquisition enterprise often results in additional complexity. Once a problem is encountered, there is a strong culture and desire to institute safeguards to prevent a reoccurrence of the same or similar problem. There is also a desire to preserve the lessons learned in the course of solving the original issue. Both of these often generate additional complexity in the form of new regulations and policies. This phenomenon occurs at all levels within the enterprise, sometimes with conflicting results.

One's role in the enterprise exerts a powerful influence of what is perceived to be important

The common phrase "where you stand depends on where you sit" holds true within the Air Force aircraft acquisition enterprise. This is true across both hierarchical and functional perspectives. Differing levels of authority within the system can have very different goals. For instance, the Congress may view jobs associated with defense work as extremely important while individual program managers and contracting officers worry little about this aspect of the acquisition enterprise.

Different career fields also have different values. Contracting officers diligently safeguard the authority vested in them in the form of warrants. This is often manifested in a more risk-adverse perspective. Thoroughness, compliance, cost savings and attention to detail are looked upon very favorably within the contracting functional profession. Program schedules tend not to be viewed as importantly.

In contrast, program managers are rewarded for obligating funding and meeting cost/schedule/delivered performance goals. Program managers therefore tend to adopt a more risk-seeking perspective with regards to accomplishing contract actions and sometimes become frustrated when contracting details slow agreement.

These differences in perspective can lead to different interpretations on how improvement initiatives are to be implemented, further reducing their efficacy.

Improvement initiatives focus on organizational structure

Since much of the complexity within the Air Force aircraft acquisition enterprise stems from higher levels within the defense acquisition system, local efforts to improve performance tend to focus on organizational structure. While changes in organizational structure can generate

performance improvement, they can also be largely ineffective if the underlying processes and level of complexity remain the same.

While working within the Air Force aircraft acquisition enterprise I was often perplexed by efforts undertaken by leadership to improve performance. Each effort seemed very similar in nature to the initiatives that had come before it. Most also seemed overly focused on organizational structure, cyclically strengthening or weakening functional power relative to program leadership.

During each assignment, I also encountered a deep level of cynicism across the workforce concerning reform initiatives and the ability of the acquisition system to improve.

Upon reading Tainter's theory concerning societal collapse and its precursors, I was struck by the similarities between his examples and my experience within the Air Force aircraft acquisition enterprise. In this thesis, I aspire to delve further into the impact of system complexity on the performance of the Air Force aircraft acquisition enterprise and its implications for improving enterprise performance.

1.4 Thesis Overview

1.4.1 Chapter 2 Overview

Chapter 2 provides a review of theories that attempt to explain why organizations collapse. Tainter's general theory is explained. Other theories focusing on societal collapse are also reviewed and compared with Tainter's theory. Theories that attempt to explain why collapse occurs at the organizational level are also examined. Societal level theories are found to be more useful for analyzing the Air Force aircraft acquisition enterprise.

1.4.2 Chapter 3 Overview

Chapter 3 focuses on Tainter's theory of collapse. The framework of the theory is explained and its applicability at the societal level is explored. The chapter reviews the four primary societal level processes Tainter uses within his framework including agriculture and resource production, information processing, sociopolitical control/specialization and overall economic production. Each area is reviewed and the lessons that also apply at the organizational level are highlighted.

1.4.3 Chapter 4 Overview

In chapter 4, the concepts of diseconomy of scale, incentives and organizational structure are discussed. Each of these concepts provides insight into why it becomes difficult to manage an organization or program effectively as it grows in size and complexity. Knowledge of these concepts helps one to understand the challenges the Air Force aircraft acquisition enterprise faces while striving to operate effectively and efficiently.

1.4.4 Chapter 5 Overview

Chapter 5 consists of a top-level stakeholder analysis of the Air Force aircraft acquisition enterprise. Prior to applying Tainter's theory of collapse to the Air Force aircraft acquisition enterprise, it is helpful to understand who the primary stakeholders are and how they interact within the enterprise. The analysis included identification of the key stakeholders, a review of their responsibilities and a listing of the value each stakeholder group extracts and delivers from the enterprise.

1.4.5 Chapter 6 Overview

Chapter 6 describes the research methodologies used. Sources of archival records are described. The structure of surveys and interviews are discussed. Lastly, insight into the choice of the specialty metal case study is provided.

1.4.6 Chapter 7 Overview

Chapter 7 establishes that there is a high level of complexity within the Air Force aircraft acquisition enterprise. This is a crucial first step in applying Tainter's theory at the enterprise level. Evidence of complexity was gathered across three primary process areas: personnel specialization/organizational structure, resource management, and regulatory guidance/policies.

1.4.7 Chapter 8 Overview

With it established that the Air Force aircraft acquisition enterprise is a highly complex organization, chapter 8 takes the next step and provides evidence that the level of complexity has reached a point of diminishing marginal returns. Examples are presented where the interplay between benefits and costs demonstrate declining marginal returns.

1.4.8 Chapter 9 Overview

Chapter 9 examines the responses senior leaders have taken to improve the performance of the Air Force aircraft acquisition enterprise in the face of high complexity and diminishing marginal returns. These responses have included both cyclical reorganizations and senior leader initiatives. Tainter's theory is used to explain why these improvement efforts have failed to meet their objectives over the long term. Additionally, the chapter describes workarounds used by stakeholders in attempts to increase productivity as predicted by Tainter's theory. Survey responses are shown to also be congruent with Tainter's theory of collapse.

1.4.9 Chapter 10 Overview

Chapter 10 provides a summary of the research supported conclusions. The Air Force aircraft acquisition enterprise is a highly complex organization that is at a point where that complexity has resulted in diminished marginal returns. Senior leader responses in the form of reorganizations and initiatives have been ineffectual since they have not reduced the level of complexity within the enterprise. In the face of high complexity and diminished marginal returns, both organizations and individuals within the enterprise utilize workarounds in an attempt to increase marginal returns.

1.4.10 Chapter 11 Overview

Chapter 11 discusses the implications of the above research for both senior leaders within the Air Force aircraft acquisition enterprise and powerful external stakeholders such as the Congress. Recommendations are also provided to both stakeholder groups including what to do if a collapse of the enterprise occurs. In conclusion, Tainter's theory provides senior leaders with an explanation why past reform efforts have fallen short of their objectives. The theory also provides leaders with the guiding principle for subsequent reform attempts to improve effectiveness: they should significantly reduce enterprise complexity.

Chapter 2 Theories of Collapse

2.1 Joseph Tainter: A General Theory of Collapse

A general theory on societal collapse was put forward in 1988 by the anthropologist Joseph Tainter in his book *The Collapse of Complex Societies.* His theory, applied at an organizational rather than societal level, provides the framework for examining the workings of the Air Force aircraft acquisition enterprise.

Tainter suggests that societies become susceptible to collapse when "continued investment in complexity as a problem-solving strategy yields a declining marginal return." (Tainter, 1988) Depending on the type of stress placed upon a society, Tainter asserts that the society will respond by making ever larger investments in "agricultural and other resource production, in hierarchy, in information processing, in education and specialized training, in defense, and so forth." Maintaining all of this complexity requires a significant "energy subsidy" and that when the "declining marginal returns" gained from adding complexity are less than the investments necessary to maintain them, the society may collapse to a form with a lower level of complexity (Tainter, 1988).

Tainter uses the diagram provided as Figure 1 to describe how increasing complexity increases the likelihood of collapse. Initially, as the level of complexity in a society is increased, the marginal benefits also increase up to the point labeled (B1,C1). Once that point is reached, "benefits still rise in response to increasing complexity, but at a declining marginal rate" up to the point (B2,C2) (Tainter, 1988). He also asserts that within the area between these two points, "collapse becomes increasingly likely." However, the region of most interest is the region between points (B2,C2) and (B1,C3) where a rise in complexity actually results in a decreasing level of benefit. Because the benefit received at point (B1,C3) is the same as what is produced with less complexity at (B1,C1), the society is in "serious danger of collapse from decomposition (as well as from any external threat)," once "constituent social units recognize that a strategy of severing their ties to the regional entity might yield highly increased marginal productivity..." (Tainter, 1988)

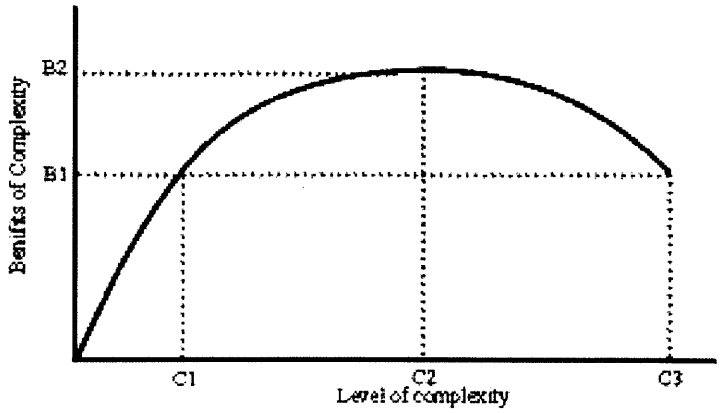

Figure 1: The marginal product of increasing complexity (Tainter, 1988)

Upon reading Tainter's book, it is apparent that his theory is applicable at the organizational level as well as at the societal level. By viewing the Air Force aircraft acquisition enterprise through the lens of Tainter's theory and what it portends are precursors to collapse, one gains valuable insight into why efforts, including multiple reorganizations and senior leader initiatives spanning the past 20 years, continue to under deliver. Tainter's theory prompts one to consider whether the level of complexity within the Air Force aircraft acquisition enterprise is appropriate. It also induces one to consider how people with the Air Force aircraft acquisition enterprise solve problems and whether those responses are congruent with what Tainter's theory postulates about the tendency to continually add additional complexity.

Before delving further into Tainter's theory and its implications for the Air Force aircraft acquisition enterprise, it is important to review the range of other theories that seek to explain the collapse of human endeavors and their applicability. One way to characterize collapse theories is by what level of organizational failure they seek to explain. Predominantly, theories can be categorized into one of two sets: those that attempt to explain failure at the broad societal or governmental level and those theories that focus on explaining failure at the corporate or organizational level.

2.2 Societal Level Theories

In order to prepare the way for his own theory, Tainter (1988) provides a succinct yet comprehensive review of preceding theories that seek to explain collapse at the societal level and why they fail to explain collapse as a "general phenomenon…not limited to specific cases, but applicable across time, space, and type of society."

Tainter's review organizes previous societal/governmental theories into eleven major themes as shown below. After outlining the leading theories within each theme and why they fall short, he concludes that while mystical explanations, "are without scientific merit", each of the other themes is "simply inadequate as presently formulated" due to the fact that they each fail to provide a generalized universal explanation that cuts across all examples of societal collapse (Tainter, 1988).

1. **Resource depletion.** Dealing with resource uncertainties is a common activity of complex societies, and may be one of the things that they do best. Where this is not the case, research has to focus on the characteristics of the society that prevent an appropriate response, rather than exclusively on the characteristics of the depleted resource.
2. **New resources.** This theme has some attraction to integration theorists, but none to conflict theorists[1]. Its usefulness is mainly restricted to simpler societies.
3. **Catastrophes.** Complex societies regularly provide for catastrophes, and routinely experience them without collapsing. If the society cannot absorb a catastrophe, then in many cases the characteristics of the society will be of greater interest, obviating the catastrophe explanation.
4. **Insufficient response to circumstances**. The assumptions made in this theme about the nature of complex societies – that they are inherently fragile, or static, or incapable of shifting directions – simply cannot be supported. Where complex societies may display such characteristics, that is a matter to be explained.
5. **Other complex societies.** Major cases, such as the Roman one, cannot be accounted for by this theme. Conflict between states more often leads to cycle of expansion and contraction than to collapse.
6. **Intruders.** The overthrow of a dominant state by a weaker one is an event to be explained, not an explanation in itself. Empirically, intruders are often difficult to detect archaeologically where they have been postulated. It is difficult to understand why barbarians would destroy a civilization if it was worth invading in the first place.
7. **Conflict/contradictions/mismanagement.** The capacity to control labor and allocate resources is intrinsic and necessary in complex societies. Collapse cannot easily be explained by factors so vital to survival, at least not without raising many more questions than are answered. Elite mismanagement and self-aggrandizement, to the extent that these are detrimental to the survival of a society, are matters to be explained. Exploitation and misadministration are normal, regular aspects of complex societies, and by themselves cannot account for an occasional event, collapse. Peasants rarely revolt except when allied with other social strata, and their rebellions are not typically aimed at collapse.

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[1] Tainter (1988) defines integration theorists as those that "argue that complexity and stratification [within societies] arose because of stresses impinging on human populations, and were positive responses to those stresses." He conversely defines conflict theorists as those that "assert that the state emerged out of the needs and desires of individuals and subgroups of society...as coercive mechanisms to resolve intra-societal conflicts arising out of economic stratification."

8. Social dysfunction. These explanations offer neither sources of strain nor causal mechanisms that can be analyzed in any objective way.
9. Mystical. Mystical explanations fail totally to account scientifically for collapse. They are crippled by reliance on a biological growth analogy, by value judgments, and by explanation by reference to intangibles.
10. Chance concatenation of events. This theme provides no basis for generalization. Collapse is not well explained by reference to random factors.
11. Economic explanations. These are structurally and logically superior to the others, at least as these others have been formulated to date. They identify characteristics of societies that make them liable to collapse, specify controlling mechanisms, and indicate causal chains between controlling mechanisms and observed outcome. While economic explanations are not universally accepted in the social and historical sciences, such scenarios remedy the logical deficiencies of the other approaches. Existing economic models often suffer from incomplete forays into political and social explanations, but this is not an 'intrinsic' flaw. The major drawback to economic explanations, for present purposes, is failure to develop an explanatory framework that is globally applicable. (Tainter, 1988)

Since the publication of Tainter's theory, a number of additional theories on societal collapse have been put forward. The most commonly known one is articulated by Jared Diamond in his 2005 book *Collapse: How Societies Choose to Fail or Succeed.* In the preface, Diamond states that a more complete description of his book would be "Societal collapse involving an environmental component, and in some cases also contributions of climate change, hostile neighbors, and trade partners, plus questions of societal responses." (Diamond, 2005) Examining Diamond's theory in the context of Tainter's eleven themes, one finds that it fits within the resource depletion theme.

Diamond argues that collapse at the societal level primarily occurs due to the interplay of factors within a "five-point framework" (Diamond, 2005). This framework consists of five sets of factors that determine whether a society will persist or collapse: environmental damage, climate change, hostile neighbors, decreased support by friendly neighbors, and the society's response to its environmental problems. The reduction or elimination of essential resources due to excessive consumption or climate change (*resource depletion*) place a society in a tenuous position. Increased pressure or failure to properly handle a crisis in any of the other five factors can then potentially serve as a trigger for societal collapse. Diamond's primary case study is the case of Easter Island where he asserts that population growth and political rivalries resulted in deforestation which became the environmental trigger for collapse. While Diamond makes a compelling argument on the detrimental effects of resource depletion and how it can lead to

collapse at the societal level, his singular focus on environmental depletion prevents application of his theory to the Air Force aircraft acquisition enterprise.

A climate-centric theory of collapse was articulated by Harvey Weiss and Raymond Bradley in their 2001 *Science* article "What Drives Societal Collapse?" After examining "high-resolution paleoclimatic data that provide an independent measure of timing, amplitude, and duration of past climate events", they conclude that disruptive climate changes are the primary precursor to societal collapses (Weiss & Bradley, 2001). Within Tainter's taxonomy, this theory would also fall within the resource depletion theme since it postulates that collapse is due to a "rapid loss of resources due to an environmental fluctuation or climatic shift." As with Diamond's theory, this focus on climatic precursors also renders Weiss' and Raymond's theory inapplicable to understanding the Air Force aircraft acquisition enterprise.

Another theory advanced since Tainter's work straddles the resource depletion and economic themes. John Greer in his paper *How Civilizations Fail: A Theory of Catabolic Collapse* models society as a set of "relationships among resources, capital, waste, and production" (Greer, 2005). As a society expands, its stock of capital assets increases. This existing capital requires an increasing amount of resources to cover maintenance costs, averting the conversion of assets to waste.

As long as resources are abundant, Greer argues that a society will oscillate between higher and lower levels of capital as maintenance costs become unbearable and established capital is laid to waste. As this occurs, maintenance costs fall, freeing resources for use in the production of new capital and the cycle continues. This line of thinking is very much aligned with Tainter's concept of higher levels of complexity resulting in diminishing marginal returns.

However, Greer points out that when resource use exceeds its replenishment rate, production of new capital is hindered. Subsequent decreases in maintenance costs do not occur quickly enough to provide a sufficient supply of resources for new capital production. Both factors then continue to decrease in a downward spiral fashion. "Catabolic" collapse occurs when new capital production approaches zero while remaining maintenance costs continue to convert existing capital to waste. This unavailability of fresh resources for continued production and maintenance activities is what generates and accelerates collapse in Greer's model. Greer argues that his theory is an improvement on Tainter's since it better explains the "temporal nature" of societal

collapse and why the aftermath of collapse frequently results in a lower level of complexity than what existed prior to the development of the society (Greer, 2005).

Greer cites the western Roman Empire as an example where a catabolic collapse occurred "driven by a combined maintenance and resource crisis." (Greer, 2005) He points out that Roman expansion and military superiority "transformed the capital of other societies into resources for Rome" as each neighboring land was conquered. While each new conquest initially provided resources for Roman use, each also came with longer term maintenance costs such as enforcing Roman rule. However, as the rate of conquest slowed and became less profitable, "the maintenance costs of empire proved unsustainable". Since these maintenance costs did not decline as fast as the drop in production of new capital and resources, a cycle of "catabolic" collapse continued until the empire completely disintegrated leaving an aftermath well below what existed before the empire's expansion began.

Greer's model is for the most part a derivative of Tainter's theory focused on macro-level capital creation and maintenance costs. Greer's concept of maintenance costs is very interesting and is congruent with Tainter's theory. As a multi-layered distributed organization that requires significant resources in terms of manpower and infrastructure, maintenance costs are an important consideration when examining the Air Force aircraft acquisition enterprise. Entire entities such as the Defense Acquisition University have been created to train and support the acquisition workforce. While undoubtedly of value, they also consume significant resources. Such large investments in overhead decrease the net amount of value gained through operation of the Air Force aircraft acquisition enterprise and hasten the onset of diminishing returns.

At the same time that Tainter was publishing his theory of collapse, a group of physicists, including Per Bak, discovered the fractal-based concept of self-organized criticality (SOC) explained "why so many physical patterns repeat in a generic way no matter what the spatial or time scale" (Brunk, 2002). The example initially used by Bak to explain SOC was a pile of sand. "As each new grain of sand is dropped on the pile, it tends to find a resting place that does not disturb the others. In other words, the pile self-organizes, and in so doing creates an increasingly complex structure as its height grows....Eventually the grains of sand become so hypersensitive to even the smallest of shocks that dropping another grain causes part of a sandpile – or, more rarely, the entire pile to collapse." (Brunk, 2002) These collapses are often referred to as "complexity cascades."

In 2002, based upon the "recognition that SOC produces a basic pattern that is also ubiquitous in biological and human systems", George Brunk articulated a new general theory of why societies collapse. Congruent with Tainter's theory, Brunk (2002) asserts that:

> "human systems are naturally self-organizing in that societies always tend to evolve toward the maximum level of complexity that is possible given current technological constraints. As they approach this limit, they experience increasingly rigidities and suffer more problems of various sorts."

Rather than return to the sandpile example, Brunk subsequently relies on an example based on the pattern of wildfires to help explain how SOC pertains to collapse. Wild fires are typically started by an external event such as a lightning strike or a carelessly discarded cigarette. The magnitude of the resulting fire is not dependent on the size of the ignition source but rather is dependent on the amount of fuel in the form of forest growth or prairie scrub brush that has built up over time. This build-up is described as analogous to the amount of complexity present within a system. Brunk asserts that if external events are allowed to impact the system regularly, the level of complexity within the system is periodically lowered which "reduces the number of very large [complexity] cascades." Brunk then translates this model into the societal realm asserting that collapses are rare because "governments or private organizations take actions to minimize the effect of SOC complexity cascades by dampening them." This ability to dampen the negative effects of shocks and prevent complexity cascades ranging from floods (levies) to bank runs (Federal Deposit Insurance Corporation) is "the fundamental reason that civilization has advanced..." (Brunk, 2002)

While Brunk credits the ability to dampen shocks as fundamental to the progress of society, he is clear that such actions do not prevent collapse indefinitely. "Ironically, instead of eliminating all complexity cascades, what the increasing bureaucratization of mature societies may do is increase the impact of the really big cascades when they overwhelm a society's barricades." He again returns to the wildfire analogy pointing out that:

> A recent example of the unintentional magnification of complexity cascades through well-intended bureaucratic behavior is the wildfires that have swept the American West. Their sizes were greatly increased by the US Forest Service's long-standing policy of immediately extinguishing fires. By not allowing small wildfires to burn freely every few years, the complexity of the western forest systems was greatly increased in terms of ability of wildfires to spread, and so too was the magnitude of the inevitable disasters that occurred at the turn of the millennium. (Brunk, 2002)

While Brunk's theory is very compelling due to its roots in physical science and its descriptive power, its reliance on "aggregate-level patterns" to explain collapse makes it difficult to use in a predictive manner. In fact, Brunk asserts that to try and do so would not be fruitful since "[complexity cascades] are unanticipated and catch people by surprise." He further goes on to challenge Tainter and others that have articulated a reduction in societal complexity as a way to stave off collapse:

> Even temporarily reducing a society's level of complexity will not permanently rid its inhabitants of the evils of periodic cascades. This is because human systems are constantly self-organizing toward a greater level of complexity, which brings with it unanticipated problems. In doing so they all seem to follow the same generic evolutionary path of expansion and sudden setbacks. (Brunk, 2002)

Even if Brunk's conjecture is correct and the collapse of all human endeavors is inevitable in the long run, all is not lost. If addressing complexity and the precursors of collapse can improve system performance and perhaps defer a catastrophe, it is worthwhile to rely on Tainter's theory for guidance.

2.3 Organizational Level Theories

Since the Air Force aircraft acquisition enterprise is a governmental entity similar in size to a very large corporation, it is important to review theories that focus on explaining collapse at the corporate/organizational level for applicability.

In 1976, John Argenti, in his book *Corporate Collapse: The Causes and Symptoms*, became one of the first to systematically study why firms collapse in the hope that such an understanding would lead to "some way of preventing their collapse..." Similar to Tainter's approach, Argenti first presents a synopsis of causes and symptoms that were put forward by his predecessors in the process of explaining individual cases of corporate collapse. Based on these individual cases, he reduces the causes and symptoms into a list of 12 items which he then links into a generalized descriptive narrative of corporate collapse that he asserts describes all corporate failures:

> If the **management** of a company is poor then two things will be neglected: the system of **accountancy information** will be deficient and the company will not respond to **change**. (Some companies, even well-managed ones, will be damaged because powerful **constraints** prevent the mangers making the responses they wish to make.) Poor managers will also make at least one of three other mistakes: They will **overtrade**; or they will launch a **big project** that goes wrong; or they will allow the company's **[leverage]** to rise so that even **normal business hazards** become constant threats. These are the chief causes, neither fraud nor bad luck deserve more than a passing mention. The following symptoms will appear:

> certain **financial ratios** will deteriorate but, as soon as they do, the managers will start **creative accounting** which reduces the predictive value of these ratios and so lends greater importance to **non-financial symptoms**. Finally, the company enters a characteristic period in the **last few months**. (Argenti, 1976)

In addition to his narrative of corporate collapse, Argenti asserts that this narrative manifests itself along three typical paths which he calls trajectories. As shown in Figure 2, each of the trajectories describes a type of corporate collapse "marked by a different combination of the causes and symptoms..." Type 1 failures are the province of newly formed, small firms. "The general health of the company probably never rises above 'poor' and it probably fails within five years." (Argenti, 1976) A Type 2 collapse trajectory is also exhibited by small firms with the difference in development attributed to a leader who is a "super-salesman". The charismatic CEO is able to achieve a "swift take-off" and attract a great deal of interest in the form of capital and media attention. Inevitably, the lack of actual performance catches up to the firm and it rapidly collapses. Lastly, Type 3 failures "occur only to mature companies which have been trading successfully for a number of years or decades." (Argenti, 1976) This trajectory is characterized by "an initial collapse, a plateau, [and] a final collapse." The initial collapse is caused by a combination of Argenti's 12 causes and symptoms which cause the firm to be injured in the face of an otherwise "normal business hazard." This drives the firm to become even more over leveraged and engage in creative accounting. This behavior keeps the firm stable for some time until once again, it is confronted with a hazard. Only this time, it is "waterlogged" by high leverage and has lost its competitive edge resulting in total collapse (Argenti, 1976).

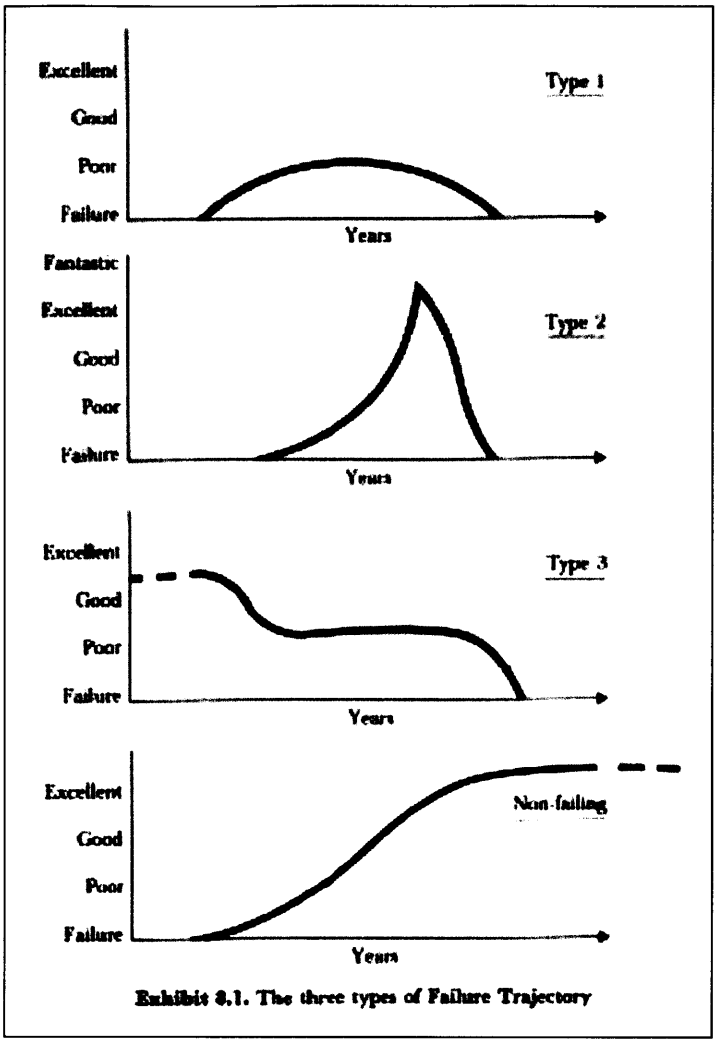


Figure 2: Three Types of Failure Trajectories (Argenti, 1976)

Between the two primary components of Argenti's theory of why corporate collapse occurs, the narrative of causes and symptoms is the most useful in the context of the Air Force aircraft acquisition enterprise. However, while the causes of poor management, failure to change and the undertaking of a large project each have impacted organizations within the public sector, the concept of commercial failure does not apply as it does in a private sector firm. An example of this difference is the massive road construction project that was undertaken in Boston known as the "Big Dig". While plagued by accusations of poor planning and management as well as overruns that drove the final cost from a planned $2.6B to more than $14.8B, the Massachusetts Turnpike Authority did not collapse (The Associated Press, 2007). The Air Force aircraft acquisition enterprise has also experienced large cost overruns in its projects that would have likely been fatal for a commercial firm dependent on investor capital. One example is the F-22

procurement where the unit cost per aircraft rose from a 1992 estimate of $125.2M to a $361.3M in 2004 due to increased development costs and reduced procurement quantities (U.S. GAO, 2006).

Since Argenti's book, research on predicting corporate failure via an analysis of financial ratios has continued. A good example of this type of research is a paper which asserts that the stability of financial ratios over time is a strong predictor of whether a firm will collapse (Dambolena & Khoury, 1980). Being dependent on the analysis of accounting ratios, these theories and models have no applicability to the Air Force aircraft acquisition enterprise.

Building upon previous qualitative and anecdotal work such Argenti (1976), another perspective on large corporate failure was put forward by Donald Hambrick and Richard D'Aveni in 1988. They relied on conclusions drawn from previous work on corporate collapse to converge upon four "major constructs" which they then used to assess 57 large firms that declared bankruptcy between 1972 and 1982. The constructs selected were domain initiative, environmental carrying capacity, slack and performance. Analysis relied on statistical evaluation of variables within each of the four construct categories as well as qualitative case studies. After examining the 57 bankrupt firms and matched surviving firms, Hambrick and D'Aveni conclude that the collapse of large firms is a "protracted process of decline" in the form of a downward spiral consisting of four phases (Hambrick & D'Aveni, 1988). The first two stages are defined as "origins of disadvantage" and "early impairment" both of which put the firm on the path towards collapse. In the first stage, lagging levels of slack and performance relative to competitor firms are the first signs of weakness. In the second stage, slack and profitability fall to marginal levels which lead to the spiral down in the final two stages. As shown in Figure 3, what occurs during the final two stages of the spiral seals a firm's fate:

> Firms enter the marginal existence stage with deficient potential slack and performance. These problems create stress, which in turn induces perceptual and process errors. The most apparent manifestations are extreme strategic behaviors (inaction or hyperaction) and wide vacillation in those behaviors. At the same time, some favorable conditions exist, notably satisfactory levels of working capital and a neutral or even munificent environment. Unfortunately, these positive signs merely provide false encouragement to decision makers, thus providing yet another basis for extreme behaviors...leaving the firm in a continued marginal state.
>
> In the death struggle, stress-induced perceptual errors are thought to intensify, still manifested as strategic extremism and vacillation. The penalties from these behaviors, coupled with a sudden decline in the environment's carrying capacity, exhaust all forms of slack and performance, and death occurs. (Hambrick & D'Aveni, 1988)

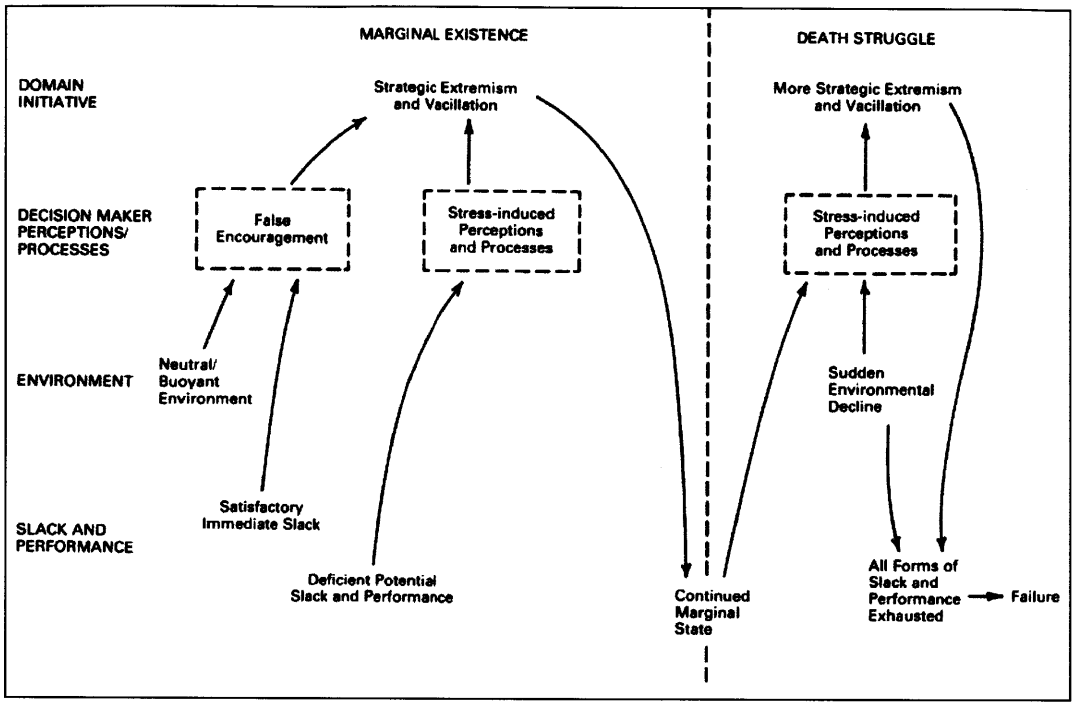


Figure 3: Elaboration of the last two stages of large firm failure (Hambrick & D'Aveni, 1988)

At its core, Hambrick and D'Aveni's theory is centered on the themes of mismanagement and resource depletion. In the final stages, mismanagement and false perceptions lead to fatal levels of strategic extremism and vacillation between bold initiatives and inaction. These ill-advised policy swings deplete the firm's resources and failure inevitably ensues.

The Hambrick and D'Aveni study is descriptive of the large firm death spiral experience. However little insight is provided concerning the mechanisms of resource depletion caused by strategic extremism. In particular, there is no discussion of what role complexity plays in the process. However, a valuable take away from their study is the empirical "central finding" that weakness appears early. A "substantial period of warning" coupled with a long process of failure affords management the opportunity to halt the downward spiral and avert collapse.

Inherent in the Hambrick and D'Aveni study is the notion of competition between firms with the weaker one succumbing to collapse. James Utterback, in his book *Mastering the Dynamics of Innovation* examines the nature of competition between firms and the role of innovation in success or failure. He proposes a model of the dynamics that occur when a new innovation is introduced. The rate of innovation surrounding the new industry is shown below as Figure 4.

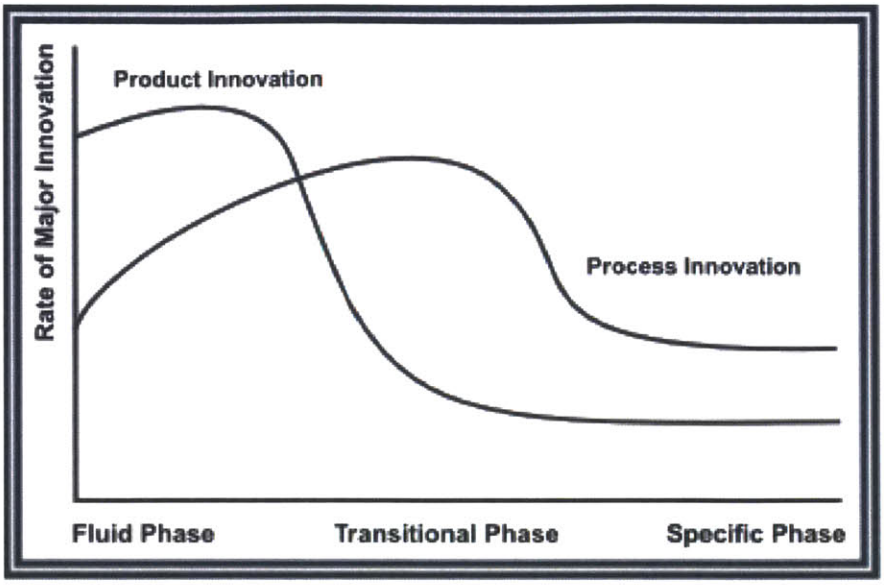


Figure 4: The Dynamics of Innovation (Utterback, 1994)

In the fluid phase, the innovation is manifested in a number of "diverse" product designs offered by a rapidly growing number of competing firms. In the transitional phase, a "dominant design" emerges and the number of firms able to effectively compete declines quickly. Competition moves from product innovation to process innovation where the "competitive emphasis in this phase is on producing products for more specific users as the needs of those users become more clearly understood." (Utterback, 1994)

As an industry based on a particular technology matures, it enters the specific phase where "the value ratio of quality to cost becomes the basis of competition." Firms that have been unable to compete in the process realm have departed or failed. Only a few firms remain; engaged in a "classic oligopoly with stable market shares." (Utterback, 1994)

Within the Utterback model of an industry built upon an innovation, firms fail when they do not effectively make the transition from one phase to the next. Collapse is the result of a failure to adapt when the nature of the competition changes.

A Darwinian perspective on why businesses collapse is provided by Theodore Piepenbrock and Charles Fine in an article synopsizing Piepenbrock's 2009 Ph.D. dissertation. As shown in Figure 5 below, Piepenbrock asserts that all commercial enterprise architectures fall along a "continuum spanning two polar opposites" based upon three criteria: objective function of the firm, enterprise boundaries and stakeholder interfaces. On one end of the continuum is the "Blue" modular enterprise architecture which seeks to only maximize shareholder value and is

very tightly scoped in both terms of boundaries and depth of stakeholder relationships. On the other end of the continuum is the "red" integral enterprise architecture which seeks to maximize value across all stakeholders while maintaining broad boundaries and high quality interaction with a smaller set of high-quality stakeholders (Piepenbrock & Fine, 2009).

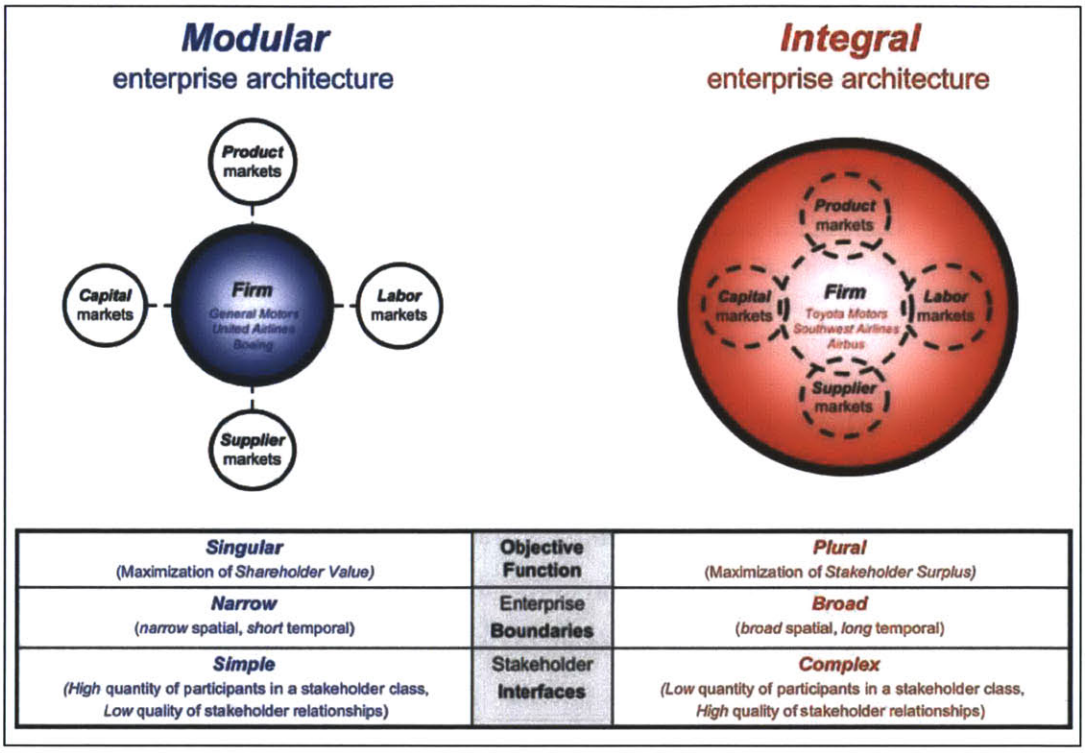


Figure 5: Enterprise architectures (Piepenbrock & Fine, 2009)

As the business environment in which firms complete against one another changes, advantage is conveyed to either modular or integrally structured enterprises:

> Enterprise architectures early in the industry's evolution are integral, for radical product innovation. They then dis-integrate for speed to build a fast-growing market, and for greater cost-leadership and more modest product innovation. As the ecosystem begins to mature, integral enterprise architectures are required for radical process innovation (Piepenbrock & Fine, 2009)

If an incumbent firm fails to adjust its structure in response to the changing environment it will be unable to effectively compete and will potentially fail as shown below in Figure 6. With an extremely effective analogy, Piepenbrock and Fine drive this point home: "In biology and business, morphology trumps physiology – i.e. species type is more important than health of the beast. A weak cactus will outlive a strong oak…*in a desert*."

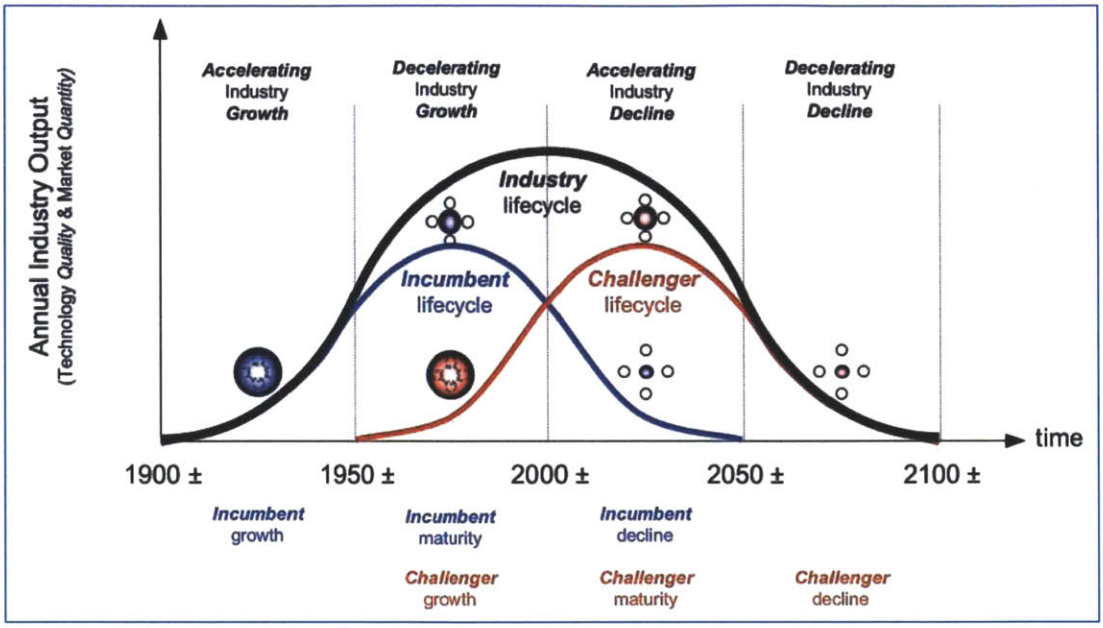


Figure 6: Industry lifecycle (Piepenbrock & Fine, 2009)

While Piepenbrock's framework elegantly explains why a firm's architecture can play a determining role in its long term success or demise, it is not very useful for examining the Air Force aircraft acquisition enterprise for precursors of collapse. As a sub-unit of the Air Force, the enterprise is shielded from many (though not all) aspects of competition. More importantly, the growth of the Air Force acquisition "industry" is controlled via the Defense department's budgeting process versus innovation and cost pressures generated by commercial market demand.

Marwa and Zairi look for links "between causes of corporate collapse/demise and the concept of quality." Their exploratory study finds there is a clear linkage between a firm's level of commitment to the concept of quality and the likelihood of eventual corporate failure. The implication of their work is that "corporations can only afford to ignore the concept of quality at their own peril." (Marwa & Zairi, 2008) This result likely is the result of competing firms utilizing quality-based measures to improve their competitive position. Firms that do not make such improvements will tend to lag behind and fail more frequently.

Lessons and techniques borrowed from the commercial world have been instrumental in improving the performance of government organizations such as the Air Force aircraft acquisition enterprise. However, because of the very different motivations behind the operation

of firms and government agencies, theories of collapse from the corporate world are for the most part not very applicable. Financial ratios are not kept and the nature of competition between entities is based upon budget and prestige vs. profit and share price.

Among both societal and corporate enterprise level explanations of collapse, Tainter's theory, based on marginal productivity, is the most applicable. By viewing the Air Force aircraft acquisition enterprise through the lens of Tainter's theory and what it portends are precursors to collapse, valuable insight is gained into why the Air Force aircraft acquisition enterprise continues to resist improvement in performance despite the multiple reorganizations and senior leader initiatives that have occurred over the past two decades.

Chapter 3 Tainter's Framework

While the previous chapter provided a review of collapse theories, this chapter focuses on Tainter's theory of collapse. The framework of the theory is explained and its applicability at the societal level is explored. In order to advance his theory of collapse and its reliance on the concept of changing cost/benefit ratios for a given investment in complexity, Tainter focuses on the behavior of four primary societal level processes. They are agriculture and resource production, information processing, sociopolitical control/specialization and overall economic production. The complexity of these processes varies from the very simple to highly complex depending on the society and time frame being examined (Tainter, 1988). Each area is reviewed and the lessons that also apply at the organizational level are highlighted.

3.1 Societal Level Processes

3.1.1 Agriculture and Resource Production

The first societal level process Tainter points to as evidence of declining marginal returns in the face of higher complexity is agriculture and resource production. He cites a number of papers from the 1960s and 1970s that show "that marginal returns on agriculture, in a subsistence economy, decline with increasing labor."

The simplest form of agriculture is commonly known as "slash and burn". In this type of farming, the forest is cleared and the resulting open space is exploited until the soil is depleted and resulting crop yields plunge. When this occurs, farmers clear yet more land and the process is repeated. In contrast, multi-cropping is a complex and intensive form of farming that produces multiple harvests over one year from a single piece of land. Tainter references Boserup (1965) who points out that "human labor per unit of agricultural output rises" as the intensity of farming increases. This additional human labor is required to perform "increasing land preparation, fertilization, and irrigation..." While population growth is often cited as the primary reason that drives a society to undertake more complex forms of agriculture, Tainter points out that "it is not necessary to accept the demographic-stress argument to grasp the point of immediate relevance. This is that marginal returns on agriculture, in a subsistence economy, decline with increasing labor." As shown in Figure 7 below, Tainter also reproduces a number of charts from Clark and Haswell (1966) that provide empirical evidence of decreasing average and marginal productivity of labor hours.

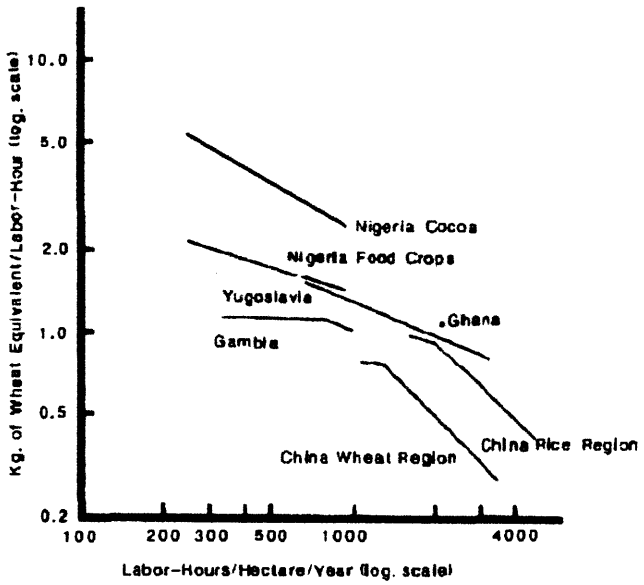


Fig. 2. Average returns of agriculture (after Clark and Haswell 1966: 83). Reproduced by permission of Macmillan Publishers Ltd., London and Basingstoke.

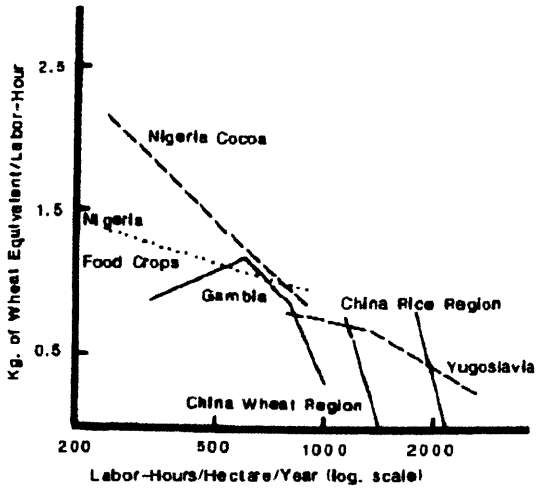


Fig. 3. Marginal returns of agriculture (after Clark and Haswell 1966: 84). Reproduced by permission of Macmillan Publishers Ltd., London and Basingstoke.

Figure 7: Evidence of Declining Returns in Agriculture (Tainter, 1988)

Tainter concludes the section by pointing out that the same declining marginal returns can be observed in both animal husbandry activities as well as energy and minerals production. Tainter's overarching explanation for this pattern is:

> Among whatever set of resources a population obtains, for whatever reasons, the law of diminishing returns is likely to apply. As demand for a commodity grows, increased production will at some point mean depletion or insufficiency of the least costly sources. At that point, more costly sources must be used, with declining marginal returns." (Tainter, 1988)

3.1.2 Information Processing

Information processing is the next societal level process reviewed by Tainter for signs of diminishing returns. Within this category he discusses a number of information intensive activities including medical research and development as well as investments in education. As with agriculture, Tainter shows that increasing levels of investment in each area have resulted in declining marginal returns. In regards to examining the Air Force aircraft acquisition enterprise, the key insight made by Tainter within this section is that in order to deal with increasing information complexity, a society must expend resources to prepare people to perform increasingly specialized roles. Tainter concludes that such highly specialized training yields benefits that "may apply only to narrow segments of the society, while its costs are spread throughout the system." (Tainter, 1988)

3.1.3 Hierarchical Specialization and Overall Economic Productivity

Next Tainter shifts from individual specialization to the growth of "hierarchical specialization" which is a succinct way of describing the growth in administrative levels of management within an organizational structure. While acknowledging Parkinson's (1955) powerful arguments concerning the growth of self-serving governmental bureaucracies, Tainter provides evidence that "a pattern of increasing hierarchical specialization characterizes the private sector as strongly as Parkinson has demonstrated for the public." Rather than blaming misaligned incentives, Tainter attributes the growth in hierarchy to complex organizations having to allocate "ever larger portions of their personnel and other resources to administration... because increased complexity requires greater quantities of information processing and greater integration of disparate parts." (Tainter, 1988) As an organization puts in place administrative solutions to solve problems, they tend to remain in place and become cumulative, reducing marginal returns.

Lastly, Tainter looks at overall economic productivity and cites evidence that "complex societies with large, well-developed economies have historically been able to sustain only rather inferior rates of economic growth." He attributes this decline in growth rate to both diminishing marginal returns in innovation and the need to expend resources to maintain existing infrastructure and organizations rather than create new structures.

3.2 Societal Level Evaluation

Once Tainter describes the development of his model concerning the relationship between increasing complexity and lower marginal returns, he evaluates the framework in a qualitative manner across three cases of societal collapse. Tainter acknowledges that

> The ideal way to evaluate this model would be to isolate and quantify the costs and benefits of various instances of social complexity, and to plot changes in these costs and benefits through time. Long-term periods of significant declining marginal returns in complexity should be periods of vulnerability to collapse. (Tainter, 1988)

The problem Tainter has in doing so is none of his three ancient societal case studies "kept the kinds of detailed records necessary for such a quantitative test." Therefore, Tainter chooses instead to show that his framework helps explain collapse in each of the three cases which were chosen to cover a wide range of sociopolitical complexity. His three case studies include the collapse of the Western Roman Empire, the Classic Maya of the Southern Lowlands and the Chocoan Society of the American Southwest.

3.2.1 The Western Roman Empire

In the case of the Western Roman Empire, Tainter focuses on two areas where the Empire encountered diminishing marginal returns. The first is conquest. Tainter cites evidence that shows that Rome established and maintained its empire using the spoils gained by dominating its neighbors. He points out that initially, the returns from this strategy were "spectacularly high". However, as the Empire became larger and larger, each successive conquest became less profitable and was unable to cover the cost of maintaining the status quo including a large standing army and provincial administration. Territory and peoples conquered earlier inevitably transitioned from being sources of plundered wealth to being net consumers of resources due to the costs of defense and administration. Citing Hammond (1946), Tainter points out that later conquests such a Britain and Dacia "probably never paid for themselves, for these were poor, distant, frontier provinces." (Tainter, 1988) The diminishing returns derived from conquest forced the empire to rely on the taxation of yearly provincial output and the sale of capital in the form of government owned lands and treasures.

The second instance of diminishing marginal returns Tainter discusses is the value of the empire itself to its subjects. Initially, accepting Roman rule provided a high level of return in the form of protection from adversaries and organizational structure in the form of a competent

governmental administration. However, as the empire and its bureaucracies grew, the empire became increasingly reliant on its own internal populations for income (via taxation) yet provided no additional benefits.

> If accounts are to be believed, at least a portion of the overtaxed peasantry openly welcomed the relief they thought the barbarians would bring from the burdens of Roman rule. And a much larger portion were evidently apathetic to the impending collapse. It seems clear that the Empire had at least partially lost its legitimacy. The costs of empire had risen dramatically, while in the face of barbarian successes the protection that the State could offer to many of its citizens proved increasingly ineffectual. To many, there were simply no remaining benefits to the Empire, as both barbarians and tax collectors crossed and ravaged their lands. (Tainter, 1988)

The case of the Roman empire provides two insights concerning diminishing marginal returns and organizations. The first is that organizations should be cautious concerning increases in size and complexity that are funded by windfalls. If unheeded, organizations may find themselves underresourced under steady state conditions and prone to a collapse.

The second insight is that an organization's survival is dependent on the willing participation of its members. If people perceive that the costs of participation outweigh the returns, they will cease to participate and will withdraw support from the organization. In the case of the Roman Empire, Tainter argues that both of these eventualities doomed the Empire to collapse. It could not maintain its size and level of complexity in a resource constrained steady-state environment without putting undue pressure on its populace who eventually withdrew their support.

3.2.2 Classic Maya Civilization

In the case of the Mayans, Tainter argues that sociopolitical complexity increased in response to a need for security. Since most of Southern Mayan territory was environmentally similar, there was little diversification between agricultural outcomes across the region. This homogeneity did not allow for different communities within the greater society to trade with one another to average out agricultural surpluses and failures. Instead, when crop failures occurred, each population center tended to resort to conflict, seizing what was necessary for survival from weaker, neighboring communities. This behavior put a complexity-increasing feedback loop into motion where each Mayan community strove to demonstrate its relative strength in the form monument construction and population size as a form of deterrence (Figure 8).

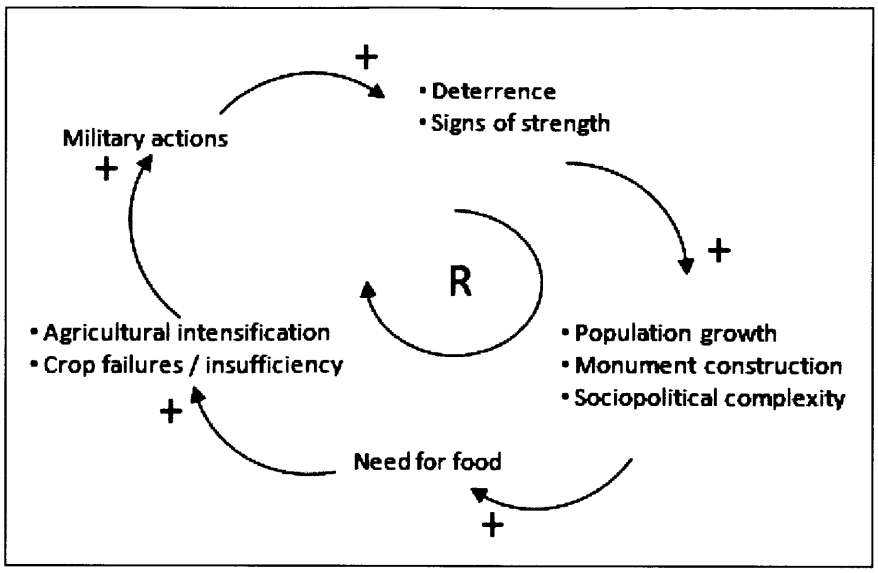


Figure 8: Mayan Complexity Spiral

As this reinforcing cycle continued, the increase in crop yields failed to keep up with what was necessary to support the increasing size of the "elite hierarchies, military and civil specialists, and an artisan class" as well as the underlying peasant population growth. In congruence with Tainter's framework:

> ...the marginal return on this investment deteriorated over time. Ever increasing investments in warfare, complexity, monumental construction, and agricultural intensification yielded no proportionately increasing return in the health and nutritional status of the populace. To the contrary, as the demands on the support population increased, the benefits accruing to that population actually declined...Whether the final push was from invaders, environmental deterioration, withdrawal of peasant support, internal conflict, or some combination of these, the fact of the collapse is no surprise. It was a predictable adjustment to an otherwise unsolvable dilemma. (Tainter, 1988)

The primary insight gained from reviewing the Mayan collapse is that leaders should be wary of reinforcing feedback when increasing the level of complexity within their organizations. If the marginal return on increased complexity is decreasing, continuing to add more is an unsustainable plan for the future.

3.2.3 Chacoan Society of the San Juan Basin

Tainter's last case study focuses on the Chacoan society of the American Southwest. It was a society that existed in what is now northwestern New Mexico. This ancient society has also been referred to as the Anasazi and as the Ancient Pueblo People (Ambler, 1977). In contrast to the Mayan case study, this society was built upon agricultural diversification. Since the society

existed in an arid and generally inhospitable environment, it relied upon a network of "Great Houses" which acted as administrators and trading centers linking different regions of the society. As the society grew, the number of trading centers increased and expanded out from the Chaco Canyon hub of the society. According to the sources cited by Tainter, these later great houses were known as "Chacoan Outliers" or simply "Outliers". This hub and spoke structure initially provided the society with a "valuable return on its investment in complexity by lowering the administrative cost, and increasing the effectiveness, of an energy averaging system. Beyond its initial establishment, however, further expansion of this system may not have been so advantageous." (Tainter, 1988) As the number of Outliers grew, the distance between them decreased and reduced each one's geographical span of control.

> After enough Outliers had been established in the region to maximally exploit its environmental diversity, the addition of each new one reduced the effectiveness of the system...The overall effectiveness of the network deteriorated. The result was that later Chacoan communities realized a proportionately lower advantage when some region experienced a surplus, and proportionately less could be distributed to each community experiencing a deficit. (Tainter, 1988).

Tainter asserts that this pattern ultimately set the stage for the society's collapse when a "severe, prolonged drought" occurred from 1134-81 A.D. The network that had carried the society through earlier droughts had become too inefficient and strained to withstand the shock. "What the final drought may have accomplished was to change the curve of marginal return on investment in complexity from a smoothly to a sharply declining one, and so to hasten the end." Communities in the southern Basin region then effectively opted out of the system since they "saw that opportunity and security lay elsewhere." (Tainter, 1988)

An interesting insight gained from the Chocoan collapse is that in the face of decreasing system effectiveness, some participants will elect to withdraw if doing so boosts their own marginal return. Organizational leaders should be mindful of this when deciding whether to maintain or expand a system's complexity in the face of decreasing marginal returns. In order to remain viable in the long term, a system must maintain a level of productivity that discourages defection.

Chapter 4 Supporting Concepts: Diseconomy of Scale, Incentives and Organizational Structure

In order to better understand the workings of the Air Force aircraft acquisition enterprise, it is important to also grasp the concepts of diseconomy of scale, incentives and organizational structure. Each of these concepts provides insight into the challenges the Air Force aircraft acquisition enterprise faces while striving to operate effectively and efficiently.

4.1 Diseconomy of Scale

As projects and organizations increase in size, both economies and diseconomies of scale may occur. Economies of scale often result when "firms produce large quantities, the technology and product design are stable, processes have been standardized, automation is effective and skill levels of the workforce are steadily improving." (Valerdi, Friedman, & Marticello, 2011)

Within the Air Force aircraft acquisition enterprise, many of these factors do not apply. Production quantities are small and the work is far from standardized. In such cases, as an organization's or project's size increases, diseconomies of scale become evident and can limit performance.

One way to avoid diseconomies of scale entirely is to remain small. George Friedman, a former chief technical officer at Northrop Corporation, is a strong advocate for keeping project design and build teams as small as feasibly possible. He points out that in its first decade of existence, "no fewer than 14 new aircraft were conceived, designed, built, tested, produced and delivered." According to Friedman, this was accomplished by centralizing the architecture of each project and working with small, dedicated teams. Northrop "minimized the complexity of the total effort by minimizing formality and the number of interactions." (Valerdi, Friedman, & Marticello, 2011)

There are a number of theories on why diseconomies of scale appear. Before briefly outlining them, it is insightful to understand the relationship between the scale of an organization's operation and the costs encountered for it to operate.

> It is necessary to recognize that a firm's expansion path does not remain linear as the input proportions change. A firm enjoys economies of scale when it doubles its output for less than twice the cost. Diseconomies of scale occur when doubling of output requires more than twice the cost. In other words, cost-output elasticity E_c

$$E_c = \frac{\Delta C/C}{\Delta q/q} = \frac{\Delta C/\Delta q}{C/q} = \frac{Marginal\ Cost}{Average\ Cost}$$

i.e., the percent change in cost per the percent change in output. When E_c is greater than 1, there are diseconomies of scale.

Diseconomies of scale work to limit the size of endeavors. Canback (2002) observes: "If diseconomies of scale do not exist, then we would presumably see much larger companies than we do today. Why are there no corporations with several million employees? No business organization in the United States has more than one million employees or more than ten hierarchical levels." (Valerdi, Friedman, & Marticello, 2011)

4.1.1 Network Complexity Theory

One reason diseconomies of scale can emerge as an enterprise grows in size has to do with what happens as the number of components in a system, people in an organization or nodes in a network increases.

Brooks (1975) and Conte (1986) suggest that diseconomies occur in systems when the number of interactions and interfaces in systems rise faster than the number of components. At a minimum, the number of possible binary two-way interactions between n components or subsystems is n(n-1), which certainly grows faster than the number of components or nodes. Many researchers have pointed out that merely examining the binary interactions in complex systems is insufficient. This is important since the primary way managers deal with increasing scale and complexity is to introduce hierarchical modularity into systems and organizations. (Baldwin, 2001) While these modules provide additional functionality, they also increase the cost of operating the complete system or organization. Whitney points out that these increasing costs are

> ...due to the need to test, and rises in proportion to the number of modules if the behavioral influence of each on the whole system is easily seen, thus requiring no additional tests beyond the module level. But the cost rises exponentially if the influence of a module is hard to see, requiring every combination to be tested. (Whitney, 2003)

Whether or not every combination is tested to ensure a true understanding of system operation, it is likely that the system "has sneak paths or emergent interconnections" which will result in unintended influences between modules and levels within the hierarchy. (Whitney, 2003) It is therefore expected that as a system or organizational network increases in scale, these unaccounted interactions can place a large burden on the enterprise. Employing the viewpoint of the power set—the set of all subsets of a set of n items, far more complexity is revealed to be present than what is expected from binary relations alone. Therefore, the complexity of the problem in the form of interactions grows as 2^n rather than approximately n^2 – substantially faster. The sources of these additional interactions are often unintended and unanticipated links between subsystems. (Valerdi, Friedman, & Marticello, 2011)

4.1.2 Emergence

The concept of emergence can also result in diseconomies of scale. Ackoff (2000) asserts for a system to exist, it must have properties or behaviors that can only be generated by all of the elements operating together. Fromm echoes this assertion in describing the concept of emergence used in introductory text books on complex systems: "A property of a system is emergent, if it is not a property of any fundamental element, and emergence is the appearance of emergent properties and structures on a higher level of organization or complexity." (Fromm, 2005) Simply put, emergence is what makes a system worth constructing. The value generated by the system as a whole is greater than the value generated by the systems components acting independently. However, emergent properties of a complex system or organization can also be of an unintended and detrimental nature as well:

> An example of detrimental emergence is the concept of bureaucratic insularity where managers within a large organization become insulated from their subordinates and shareholders. As a result of this insulation from accountability, a tendency to place personal gain ahead of overall enterprise performance emerges. (Canback, 2002) This phenomenon was directly observed [by George Friedman] during his service as an executive at Northrop Corporation. The largest meeting rooms in the company were built to accommodate government review teams—which often outnumbered the engineers actually working on the reviewed program. John Moore commented:
>
> > It is necessary that the increasing levels of size and complexity require more personnel, but there is a growing proliferation of activities by individuals who enjoy substantially above average standards of living who contribute little or nothing to progress, and either interfere with the productivity of others or live on their output, endlessly churning words, paper and contacts among themselves. They are the unnecessary administrative personnel and activities which are required to meet the demands imposed by excessive regulations and bureaucracies. (Moore J.)
>
> Bureaucratic insularity and its detrimental effects can be amplified by the nature of the organizational network. Gladwell speaks about a class of people known as connectors, who have significantly larger social networks than average and therefore have the ability to exert greater influence. (Gladwell, 2000) The presence of such individuals tends to result in a network that more closely exhibits a scale-free nature where some nodes have many more connections than others with the distribution following a power law. (Whitney, 2003) In scale free networks, the influence of such high-connection nodes over the behavior of the system can be extremely large and disproportionate. (Valerdi, Friedman, & Marticello, 2011)

4.2 Incentives

Grossi (2003) defines an enterprise's stakeholder as "any group or individual that directly or indirectly affects or is affected by the level of achievement of an enterprise's value creation process." Broadly, the list of primary stakeholders of an enterprise includes the owners and

managers of the enterprise as well as employees, customers and government regulators. Performing a stakeholder analysis is a powerful way to reveal an enterprise's primary stakeholders and aids in understanding their interests. These interests will incentivize stakeholders to behave in ways that ultimately may or may not align with the goals of the enterprise.

When the goals of the organization and its primary stakeholders are aligned, the actions that stakeholders take in their own interest generally also benefit the organization as a whole. Extensive research has been conducted in employment contracts and agency theory in an effort to understand and shape the motivations and behaviors that occur amongst individuals within organizations.

As discussed above, one negative phenomenon that can occur in large organizations is bureaucratic insularity. This can result in a divergence between the goals of the organization and the self-interest of managers who are insulated from accountability within a large organization. In addition to being a potential diseconomy of scale, the way people are managed and compensated within a large organization can result in a misalignment of incentives:

> Rasmusen and Zenger point out "the costs of organizing rise with firm size because larger firms are less efficient than smaller firms in offering contracts that induce high effort and attract high-ability workers" (Zenger, 1990) Small firms tend to compensate employees using incentive contracts that reward higher levels of performance with higher levels of compensation. On the other hand, larger firms tend to rely on fixed-wage contracts and rely on management to monitor individual and group performance. Rasmusen and Zenger go on to conclude that smaller firms are able to extract higher levels of effort from their employees than larger firms. (Zenger, 1990) This is congruent with what we have seen in actual practice. As system development teams grow, productivity increases as the talents and resources of the group are harnessed. However, as group size increases, diseconomies of scale begin to surface in the form of freeloading and ineffective coordination and communication. (Valerdi, Friedman, & Marticello, 2011)

Primary stakeholders who reside outside of an enterprise's organizational structure may exercise significant power over an enterprise. They may control resources or approvals that are necessary for an organization to successfully operate. Unfortunately, these external stakeholders may be incentivized to behave in ways that run counter to the primary goals of the enterprise due to competing interests.

Elected legislators are an example of a stakeholder with competing interests. Legislators must balance the desires of those who elected them with other interests which include the

effective operation of government and adherence to their political party's ideology or framework. After examining the voting records of the United States Senate from 1979 to 1980, Sam Peltzman concluded that when dealing with issues of economic interest, the votes of senators closely adhered to the desires of their electorate and contributors. Only when economic benefits were less relevant did political party or ideology provide greater explanatory power (Peltzman, 1981).

Incentives clearly drive behavior, both at the individual and group level. A stakeholder analysis can be used to reveal the level of alignment between the interests of the enterprise and those of its primary stakeholders.

4.3 Organizational Structure

There are primarily three ways to structure an enterprise whose primary purpose is to manage projects. The first is the traditional hierarchical organization where each of the underlying divisions is based upon a functional specialty. According to Youker (1977), the strength of this structure lies in "its centralization of similar resources." This centralization helps with the functional development of employees since all members of a division have training and experience within the same functional discipline (Figure 9). This type of organizational structure tends to incentivize functional excellence since employees are judged by those within their same profession.

A key disadvantage of a functional structure is "when it is involved in multiple projects, conflicts invariably arise over the relative priorities of these projects in the competition for resources." (Youker, 1977)

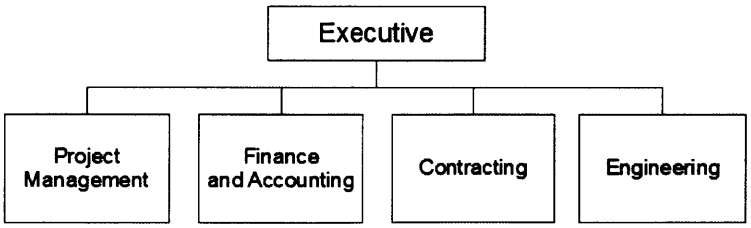


Figure 9: Functional Organization

The second basic organizational structure is one that is organized around each individual project (Figure 10). This structure is often referred to as a project-based structure. A project manager operating within this type of structure "is given considerable authority over the project and may acquire resources from either inside or outside the overall organization. All personnel

on the project are under the direct authority of the project manager for the duration of the project." (Youker, 1977) The main advantage to this type of structure is that the focus is clearly placed on project success. However, this approach also has its disadvantages. Resources are often duplicated across multiple projects. The skill level of personnel may also degrade since functional departments have little authority to make professional growth a priority.

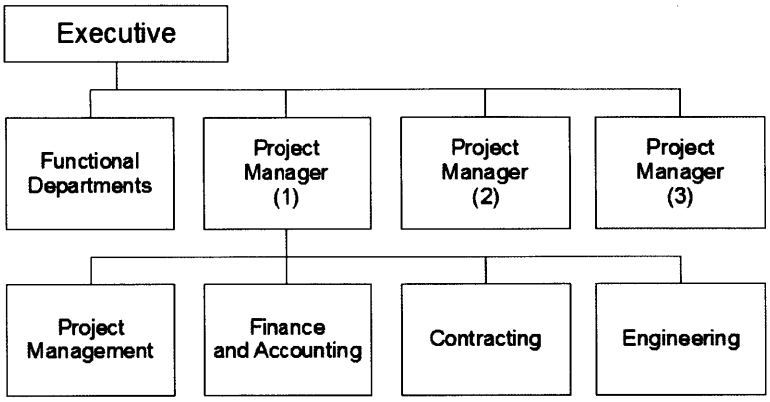


Figure 10: Project-based Organization

The third basic organizational structure is the matrix and is the most commonly seen since it tries "to maximize the strengths and minimize the weaknesses of both the project and functional structures." (Youker, 1977) The structure attempts to balance the needs of project managers with effective management of functional personnel Figure 11. The main disadvantage with this structure is that personnel assigned to projects have two supervisors; the project manager and their functional supervisor. Conflicting direction can generate confusion and create tension between project managers and functional leads. A common source of tension is assignment of high quality personnel. Each program manager naturally wants the best personnel working on his team and conflicts may occur if the functional lead chooses to place them on another team.

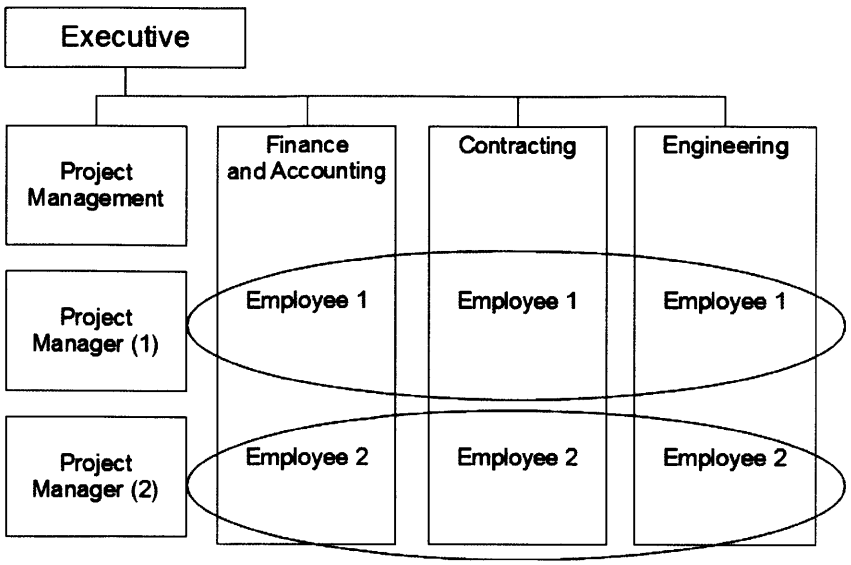


Figure 11: Matrix Organization

If an enterprise has existed long enough, it is likely that it has experienced all three structures. Since organizational structure is very visible it is often the first thing modified during efforts to improve the performance of an enterprise.

Chapter 5 Air Force Aircraft Acquisition Enterprise Stakeholder Analysis

Prior to applying Tainter's theory of collapse to the Air Force aircraft acquisition enterprise, it is helpful to understand who the primary stakeholders are and how they interact within the enterprise. Grossi (2003) as well as the MIT Lean Advancement Initiative's *Enterprise Strategic Analysis for Transformation* methodology provide guidance for completing a stakeholder analysis. A top-level stakeholder analysis of the Air Force aircraft acquisition enterprise was performed that included identification of the key stakeholders, a review of their responsibilities and a listing of the value each stakeholder group extracts and delivers from the enterprise.

5.1 Stakeholder Identification

Based upon Defense Acquisition University training materials and personal experience, the primary stakeholders of the Air Force aircraft acquisition enterprise can be categorized into six primary stakeholder groups as shown below in Table 1.

Table 1: Stakeholder Categories within the Air Force Aircraft Acquisition Enterprise

Categories	Stakeholders
Users (Customers)	• Chief of Staff of the Air Force (CSAF) • Combatant commands • Air Force major commands • Airmen in operational roles
Senior Acquisition Leadership	• Office of the Undersecretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) • Secretary of the Air Force (SECAF) • Assistant Secretary of the Air Force for Acquisition (SAF/AQ) • Program Executive Officers (PEOs)
Acquisition Workforce	• SAF/AQ workforce • Product center workforce (Military, Civ, Ctr)
Defense Contractors	• Shareholders • Defense contractor workforce
Supporting agencies (External)	• Defense Contract Management Agency • Defense Contract Audit Agency • Small Business Administration • General Services Administration
US Government (Legislative Branch)	• Legislators (House and Senate) • Congressional staffers • US Government Accountability Office (GAO)
Taxpayers	• US Population

5.1.1 Users (Customers)

Broadly speaking, the customers of the Air Force aircraft acquisition enterprise are those who will use the weapon systems and supporting equipment that is acquired to perform military missions. Within the acquisition community, these customers are often referred to as "users". Predominantly, these users are Airmen—operational Air Force members. Each of the military services has the responsibility to organize, train and equip forces for use by combatant commanders (U.S. Joint Chiefs of Staff). The Air Force Chief of Staff is responsible for carrying out these actions for the Department of the Air Force.

When engaged in operations, airmen fall under the authority of combatant commanders. Therefore, by extension, the combatant commands should also be considered users. In fact, combatant commanders have frequently exerted pressure to ensure their needs are met by each of the services.

Adhering to the Joint Capabilities Integration and Development System (JCIDS) process, requirements for new systems within the Air Force are generated by each of the operational Air Force major commands such as Air Combat Command and Air Mobility Command and are ultimately endorsed by the CSAF and the Joint Chiefs of Staff.

5.1.2 Acquisition Senior Leadership

At the broadest level, the senior leadership of the Department of Defense relies upon three inter-related systems (processes) to make decisions concerning requirements, planning, programming and budgeting and acquisition as shown in Figure 12.

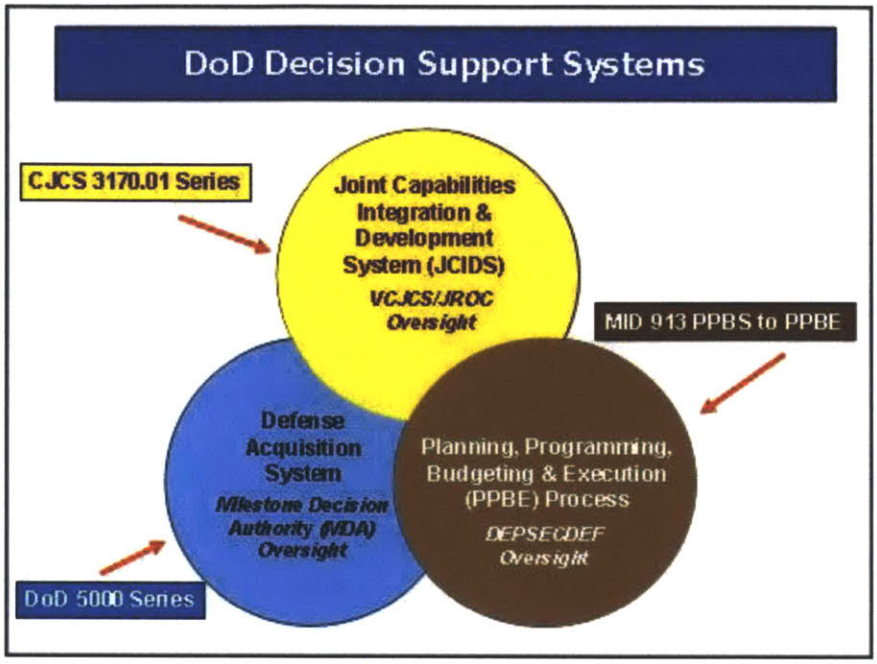


Figure 12: DoD Decision Support Systems (DAU, 2010)

Each of these systems empower a set of leaders within the executive branch to make decisions within one or more of the systems. The authority to acquire weapon systems resides in a specialized chain of command that flows from the Department of Defense to the services as outlined by Defense Acquisition System regulations. "DoD Directive 5000.01, The Defense Acquisition System, provides the policies and principles that govern the defense acquisition system. DoD Instruction 5000.02, Operation of the Defense Acquisition System, in turn establishes the management framework that implements these policies and principles" as shown in Figure 13 (DAU, 2010)

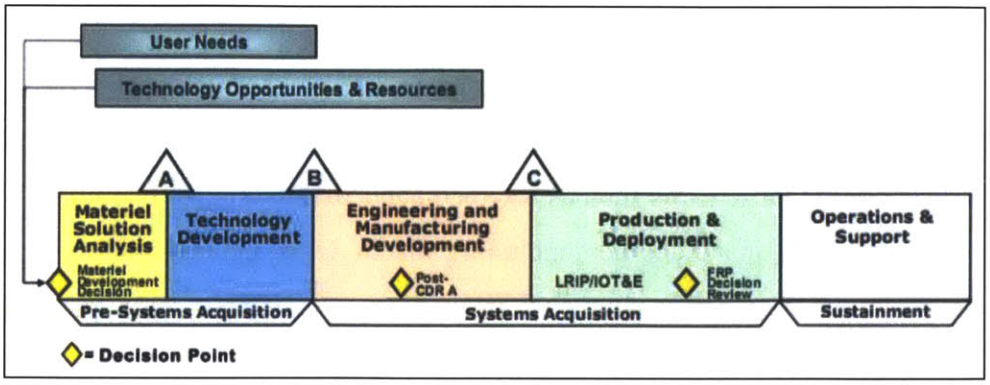


Figure 13: DoD 5000 Acquisition System--Lifecycle view (DAU, 2010)

At the DoD level, this process is led by the Defense Acquisition Executive (DAE) who also holds the title of Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)). The Air Force aircraft acquisition enterprise operates within this overarching DoD framework and is managed by a leadership structure led by the Assistant Secretary of the Air Force for Acquisition (SAF/AQ). Authority flows from this individual to Program Executive Officers (PEOs). These PEOs manage a portfolio of programs, each led by a program manager. This stakeholder group is responsible for managing the acquisition process as well as each program to ensure products are acquired and delivered to the users (DAU, 2010).

5.1.3 Acquisition Workforce

The acquisition workforce stakeholder group consists of the rank and file employees within the Air Force aircraft acquisition enterprise. This workforce includes military members assigned to the Air Force aircraft acquisition enterprise, government civilian employees and support contractors. As of September, 2011 this stakeholder group included just over 5,600 individuals (Fecher, 2011). Within this group, there are a number of functional specialties, including contracting officers, program managers, financial managers and logisticians. They are charged with completing the day to day tasks as outlined in Defense and Air Force acquisition system regulations.

5.1.4 Defense Contractors

Defense contractors are a powerful group of stakeholders within the Air Force aircraft acquisition enterprise. They are responsible for designing and producing the equipment that is ultimately acquired by the Air Force aircraft acquisition enterprise. Their efforts are primarily governed by contracts awarded and managed by the Air Force aircraft acquisition enterprise workforce. Example firms within this stakeholder group include Boeing, Lockheed Martin and Northrop Grumman. Besides the "Big Three" prime contractors, this group also includes all subcontractors including large firms such as Raytheon and BAE Systems. Each firm within this group includes its own set of stakeholders including shareholders, management and employees.

5.1.5 External Supporting Agencies

Outside of the workforce assigned to the Air Force aircraft acquisition enterprise, there are a number of government agencies which support the enterprise externally. Some of these activities

are supportive in nature while others are performed in an oversight type manner. The agencies exercise a great deal of power and can affect the content and award of contracts.

Example agencies that fall within this category of stakeholders are the Defense Acquisition University (DAU) and the Defense Contract Audit Agency (DCAA). According to DAU's mission statement, the purpose of the organization is to "Provide a global learning environment to support a mission-ready Defense Acquisition Workforce that develops, delivers, and sustains effective and affordable warfighting capabilities." In addition to providing training and education, DAU manages the acquisition certification process, provides direct assistance to acquisition organizations and maintains an extensive library of on-line training and reference material (DAU, 2010). The DCAA provides both support and oversight:

> The DCAA, while serving the public interest as its primary customer, shall perform all necessary contract audits for the Department of Defense and provide accounting and financial advisory services regarding contracts and subcontracts to all DoD Components responsible for procurement and contract administration. These services are provided in connection with negotiation, administration, and settlement of contracts and subcontracts to ensure taxpayer dollars are spent on fair and reasonable contract prices." (Defense Contract Audit Agency).

5.1.6 Legislative Branch

Article I, Section 8 of the U.S. Constitution provides the Congress with the authority to raise and support armies and a navy (U.S. Const. art. I, § 8). It is this power of the purse which makes the legislative branch the most powerful of stakeholder groups. The primary stakeholders within this group are the legislators themselves, both in the House of Representatives and the Senate. Also within this stakeholder group are the supporting congressional staff members. Career congressional staffers dedicated to defense issues are highly knowledgeable and exert considerable influence. Another stakeholder in this group is Congress's investigative arm, the Government Accountability Office. The GAO "is an independent, nonpartisan agency that works for Congress. Often called the "congressional watchdog," GAO investigates how the federal government spends taxpayer dollars." Members of Congress often call upon the GAO for the following purposes:

- auditing agency operations to determine whether federal funds are being spent efficiently and effectively;
- investigating allegations of illegal and improper activities;
- reporting on how well government programs and policies are meeting their objectives;
- performing policy analyses and outlining options for congressional consideration; and

- issuing legal decisions and opinions, such as bid protest rulings and reports on agency rules. (U.S. GAO)

5.1.7 Taxpayers

The last group of stakeholders are the U.S. taxpayers. While they do not play a direct role in the day-to-day operation of the Air Force aircraft acquisition enterprise, they are ultimately the source of funding and authority for the enterprise as a whole. Their perceptions concerning the operation of the system can greatly influence the behavior and motivations of elected officials and their subordinate stakeholders within the legislative branch.

5.2 Stakeholder Responsibilities and Value Exchange

Each of the stakeholder groups identified above have responsibilities within the context of the Air Force aircraft acquisition enterprise. Table 2 below provides a listing of the top-level responsibilities of each group.

Table 2: Responsibilities of Stakeholders within the Air Force Aircraft Acquisition Enterprise

Stakeholder Group	Defense Acquisition System Responsibilties
Users (Customers)	• Provide requirements • Advocate for and obtain funding • Program priority recommendations
Senior Acquisition Leadership	• Resource allocation decisions o Funding and manpower • Enforce program priorities • Programming and budgeting

Acquisition Workforce	• Manage programs
	  o Define schedules
	  o Estimate costs
	  o Define technical specifications
	• Initiate and maintain Contracts
	• Comply with law and policy

Defense Contractors	• Provide capabilities and products • Perform as contracted • Innovate and preserve advantage • Comply with law and policy
Supporting agencies (External)	• Enhance enterprise performance • Ensure compliance with law and policy
US Government (Legislative Branch)	• Appropriations and authorizations • Serve constituents
Taxpayers	• Elect legislators • Provide funding

Each primary stakeholder group both contributes and extracts value from its interaction with the Air Force aircraft acquisition enterprise. It is important to understand these interactions because they act as incentives and motivations for behavior. Table 3 provides a top-level listing of the values extracted and contributed to the Air Force aircraft acquisition enterprise by each of the primary stakeholder groups.

Table 3: Air Force Aircraft Acquisition Enterprise Stakeholder Value Exchange

Value Extracted From the Enterprise	Stakeholder Group	Value Contributed to the Enterprise
• Weapon systems • Products and services • Delivery Timeliness • Cost-effectiveness	Users (Customers)	• Requirements • Operational insight • Program advocacy
• Weapon systems • Program management • Accurate estimates • Expert knowledge • Regulatory Compliance	Senior Acquisition Leadership	• Program decisions • Program priorities • Resource allocations • Support for Air Force aircraft acquisition enterprise
• Employment • Suitable training • Support	Acquisition Workforce	• Acquisition strategy and execution • Contract actions • Source selections • Subject matter expertise
• Compensation • Profits • Risk reduction • Clear expectations	Defense Contractors	• Weapon Systems • Products and services • Subject matter expertise • Program execution
• Utilization • Support • Compliance	Supporting agencies (External)	• Education/training • Policy enforcement • Approvals • Oversight
• Weapon systems • Employment • Compliance	US Government (Legislative Branch)	• Appropriations • Authorization • Approvals • Oversight
• Weapon systems • Stewardship	Taxpayers	• Funding • Support

The primary value of the Air Force aircraft acquisition enterprise is producing weapon systems as well as supporting products and services. These weapon systems are used by operational users to generate combat capability which by extension provides national security to both the government as well as taxpayers.

Value is also extracted from the Air Force aircraft acquisition enterprise in the form of compensation and profits, primarily by the Air Force aircraft acquisition enterprise workforce and defense contractors. Support in the form of sponsorship and funding is also provided to supporting agencies. Lastly, a key value extracted from the enterprise is employment. This is a key concern for the legislative stakeholder group. Employment within a legislator's jurisdiction may include both government and/or contractor positions. Since these jobs tend to be highly skilled and well-paying, they are highly sought after and zealously protected by legislators at all levels of government. The predominant value contributed by the primary stakeholder groups to the enterprise arrives in the form of requirements, funding and approvals.

This top-level stakeholder analysis provides an understanding of the key players within the Air Force aircraft acquisition enterprise. These stakeholders drive the both the structure and operation of the Air Force aircraft acquisition enterprise. Understanding their motivations and contributions provides a basis for examining the Air Force aircraft acquisition enterprise in the context of Tainter's theory.

Chapter 6 Research Methodology

Since Tainter developed and applied this theory at the societal level, careful consideration was given to how best to apply it at the enterprise level in an analysis of the Air Force aircraft acquisition enterprise. In each of his societal case studies, Tainter followed a common pattern. The first step was articulating how and where complexity grew in the society over time. This was done by citing sources that documented increases in complexity within one of his four primary societal processes: agriculture and resource production, information processing, sociopolitical control/specialization and overall economic production. Next, Tainter focused on evidence of diminishing marginal returns within these processes as complexity within them grew. Lastly, Tainter described what impact the declining returns had on the society and how they culminated in an increased probability of collapse.

A similar research methodology was followed for the analysis of Air Force aircraft acquisition enterprise. First, evidence of complexity was gathered across three primary process areas: personnel specialization/organizational structure, resource management, and regulatory guidance/policies. Next, evidence of diminishing marginal returns in the effectiveness of the enterprise was documented. Information was then gathered on what actions were took in an effort to improve the performance of the enterprise. In this area, the focus was on the last 20 years, and was concentrated on the internal workings of the Aeronautical Systems Center.

6.1 Archival Records

A tremendous amount of information was obtained from the archival records maintained by the Aeronautical Systems Center History Office. Specifically, annual historical reports authored by staff historians as well as archived organizational documentation were used. The ASC Historian, Mr. Henry Narducci and his assistant historian, Ms. Tasha Hairston provided access to the unclassified archives and provided guidance on where to locate particular types of information.

In addition to the ASC history office, a considerable amount of information was gathered from material produced and placed on-line by the Defense Acquisition University (DAU) and the Office of the Secretary of the Air Force for Acquisition (SAF/AQ)

The DAU maintains a large repository of defense acquisition training and guidance information on line. This information includes defense acquisition processes, recommended practices, and regulatory guidance. Documentation types include course materials, articles, tool

kits and guidebooks. One DAU source that was particularly useful was the Defense Acquisition Guidebook which serves as a reference for acquisition policies and a "discretionary best practices guide" (DAU, 2010)

Another source of information concerning the acquisition policies and procedures of the Air Force aircraft acquisition enterprise was the Office of the Assistant Secretary of the Air Force for Acquisition (SAF/AQ). While also acting in a supervisory role over the Air Force aircraft acquisition enterprise, SAF/AQ is also responsible for ensuring that the acquisition workforce is properly trained as required by law, Department of Defense and Department of the Air Force regulations (Office of the Assistant Secretary of the Air Force). SAF/AQ is aided in this effort by the Air Force Materiel Command (AFMC) which is the Air Force major command tasked with managing, training and equipping the Air Force aircraft acquisition enterprise workforce.

All of the above archival sources provided evidence of system complexity. The ASC annual historical reports were a primary source of information concerning changes over time in the enterprise's organizational structure as well as information on what the responses of leadership were to perceived diminishing returns and inadequacies in Air Force aircraft acquisition enterprise performance. Information concerning complexity within the areas of resource management was gathered primarily from DAU materials dealing with financial management and program control. DAU and SAF/AQ were primary sources for information concerning defense acquisition regulations and policies. The GAO was also a very useful source for historical program information.

6.2 Interviews

A number of interviews were conducted in order to gain first hand insight concerning the operation of the Air Force aircraft acquisition enterprise. Interviewees were categorized by their seniority and level of experience as shown below in Table 4.

Table 4: Interviewee Demographics

Interviewee Category	Interviewees

Senior-level personnel
• Significant defense acq experience
  ○ Greater than 10 years exp.
	• Military (2)
	  ○ Rank of Colonel or higher
	• Government Civilians (5)
	  ○ Grade of GS-15 or SES
	• Defense Contractors (3)
	  ○ Senior managers / vice-presidents

Mid-level personnel
• Moderate defense acq experience
  ○ Greater than 5 years exp.
	• Military (5)
	  ○ Rank of Major or Lt Colonel
	• Government Civilians (2)
	  ○ Grade of GS-12 –GS-14

Low-level personnel
• Some defense acq experience
  ○ Less than 5 years exp.
	• Military (2)
	  ○ Rank of Captain

Interviews primarily served two research purposes. The majority of interviews were used to gain insight into what individuals working within the Air Force aircraft acquisition enterprise felt were the causes of organizational ineffectiveness or inefficiency. These interviews also included questions concerning complexity and its perceived impact across the enterprise. Lastly, questions were asked to gain an understanding of how people really operated within the enterprise in order to accomplish the mission. In particular, what kind of workarounds were the most prevalent. At a minimum, the following questions were asked during these types of interviews:

- What are the reasons for ineffective performance within the Air Force aircraft acquisition enterprise?
- What role do the following concepts play in the success of acquisition programs?
- Economies and diseconomies of scale?
- Incentives?
- Organizational structure?
- Complexity?
- What do people do in situations where the size or complexity of a project has grown too large?
- What do people in your organization do in the face of very restrictive processes or regulations that are perceived to hamper progress on a project?

- What effect does process and/or organizational complexity have on acquisition program success?
- What would you do to improve the effectiveness of the enterprise?

The second type of interview focused on obtaining information concerning the issue of specialty metal use. This information was used to augment case study research documentation. Interviews were conducted with individuals who were familiar with the issues caused by the use of foreign titanium by defense contractors. Primary interviewees concerning this topic were:

- Mr. Rick Buschagen
    - Former Chief of Compliance within the Aeronautical Systems Center Contracting Functional
- Major Greg Watson, USAF (Ret)
    - Former lead Air Combat Command representative and current government civilian program manager within the F-15 system program office

As the former chief of compliance, Mr. Buschagen had a tremendous amount of firsthand knowledge concerning the issues surrounding the use of foreign source specialty metal in aircraft acquisitions. Maj Watson also had firsthand knowledge of the issue but from the perspective of a customer who was impacted by the delays caused by the issue.

6.3 Surveys

In addition to interviews, an informal survey was conducted at the start of the effort in order to gain an understanding of how individuals viewed complexity, especially when manifested in ways that created diseconomies of scale. Forty survey responses were collected from engineering and program management professionals with experience in defense acquisition. Survey responses were collected in two venues. The first venue was an INCOSE systems engineering conference conducted in Los Angles California on April 15th and 16th, 2011. The second venue was the Aeronautical Systems Center at Wright-Patterson AFB, Ohio. Responses at this venue were collected during research trips in August and October 2011. The number of survey responses collected across each level of defense acquisition related experience is shown below in Figure 14.

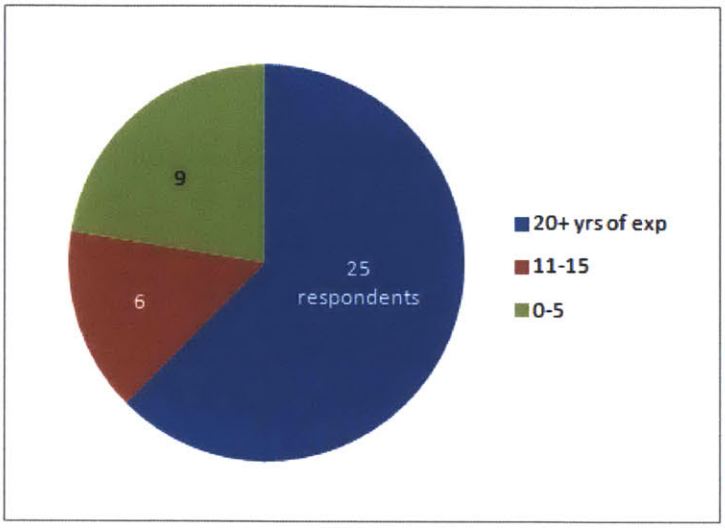


Figure 14: Experience Level of Survey Respondents

The first of three survey questions asked respondents how they knew a program had become too large. Since the term "complexity" can be construed in many ways, the term "complex" was replaced with "large", which often is also accompanied with a high level of complexity. The first response to be rated dealt with the time it takes to make a decision.

The second response question dealt with incentives and how a large, complex project may result in changes in the behavior of decision makers within the enterprise. Lastly, room was left to collect handwritten comments from respondents as well (Figure 15).

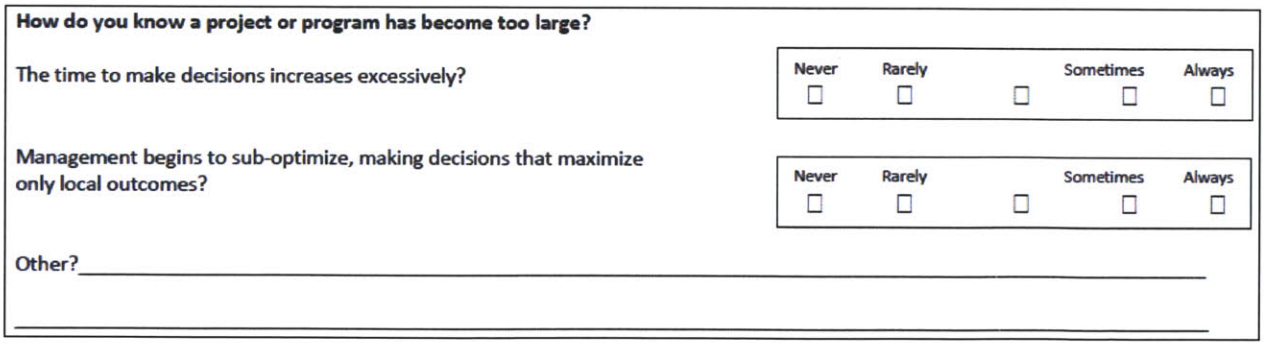


Figure 15: Survey Question 1

The second question was geared towards understanding what individuals do when a program's size or level of complexity becomes too great. As shown in Figure 16, respondents were asked to rate three responses. The first dealt with increasing hierarchical complexity while

the second and third dealt with additional administrative complexity in the form of additional processes or interactions.

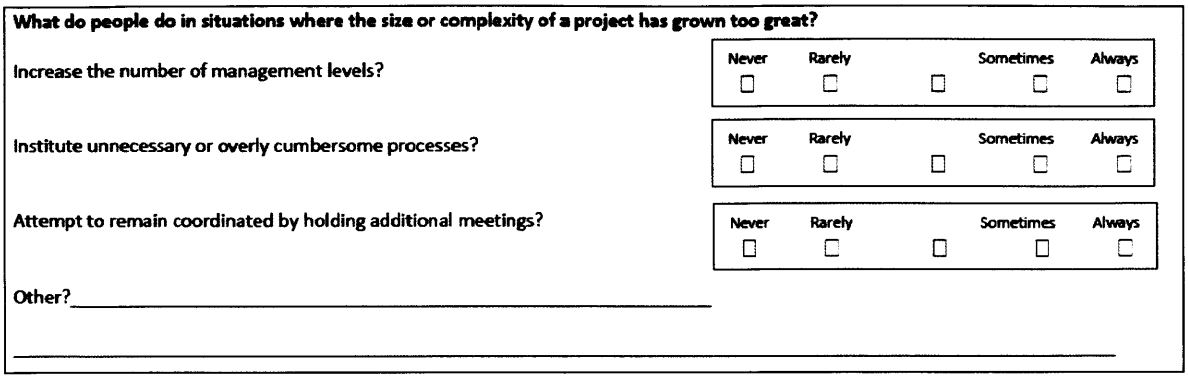


Figure 16: Survey Question 2

The final question of the survey was open ended, asking: "What do people do in the face of very restrictive processes or regulations that are perceived to hamper progress on a project?" The intent of this question was to look for evidence of what Tainter calls "scanning behavior", where individuals frustrated with the level of complexity and the perception of low marginal return on their efforts seek "alternatives that might provide a preferable adaption." (Tainter, 1988)

6.4 Berry Amendment Specialty Metals Case Study

Lastly, research for this thesis included gathering information to document a case study involving the use of specialty metals. Between 1991 and 2008, the use of foreign specialty metals in military aircraft acquisitions was a contentious issue. This topic was selected for inclusion since it was particularly illustrative of the challenges and the costs created by complexity within the Air Force aircraft acquisition enterprise. Specifically, the case provides insight into how complexity within the areas of stakeholder incentives, policies, and organizational structure can result in diminished returns.

Chapter 7 Evidence of Complexity

As discussed above, Tainter defines complexity as the combination of structural differentiation and organization. The first step in demonstrating that Tainter's theory has relevance for the Air Force aircraft acquisition enterprise is verifying that there is a high level of complexity present within the organization. This was done by gathering evidence of complexity across three primary process areas: personnel specialization/organizational structure, resource management, and regulatory guidance/policies.

Information on personnel special qualifications and training requirements was gathered from material produced by the Defense Acquisition University (DAU), the Office of the Secretary of the Air Force for Acquisition (SAF/AQ) and the Aeronautical Systems Center. The DAU is the Department of Defense's "corporate university" for defense acquisition workforce. According to its mission statement, it is responsible for supplying the Air Force aircraft acquisition enterprise workforce with:

- Acquisition certification and leadership training
- Mission assistance to acquisition organizations and teams
- Online knowledge-sharing resources
- Continuous learning assets (DAU, 2010)

While also acting in a supervisory role over the Air Force aircraft acquisition enterprise, the Office of the Assistant Secretary of the Air Force for Acquisition (SAF/AQ) is also responsible for ensuring that the Air Force aircraft acquisition enterprise workforce is properly trained as required by law, Department of Defense and Department of the Air Force regulations (Office of the Assistant Secretary of the Air Force). It is aided in this effort by the Air Force Materiel Command (AFMC) which is the Air Force major command tasked with managing, training and equipping the Air Force aircraft acquisition enterprise workforce.

Lastly, the Aeronautical Systems Center is the core Air Force organization operating within the Air Force aircraft acquisition enterprise. It is one of three product centers within AFMC and is responsible for the acquisition of "aerospace weapon systems". According to AFMC, ASC's parent organization:

> ASC designs, develops and delivers dominant aerospace weapon systems and capabilities for the Air Force, other U.S. military, allied and coalition-partner warfighters. ASC is charged with acquiring and modernizing the Air Force's aerial systems. The center focuses on speed and innovation in acquisition management, as well as on rapid transition of

technology into systems, business practices, development and retention of a high performance work force. (AFMC Public Affairs, 2011)

Based upon the above description of its responsibilities, the Aeronautical Systems Center is responsible for both developing and retaining a workforce prepared to conduct defense acquisition work focused on aerospace weapon systems.

Evidence of complexity in the area of organizational structure and hierarchical specialization was gathered by examining Aeronautical Systems Center History Office records. Specifically, annual historical reports authored by staff historians as well as archived organizational documentation were used. Information concerning complexity within the areas of resource management was gathered primarily from DAU materials dealing with financial management and program control. DAU and SAF/AQ were also the primary sources for information concerning defense acquisition regulations and policies.

7.1 Personnel Specialization/Organizational Structure

At the societal level, Tainter discusses how complexity tends to grow in the areas of information processing and sociopolitical control/specialization. Within the realm of information processing, one clear sign that complexity has increased is reliance on specialized training also increases (Tainter, 1988). The Air Force aircraft acquisition enterprise workforce is very large and highly specialized.

Considering only those directly employed by the U.S. Air Force at the Aeronautical Systems Center at Wright-Patterson AFB, there are over 5,600 people engaged in the enterprise (Fecher, 2011). In comparison, in 2008, less than 2,000 commercial firms out of the 27,281,452 operating within the United States employed over 5,000 people (U.S. Census Bureau, 2011).

Table 5: Aeronautical Systems Center Personnel (Fecher, 2011)

Employee Type	Count
Officesr	562
Enlisted Airmen	176
Government Civilians	3,621
Contracted Employees	1,246
Total	**5,605**

7.1.1 Career Field Specialization

In order to become a member of the Air Force aircraft acquisition enterprise workforce, a significant amount of specialized training is required. In addition to being segmented by their type of employment contract, each employee within the active duty and government civilian types is also categorized according to a career field or functional designation. According to SAF/AQ, there are at least nine functional specialties within defense acquisition. They are

- Contracting
- Systems Engineering
- Financial Management
- Program Management
- Information Technology
- Logistics
- Scientific Research and Development
- Test and Evaluation
- Production, Manufacturing & Quality Assurance (SAF/AQ, 2011)

Rather than the nine functional categories described above, the Defense Acquisition University divides the workforce into 15 functional career fields for certification and qualification tracking. As shown in Figure 17 below, each career field is also divided into three levels of expertise based upon training completed and duration of experience serving in the field.

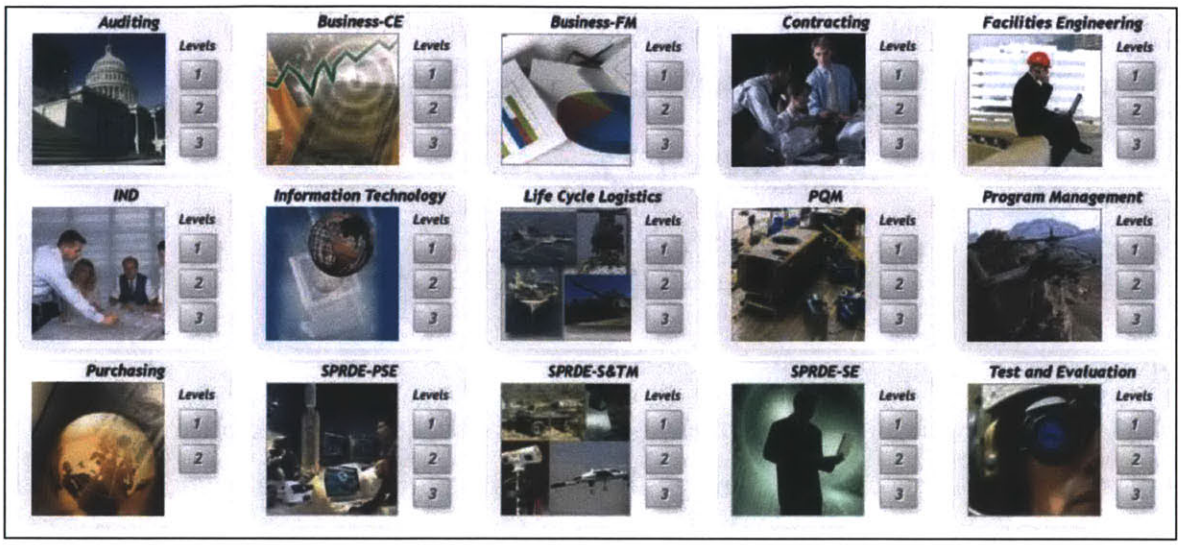


Figure 17: Defense Acquisition Workforce Career Fields (DAU, 2011)

Exploring the Business-Cost Estimating career field further provides additional evidence of the large amount of personnel specialization and organization present across the defense acquisition workforce. As shown in Figure 18, in order to achieve Level 1 basic certification, an individual must first complete a "baccalaureate degree engineering, statistics, or other math intensive field of study." (DAU, 2011) In addition to the college degree, required and optional additional training is also called for in the form of DAU courses on acquisition fundamentals, financial management and cost analysis. Lastly, two years of experience working in a cost estimating role are required for basic certification.

CERTIFICATION STANDARDS & CORE PLUS DEVELOPMENT GUIDE
BUSINESS – COST ESTIMATING LEVEL I

Type of Assignment	Representative Activities
Cost Estimator	Relates the processes of life cycle cost estimating within the context of materiel system acquisition in the Department of Defense

Core Certification Standards (required for DAWIA certification)	
Acquisition Training	ACQ 101 Fundamentals of Systems Acquisition Management
Functional Training	● BCF 102 Fundamentals of Earned Value Management ● BCF 103 Fundamentals of Business Financial Management ● BCF 106 Fundamentals of Cost Analysis ● BCF 107 Applied Cost Analysis (R)
Education	● Baccalaureate degree (any field of study) ● 3 semester credit hours from a calculus course ● 21 semester credit hours in any combination of the following fields of study: operations research, economics, mathematics, chemistry, physics or other sciences where the utilization of advanced mathematical skills in geometry, trigonometry, statistics, probability, and/or quantitative analysis
Experience	2 years of acquisition experience in Cost Estimating

Core Plus Development Guide (desired training, education, and experience)	Type of Assignment
Training	Cost Estimator
CLB 014 Acquisition Reporting Concepts and Policy Requirements for APB, DAES, and SAR	✔
CLB 016 Introduction to Earned Value Management	✔
CLB 017 Performance Measurement Baseline	✔
CLB 018 Earned Value and Financial Management Reports	✔
CLB 019 Estimate at Completion	✔
CLB 020 Baseline Maintenance	✔
CLC 005 Simplified Acquisition Procedures	✔
CLM 016 Cost Estimating	✔
Education	
Baccalaureate degree in engineering, statistics, or other math intensive field of study	
Experience	
2 years of acquisition experience in Cost Estimating	

Notes:

1 The Core Certification Standards section lists the training, education, and experience REQUIRED for certification at this level.

2 "(R)" following a course title indicates the course is delivered as resident based instruction.

3 When preparing your IDP, you and your supervisor should consider the training, education, and experience listed in this Core Plus Development Guide if not already completed.

Figure 18: Basic Qualifications for Cost-Estimating Career Field (DAU, 2011)

Figure 19 and Figure 20 provide listings of what is required to be certified at the intermediate and senior levels in the cost estimating career field. In order to produce a professional in the cost estimating career field, a significant amount of time and resources in the form of additional training must be expended. In fact, a minimum of seven years of experience is required before an individual is considered Level III certified (DAU, 2011).

CERTIFICATION STANDARDS & CORE PLUS DEVELOPMENT GUIDE
BUSINESS – COST ESTIMATING LEVEL II

Type of Assignment	Representative Activities
Cost Estimator	Applies the cost-estimating process in the construction of a cost estimate

Core Certification Standards (required for DAWIA certification)	
Acquisition Training	● ACQ 201A Intermediate Systems Acquisition, Part A ● ACQ 201B Intermediate Systems Acquisition, Part B (R)
Functional Training	● BCF 204 Intermediate Cost Analysis (R) ● BCF 206 Cost Risk Analysis (R) ● BCF 211 Acquisition Business Management (R) ● BCF 215 Operating and Support Cost Analysis (R) ● CLB 026 Forecasting Techniques ● CLB 030 Data Collection and Sources
Education	● Baccalaureate degree (any field of study) ● 3 semester credit hours from a calculus course ● 21 semester credit hours in any combination of the following fields of study: operations research, economics, mathematics, chemistry, physics or other sciences where the utilization of advanced mathematical skills in geometry, trigonometry, statistics, probability, and/or quantitative analysis
Experience	4 years of acquisition experience in Cost Estimating

Core Plus Development Guide (desired training, education, and experience)	Type of Assignment
Training	Cost Estimator
ACQ 265 Mission-Focused Services Acquisition (R)	✔
BCF 207 Economic Analysis (R)	✔
BCF 262 EVMS Validation and Surveillance (R)	✔
BCF 263 Principles of Schedule Management (R)	✔
CLC 007 Contract Source Selection	✔
CLC 008 Indirect Costs	✔
CLC 104 Analyzing Profit or Fee	✔
CLL 015 Product Support Business Case Analysis (BCA)	✔
CLL 017 Introduction to Defense Distribution	✔
CLM 012 Scheduling	✔
CLM 014 IPT Management and Leadership	✔
CLM 024 Contracting Overview	✔
CLM 032 Evolutionary Acquisition	✔
LOG 101 Acquisition Logistics Fundamentals	✔
PMT 251 Program Management Tools Course, Part I	✔
PMT 257 Program Management Tools Course, Part II	✔
SAM 101 Basic Software Acquisition Management	✔
Education	
Baccalaureate degree in engineering, statistics, or other Math intensive field of study	
Experience	
4 years of acquisition experience in Cost Estimating	

Notes:

1 The Core Certification Standards section lists the training, education, and experience REQUIRED for certification at this level.

2 "(R)" following a course title indicates the course is delivered as resident based instruction.

5 When preparing your IDP, you and your supervisor should consider the training, education, and experience listed in the Core Plus Development Guide at this and the lower level(s) if not already completed.

Figure 19:Intermediate Qualifications for Cost-Estimating Career Field (DAU, 2011)

CERTIFICATION STANDARDS & CORE PLUS DEVELOPMENT GUIDE
BUSINESS – COST ESTIMATING LEVEL III

Type of Assignment	Representative Activities
Cost Estimator	Performs analyses and estimates for a variety of programs and takes on management activities to ensure cost analysis is conducted properly

Core Certification Standards (required for DAWIA certification)	
Acquisition Training	Acquisition Training identified at level II must have been completed
Functional Training	● Functional Training identified at Level II must have been completed ● BCF 302 Advanced Concepts in Cost Analysis (R) ● CLB 023 Software Cost Estimating ● CLB 029 Rates
Education	● Baccalaureate degree (any field of study) ● 3 semester credit hours from a calculus course ● 21 semester credit hours in any combination of the following fields of study: operations research, economics, mathematics, chemistry, physics or other sciences where the utilization of advanced mathematical skills in geometry, trigonometry, statistics, probability, and/or quantitative analysis
Experience	7 years of acquisition experience in Cost Estimating

Core Plus Development Guide (desired training, education, and experience)	Type of Assignment
Training	Cost Estimator
ACQ 450 Leading in the Acquisition Environment (R)	✔
ACQ 451 Integrated Acquisition for Decision Makers (R)	✔
ACQ 452 Forging Stakeholder Relationships (R)	✔
PMT 352A Program Management Office Course, Part A	✔
PMT 352B Program Management Office Course, Part B (R)	✔
Education	
Graduate degree in engineering, statistics, or other Math intensive field of study	
Experience	
7 years of acquisition experience in Cost Estimating	

Notes:

1 The Core Certification Standards section lists the training, education, and experience REQUIRED for certification at this level.

2 "(R)" following a course title indicates the course is delivered as resident based instruction.

5 When preparing your IDP, you and your supervisor should consider the training, education, and experience listed in the Core Plus Development Guide at this and the lower level(s) if not already completed.

Figure 20: Senior Qualifications for Cost-Estimating Career Field (DAU, 2011)

Similar qualification requirements exist for the other 14 career fields. It is clear from these qualification listings alone that there is large amount of personnel specialization present in the Air Force aircraft acquisition enterprise. This specialization is also paired with a substantial amount of organization. DAU provides the instructors, coursework, and supporting physical and IT infrastructure necessary to administer the training classes. Additionally, each military service maintains information on the acquisition qualifications of their workforce. For the Air Force, this is done through the Air Force Internet Registrations System for Acquisition Training, commonly known as the ACQ Now system (ATTRS Online System, 2011). The system allows individuals to apply for courses and generate training plans which are then both reviewed and approved by

their supervisors. The system also maintains a record of work completed and qualifications attained which are also then recorded in individual personnel employment records.

7.1.2 Hierarchical Specialization

In addition to specialization at the personnel level, hierarchical specialization is also present within the Air Force aircraft acquisition enterprise. If we again narrow our focus to only the military organization at the Aeronautical Systems Center, we find in place the organizational structure shown in Figure 21. The fact that the individual blocks are barely legible is an indicator itself that the level of hierarchical specialization is high. The Acquisition Systems Center is led by a 3-star general who serves as the center commander. Beneath him, the organization is divided into 5 mission-specific directorates, two geographical support organizations and 10 functional organizations. Another layer down, each directorate includes a number of additional subdivisions in the form of divisions, branches and offices.

The mission directorates are organized in a matrix type structure with each one managing projects within a single aerospace mission space. For example, the fighters and bombers directorate is responsible for overseeing program offices managing fighter procurement and upgrades for the F-22, F-16, F-15 and A-10. It is also overseeing efforts to upgrade the B-2, B-1, and B-52 bombers. Within the F-15 program office alone, there are more than 50 people assigned (Fecher, 2011). This workforce includes individuals from each of the personnel specialties discussed above including program managers, contracting officers and engineers. These individuals are managed both by the leaders of their mission area organizations as well as their functional leads within the functional organizations (Fecher, 2011).

Clearly there is a substantial amount of hierarchical complexity within the Air Force aircraft acquisition enterprise. The matrix organizational structure contains both hierarchical specialization, grouped by mission area and function as well as a great deal of organization based upon a military chain of command and functional supervision.

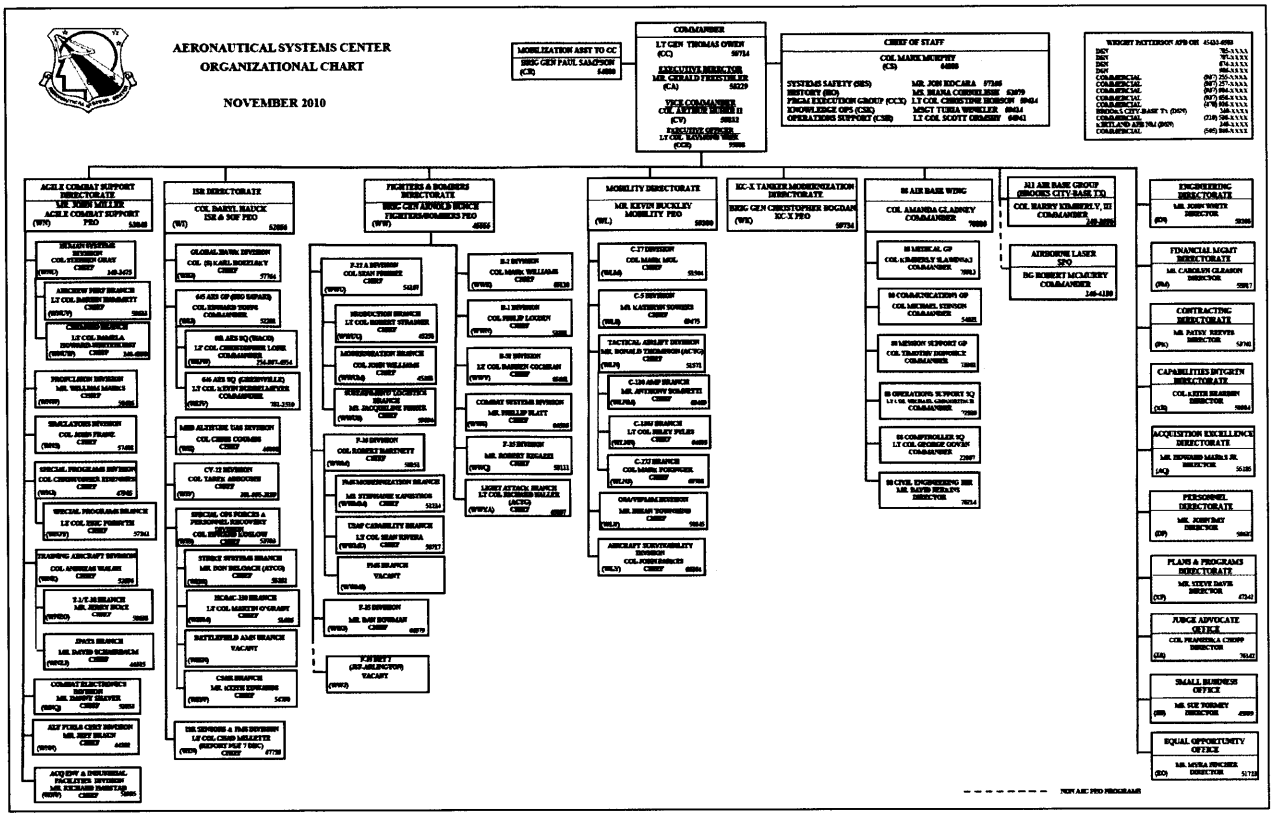


Figure 21: Aeronautical Systems Center Organizational Chart, November 2010

7.2 Resource Management

The second area within the Air Force aircraft acquisition enterprise where evidence of complexity can be verified is in resource management. Two examples of complexity within this area are the Future Year Defense Program structure and earned value management.

7.2.1 Future Year Defense Program

In contrast to the old adage, not all money is "green" within the Air Force aircraft acquisition enterprise. The U.S. stipulates that only the Congress has the authority to appropriate funds for military use (U.S. Const. art. I, § 8). This power is zealously protected by the legislative branch. In order to ensure compliance with Congress's intent and account for funding, the DoD relies upon the Future Year Defense Program (FYDP). The DoD's handbook on the FYDP structure provides a general description of the resource management system:

> The FYDP summarizes resources ([total obligation authority], manpower, and forces) associated, by fiscal year, with Department of Defense programs, as approved by the Secretary or the Deputy Secretary of Defense. These programs reflect decisions embodied in Planning, Programming, Budgeting, and Execution (PPBE) documents such as the Strategic

Planning Guidance (SPG), the Fiscal Guidance, the Joint Programming Guidance (JPG), the Program Decision Memoranda (PDM), and Program Budget Decisions (PBDs) (all internal DoD documents that are not available for public release).

The FYDP contains prior year (PY), current year (CY) and the two budget years (BY1 and BY2) through BY2 + 4 years (BY2 +7 years for forces). It is updated with every program and budget submission to OSD and with the President's Budget Submission each year, in accordance with DoDI 7045.7 (reference (a)). (U.S. Department of Defense, 2011)

The FYDP structure consists of a "two-dimensional matrix report that links DoD resources and programs." The first of the two dimensions consists of "eleven Major Force Programs (MFP) -- six combat force-oriented programs and five support programs." (U.S. Department of Defense, 2011).

- Program 1 - Strategic Forces *
- Program 2 - General Purpose Forces *
- Program 3 - Command, Control, Communications, and Intelligence *
- Program 4 - Mobility Forces *
- Program 5 - Guard and Reserve Forces *
- Program 6 - Research and Development
- Program 7 - Central Supply and Maintenance
- Program 8 - Training, Medical, and Other General Personnel Activities
- Program 9 - Administration and Associated Activities
- Program 10 - Support of Other Nations
- Program 11 - Special Operations Forces *

*Combat Forces Program

These eleven MFPs are divided into thousands of individual [program elements]. In its second dimension, the FYDP has three broad categories of resources: TOA (enumerating dollars (in thousands)), manpower (enumerating military endstrength and civilian full-time-equivalent workyears), and forces (either items of equipment or combat units). Generally, the FYDP's programs may be considered to be outputs, while its resources may be considered to be inputs. Hence, the FYDP crosswalks the Department's internal review structure (which is primarily output oriented) with the congressional review structure (which specifies inputs to the Department). The Department's official record on DoD outputs (to satisfy the requirements of the Government Performance and Results Act (GPRA)) is the Department of Defense Annual Report to the President and the Congress (reference (c)).

FYDP PEs are both mutually exclusive and exhaustive, and are continually scrutinized to maintain proper visibility of defense programs as the programs themselves change and as the Department's leadership requires new ways of examining DoD programs and resources. (U.S. Department of Defense, 2011)

Within the FYDP structure, the Air Force is assigned program element codes for each one of its efforts that require funding. These efforts include aerospace weapon system acquisition

programs managed by the Air Force aircraft acquisition enterprise. As an example, all funding associated with the F-15 A/B/C/D has a program element number that includes code 0207130F. When a contract or order is cut for a product or service, a fund cite is attached that provides an accounting of the funds used for the action as shown in Figure 22.

Fund Cite Structure (For RDT&E Appn Fund Type C)

5713600 291 4720 681307 020100 00000 27130F 503000 F03000

Department 57
Fiscal Year 1
Appropriation Symbol 3600
Fund Code 29
Fiscal Year 1
Operating Agency Code 47
Allotment Serial Number 20
Budget Program (First 2 digits of BPAC) 68
Project Number (3rd thru 6th digits of BPAC) 1307
Material Program Code (MPC) 020100
Elements of Expense/Investment Code (EEIC) 000000
Program Element Code (PEC) 27130F
Accounting and Disbursing Station Number (ADSN) 503000
Department of Defense Activity Address Directory Code (DODAAD) F03000

Figure 22: Fund Cite Structure (Ark, 2007)

Besides the program element, the appropriation symbol is important because it provides information on what kind of activities may be funded by a particular Congressional appropriation. In the above example, the code 3600 is used. This code is indicates that the funding is reserved for efforts that involve research and development and/or test and evaluation. Within the Air Force, the following appropriation symbols are commonly used:

Investment Appropriations:

- Research, Development, Test, and Evaluation (RDT&E) (3600)
- Aircraft Procurement (3010)
- Missile Procurement (3020)
- Other Procurement (3080)
- Military Construction (MILCON) (3300)

Operation and Maintenance Appropriations

- Operation and Maintenance Appropriations (O&M) (3400)
- Military Personnel (MILPERS) (3500) (Ark, 2007)

It is evident from the FYDP structure that a high level of complexity is present. Funding is distributed by Congress to meet a myriad of military requirements ranging from research and development to military personnel pay. This specificity is coupled with a highly organized accounting structure and a highly specialized financial management workforce to ensure funding is only used for its intended purpose.

7.2.2 Earned Value Management

Once funds are appropriated and obligated on a particular acquisition project within the Air Force aircraft acquisition enterprise, the performance associated with those funds are often tracked using Earned Value Management (EVM). This system of tracking the relationship between cost, schedule and performance began evolving in the 1950s from a predecessor system known as PERT (Program Evaluation and Review Technique). As EVM has evolved within defense acquisition from the 1950s to the present, it has grown in sophistication and has returned to its original role as a program management tool. Within the Air Force aircraft acquisition enterprise, prior to the late 1990s, EVM was often viewed only as a financial management tool and was not used by program managers to the extent it is today (Abba, 2004).

The intent here is not to provide a primer on the workings of EVM but to show that the tracking system is a source of complexity within the realm of resource management within the Air Force aircraft acquisition enterprise. Figure 23 below is the EVM reference sheet distributed by the Defense Acquisition University. It is evident from this artifact alone that collecting the data necessary to compute EVM measures of performance requires a high level of complexity in the form of specialized expertise and organization. Additional complexity is required to properly interpret and act upon the information produced by EVM reporting systems.

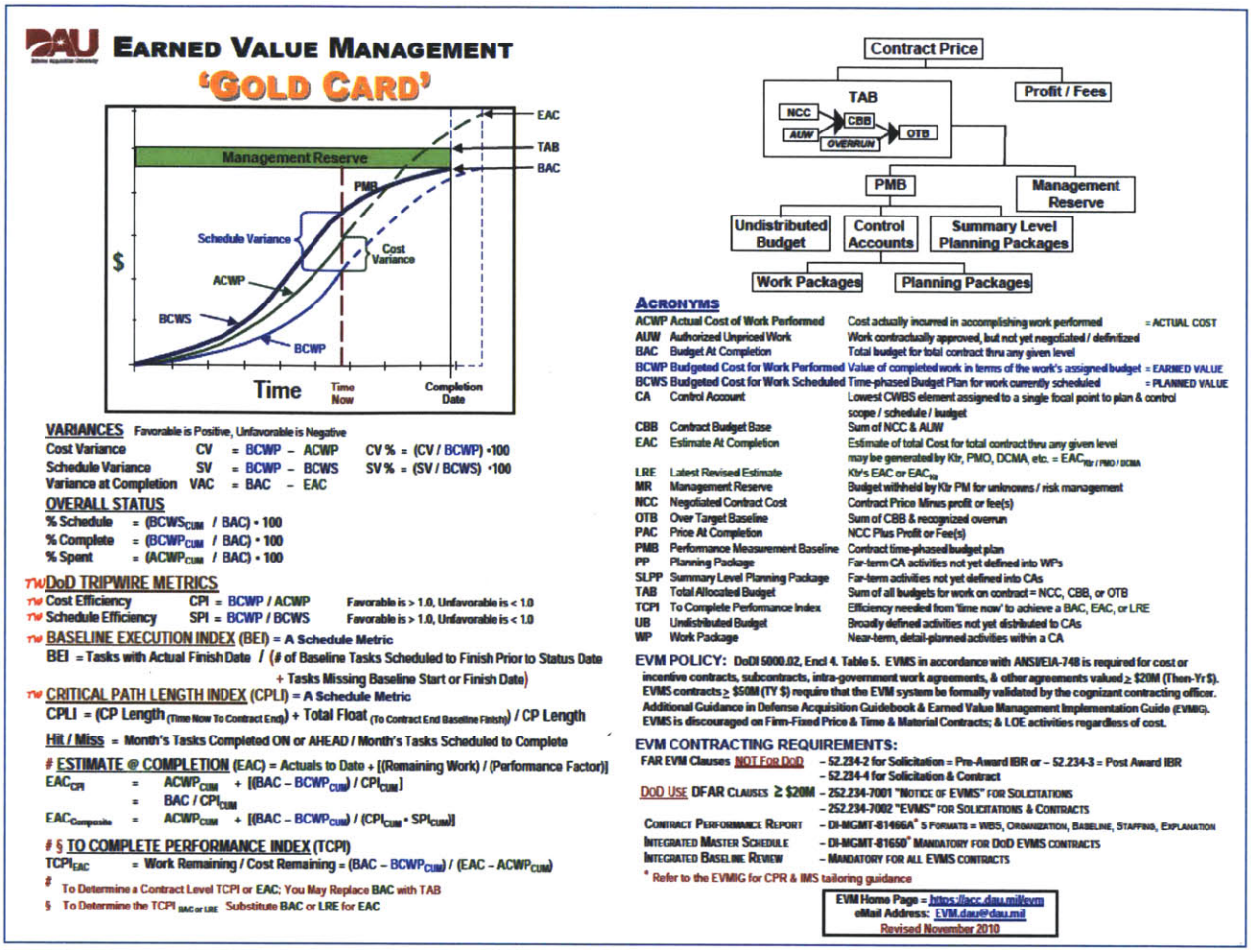


Figure 23: Earned Value Management Reference Sheet (DAU, 2011)

Just as a great deal of complexity was found to be present within the personnel and hierarchical aspects of the Air Force aircraft acquisition enterprise, it is clear that a significant amount of complexity is present within the resource management area as well. The appropriation of funding and the tracking of its use rely upon the FYDP structure. This structure helps ensure that funding valued in the billions annually is used for the purpose it was intended. Accomplishing this task requires a high level of complexity both in the nomenclature and the organization necessary for the system to function.

Earned Value Management is undoubtedly a powerful tool for tracking acquisition program progress. However, the insight it provides to the Air Force aircraft acquisition enterprise also comes with a cost. It also requires a high level of complexity to properly collect the data and process it across programs valued in the millions of dollars and employing thousands of defense contractors.

7.3 Regulatory guidance and policies

A final area where evidence of high complexity was gathered was regulatory guidance and policies. Within the defense acquisition environment including within the Air Force aircraft acquisition enterprise, two primary sources of guidance exist. The first are regulations under the umbrella of the Federal Acquisition Regulation. The second is the DoD 5000 series regulations.

7.3.1 Federal Acquisition Regulations

All work done for the U.S. government is ideally performed under the provisions of a contract between the government and the entity performing the service or providing the product. The regulations that govern this contracting process are referred to as the Federal Acquisition Regulation, commonly known as the "FAR". As discussed in the course materials for CLC-011, a DAU introductory course on federal contracting:

> The size of the regulations that govern the Federal, and in turn the DOD contracting processes, is legendary. A full understanding of DOD contracting requires having a sense of the various requirements, procedures, guidelines, and forms that contracting officers must work with daily as they attempt to meet their customers' requirements.
>
> The Federal Acquisition Regulation (FAR) governs the Federal procurement process, while the Defense Federal Acquisition Regulation Supplement (DFARS) provides guidance specifically for the DOD environment. The FAR consists of 53 parts, and the DFARS supplements 49 of those parts. The military departments and agencies, in turn, provide their own supplements. (DAU, 2011)

When pasted into Microsoft Word using a 12-point font, the table of contents for the FAR alone numbers 107 pages in length. The total length of the regulations and guidance under each of the 53 parts numbers in the thousands of pages. For illustration, a portion of the table of contents for FAR Part 13, Simplified Acquisitions is included in Figure 24. It includes 5 sub parts that consist of 29 sections. Clearly this level of specificity and the organization required to manage it result in a high level of complexity.

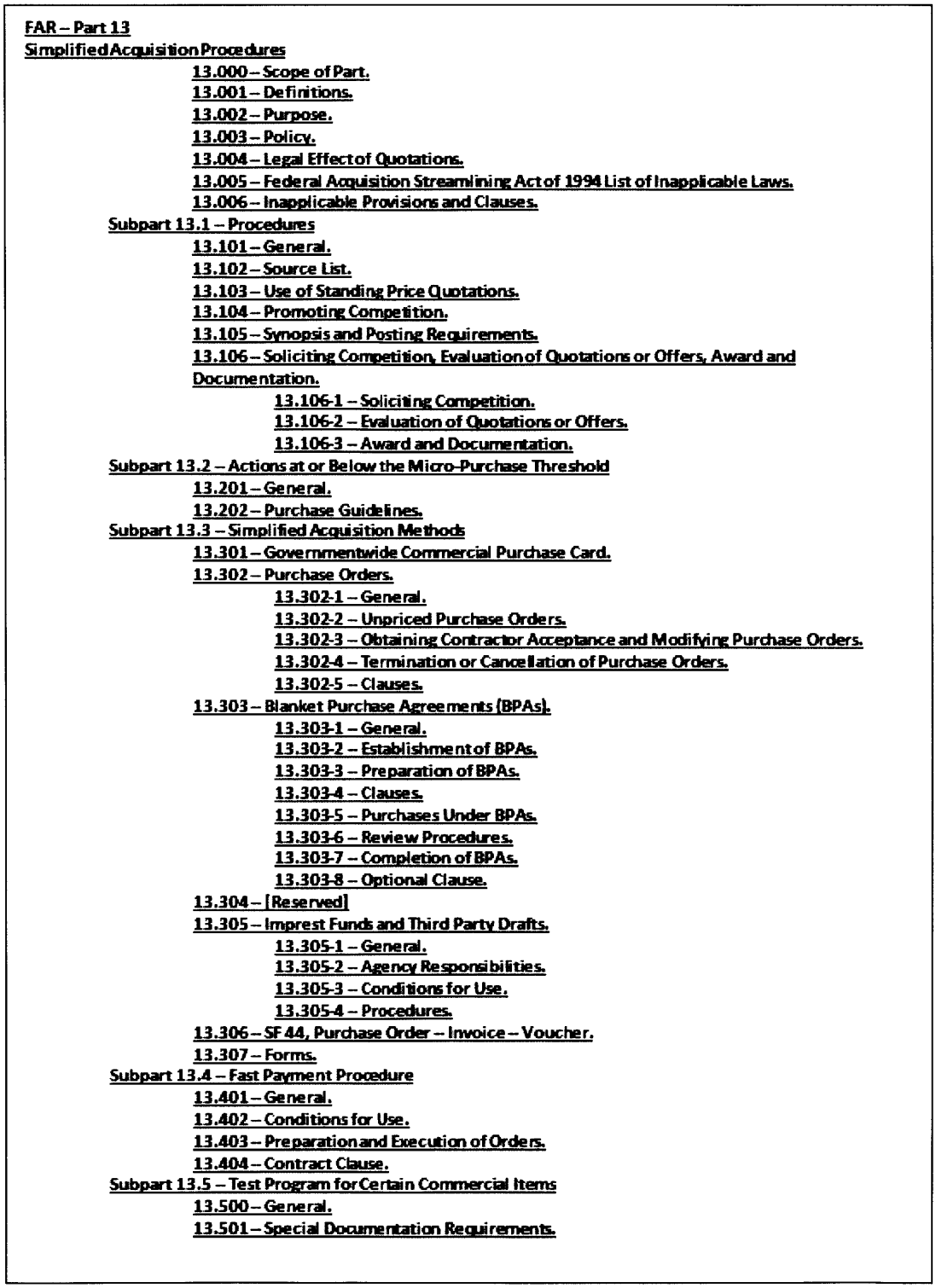


Figure 24: FAR Part 13 Table of Contents (U.S. Federal Acquisition Regulation)

Additionally, as mentioned above, the guidance in the FAR is further refined for defense acquisitions by the Defense Federal Acquisition Regulation Supplement. This document also

encapsulates a tremendous amount of complexity. Compliance with the FAR and the appropriate supplements are the responsibility of the contracting officers within the Air Force aircraft acquisition enterprise. The length and depth of these regulations are clear evidence that the enterprise operates within a very complex environment.

7.3.2 Department of Defense 5000 Series Regulations

In addition to the FAR and its supplements which govern the contracting process. The Air Force aircraft acquisition enterprise must also adhere to a set of DoD regulations known collectively as the DoD 5000 series.

> DoD Directive 5000.01, The Defense Acquisition System, provides the policies and principles that govern defense acquisition. DoD Instruction 5000.02, Operation of the Defense Acquisition System, establishes the management framework that implements these policies and principles. The Defense Acquisition Management System is an event-based process. Acquisition programs proceed through a series of milestone reviews and other decision points that may authorize entry into a significant new program phase. Details of the reviews, decision points, and program phases are found beginning with in paragraph 3 of Enclosure 2 of the Instruction. The Instruction also identifies the specific statutory and regulatory information requirements for each milestone and decision point. (DAU, 2010)

As stated above, the directives and instructions describe a management system that includes milestones and associated reviews by senior acquisition leaders. At its simplest, this process can be described by the lifecycle view introduced above as Figure 13 and repeated immediately below as Figure 25. However, this view is deceptively simple and does not capture the tremendous amount of work that is required by the process to move from one phase to the next.

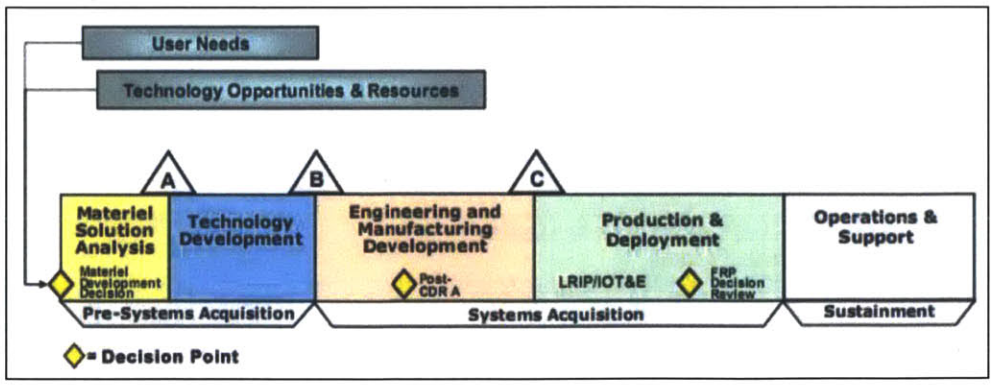


Figure 25: DoD 5000 Acquisition System--Lifecycle view (DAU, 2010)

The table, included as Appendix A, was excerpted from DoD 5000.2 and lists all of the statutory requirements each acquisition program must meet in order to proceed through each of the milestones. While this table alone spans nearly seven pages, additional requirements not shown in the table are levied on large Major Defense Acquisition Programs (MDAPs) and Major Automated Information System programs (MAIS).

In addition to the published versions of the Federal Acquisition Regulations and its supplements and the DoD 5000 series regulations, there is a host of policy memorandums and clarifications in effect at any one time as shown in Figure 26.

Recent DoD policy memoranda, including Directive-Type Memoranda (DTMs):

- **Acquisition Policy for Defense Business Systems (DBS) (DTM 11-009)** | *Dated 23 Jun 2011*
- **Reliability Analysis, Planning, Tracking, and Reporting (DTM 11-003)** | *Dated 21 Mar 2011*
- **Implementation Directive for Better Buying Power - Obtaining Greater Efficiency and Productivity in Defense Spending** | *Dated 3 Nov 2010*
- **Development Planning to Inform Materiel Development Decision (MDD) Reviews and Support Analyses of Alternatives (AoA) (DTM 10-017)** | *Dated 13 Sep 2010; Change dated 16 May 2011*
- **Requirements for Life Cycle Management and Product Support (DTM 10-015)** | *Dated 7 Oct 2010; Change dated 29 Apr 2011*
- **Implementation of the Weapons Systems Acquisition Reform Act (WSARA) of 2009 (DTM 09-027)** | *Dated 4 Dec 2009; Change 1 dated 21 Oct 2010; Chage 2 dated 31 Aug 2011*
- **Space Systems Acquisition Policy (SSAP) (DTM 09-025)** | *Dated 18 Oct 2010; Change dated 10 Jun 2011*
- **Supply Chain Risk Management (SCRM) to Improve the Integrity of Components Used in DoD Systems (DTM 09-016)** | *Dated 25 Mar 2010; Change dated 16 Sep 2010*

Other recent memoranda, including guidance and expected business practices:

- **Document Streamlining -Life-cycle Sustainment Plan (LCSP)** | *Dated 14 Sep 2011*
  - **Life-Cycle Sustainment Plan (LCSP) Outline (Word version)** | *Dated 14 Sep 2011*
- **Document Streamlining - Program Protection Plan** | *Dated 18 July 2011*
  - **Program Protection Plan Outline** / *Dated 18 July 2011*
- **Improving Milestone Process Effectiveness** | *Dated 23 Jun 2011*
- **Improving Technology Readiness Assessment Effectiveness** | *Dated 11 May 2011*
- **Joint Memorandum on Savings Related to "Should Cost"** | *Dated 22 Apr 2011*
- **Document Streamlining - Program Strategies and Systems Engineering Plan** | *Dated 20 Apr 2011*
  - **Systems Engineering Plan (SEP) Outline** | *Dated 20 Apr 2011*
  - **Technology Development Strategy [or] Acquisition Strategy: Sample Outline** | *Dated 20 Apr 2011*
- **Expected Business Practice: Post-Critical Design Review Reports & Assessments** | *Dated 24 Feb 2011*
- **Interim Acquisition Guidance for Defense Business Systems (DBS)** | *Dated 15 Nov 2010*
- **Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending** | *Dated 14 Sep 2010*
- **Technology Development Strategy and Acquisition Strategy Documents** | *Dated 20 Aug 2010*

Figure 26: Recent Defense Acquisition Guidance

The Air Force aircraft acquisition enterprise is governed by a large set of regulations and policies. The bulk of these reside in the Federal Acquisition Regulation and its supplements as well as the DoD 5000 series regulations. The large number of these directives and the organization necessary to implement them provide clear evidence that the Air Force aircraft acquisition enterprise is a highly complex system.

7.4 Research Result and Conclusion

A high level of organizational (structural and procedural) complexity exists across the Air Force aircraft acquisition enterprise

As one looks across all the three areas of personnel specialization/organizational structure, resource management, and regulatory guidance and policies, it is evident that there is a

tremendous amount of both structural differentiation and organization present within the enterprise. According to Tainter, this combination is the very definition of complexity, all of which requires resources to maintain.

The high level of complexity present within the enterprise can be further categorized into specific types beyond Tainter's general definition. Young, Farr, and Valerdi (2010) conducted a thorough accounting of the types of complexities that influence system engineering cost estimates. The examples of complexity discussed above can be characterized as organizational complexity both structural as well as procedural.

Chapter 8 Evidence of Diminishing Returns

According to Tainter's theory of collapse, the level of complexity within a society reaches a point where additional increases in complexity result in diminishing marginal returns. In other words, each additional investment in the system results in less and less additional productivity.

Having established that the Air Force aircraft acquisition enterprise is a large, highly complex organization, the next step in applying Tainter's theory at the organizational level is to explore whether the level of complexity has reached a point of declining marginal returns.

Just as Tainter found at the societal level, it is difficult to effectively isolate and determine the costs and benefits of each quantum of increasing complexity within the Air Force aircraft acquisition enterprise. However, it is possible to gather evidence of declining returns by looking for examples that meet one of the four conditions that result in declining marginal returns:

- Benefits falling with costs rising
- Benefits rising with costs rising faster
- Benefits constant with costs rising
- Benefits falling with costs remaining constant (Tainter, 1988)

8.1 An Independent Assessment

At the enterprise level, the primary perception among senior military leaders is that the performance of the Air Force aircraft acquisition enterprise has declined since the early to mid 1990s. A 2009 CNA research report commissioned by the Secretary of the Air Force to conduct a "broad-ranging, top-to-bottom assessment of the current state of AF acquisition" provided a very negative assessment of the enterprise:

> Today the Air Force acquisition community is a mere shell of its former self, consisting of approximately 24,000 military and civilian professionals, with no four-star seat at the "Corona" table. Since the mid-1990s, not only has cost growth for Air Force programs been rising at an ever-increasing rate, but it is worse than the cost performance of its sister Services. Every day it seems, there is a new story in the public media suggesting Air Force acquisition incompetence.
>
> Certainly, the Navy has its Littoral Combat Ship, the Army has its Armed Reconnaissance Helicopter, the Marines its Expeditionary Fighting Vehicle, but the Air Force has its Space-Based In-frared Radar System, CSAR-X search and rescue helicopter, and KC-X aerial tanker, now in its fourth attempt to award a contract. The Undersecretary of Defense for Acquisition, Technology, and Logistics, regularly rails against Air Force acquisition performance. As recently as 27 January 2009, the Secretary of Defense, in testimony before the Senate Armed Services Committee, singled out the Air Force as an

example of the general deterioration of the acquisition workforce. (Christie, Davis, & Porter, 2009)

8.2 Benefits Falling with Costs Rising

In light of the Aeronautical Systems Center's mission to acquire aerospace weapon systems, an indicator of the enterprise's performance is the state of the Air Force's aircraft fleet. There are two primary factors that go into deciding that it is time to replace an existing aircraft type with a new design: cost and military advantage. While Keating and Dixon, (2004) provide a decision model for replacement of aircraft based solely on a cost comparison model, they acknowledge that their model does "not consider technological change". The need to preserve technical superiority over one's adversaries would seem to bestow an advantage on a younger fleet of aircraft over an older one. This is especially true for aircraft designed for combat operations such as fighters and bombers. Therefore, one would expect a well-functioning acquisition enterprise to procure replacement aircraft at a rate that kept fleet aging in check in order to preserve military benefit. However, as shown in Figure 27, the age of the Air Force's fleet continues to increase. Additionally, the below chart was produced before the 2009 decision was made to limit the production of the F-22 Raptor aircraft to only 187 aircraft (Matthews, 2009). If this change was incorporated, the rate of aging for both the fighter and total fleets would further increase.

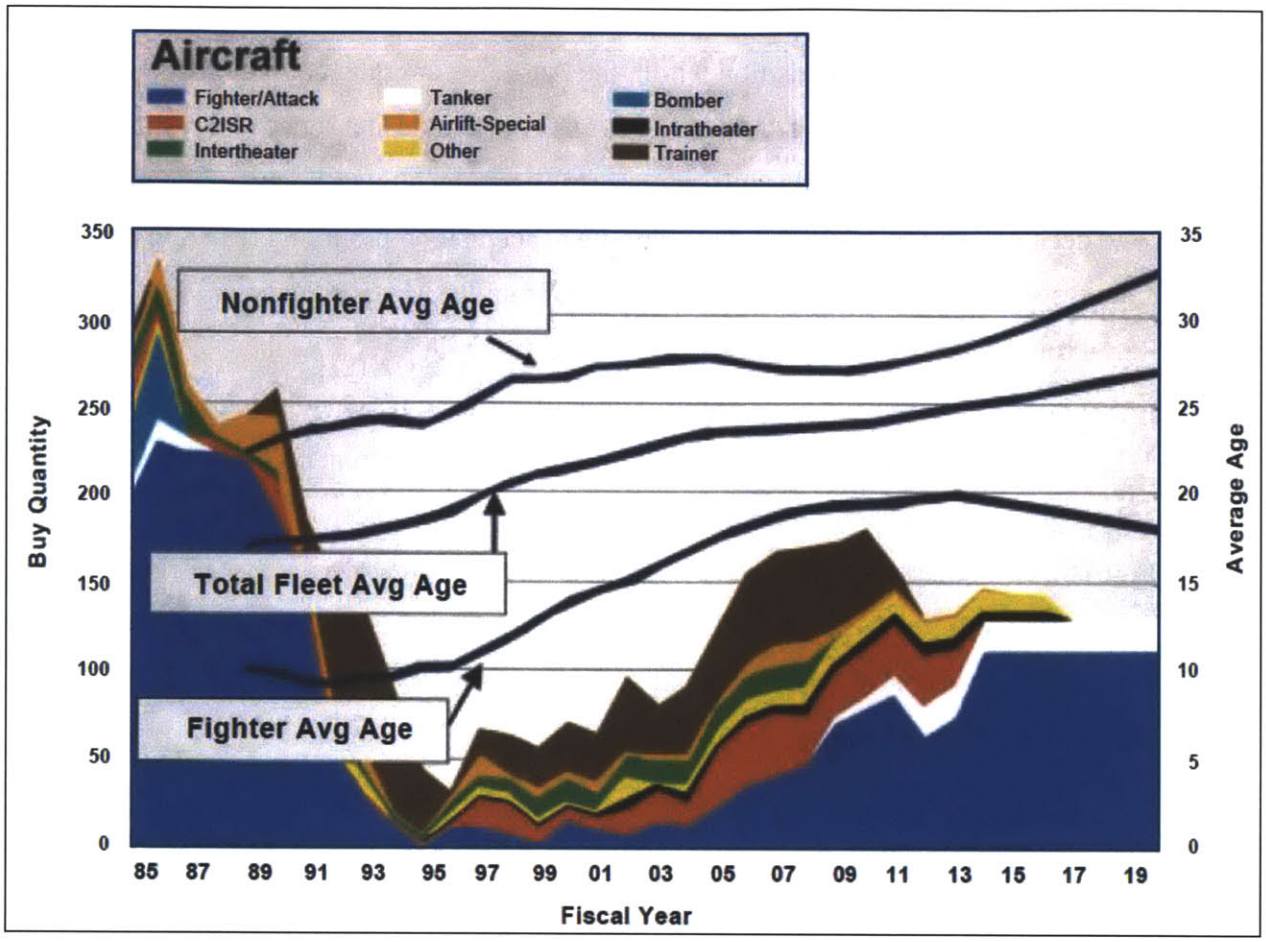


Figure 27: U.S. Air Force Fleet Age (Mehuron, 2004)

While the benefits of the aging fleet continue to decline due to technical obsolescence, the costs of maintaining the fleet continue to increase:

> [Air Force] officials estimate that operation and maintenance costs have grown by a staggering 180 percent in the last decade, largely due to extensive and continuous repairs required on the airframes.
>
> Older aircraft have known problems, such as overstressed center wing boxes on C-130Es, but old fleets are also plagued with "the unknown unknowns," the Air Staff's Pennington said. "We simply haven't had airplanes that have flown this long [and] that you're going to continue to fly," he noted, making it increasingly difficult to predict what might break next. (Scully, 2007)

The Air Force's aging fleet is clearly an example of diminishing marginal returns. Keeping aging aircraft flying provides a smaller level of military benefits over time while the cost to maintain that fleet continues to increase.

Another example of benefits falling with costs rising can be found by examining the internal processes that govern defense acquisition within the Air Force aircraft acquisition enterprise. Professor Jan Kinner at the Defense Acquisition University provided a set of slides summarizing an analysis of the DoD 5000 series acquisition process performed by an anonymous Army officer. The draft presentation asserted that a "notional acquisition program created to provide a basis for analysis" would "likely take 16.5 years to go from the Materiel Development Decision to Full Rate Production." (Kinner, 2011)

The assumptions used by the anonymous Army officer were reasonable and assumed an ACAT 1D program to procure a ground vehicle utilizing low to medium risk technologies. An ACAT 1D program is one that requires DoD oversight due to its expected high dollar value. The threshold for this designation is a projected cost "estimated by the USD(AT&L) to require an eventual total expenditure for research, development, test and evaluation (RDT&E) of more than $365 million in fiscal year (FY) 2000 constant dollars or, for procurement, of more than $2.190 billion in FY 2000 constant dollars." (DAU, 2010) The general assumptions in the notional program analysis included reasonable estimates for both approval processes and contracting processes:

Documentation Assumptions

- Writing Milestone Documentation and going through WIPT/Stakeholder reviews generally takes 6 months prior to submitting it for approval. "Living documents" should be written earlier and updated throughout the program lifecycle.
- Approval process generally takes:
    - PM: 5 business days, PEO staff: 5 business days, PEO: 5 business days
    - OASA(ALT)/Army: 20 business days, AAE: 20 business days
    - OSD: 20 business days, DAE: 10 business days
- Approval process known to take longer (JCIDS, AoA, cost documentation, etc.) use appropriate extended timelines.
- All documentation (including test evaluations) are due to OSD 45 business days prior to the DAB

Contracting Assumptions

- There will be a down-select of Contractors between each phase (from 3 to 2 to 1), and long lead is purchased during the previous phase.
- Proposal preparation takes at least 6 months, requests for proposal (RFP) are on the street for 3 months, and negotiation/evaluation takes 6 months.
- There will not be any protests. (Kinner, 2011)

A key take away from the Army officer's analysis was that coordination and approval of required documentation through the system can end up determining the length of a DoD 5000

series compliant acquisition program. In other words, the approval of documentation occupies a place on the program's critical path. This is especially true if the technology being used is low or medium risk. Therefore, "no matter how much design, build and test are reduced", the overall process will still result in elongated acquisition timeline (Kinner, 2011).

In today's competitive, fast-paced technological environment, an acquisition process that can be expected to take 16.5 years to complete is one that provides less benefit than a process that delivers new capability faster. Additionally, a program with such a long duration consumes considerably more resources in the form of overhead costs than a shorter program. Therefore, the DoD 5000 acquisition process is clearly providing diminished marginal returns since benefits are falling and costs are increased in comparison to the shorter duration, less complex acquisition processes of the past.

8.3 Benefits Rising with Costs Rising Faster

Tainter and Patzek (2012) specifically address diminishing returns in military hardware acquisition in the following excerpt:

> Competition spurs complexity, as each competitor seeks to outdo its rivals...Military hardware grows increasingly complex and capable, but also increasingly costly. The growing costs mean that fewer and fewer weapons can be procured. The United States ended World War II, for example, with a fleet of 32 aircraft carriers, and with several more in production. Today the U.S. Navy struggles to support 11 carriers. These are, to be sure, highly capable weapons platforms, but 11 carriers cannot be in 32 places at once. In this sense, the cost of complexity constrains capability. Similarly in the early years of the Cold War, the U.S. produced 744 B-52 strategic bombers. Many of them are still flying today, and some are expected still to be flying in the 2030s. When the B-1 bomber entered production in the 1980s, only 100 were made. Of the most recent strategic bomber, the B-2, merely 21 were produced.
>
> Those are 21 amazing planes, but they can only be in 21 places at the same time. The military refers to this process as the death spiral. Because of high costs, fewer planes are bought. The cost of each plane rises, even fewer planes are bought, and the unit cost rises still further. It is an inevitable outcome of complexification, whether in military technology or in other areas of our lives. Whenever we must escalate technology to accomplish our goals, even to maintain the status quo, the increasing costs will constrain capability.

A similar result occurred within the F-22 fighter acquisition program. In 1991, the projected buy of F-22s was 650 aircraft at $100M per aircraft (Pearlstein & Gellman, 1991). By the time the first F-22 aircraft became operational in 2005, the cost of each had increased to $360M including developmental costs (Matthews, 2009).

The F-35 Joint Strike Fighter, an acquisition program still underway, appears to be following the same pattern:

> Sen. John McCain (R-Ariz.) took the Senate floor on Dec. 15 and described the F-35 fighter program as "a mess."
>
> What upset the senator was not just that the cost of each plane had risen nearly 100 percent from its original estimate of $69 million to $133 million today, or the fact that testing was only 20 percent complete while more than 90 planes had already been bought, or the fact that software — key to 80 percent of the stealth plane's warfighting capability — wouldn't be ready for another four years... (Pincus, 2011)

By January 2012, defense analysts were predicting a third F-35 program restructuring in order to delay the production of 120 additional planes. The delay would allow time for the completion of more development work as well as defer expenses into later year budgets:

> Virginia-based defense consultant Jim McAleese said he expected the Pentagon to defer production of well over 120 F-35 fighter planes until later years, cutting the cost of the program by about 25 percent over that time period.
>
> But he said it was crucial that the department was sticking to its overall target of buying 2,443 fighters for the Air Force, Navy and Marine Corps. That, he said, would keep the unit cost of the airplane from rising dramatically and triggering a congressionally mandated review that could lead to the program's cancellation. (Shalal-Esa, 2012)

While new aircraft deliver greater benefits in terms of capability than the systems they replace, their rising acquisition costs and extended schedules often result in smaller total procurements and work to diminish each program's marginal return. In the aggregate, the diminishing marginal return of each acquisition program contributes to an overall lower return for the Air Force aircraft acquisition enterprise as a whole.

8.4 Benefits Constant with Costs Rising

As the highly complex acquisition enterprise conducts its business, it is inevitable that unforeseen issues will arise. These issues must be surmounted in order to deliver aerospace weapon systems. Even if one assumes that these issues do not diminish the benefits obtained from the acquisition effort, it is likely that additional resources will be expended in the course of resolving the issue. Therefore, they will still tend to diminish marginal returns.

8.4.1 Specialty Metals: A Case Study

When there is misalignment of goals and incentives between Air Force aircraft acquisition enterprise stakeholders, productivity of the enterprise is reduced due to resources being diverted

from directly contributing to the mission. The following case study concerning specialty metals demonstrates how such sociopolitical complexity can diminish returns and impact the performance of the enterprise.

8.4.1.1 **Origin of the Issue**

Since the passage of the Buy American Act (BAA) of 1933, the U.S. Congress has actively provided domestic suppliers with an advantage over foreign sources when competing for government contracts. In 1941, additional legislation, known as the Berry Amendment, was passed that placed additional restrictions on military related contracts:

> The Berry Amendment, which dates from the eve of World War II, was established for a narrowly defined purpose: to ensure that U.S. troops wore military uniforms wholly produced within the United States and to ensure that U.S. troops were fed with food products solely produced in the United States. Other industries, such as tools and specialty metals, were added later. Originally enacted on the eve of World War II, it overrode exceptions added to the Buy American Act of 1933 for products procured by the Department of Defense. (Grasso, 2011)

Within the DFARS (252.225-7008 Restriction on Acquisition of Specialty Metals, July 2009), the term specialty metals is defined in the following manner:

> (a) Definitions. As used in this clause—
>
> (1) "Alloy" means a metal consisting of a mixture of a basic metallic element and one or more metallic, or non-metallic, alloying elements.
>
> (i) For alloys named by a single metallic element (e.g., titanium alloy), it means that the alloy contains 50 percent or more of the named metal (by mass).
>
> (ii) If two metals are specified in the name (e.g, nickel-iron alloy), those metals are the two predominant elements in the alloy, and together they constitute 50 percent or more of the alloy (by mass).
>
> (2) "Produce" means the application of forces or processes to a specialty metal to create the desired physical properties through quenching or tempering of steel plate, gas atomization or sputtering of titanium, or final consolidation of non-melt derived titanium powder or titanium alloy powder.
>
> (3) "Specialty metal" means—
>
> (i) Steel—
>
> (A) With a maximum alloy content exceeding one or more of the following limits: manganese, 1.65 percent; silicon, 0.60 percent; or copper, 0.60 percent; or
>
> (B) Containing more than 0.25 percent of any of the following elements: aluminum, chromium, cobalt, molybdenum, nickel, niobium (columbium), titanium, tungsten, or vanadium;
>
> (ii) Metal alloys consisting of—
>
> (A) Nickel or iron-nickel alloys that contain a total of alloying metals other than nickel and iron in excess of 10 percent; or

(B) Cobalt alloys that contain a total of alloying metals other than cobalt and iron in excess of 10 percent;

(iii) Titanium and titanium alloys; or

(iv) Zirconium and zirconium alloys.

(4) "Steel" means an iron alloy that includes between .02 and 2 percent carbon and may include other elements.

(b) Any specialty metal delivered under this contract shall be melted or produced in the United States or its outlying areas.

8.4.1.2 **Foreign Competition Brings Attention**

In order to gain additional insight in the impact of the Specialty Metal provision within the Berry Amendment, an interview was conducted with Mr. Rick Buschagen. As a retired contract officer and the former Chief of Compliance within the Aeronautical Systems Center Contracting Functional, Buschagen had a unique first hand perspective on the evolution of the issue.

Buschagen's recollection concerning specialty metals begins in the mid-70s while serving as a contracting officer in the F-16 program office within the Aeronautical Systems Center. He remembers that restrictions on the origins of specialty metals were added to the Defense Federal Acquisition Regulation Supplement at that time. Since e-mail was not yet in use, the policy arrived at Wright-Patterson Air Force Base via postal mail and was greeted with little attention. At the time, it was presumed that aerospace defense contractors were using domestic sources of specialty metals (Buschagen, 2011).

Buschagen stated that the topic remained a "non-issue" until the 1990s and the end of the Cold War. At that time, the Russians began exporting high-quality titanium at very competitive prices. This foreign competition threatened domestic smelters of titanium and they appealed to Congress for more stringent enforcement of the Berry Amendment's specialty metal provisions. In response to this Congressional pressure, SAF/AQ dispatched a team of 14 lawyers and contracting officers to Dayton with direction to check Aeronautical Systems Center contracts for compliance. Buschagen went on to say that many contracts were found that did not properly include the clause. This determination was the beginning of a lot of "turmoil" within the ASC. The enterprise struggled with how to deal with weapon systems that were found to include titanium whose origin was questionable. The enterprise also struggled with how to handle the situation going forward (Buschagen, 2011).

8.4.1.3 **Withholding Payment**

In the face of Congressional pressure and increased headquarters oversight, Aeronautical Systems Center contracting officers began asking suppliers to identify products that were under contract with foreign or untraced specialty metal content. When contractors reported that they could not verify the source of their specialty metal content was domestic, government contracting officers began refusing delivery. An example of the Air Force refusing delivery of F-15 aircraft with questionable specialty metal content is illustrated in the below excerpt from an internal program office monthly report. Since the Air Force did not accept delivery of the aircraft, Boeing did not receive expected payments:

> a. Pursuant to the contracting officer's letter dated December 29, 1999, relative to the Russian titanium issue, aircraft #222 & #223 were not accepted in December. Boeing did not request an exemption to the statute nor a waiver to DFARS 252.225-7014, preference for domestic specialty metals. We were further instructed to make no further payments, including progress payments, for aircraft containing Russian melted titanium.
>
> b. Presently, Boeing is withholding submittal of progress payments totaling $7.1 mil. In addition, Boeing is unable to invoice the unliquidated value of 2 aircraft equating to $16.9 mil. (F-15 System Program Office Monthly Report, 2000)

According to Buschagen, to allow delivery of products with questionable specialty metal content, contracting officers began using two workarounds. Since the use of appropriated funds could not be used to purchase foreign specialty metals, some contractors agreed not to charge the government for the cost of the individual components where compliance could not be verified.

In cases where the contractor would not agree to a discount, the contracting officer would reduce the payment made to the contractor for the cost of the non-compliant components, "withholding" the difference until the contractor could verify compliance or agreed to replace the questionable material. These withholds became contract contingencies that remained open for the remaining life of the contract, placing an additional administrative burden on the system. This second approach often resulted in conflict between the government and suppliers over the size of the withhold contingency and what paperwork and/or changes were required to become compliant. Some contractors initially refused to deliver finished products if withholding contingencies were stipulated but most eventually acquiesced in order to receive at least partial payment (Buschagen, 2011).

8.4.1.4 **Commercial Derivatives and Fasteners**

According to Buschagen, two issues were responsible for the majority of specialty metal problems. The first issue was acquisitions involving derivatives of commercially produced aircraft. In the commercial world, there were no restrictions on the use of foreign titanium. Prime contractors such as Boeing were therefore loathe to set up two supply chains for commodities such as titanium, especially if the size of the military acquisition program was much smaller than sales in the commercial market (Buschagen, 2011).

The second issue involved fasteners such as screws, bolts and retaining clips. Prime contractors often specified and used commercially produced fasteners in their military products. Since the majority of fasteners were produced for commercial users, documentation as to the origin of the specialty metal used in fastener production was non-existent. Since military fastener use was dwarfed by commercial uses, it was difficult to get fastener manufacturers to verify compliance at any cost (Buschagen, 2011).

One case involving the B-2 bomber demonstrates the magnitude of the problem. According to Buschagen, Northrop-Grumman could not verify that 18 fasteners used within the radar system were compliant with the Berry Amendment. Each of the fasteners was valued at less than $20 apiece. However, replacing the fasteners on an already completed bomber required upwards of $3M in disassembly/reassembly costs (Buschagen, 2011).

8.4.1.5 **A Continuing Battle**

As contracting officers struggled to enforce the provisions of the Berry Amendment, both aerospace prime contractors and specialty metal producers continued to lobby Congress to settle the issue in their favor.

Congressional testimony in 2003 by Mr. Timothy Rupert, President and CEO of the Ohio based titanium smelter RTI International Metals, demonstrates level of stakeholder intensity surrounding the issue:

> Thank you. Mr. Chairman, we thank you for the opportunity to testify here today on a matter of critical importance to my company as well as to my industry. My name is Timothy G. Rupert. I am the President and CEO of RTI International Metals, Inc. I am also the President of the International Titanium Association. Titanium due to its unique strength-to-weight ratio is critical to the production of jet aircraft. In fact, the industry was born out of the military's need for high performance metal from which to build key components of new jet fighters, as Ms. Patrick has already testified. It is for this reason that in 1973 Congress placed titanium, along with other specialty metals, under the protection of the specialty

metals clause of the Berry Amendment, requiring that specialty metals be produced domestically. You cannot build military aircraft without titanium. Approximately 90 percent of primary titanium production in this country comes from just three companies. Generally three-fourths of the industry's product goes into the production of aircraft, both commercial and military. These are small companies relative to their customers and following 9/11 they comprise a financially fragile industry. Earnings have steadily declined over the past five years, with the industry losing $163 million last year alone. To put that number in perspective, it represents about one-fourth of our combined market value. Obviously, this trend cannot continue much longer. The only other significant supplier in the world qualified for critical aerospace applications is a Russian producer, VSMPO, whose capacity is larger than the three U.S. producers combined. Yet while the domestic industry continues to shrink, VSMPO's shipments and earnings have steadily grown, in large part due to favorable treatment by the U.S. Government at the expense of domestic producers...

An even bigger threat to the U.S. titanium industry is the current attack on the Barry (sic) Amendment. Increased military spending, particularly aircraft, is one of the few bright spots in our marketplace. However, attempts to abolish or undermine the specialty metals clause in what I will refer to as midnight waivers of its requirements threaten to take away that lifeline. After operating as intended for 25 years, suddenly the specialty metals clause has fallen victim to increasing misinterpretation, its requirements violated and its intent ignored all together...The effect of these waivers has been to seriously weaken the U.S. titanium industry and, in our opinion, if this trend continues, we believe that it will have a direct and negative impact on national security. (U.S. House of Representatives, 2003)

The battle between the two interest groups dragged on for years while the DoD, the Air Force and their prime contractors pursued waivers and "Domestic Non-Availability Determinations" (DNADs). Guidance from DoD and the Air Force varied over time which generated delays in the form of extended contract negotiations (Buschagen, 2011).

According to an October 2008 Aerospace Industry Association fact sheet, the specialty metals issue continued to be a problem 17 years after the end of the Cold War increased the availability of foreign titanium:

The United States has implemented extensive and complex rules aimed at restricting the use of non-domestic "Specialty Metals" in the defense acquisition process. The stated goal is to protect the U.S. defense industry from becoming overly dependent on foreign sources of supply, especially in times of conflict. These rules are codified in public laws such as the "Berry Amendment" (10 U.S.C. 2533a) and the National Defense Authorizations Acts of FY 2006 and 2007 (10 U.S.C. 2533b and revisions).

Since December 2006, the Department of Defense (DoD) has issued an increasing number of memos attempting to regulate, clarify and otherwise implement the intent of these laws. Most of the legislative and regulatory changes over the last two years have been the result of lobbying struggles in Washington and attempts to explain the application of the law to a very confused domestic defense supply base. (Aerospace Industry Association, 2008)

8.4.1.6 Enterprise Impacts

While it is impossible to quantify all of the costs to the Air Force aircraft acquisition enterprise due to the conflict over the specialty metals portion of the Berry Amendment, it is clear that a tremendous amount of time and resources were expended from the early 1990s to 2008 on the issue. The issue also created a large increase in performance-inhibiting complexity, in the form of additional oversight, policy guidance and specialty metal origin tracking documentation. Appendix B includes a March 14th 2008 slide presentation by Buschagen summarizing the guidance provided at that time to Aeronautical Systems Center contracting officers. The 40-slide presentation is merely one artifact documenting the resources expended to resolve the contentious issue.

In summary, the specialty metal issue is a good case study of how the competing interests of a diverse set of stakeholders can increase the level of complexity and diminish returns. Even with benefits of each acquisition program assumed constant, the additional resources expended handling the specialty metal issue caused the marginal return of the enterprise to decline.

8.5 Research Result and Conclusion

The examples presented above describe three of the four conditions which result in declining marginal returns. An aging aircraft fleet and an elongated acquisition approval process are both examples where benefits are falling while costs are rising. The procurement of new aircraft with their accompanying cost and schedule overruns are a good example of benefits rising with costs rising faster. Lastly, the specialty metals case is an example of benefits remaining constant with the costs rising. The last condition, benefits falling with costs remaining constant, was not discussed since costs are rarely static over timeframes of interest. When one considers the above evidence in aggregate, it is reasonable to conclude:

The level of investment in complexity within the Air Force aircraft acquisition enterprise has reached a point of declining marginal returns.

Chapter 9 Responses to Complexity

The previous two chapters demonstrated that both a high level of complexity is present within the Air Force aircraft acquisition enterprise and that marginal returns are being diminished. The next step is to examine the recurring efforts taken to improve the performance of the Air Force aircraft acquisition enterprise while relying on Tainter's framework to understand why they have not been as effective as expected.

9.1 Cyclical Reorganizations

Tainter states that when a society begins to see marginal returns decline, it usually responds to the "stress by increasing complexity. In doing so it increases investment in agricultural and other resource production, in hierarchy, in information processing, in education and specialized training, in defense and so forth." (Tainter, 1988) What Tainter observed at the societal level appears to also hold true at the enterprise level. As can be expected of any customer, the operational Air Force would like its new systems delivered faster and with less cost. Therefore, leaders of the Air Force aircraft acquisition enterprise are always under pressure to improve the effectiveness of their organizations. Since the early 1990s, as performance of the Air Force aircraft acquisition enterprise has declined, leadership has attempted to reverse the decline by altering the organizational structure of the enterprise.

Between 1991 and 2010, the leadership of the Aeronautical Systems Center made significant changes to the organization's structure five times in the pursuit of performance. All of these changes required large time and resource investments in the form of planning, securing higher headquarter approvals and the reorganization implementation itself. A reorganization therefore increases complexity and diminishes marginal returns over the near term. Unfortunately, it appears that over the longer term, effectiveness of the enterprise did not increase either.

In 1991, the hierarchy of the organization of the Aeronautical Systems Division was relatively flat. Program offices reported directly to the three-star center commander and were each singularly focused on an individual weapon system acquisition. For example, F-15, F-16 and Advanced Tactical Fighter (later F-22) program offices all directly reported to Lt Gen Ferguson (Aeronautical Systems Division, 1991).

In 1992, Lieutenant General Ferguson began a series of hierarchical changes in order to establish "an efficient workforce mix at ASD." As a result of the flat organizational structure, it was found that management to worker ratios were low and that there was a perceived over

reliance on support contractors. "Gen Ferguson's ultimate goal was to eliminate [support] contractors, but his realistic short term goal was to restrict [support contractors] to less than 3% of the ASD workforce." One reason behind this change was to free up funding for additional Air Force personnel. While not explicitly stated in the historical documentation, it appears that Gen Ferguson felt that a reduction in contracted employees would also increase organizational effectiveness (Aldridge, Cornelisse, Kallander, Romesburg, & Wolf, 1993).

In May of 1993, Lieutenant General Fain assumed command of the Aeronautical Systems Center and shifted the focus from workforce mix to the relationship between program managers and functional leadership:

> One primary programmatic concern of General Fain was the often abstruse relationship between ASC's system program managers (SPDs) and the organization's functional organizations...Of particular concern to him was the SPD's occasional difficulty in working with the Integrated Engineering and Technical Management Office, known by its long time organizational chart symbol "EN". While working in program offices during the 1980s, General Fain observed that the EN home office exerted excessive and inappropriate control over SPOs. More recently he observed the pendulum had swung too far in the other direction. The program manager had achieved an inordinate amount of control with collocated engineering personnel receiving inadequate guidance and support from the EN home office. In an effort "...move the pendulum back to the middle...,"General Fain tasked James F. Blair, Director of the [EN], to prepare a White Paper that would specifically define the roles and responsibilities of SPDs and functionals. (Aldridge, Cornelisse, Ferguson, Kallander, & Romesburg, 1994)

The October 1994 organizational chart begins to diverge from the 1991 version. Functional organizations for the first time are grouped together on one side of the chart while program offices are organized by whether they are subject to programmatic oversight by the center commander versus those that are only provided "resources and acquisition expertise to support execution..." (Aeronautical Systems Center, 1994)

The organization structure again changed in 1996 with the introduction of an additional level of management. Mission Area Groups (MAGs) and product support groups were created in the face of SAF/AQ directed personnel grade and head count reductions. The program offices were thus divided into categories based upon their mission area or product type. Some program offices were merged and their programs were managed collectively at the group level. Other program offices remained distinct and either reported to their respective mission area, product group director or the center commander. Functional offices were also consolidated in order to "accommodate continued downsizing of the workforce." The introduction of the MAG level of

management was an attempt to encourage the "sharing of functional expertise to optimize the use of manpower." The reorganization also had the side effect of once again strengthening the program management leadership chain within the matrix structure while correspondingly reducing the power of the functional reporting chain (Aldridge, Cornelisse, Ferguson, Narducci, Dunn, & Romesburg, 1997).

In fiscal 1997, the pendulum again swung concerning the use of support contractors. Although General Ferguson had worked to reduce the number of support contractors only five years earlier:

> Secretary Cohen wanted the DoD to have a mix of both organic and temporary employees to maximize the benefit gained by permanent employees working toward the organization's core mission while reaping the savings achieved by using non-organic employees for peripheral support activities. (Aldridge, Cornelisse, Ferguson, Narducci, Dunn, & Romesburg, 1998)

Lieutenant General Raggio assumed command of the Aeronautical Center on 1 June 1998 and "quickly made a number of changes which suggested that he had a somewhat different vision for the Center and for his own role as commander...over the next few months General Raggio also directed organizational changes which swept away significant elements of the structure erected by his predecessors." (Aldridge, Cornelisse, Ferguson, Narducci, Dunn, & Romesburg, 1999) By October of 1998, General Raggio had "ended five years of experimentation with the fundamental organizational structure of ASC's organizational community..." The resulting organization restored power to the functional organizations who again managed workforce movement between discrete program offices (Aldridge, Cornelisse, Ferguson, Narducci, Dunn, & Romesburg, 1999).

The organization of the Aeronautical Systems Center remained relatively stable for approximately six years until 2003 when General Gregory S. Martin became the commander of the Air Force Materiel Command. While assigned to Gen Martin's staff, I witnessed firsthand his desire to alter the culture of AFMC which he felt had become insular with respect to the rest of the Air Force. One manifestation of this desire was to change the organizational structure of the centers so they would more closely resemble the structure of the operational Air Force. The Aeronautical Systems Center, along with the other centers, was directed to adopt an organization structured in the form of wings, groups and squadrons. Planning for the reorganization was initially led by General Martin's special assistant, Colonel Andrew Weaver and spanned nearly

two years before its approval and implementation in 2005. The new structure greatly increased the power of the program management chain since program directors were now also commanders with a higher level of authority over their workforce. The strength of the functional home offices was viewed as greatly reduced. They now were seen to be acting in primarily a consulting role to the commanders.

The wing/group/squadron structure proved to be very unpopular with the Air Force aircraft acquisition enterprise workforce and did little to improve interactions between the operational commands and the acquisition community. In the course of conducting its 2009 independent assessment, the CNA concluded that the new structure was actually detrimental:

> Of the 48 interviews we conducted only one person thought the wing/group/squadron (WG/GP/SQ) structure had been successful. These findings are consistent with CNA's findings in 2006. We believe the wing structure is a major inhibitor to efficient and effective execution of the acquisition process. It inhibits efficient reallocation of personnel resources, disconnects employees from what should be their functional mentors and inhibits proper career management. Furthermore, we were frequently told the command selection process for wing commanders has resulted in wing commanders with little or no acquisition experience. (Christie, Davis, & Porter, 2009)

In 2010, the wing/group/squadron construct was discarded and the Aeronautical Systems Center assumed a structure that closely resembled its appearance in 1996. Wings were changed into directorates which are very similar to the 1996 MAG construct. Functional power was also increased with an increased level of workforce management authority. During this same timeframe, the pendulum again swung against the use of support contractors. In 2009, the DoD announced its intent to convert over 11,000 support contractors into government employees (Aviation Dayton, 2009).

Figure 28a and Figure 28b provide a visual synopsis of the reorganizations and power shifts that took place between 1991 and 2010. The colloquial analogy of a pendulum swinging between two states is not far from the mark. Across the two decades, the organizational structure alternated between more and less levels of structural hierarchy. Power between the two organizational matrix dimensions (program management and functional) also alternated over time as did reliance on support contractors.

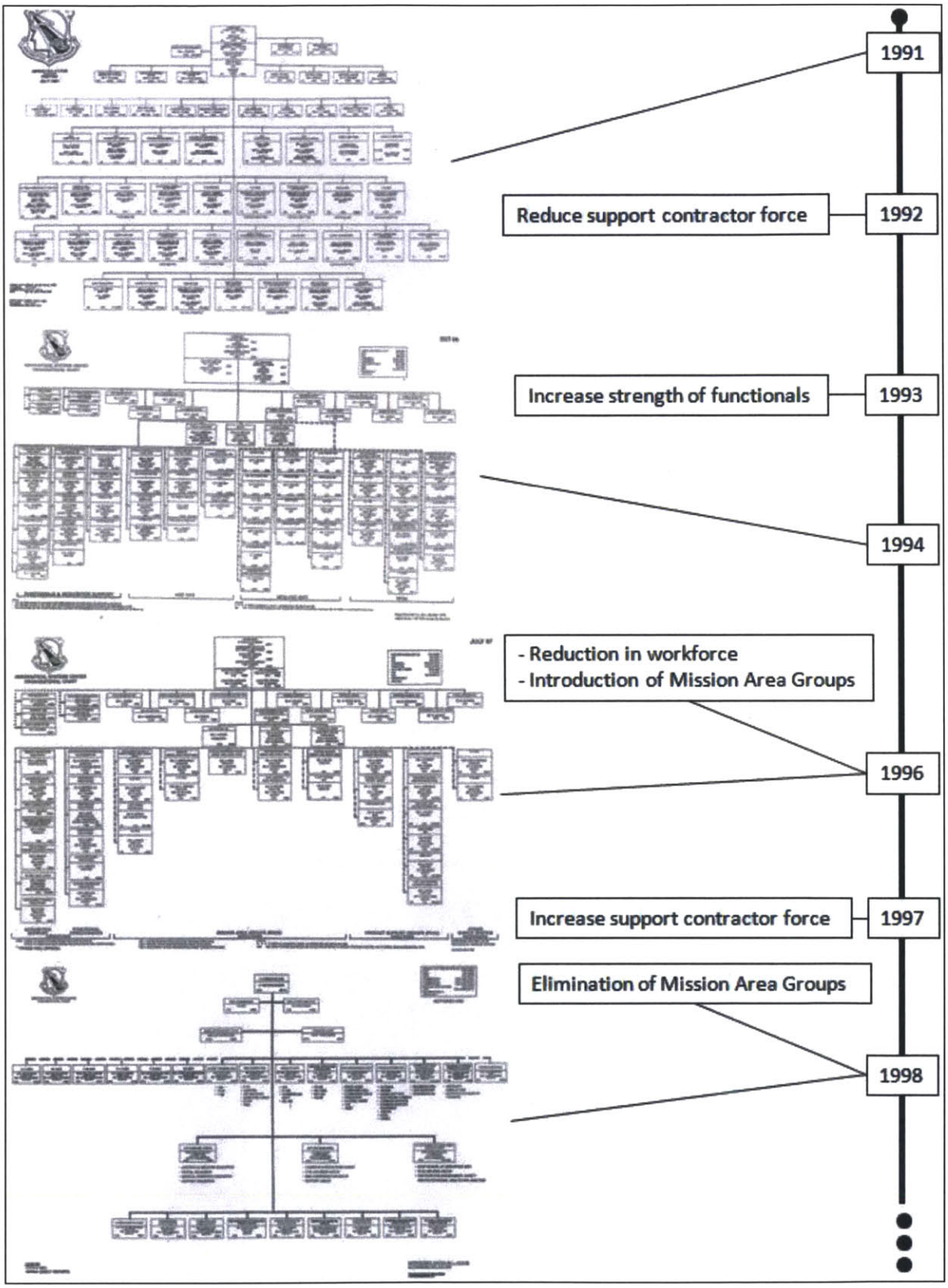


Figure 28a: Aeronautical Organizational Structure (1991-1998)

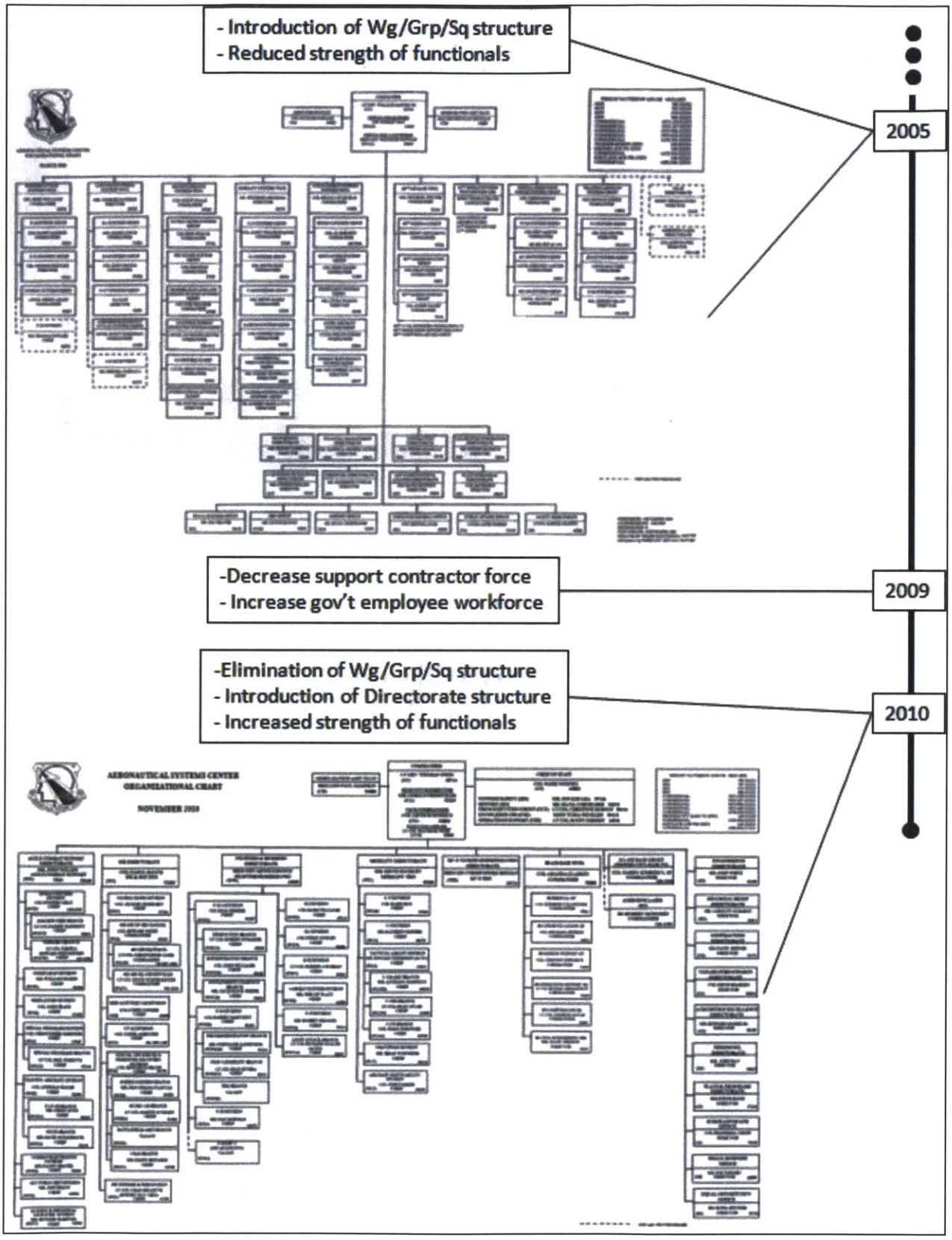


Figure 28b: Aeronautical Organizational Structure (1998-2010)

This long term organizational behavior is congruent with Tainter's theory. Leaders of the Air Force aircraft acquisition enterprise have expended considerable amounts of time and resources over the past two decades in search of a better performing structure yet none of the reorganizations appeared to have explored lowering the level of system complexity in any significant manner. Problem solving has instead focused on the balance of authority between the program manager and functional matrix dimensions and on the right mix of support contractors and civilian employees. While these power shifts may have resulted in transitory improvement, the underlying high level of complexity remained in place and continued to operate in a fashion that reduced marginal returns. Additionally, as mentioned earlier, the very act of reorganization and its use of resources further diminished marginal returns during each reorganization. If future reorganizations also fail to lower the level of underlying complexity, they will also fail to improve overall system performance.

9.2 Senior Leader Improvement Initiatives

In addition to cyclical reorganizations, another response of leadership in the face of diminishing returns is to introduce top-down initiatives intended to improve performance. Tainter (1988) makes the observation that as complexity increases and returns fail to improve, the hierarchy is forced to "allocate still more of a shrinking resource base to legitimization and/or control." (Tainter, 1988) Two sets of initiatives are examined below. One set from the mid-1990s and another more recent set from 2010.

9.2.1 Lightning Bolt Initiatives

In 1995, under the direction of Darleen Druyun, the Principal Deputy Assistant Secretary of the Air Force For Acquisition and Management, SAF/AQ issued a set of nine "Lightning Bolt" initiatives intended to improve the performance of Air Force acquisition. Two more were added to the list in the spring of 1996. As described in an Air Force presentation to the Senate Armed Services Committee, the lightning bolts:

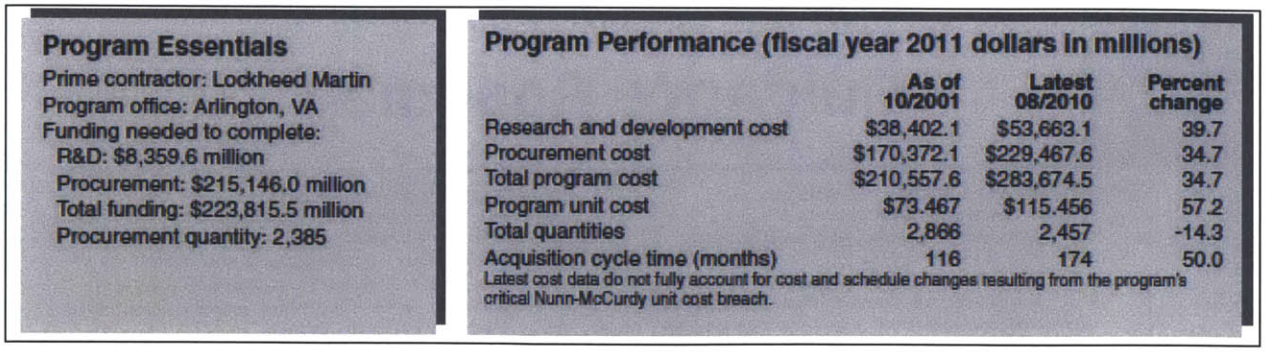
1. Created a centralized Request for Proposal (RFP) support team to implement acquisition reform in all RFPs, contract options, and contract modifications over $10M.
2. Created a standing Acquisition Strategy Panel of senior-level Air Force acquisition personnel.
3. Set goal to reduce the size of our program offices by 50 percent.

4. Tackled policy creep that had created inconsistent acquisition policies across centers
5. Reinvented the Air Force process for reaching program milestone decisions.
6. Enhanced the role of past performance in source selections.
7. Replaced numerous acquisition documents with a Single Acquisition Management Plan (SAMP).
8. Revised the Program Execution Officer (PEO) and Designated Acquisition Commander (DAC) portfolio review to add a section that deals specifically with acquisition reform.
9. Enhance our acquisition workforce with a comprehensive education and training program that integrates acquisition reform initiatives.
10. Reduce the time from requirement definition to contract award.
11. Enhance the capabilities of our laboratories by adopting improved business processes. (Dept. of the Air Force, 1999)

Many of the lightning bolt initiatives included measures designed to streamline the enterprise, including a reduction in workforce size, simplified documentation and a greater reliance on commercial standards versus unique government specifications. Following their implementation, they were trumpeted as an overwhelming success. In his 1998 Annual Report to the President and the Congress, Secretary of Defense William Cohen included the following paragraph:

> Acquisition Reform. The Air Force is changing the culture of acquisition. The emphasis is to provide weapon systems better, cheaper, faster, and in a more streamlined and consistently smoother process. Virtually every new acquisition program is taking advantage of commercial practices by altering its strategy toward commercial specifications and standards, privatization, outsourcing, commercial off-the-shelf technology, and contractor system responsibility. Through its Lightning Bolt initiatives in streamlining, teaming, and innovative acquisition strategies, the Air Force has realized $6 billion in cost savings and $11 billion in cost avoidance. Newer efforts focus on continuous improvement and establishing strategic steps to ensure acquisition reform becomes the norm. To accomplish these objectives, we will continue to advance the professional development of our acquisition work force by providing quality continuing education and training. (Cohen, 1998)

However, the benefits realized from these reforms appear to have been fleeting and largely limited to smaller, less complex programs such as the Joint Directed-Attack Munition (JDAM) (Air Force News Service, 1999). Large, complex acquisition programs on the other hand continue to exceed their original cost and schedule estimates. The Joint Strike Fighter program formally began in 1996 just as the Air Force's Lightning Bolts were implemented. Unfortunately, as Figure 29 shows, the Joint Strike Fighter Program's expected total program cost increased by nearly 35% between 2001 and 2010.



Program Essentials

Prime contractor: Lockheed Martin
Program office: Arlington, VA
Funding needed to complete:
R&D: $8,359.6 million
Procurement: $215,146.0 million
Total funding: $223,815.5 million
Procurement quantity: 2,385

Program Performance (fiscal year 2011 dollars in millions)

	As of 10/2001	Latest 08/2010	Percent change
Research and development cost	$38,402.1	$53,663.1	39.7
Procurement cost	$170,372.1	$229,467.6	34.7
Total program cost	$210,557.6	$283,674.5	34.7
Program unit cost	$73.467	$115.456	57.2
Total quantities	2,866	2,457	-14.3
Acquisition cycle time (months)	116	174	50.0

Latest cost data do not fully account for cost and schedule changes resulting from the program's critical Nunn-McCurdy unit cost breach.

Figure 29: Joint Strike Fighter Program Performance (U.S. GAO, 2011)

9.2.2 2010 USD(AT&L) Initiatives

On September 14, 2010, Ashton B. Carter, the Undersecretary of Defense for Acquisition, Technology and Logistics issued a memorandum titled "Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending". The memorandum enumerated "23 principal actions to improve efficiency organized in five major areas." Carter further stated that the principal actions would be followed up with specific guidance in the form of directives to the acquisition workforce (Figure 30).

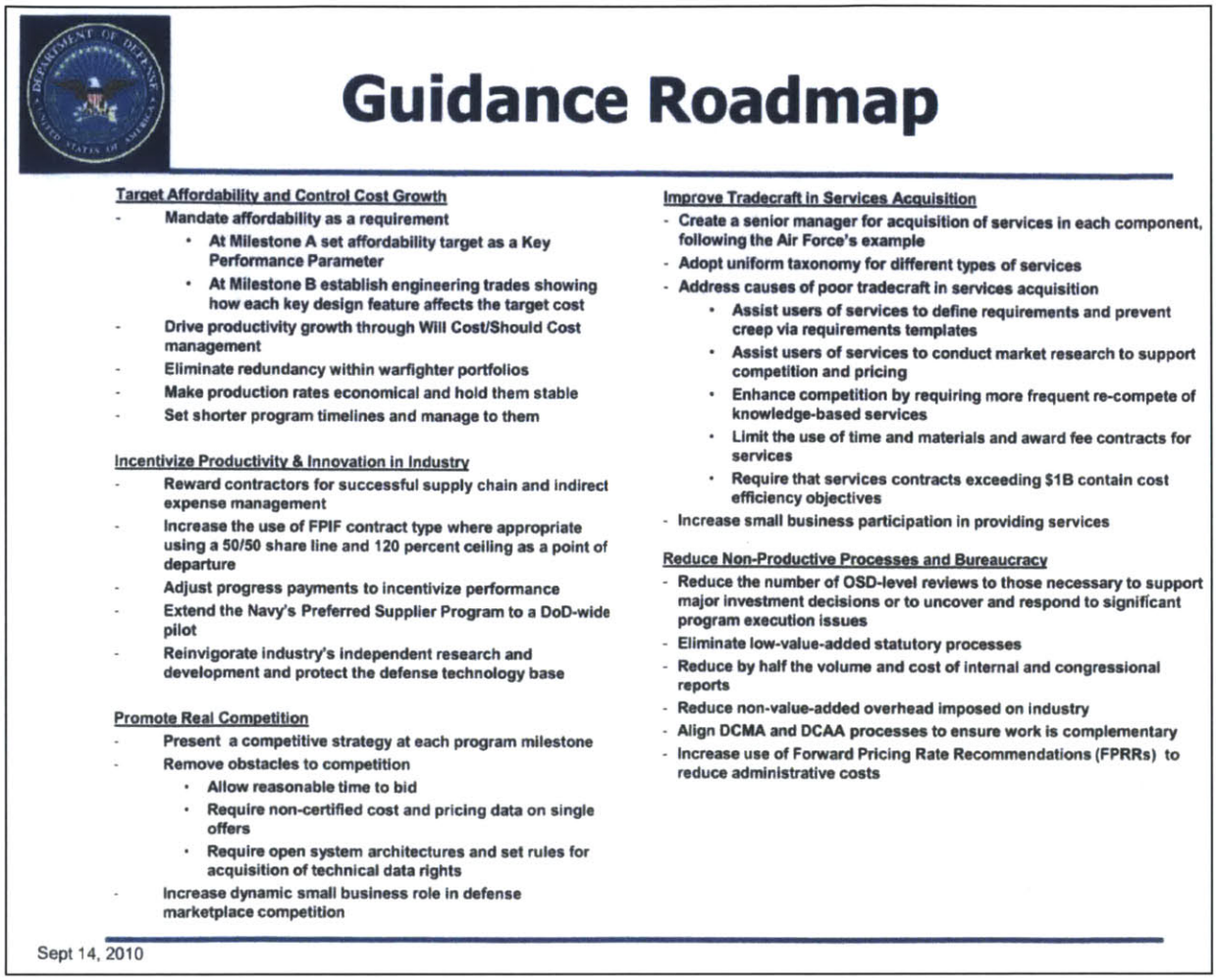


Figure 30: USD (ATL) Guidance Roadmap (Carter, 2010)

While 15 years separates the two sets of initiatives, there are definite similarities between the two lists. Both sets of initiatives include measures designed to streamline the acquisition process. Both sets also attempt to incentivize contractors to perform more efficiently. Secretary Carter's guidance recommends the use of incentive-fee contracts and progress payments.

In the face of high complexity, poor programmatic performance and diminishing returns, the reaction of senior leaders in 2010 is very similar to 1995. While both leaders issued sets of initiatives intended to improve effectiveness of the enterprise, neither advocated scrapping the highly complex existing system. This response is congruent with Tainter's observations at the societal level. He points out that the latter alternative may be more advantageous to the society as a whole but certainly not to the administrators of the current system (Tainter, 1988). Therefore the underlying complexity tends to remain untouched, preventing significant improvement in

marginal returns and overall system effectiveness despite the introduction of senior leader initiatives.

9.3 Increasing Reliance on Workarounds

When individuals and organizations become frustrated with the performance of a system in the face of diminishing marginal returns and high complexity, they engage in a behavior that Tainter calls scanning: "The system as a whole engages in 'scanning' behavior, seeking alternatives that might provide a preferable adaption." (Tainter, 1988) There are clear examples of scanning occurring within the Air Force aircraft acquisition enterprise. Two instances of such behavior include the use of undefinitized contract actions and a growing reliance on alternative organizational structures such as the Rapid Capability Office (RCO).

9.3.1 Undefinitized Contract Actions

Within the Air Force aircraft acquisition enterprise, a common workaround appears to be the use of Undefinitized Contract Actions (UCAs):

> When a requirement needs to be met quickly and there is insufficient time to use normal contracting vehicles, federal regulations permit the use of a UCA. UCAs are binding commitments used when the government needs the contractor to start work immediately and there is insufficient time to negotiate all of the terms and conditions for a contract. UCAs can be entered into via different contract vehicles, such as a letter contract (a stand-alone contract), a task or delivery order issued against a pre-established umbrella contract, or a modification to an already established contract. (U.S. GAO, 2007)

The key advantage of a UCA is that it allows for the immediate obligation of funds and allows work to begin before contract terms and conditions are finalized. Program managers are always under pressure to show they are making progress. One way progress is measured is by tracking the obligation of funds. A UCA is a fast way to obligate up to 50% of expected contract cost without first having to finalize often complex contract terms governed by the FAR and its supplements.

In 2007, the U.S. Government Accountability Office conducted a review of the use of UCAs that included the Aeronautical Systems Center (Figure 31). Among all of the UCAs reviewed, about half of the UCAs were awarded just to maintain program schedules. "In addition, 10 of the UCAs we reviewed were attributable to inadequate planning. For example, one UCA for the continuation of ongoing services was awarded the day after the previous contract expired." (U.S. GAO, 2007)

Table 1: Obligations on Undefinitized Task and Delivery Orders during Fiscal Years 2004-2005 at Locations Visited

Location	Obligations (dollars in millions)	Number of actions
Aeronautical Systems Center	$524.7	91
Aviation and Missile Command	81.0	12
Naval Air Systems Command	8.0	5
Naval Sea Systems Command	49.3	1
Warner Robins Air Logistics Center	14.9	2
Total	**$677.9**	**111**

Source: GAO analysis of DOD data.

Note: The Army's TACOM Life Cycle Management Command reported no UCA orders during this period. The National Geospatial-Intelligence Agency had undefinitized orders during this period but does not track this information for its DOD contracts.

Figure 31: Undefinitized Contract Actions (U.S. GAO, 2007)

Overuse of UCAs is not surprising since they appear to be an effective effective scanning behavior in the face of high complexity. Therefore it is not be surprising that the Aeronautical Systems Center had 91 outstanding UCAs during Fiscal Years 2004-2005 (Figure 32).

	Description of goods or services	Award date	Definitization date	Not-to-exceed amount	Obligation amount at award	Total dollar value at award	Contract/ order pricing type[a]
Air Force							
	Aeronautical Systems Center						
1	B-2 aircraft aft deck inner mold kits	2/17/04	8/17/04	$16,737,000	$8,368,500	N/A[b]	CPFF
2	Required navigational performance link for C-17 aircraft	9/5/02	12/23/03	5,250,000	2,146,118	N/A[b]	CPAF
3	Common crypto appliqué for F-15 aircraft	2/20/04	7/1/04	1, 366, 402	683,201	N/A[b]	CPFF
4	Enterprise support infrastructure	5/28/04	7/24/04	1,508,938	1,131,704	N/A[b]	FFP
5	Threat Situational Awareness System for B-1 aircraft	12/19/03	6/1/05	23,100,000	10,781,000	N/A[b]	CPFF
6	Aircraft Defense Systems for Army C-37A aircraft	12/8/04	5/2/05	6,038,000	3,019,000	N/A[b]	FFP
7	Receiver/exciter controller upgrade kits	9/30/05	5/18/06	1,287,000	965,250	$965,250	FFP
8	9 Lynx radar upgrade for Predator unmanned aerial vehicle	7/29/05	9/29/06	13,867,301	10,400,476	10,400,476	FFP
9	Tactical Micro Unmanned Aerial Vehicle improvements	2/8/05	5/18/05	2,202,337	1,101,169	2,202,337	FFP/T&M
10	Receiver/exciter controller upgrade kits for ASARS-2A radar system	5/19/04	2/25/05	5,938,414	4,453,811	8,889,104	FFP
11	Readiness spare package kits for Predator unmanned aerial vehicle	7/1/04	8/24/05	26,427,245	26,427,245	131,028,443	FFP
12	Battlefield Air Targeting Camera Autonomous Micro-Air Vehicles	9/29/05	3/8/06	619,852	309,925	309,925	FFP

Figure 32: GAO Reviewed Aeronautical Systems Center UCAs (U.S. GAO, 2007)

It is also not surprising that among the 12 UCAs reviewed by the GAO at the Aeronautical Systems Center, the average number of days before contract definitization occurred was 261. Even though a UCA must be definitized in 180 days or less, there is little incentive for either the government or the contractor to move quickly. Definitization involves dealing with all of the complexity that was initially avoided.

Unfortunately, the use of UCAs does not benefit the enterprise as a whole over the long run. Definitization must still be accomplished albeit now in a situation where the government has much less leverage since some funding is already in the contractor's possession. While markedly less work than contract definitizations, the effort expended to issue UCAs still consumed time and resources that could have been put initially towards definitization tasks. Both of these factors combine to further diminish the marginal returns of the Air Force aircraft acquisition enterprise.

9.3.2 Use of Alternative Organizations

Another scanning behavior observed within the Air Force aircraft acquisition enterprise is the use of alternative organizations. Rather than rely on the mainline organization (ASC), leaders seek to improve their marginal returns by relying on alternative organizations with less complexity. During interviews, two senior level acquisition professionals independently stated that there is a strong incentive to keep an acquisition program classified as long as possible since acquisition approval procedures within the classified realm are less cumbersome than the approval coordination process that must be followed for an unclassified effort. A simple illustration of why this is involves approval packages. Due to higher levels of security, there are often a smaller number of people who must review and approve documentation before an action can be implemented. The lower number of reviewers decreases the likelihood that the approval documentation will be returned for changes.

While this scanning behavior continues, two senior-level ASC interviewees indicated that procedures within the classified realm had become more stringent over the past few years and that the advantage gained by keeping a program classified was no longer as large as it had been in the past. This "tightening up" was described to be as a result of program failures within the classified realm due to insufficient oversight.

Additionally, as a program grows in size, the benefits of streamlined approval processes are overwhelmed with the costs of operating a large organization securely:

> In theory, so-called black world acquisition streamlines the process and lowers cost. Yet here again the B-2 program offers a cautionary tale. It, too, was a totally classified program but heavy secrecy actually imposes heavy costs. All the management, labor, and accounting procedures integral to any major program were required for the B-2, but every single person had to have a security clearance...clearances often took months, slowing the overall project. New workers stayed on the program payroll while awaiting clearances...Kinnu and Waaland later estimated that security alone added between 10 percent and 20 percent to the overall B-2 program cost, a figure consistent with that for the F-117 program. (Grant, 2012)

In an interview with another senior leader from the Aeronautical Systems Center, frustration was expressed when discussing the Air Force's Rapid Capability Office, known within acquisition circles as the "RCO". According to the Air Force's public fact sheet on the RCO, its mission is described as follows:

> The Air Force Rapid Capabilities Office expedites development and fielding of select Department of Defense combat support and weapon systems by leveraging defense-wide technology development efforts and existing operational capabilities. The Board of Directors tasks the office directly to address needs that involve mission applications and operational concepts requiring specialized expertise, and involve sensitive activities managed by other government agencies. The office also conducts projects on accelerated timelines. (U.S. Air Force, 2011)

The fact sheet also indicates that the organization's board of directors includes top acquisition leaders including the Undersecretary of Defense for Acquisition, Technology, and Logistics as well as the Secretary of the Air Force, the Air Force chief of staff, and SAF/AQ.

The ASC senior leader believed that the Aeronautical Systems Center was being "passed over" for work because "leaders in Washington" favored the streamlined approval processes in place at the RCO versus the "zero-value added" processes that were in place at the Aeronautical Systems Center. His frustration was centered on the belief that he and the Aeronautical Systems Center were unfairly required to follow more stringent processes which reduced organizational competitiveness.

Regardless of whether the senior leader's frustration is justified, it does appear that the RCO is managing projects that otherwise would be managed at a product center. Examples from the public fact sheet include the X-37B Orbital Test Vehicle and a sensitive airborne receiver system (U.S. Air Force, 2011).

Just as an electrical current will utilize the path of least resistance, Tainter's framework indicates that individuals and organizations will also seek out the path of least resistance when confronted with a highly level of complexity and diminishing marginal returns. If workarounds

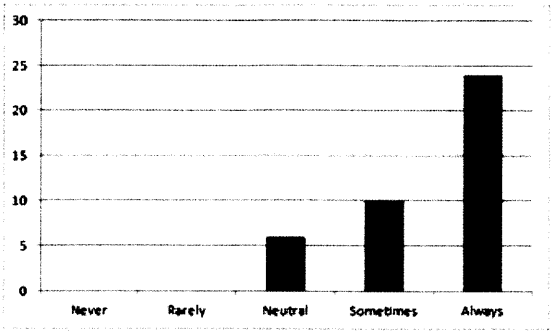
such as UCAs and alternative organizations are perceived to provide a pathway to accomplishing an acquisition program more efficiently, it is to be expected that they will be utilized whenever possible. One problem with this approach is it cannibalizes work from the mainline enterprise further reducing its output and diminishing its marginal returns. Additionally, all work cannot be transferred to an alternative organization without raising the ire of stakeholders in the primary system such as employees and the Congress. These stakeholders will eventually react and restrict the use of alternative pathways. Lastly, what may be expedient in the short term may impose higher costs over the long term.

9.4 Survey Responses

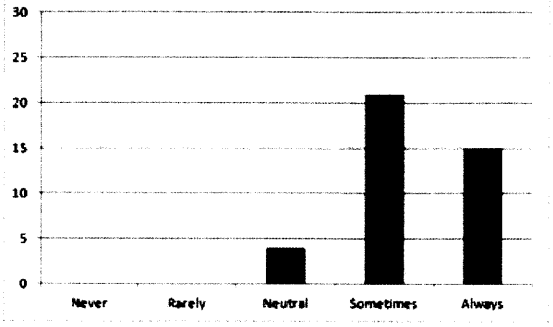
In addition to the information gathered above documenting responses to a high level of complexity, a survey of individuals was also conducted. The objective of the survey was to verify both how individuals recognize that a program has grown too large and complex and what typically is done in such circumstances. The focus was also kept at the program level versus the enterprise level since that is the level where program managers and engineers have the most experience.

How do you know a project or program has become too large?

The time to make decisions increases excessively?



Management begins to sub-optimize, making decisions that maximize only local outcomes?



Other Notable Written Responses:

- Insufficient communication and sharing among participants
- [People] lose track of the big picture
- Working groups get so large that they're unwieldy
- To much rework
- Designers cannot get proper information in time
- Unable to explain most facts on 1-2 slides
- Morale decreases
- ACAT I
- Schedule extends, cost overruns
- Loss of understanding of objectives and means to get there
- Teams make decisions without coordinating with other teams
- Annual budget of $1M+ is used only to "maintain", not to produce anything and there is no funding for the other things
- AKA "ACAT 1"

Figure 33: Survey Question 1 Responses

Figure 33 provides a listing of the responses to the first survey question. The majority of respondents felt that as a program grows in size both the timeliness and quality of decisions at least sometimes decrease. The comments are also insightful, identifying increasing rework, declining information quality and reduced coordination as indicators that an effort has grown too large. This result provides insight into how diseconomies of scale result in declining marginal returns.

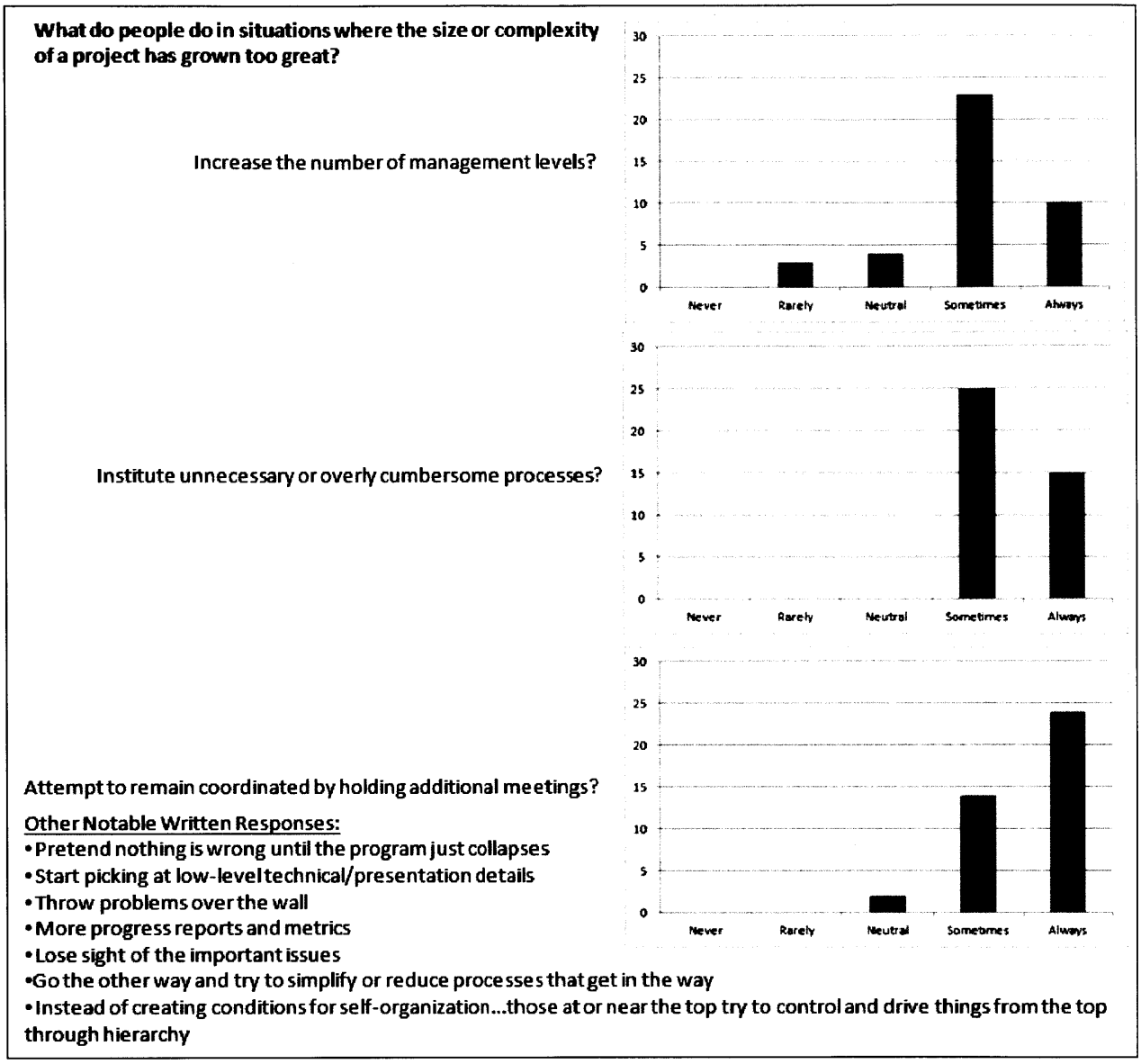


Figure 34: Survey Question 2 Responses

The responses to the survey's second question are summarized above in Figure 34. The majority of respondents confirmed that increases in hierarchy at least sometimes occur as programs become too large or complex. Respondents predominantly agreed that these increases in hierarchy are in the form of increasing levels of management and additional processes. As with question 1, this result also illustrates how diseconomies of scale work to decrease returns. The comments also referenced other signs of increasing hierarchy including "more progress reports and metrics" and over control in the form of excessive attention to low level details and top-down control.

What do people do in the face of very restrictive processes or regulations that are perceived to hamper progress on a project?

Notable Written Responses:

- Ignore and work around
- Bypass them
- Shut down, become less productive
- Avoid them!
- Ignore them (x3)
- Ignore them and pay the price later
- Get deviations and waivers
- Bypass whenever possible
- ACTDs (Advanced Concept Technology Demonstrations)
- Loopholes
- Workarounds
- Play the game and/or get out
- Work around them (see "pushers" in Soviet Russia)
- Become angry and settle for "just a paycheck" and no accomplishment
- [People] lose their motivation to add value through collaboration and cooperation (and competition) and focus on other things pursuing self-interest

Figure 35: Survey Question 3 Responses

The last question in the survey specifically asked respondents what people did in the face of restrictive processes and regulations; the type of environment in an organization with a high level of complexity and a high level of hierarchy. The responses confirmed that scanning occurs in the form of seeking workarounds. Most responses either fall in the category of work arounds or outright disregard for enterprise processes. This is congruent with Tainter's description of what occurs when complexity becomes excessive. Individuals will engage in scanning behavior in an attempt to find an easier way and boost returns.

Across all three questions, the survey's results provided additional insight into what occurs within a program as its size and complexity increase. Diseconomies of scale result in the form of extended decision times, increasing hierarchy and sub-optimization. Additionally, the survey verified that when operating in such conditions, individuals will engage in "scanning" behaviors.

9.5 Research Results

The above research reveals that efforts to improve the performance of the Air Force aircraft acquisition enterprise tend to be similar in nature across time. Reorganizations follow a cyclical pattern that tends to alternatively empower the program management or functional hierarchies. Senior leader initiatives also periodically issue and mandate change to the enterprise's processes.

Past reform efforts have been ineffective because they have failed to significantly address the underlying complexity of the Air Force aircraft acquisition enterprise.

Over the course of the last 20 years, productivity has not been enduringly improved following multiple reorganizations and multiple issuances of new initiatives. At the macro level, current performance of large acquisition programs is no better than their predecessors. For example, the Joint Strike Fighter program is encountering the same types of issues that were experienced during the development of the F-22 a decade earlier. The reason why these efforts to improve are unsuccessful is because top-level reorganizations and sets of initiatives do not significantly reduce the underlying complexity of the enterprise. Without such a reduction, marginal returns remain diminished and overall performance does not improve over the longer term.

In the face of continuing poor enterprise performance, individuals engage in scanning behavior and seek workarounds.

One example of this is the use of undefinitized contract actions to expedite the obligation of funds and program initiation. Another example is the use of alternative organizations that operate at a lower level of complexity with higher marginal returns. Both of these examples do not benefit the enterprise over the long run. UCAs must ultimately be definitized and with a lower amount of leverage over the contractor. The use of alternative organizations reduces the output of the primary enterprise further reducing its marginal returns to the detriment of a larger set of stakeholders.

Lastly, survey responses demonstrated that individuals within an enterprise are cognizant of when a program has grown too large and complex. The majority of respondents recognized the symptoms from their own experiences. Congruent with Tainter, respondents also predominantly identified workarounds as a way they overcome restrictive processes and regulations in high complexity environments.

Chapter 10 Research Summary and Conclusions

C1: A high level of organizational (structural and procedural) complexity exists across the Air Force aircraft acquisition enterprise

The Air Force aircraft acquisition enterprise is a highly complex organization engaged in the development of highly complex aerospace weapon systems. This high level of complexity is evident in the areas of personnel specialization/organizational structure, resource management, and regulatory guidance/policies.

An examination of the enterprise's workforce revealed a tremendous amount of specialization across multiple disciplines including program management, engineering, logistics, auditing and contracting. All of this specialization is organized and managed through a training and certification system largely administered by the Defense Acquisition University. Coupled with this high level of personnel specialization is a large matrixed organization led by a 3-star general who serves as the Aeronautical Systems Center commander. Beneath him, the core Air Force organization is divided into 5 mission-specific directorates, two geographical support organizations and 10 functional organizations.

A great deal of complexity is also employed in the management of resources. A complex FYDP structure is in place to ensure funding is used in accordance with congressional intent. Performance is tracked using earned value management which requires significant complexity including work breakdown structures and work package completion tracking.

The regulatory guidance and policies that govern the operation of the ASC are extremely complex. In-depth knowledge and expertise is required to ensure compliance with the Federal Acquisition Regulation and its supplements including the Defense Federal Regulation Supplement. Additionally, the entire acquisition approval process is highly structured and governed by the DOD 5000 series regulations and their supplements.

C2: The level of investment in complexity within the ASC has reached a point of declining marginal returns

Tainter (1988) outlines four sets of conditions where declining marginal returns result.

- Benefits falling with costs rising
- Benefits rising with costs rising faster
- Benefits constant with costs rising
- Benefits falling with costs remaining constant

Chapter 8 provided examples for three out of the four sets of conditions. The below table provides a summary of those examples.

Table 6: Evidence of Diminishing Marginal Returns

Condition	Evidence Provided
Benefits falling with costs rising	Aging aircraft fleet o Technologically obsolescence o Maintenance costs increase Elongated Approval process o Delay in fielded capability
Benefits rising with costs rising faster	Procurement of new aircraft (F-22, etc) o Cost and schedule overruns o Unit cost increasing
Benefits constant with costs rising	Increasing cost of regulatory compliance o Specialty Metal case study

Competitive advantage in the military sphere can be a fleeting condition if not aggressively maintained. Therefore, anything that delays the fielding of a new technology can quickly erode the benefit provided by a weapon system. Alternatively, any event that increases the cost of delivering a new weapon system diminishes the effectiveness of the acquisition process. Both scenarios result in diminished marginal returns. Unfortunately, the high level of complexity present within the ASC increases the probability of both scenarios.

C3: Past reform efforts have been ineffective because they have failed to significantly address the underlying complexity of the ASC.

Efforts to improve the performance of the enterprise have generally been centered on either reorganizations or set of improvement initiatives. Reorganizations tend to occur every few years and for the most part follow a cyclical pattern that tends to alternatively empower the program management or functional hierarchies within the matrix structure.

Sets of reform initiatives designed to improve the system are also frequently introduced by senior leaders on a periodic basis. However, in spite of these recurring improvement actions, productivity of the ASC has not enduringly improved. In 2009, an independent CNA report described continuing poor performance:

> In recent years, the Air Force has experienced a number of symptoms that indicate problems with its acquisition system and processes. Some of the most pressing of these symptoms have been:
>
> - Frequent cost-schedule performance issues;
> - Numerous Nunn-McCurdy Breaches;

- Increased time to bring major systems to the field; and
- Successful protests by contractors on major programs. (Christie, Davis, & Porter, 2009)

The reason for continued poor performance is neither reorganizations nor sets of new initiatives significantly reduce the underlying complexity of the enterprise. Tainter's general theory of collapse is clear that without such a reduction, the marginal returns of the system do not improve and overall performance does not improve.

C4: In the face of continuing poor enterprise performance, individuals engage in scanning behavior and seek out lower complexity workarounds

Individuals within the Air Force aircraft acquisition enterprise will seek more effective, alternative ways to accomplish their goals. These alternatives can be viewed as workarounds in the face of performance diminishing complexity. One example of a commonly used workaround is the use of undefinitized contract actions. They allow the obligation of funds before all contract terms are negotiated. Because contract terms are governed by the highly complex Federal Acquisition Regulation and its supplements which necessitates a long and cumbersome approval process, contract definitization is difficult to accomplish on schedule.

Another example of a commonly used workaround is the use of alternative organizations. By keeping programs classified or relying on outside organizations, complexity is avoided and productivity is increased. While effective in the short term, workarounds do not benefit the enterprise over the long run. They tend only to treat symptoms instead of the underlying disease. Internal workarounds must eventually be legitimized requiring additional effort. The use of outside organizations robs the enterprise of resources and reduces overall output of the primary enterprise, further reducing marginal returns. As the enterprise becomes increasingly marginalized, it becomes more susceptible to collapse.

Chapter 11 Implications and Recommendations

11.1 Implications and Recommendations for Senior Acquisition Leadership

Examining the Air Force aircraft acquisition enterprise through the lens of Tainter's general theory of societal collapse provides insight into why past improvement efforts have fallen short This has implications for senior leaders contemplating efforts to improve enterprise performance.

11.1.1 Complexity as a Criteria

From the senior leader stakeholder perspective, the primary implication of this analysis is that future efforts to improve acquisition performance must address the overall level of complexity present within the system. Unless an improvement action will result in a significant decrease in system complexity, it is not likely to generate increasing marginal returns over the long term. As categorized by Young, Farr and Valerdi (2010), the focus should be on organizational complexity within the management realm. Product complexity will remain high due to the competitive pressure imposed by potential adversaries. However, the level of organizational complexity, both structural and procedural, within the enterprise should be closely examined.

R1: Prior to implementation, senior leaders should evaluate an improvement effort against what effect it will have on system complexity.

The Air Force aircraft acquisition enterprise has already reached and exceeded the level of complexity when marginal returns begin to diminish. Therefore, unless an improvement significantly reduces the level of specialization or organizational control within the acquisition enterprise, it is likely to further decrease marginal returns and thus fail to markedly improve performance over the long run.

R2: Senior acquisition leaders should actively work with other powerful stakeholders, including DoD and the legislative branch, to reduce the level of complexity required by enterprise regulations and policies.

Since a large amount of complexity is top-down driven in the form of policies and processes mandated in the FAR and its supplements as well as the DoD 5000 series regulations, the focus should "up" rather than "down" the chain of command.

11.1.2 Examine Workarounds to Gain Insight

Identifying and examining workarounds has the potential to yield significant benefits. A high use of workarounds in one organizational or procedural area is a clear indicator that the complexity present in the formal system has grown too high.

R3: Workarounds used routinely should be identified and analyzed for organizational insight

Individuals familiar with the operation of the enterprise will be able to provide a researcher with a list of workarounds routinely used. These workarounds should be viewed for what they are: the result of individuals engaged in scanning behaviors in an effort to obtain reasonable marginal returns on their investments of time and effort.

Rather than being simply dismissed as unauthorized deviations, workarounds can be harnessed as a source of potentially innovative ideas. The structure of the workarounds may be emulated to help streamline processes, removing the components that are non-value added or overly burdensome. At the very least, they can identify areas that would benefit from a reduction in complexity.

11.1.3 Vulnerability to Collapse

As stakeholders have sought to solve problems and secure benefits, they have over time irresistibly increased the level of complexity present across the Air Force aircraft acquisition enterprise.

The level of complexity has reached a point where the system is now also vulnerable to collapse. Tainter (1988) describes two scenarios of collapse which are modified here for application to the Air Force aircraft acquisition enterprise:

1. As performance and marginal returns remain low or decline further, capital surpluses (both physical and political) are depleted. Subsequently when a major stress impacts the system (e.g., a large weapon system program Nunn-McCurdy breach), there is no reserve of capital to draw upon. External stakeholders may then decide enough is enough and bring about a collapse of the enterprise.
2. As performance and marginal returns decline further, stakeholders recognize advantage by avoiding use of the enterprise altogether. These stakeholders then "overtly attempt to fully break away" and either employ their resources elsewhere

with alternative organizations or simply withhold resources. In either case, this is a form of "soft collapse" where the enterprise becomes increasingly disregarded and irrelevant.

While both scenarios have become real possibilities likely as complexity has increased, scenario 1 is becoming increasingly likely due to the current economic state of the United States. There is increasing pressure to reduce the federal deficit. Any realistic attempt to do so will include cuts in military spending. Due to these constraints, the likelihood that a severe acquisition failure will result in the collapse of the Air Force aircraft acquisition enterprise in its current form is increasing.

11.1.4 A Beneficial Collapse?

If a severe acquisition effort failure precipitates a collapse of the entire enterprise, the results would likely be catastrophic to the near term capabilities of the Air Force. Acquisition programs would stall while powerful stakeholders worked to create a new system that protected their interests.

Short of a collapse, it is incredibly difficult to get stakeholders to voluntarily reduce complexity. Tainter and Patzek (2012) point out that at the societal level, "the Byzantine Empire may be history's only example of a complex society surviving through simplification" and they only did so only under extreme duress.

R4: Senior acquisition leaders should be prepared to advocate for a steep reduction in enterprise complexity should a collapse occur.

Within the political sphere, a common rule of thumb is to never allow a serious crisis to go to waste (Seib, 2008). Senior leaders should heed this and be ready to articulate a vision that includes much less complexity that the current system. In the face of a collapse, stakeholders are more open to significant structural changes. Having a strong, consistent message that advocates for a reduction in complexity will help ensure that a collapse doesn't result in the emergence of an even more complex and constrained replacement. If complexity is greatly reduced as a result of a collapse and marginal returns are significantly increased, the collapse may actually benefit the greater Air Force enterprise over the long term.

11.1.5 Extensions and Limitations

While this work has focused on the Air Force aircraft acquisition enterprise, it is only a subset of the larger defense acquisition system within the Department of Defense. Furthermore, while it is a large federal department, the Department of Defense is only one of 15 cabinet level departments within the Executive Branch of the United States. Among the remaining 14, included is the Department of Homeland Security, the Department of Energy and the Department of Veterans Affairs. Since all of these departments are similarly structured and subject to the same human problem solving routines that tend to increase complexity, it is reasonable to contemplate similar complexity issues existing across the entire federal agency enterprise. Therefore, the conclusions and recommendations given here for use at the Air Force aircraft acquisition enterprise are likely to also provide insight into how to improve effectiveness at the larger scale as well.

One fundamental difference between applying Tainter's theory at the societal level and at the enterprise level is that at the enterprise level, there is a higher level organizational entity that can intervene to prevent collapse. When this occurs, the intervention often requires the commitment of additional resources, allowing the enterprise to continue functioning yet simultaneously further diminishing marginal returns.

A recent example of a higher level entity bailing out a subordinate enterprise is the financial bailout of the government-sponsored enterprises Fannie Mae and Freddie Mac. While the root cause of their failure is not relevant to discuss here, as part of the 2008 financial crisis, both firms were pushed "toward insolvency and into government control. Since then, the two companies have borrowed more than $153 billion from a U.S. Treasury Department lifeline to continue operating." (Bloomberg, 2012)

As long as such interventions are possible, the predictive power of Tainter's theory at the enterprise level is limited. Collapse can be indefinitely deferred through periodic intervention by a larger parent entity. However, one should consider that the resources available to the higher entity are also finite. As the marginal returns of the parent entity are reduced, it too is subject to collapse. In fact, the collapse of a society in the aggregate is likely preceded by the need to frequently intervene to stave off collapse at the enterprise level. The interrelationship between enterprise and societal collapse is an area for future research.

11.2 Conclusion and Summary of Research Conclusions and Recommendations

In conclusion, Tainter's theory provides senior leaders with an explanation why past reform efforts have fallen short of their objectives. The theory also provides leaders with insight into how to structure future reform efforts including harnessing current workarounds for insight. Lastly, senior leaders should be prepared to articulate a new vision should a collapse of the current enterprise occur. A summary listing of the resulting conclusions and recommendations is provided below:

Research Conclusions

- **C1: A high level of organizational (structural and procedural) complexity exists across the Air Force aircraft acquisition enterprise.**
- **C2: The level of investment in complexity within the ASC has reached a point of declining marginal returns.**
- **C3: Past reform efforts have been ineffective because they have failed to significantly address the underlying complexity of the ASC.**
- **C4: In the face of continuing poor enterprise performance, individuals engage in scanning behavior and seek out lower complexity workarounds.**

Recommendations

- **R1: Prior to implementation, senior leaders should evaluate an improvement effort against what effect it will have on system complexity.**
- **R2: Senior acquisition leaders should actively work with other powerful stakeholders, including DoD and the legislative branch, to reduce the level of complexity required by enterprise regulations and policies.**
- **R3: Workarounds used routinely should be identified and analyzed for organizational insight.**
- **R4: Senior acquisition leaders should be prepared to advocate for a steep reduction in enterprise complexity should a collapse occur.**

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Appendix A: DoD Instruction 5000.02 Enclosure 4

Statutory and Regulatory Information and Milestone Requirements

Table 3. Regulatory Requirements Applicable to All Acquisition Programs (unless otherwise noted). Regulatory policy applicable to Acquisitions of Services is discussed in Enclosure 9. Information requirements stated in this table do not apply to these acquisitions unless specifically addressed in Enclosure 9.

INFORMATION REQUIRED	SOURCE	WHEN REQUIRED
Acquisition Information Assurance Strategy (All IT-including NSS)	DoDI 8580.1 (Reference (ai)) This Instruction	MS A MS B MS C Full-Rate Production DR (or Full Deployment DR)
Acquisition Strategy	This Instruction	Program Initiation for Ships MS B MS C Full-Rate Production DR (or Full Deployment DR)
ADM	This Instruction	Program Initiation for Ships MS A MS B MS C Each Review
Affordability Assessment	This Instruction	MS B MS C
AoA	This Instruction	MS A

		MS B (updated as necessary) MS C (updated as necessary) Full Deployment DR (for AIS)
AoA Study Guidance	This Instruction	Materiel Development Decision (updated as necessary)
AoA Study Plan	This Instruction	Immediately following the Materiel Development Decision consistent with MDA Direction (updated as necessary)
APB	This Instruction	Program Initiation for Ships MS B MS C (updated, as necessary) Full-Rate Production DR (or Full Deployment DR)
CDD	Reference (h)	Program Initiation for Ships MS B
CIO Confirmation of CCA Compliance (See Enclosure 5)	This Instruction	MS A Program Initiation for Ships MS B MS C (if Program Initiation or if equivalent to Full Deployment DR) Full-Rate Production (or Full Deployment) DR
Component LFT&E Report	This Instruction	Completion of Live Fire Test and Evaluation

(OSD LFT&E oversight programs only)		
Cost Analysis Requirements Description (CARD) (MDAPs and MAIS acquisition programs only) (CARDs shall be prepared according to the procedures specified in Enclosure 7 of this Instruction)	This Instruction	For MDAPs - Program Initiation for Ships - MS B - MS C - Full-Rate Production DR For MAIS - Any time an Economic Analysis is required-either by statute or by the MDA
Corrosion Prevention Control Plan (part of Acquisition Strategy) (ACAT I only)	DoDI 5000.67 (Reference (aj)) This Instruction	MS B MS C
CPD	Reference (h)	MS C
Defense Acquisition Executive Summary (MDAPs and MAIS only)	This Instruction	Quarterly Upon POM or BES submission Upon unit cost breach
DoD Component Cost Estimate (mandatory for MAIS; as required by CAE for MDAP)	This Instruction	MS A For MDAPs - Program Initiation for Ships - MS B - Full-Rate Production DR For MAIS

		- Any time an Economic Analysis is required-either by statute or by the MDA
Exit Criteria	This Instruction	Program Initiation for Ships MS A MS B MS C Each Review
ICD	Reference (h)	Materiel Development Decision MS A MS B MS C (if Program Initiation)
Independent Technology Readiness Assessment (ACAT ID only) (if required by the office of the Director, Defense Research and Engineering)	This Instruction	MS B MS C
Information Support Plan (ISP) (All IT-including NSS)	DoD Directive 4630.05 (Reference (ak)) DoD Instruction 4630.8 (Reference (al))	Program Initiation for Ships (Initial ISP) MS B (Initial ISP) CDR (Revised ISP) (unless waived) MS C (ISP of Record)
IT and NSS Joint Interoperability Test Certification (All IT-including NSS)	Chairman of the Joint Chiefs of Staff Manual 3170.01 (Reference (am)) CJCSI 6212.01 (Reference	Full-Rate Production DR (or Full Deployment DR)

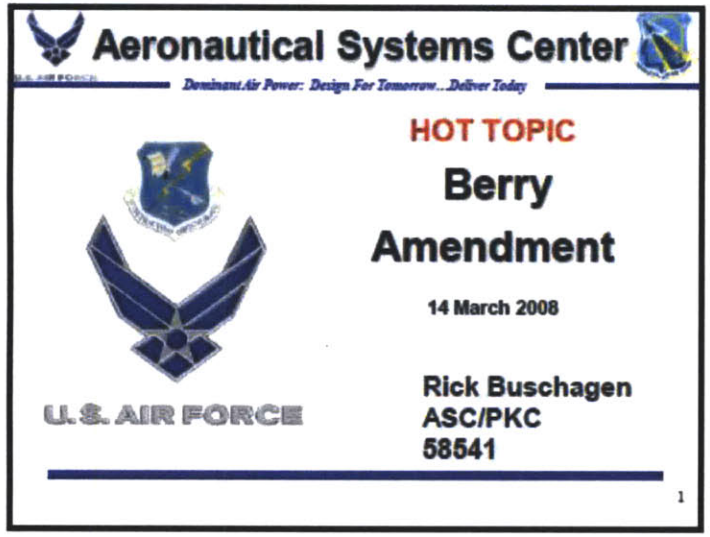
	(an)) Reference (ak)	
IUID Implementation Plan	DoD Instruction 8320.04 (Reference (ao))	MS A (summarized in SEP) MS B (annex to SEP) MS C (annex to SEP)
LCSP ; (part of Acquisition Strategy)	This Instruction	MS B MS C Full-Rate Production DR
Life-Cycle Signature Support Plan	DoD Directive 5250.01 (Reference (ap))	MS A (summarized in TDS) Program Initiation for Ships MS B MS C (updated as necessary)
Net-Centric Data Strategy (Approach summarized in TDS and detailed in ISP)	Reference (l)	MS A Program Initiation for Ships MS B MS C
Operational Test Agency Report of Operational Test and Evaluation Results	This Instruction	MS B MS C Full-Rate Production DR
PDR Report	This Instruction	MS B Post-PDR Assessment if PDR is conducted after MS B
Post-CDR Report	This Instruction	Post-CDR Assessment
Program Deviation Report	This Instruction	Immediately upon a

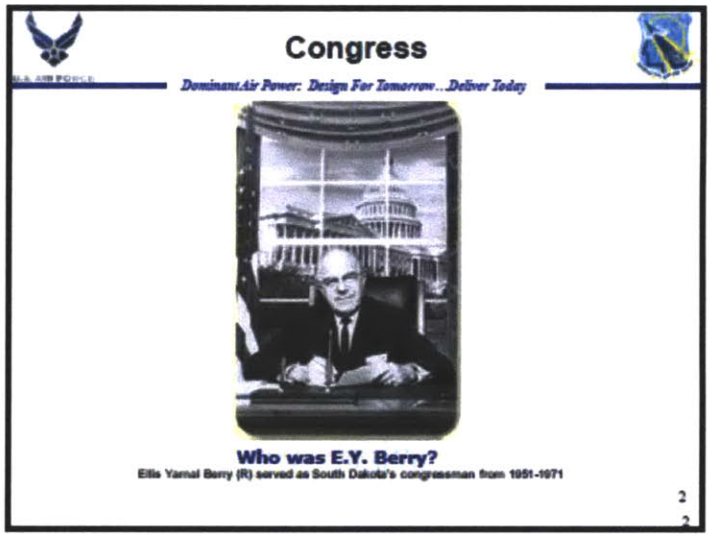
		program deviation
Program Protection Plan (PPP) (for programs with critical program information) (includes Anti-Tamper Annex) (also summarized in the Acquisition Strategy)	Reference (m)	MS A (CPI stated in TDS) MS B MS C
Spectrum Supportability Determination (applicable to all systems/equipment that use the electromagnetic spectrum in the U.S. and in other host nations)	DoD Directive 4650.1, Reference (aq)	MS B MS C
System Threat Assessment Report (STAR) - validated by Defense Intelligence Agency (DIA) for ACAT ID programs) - validated by DoD Components for ACAT IC programs - Programs on the DOT&E Oversight List require a STAR regardless of ACAT designation (MAIS programs use the DIA validated Information Operations Capstone Threat Assessment)	This Instruction DoD Directive 5105.21 (Reference (ar)) Reference (q) DIA Instruction 5000.002 (Reference (as))	Program Initiation for Ships MS B MS C
System Threat Assessment (STA) - validated by DoD Components for ACAT II programs (AIS programs may use the DIA validated Information Operations Capstone Threat	This Instruction Reference (ar) Reference (q) Reference (as)	MS B MS C

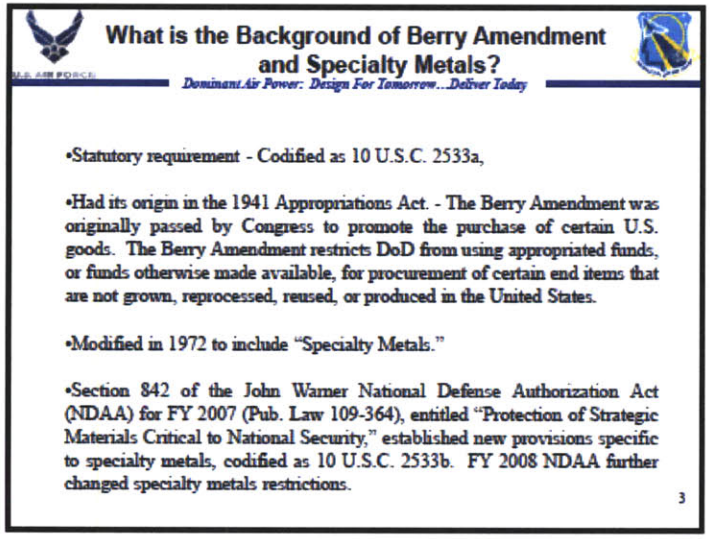
Assessment)		
Systems Engineering Plan	This Instruction	MS A MS B MS C
TDS (ACAT II and below)	This Instruction	MS A
Technology Readiness Assessment	This Instruction	Program Initiation for Ships (preliminary assessment) MS B MS C
TEMP	This Instruction	MS B MS C (update, if necessary) Full-Rate Production DR (or Full Deployment DR)
TES	This Instruction	MS A

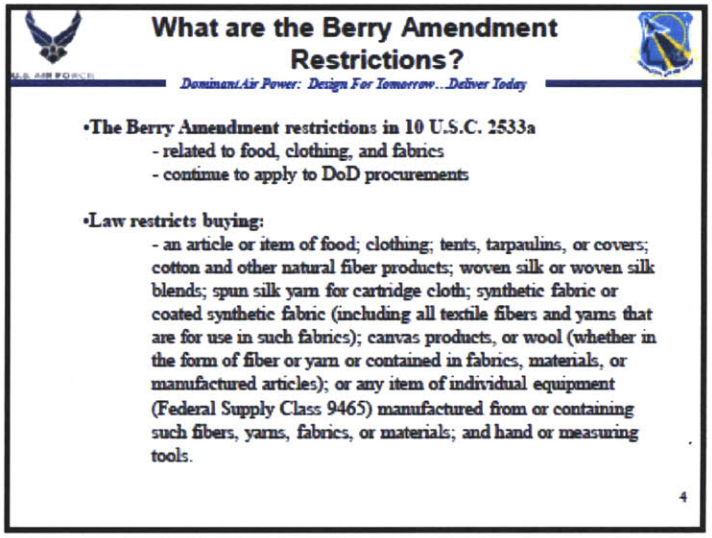
Appendix B: Berry Amendment Slide Presentation

- (Buschagen,R. Hot Topic: Berry Amendment. ASC/PKC, March 14, 2008)









What are the Specialty Metals Restrictions?

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Generally, the Specialty Metals restrictions in 10 U.S.C. 2533b require that any specialty metal delivered as an end product or an article containing specialty metal if the article is an end product or a component of aircraft, missile and space systems, ships, tank and automotive items, weapon systems or ammunition be either produced or "melted/smelted" in the United States.

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What are the Specialty Metals?

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- Specialty metals are defined in DoD Federal Acquisition Regulation Supplement (DFARS) Clause 252.225-7014 as:
- **Steel:**
  - With a maximum alloy content exceeding one or more of the following limits: 1.65% manganese, .60% silicon, .60% copper
  - Containing more than .25% of any of the following elements: aluminum, chromium, cobalt, molybdenum, nickel, niobium (columbium), titanium, tungsten, vanadium
- **Metal alloys**:
  - Nickel or iron-nickel alloys that contain a total of alloying metals other than nickel and iron in excess of 10%
  - Cobalt alloys that contain a total of alloying metals other than cobalt and iron in excess of 10%
- **Titanium** and titanium alloys
- **Zirconium** and zirconium base alloys

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Where Can I Find Berry Amendment and Specialty Metals Regulations?

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- The Berry Amendment and Specialty Metals legislation are implemented through the DFARS and Air Force Federal Acquisition Regulation Supplement (AFFARS):
- (1) DFARS, Subpart 225.70
- (2) DFARS Procedures, Guidance, and Information (PGI) 225.7002
- (3) DFARS Clause 252.225-7014 [DEVIATION 2008-O0002] and Alternate I (DEVIATION 2008-O0002) are Specialty Metals clauses
- (4) DFARS 252.225-7012 and 252.225-7015 are Berry Amendment clauses
- (5) AFFARS, Subpart 5325.7002
- (6) AFFARS Mandatory Procedure MP5325.7002-2, DNAD Procedures and Sample Formats
- (7) AFFARS Mandatory Procedure MP5325.103, Exceptions to Buy American Act
- (8) DFARS 212.570 includes applicability of Specialty Metals to Commercially Off-The-Shelf (COTS)

7

What are the Exceptions to the Specialty Metals Requirements?

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- For contracts awarded on or after 29 January 2008, the following exceptions apply. When using any of the exceptions, the contracting officer shall ensure that appropriate determinations or documentation are in the contract file
  - **SAT Acquisitions at or below the simplified acquisition threshold (SAT)—currently $100,000**
  - **Combat operations Acquisitions outside the U.S. in support of combat operations**
  - **Contingency operations Acquisitions in support of contingency operations**
    - **What defines "in support of contingency operations?"**
    - **This exception generally includes actions that are GWOT funded or determined by the Contracting Officer (CO) on a case-by-case basis to be in direct support of contingency operations. The CO, with the support of his/her legal advisor, shall document the auditable trail to contingency operations and ensure the decision can pass the disinterested party test.**

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What are the Exceptions to the Specialty Metals Requirements?

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- **Unusual and Compelling** Acquisitions that have been approved IAW FAR 6.302-2, Unusual and Compelling Urgency
- **Commissaries** Acquisitions of items specifically for resale in commissaries
- **Electronic components** Acquisitions of electronic components are excepted, unless the Secretary of Defense has determined a particular electronic component is critical to national security
- **COTS items** Commercially available off-the-shelf (COTS) items, excluding high performance magnets and fasteners, unless the magnets or fasteners are incorporated into COTS items

9

What are the Exceptions to the Specialty Metals Requirements?

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- **Commercial Fasteners** Acquisition of commercial fasteners which are not incorporated into COTS items are excepted if the manufacturer certifies that it will purchase, during the relevant calendar year, an amount of domestically produced specialty metals that is not less than 50% of the total amount of specialty metals required to produce such fasteners for all its customers.
- **2% Weight *de minimis* exception** If the weight of non-compliant specialty metal (that is not otherwise exempt) does not exceed 2% of the total weight of specialty metal, DoD may accept the item.
- **Qualifying Country** Acquisitions which further an agreement with a qualifying country (see DFARS 225.872-1 for a list of the qualifying countries). This exception does not apply when buying specialty metal as an end product (i.e., Contractor must comply with basic clause DFARS 252.225-7014 (DEVIATION 2008-O0002); however, Alternate I (DEVIATION 2008-O0002) includes an exemption for items manufactured in a qualifying country.)

10

What are the Exceptions to the Specialty Metals Requirements?

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- **Commercial Derivative Military Articles (CDMA)** are exempt if:
  - The Secretary of the Air Force determines that the item is a commercial derivative military article; and
  - The contractor certifies compliance based on equivalent purchases of domestic specialty metal. The contactor and subcontractor(s) must agree, based on good faith estimate, to purchase domestic metals for use during the contract period in an amount that is at least equivalent to the greater of:
    - (1) 120% of specialty metal required to produce the CDMA; or
    - (2) 50% of the specialty metal required to produce both the CDMA and the related commercial article, during the period of contract performance at all contract and subcontract levels.

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What are the Exceptions to the Specialty Metals Requirements?

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- Domestic Non-Availability Determination (DNAD)

  Procurements that have an approved Secretary of the Air Force "DNAD" waiver because the items cannot be procured in satisfactory quality, sufficient quantity, and in the required form*, as and when needed. Fair and reasonable cost may be considered as a factor, but cost is not an exception itself within the law. *(reference PGI 225.7002-2(b)(3) and AFFARS 5325.7002-2(b))*

** "Required form" means in the form of mill product, such as bar, billet, wire, slab, plate or sheet, and in the grade appropriate for the production of (i) a finished end item delivered to the DoD; or (ii) a finished component assembled into an end item delivered to DoD.*

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What are the Exceptions to the Specialty Metals Requirements?

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- National Security Waiver

The Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) may determine in writing that acceptance of an end item containing noncompliant materials is necessary to the national security interests of the U.S. This authority applies only to non-compliance discovered after contract award.

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What is considered COTS?

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"Commercially available off-the-shelf item" (COTS) is defined in ALTERNATE I (DEVATION 2008-O0002) as any item of supply that is:

A commercial item (as defined in FAR 2.101);
Sold in substantial quantities in the commercial marketplace;

Offered to the Government, under a contract or subcontract at any tier, without modification, in the same form in which it is sold in the commercial marketplace; and

Does not include bulk cargo, as defined in section 3 of the Shipping Act of 1984 (46 U.S.C. App. 1702), such as agricultural products and petroleum products

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More about the COTS Exemptions from the FY08 NDAA

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- **A COTS item exemption was added by the FY08 NDAA for COTS items, but included exclusions. Here is a summary of what is and isn't exempt when it comes to commercial products:**
  - **Direct acquisitions of specialty metals which are mill products are not exempt. (Examples of mill products: bar, billet, slab, wire, plate and sheet.)**
  - **Forgings or casting incorporated into a COTS end item are exempt.**
  - **COTS high performance magnets incorporated into a COTS end item are exempt.**
  - **COTS fasteners incorporated into a COTS end item are exempt.**

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More about the COTS Exemptions from the FY08 NDAA

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- **Commercial fasteners not incorporated into a COTS items are exempt if the manufacturer certifies in good faith that it will purchase during the relevant calendar year, an amount of domestic specialty metals not less than 50% of the total amount of specialty metals needed to produce such fasteners for all its customers. This is referred to as the "*market basket*" approach to compliance.**

- **The COTS exemption is applied when the COTS item is first purchased at the lowest level of the subcontractor/supplier chain. A COTS item is considered to be "offered without modification" as long as it is not modified prior to contractual acceptance by the next higher tier in the supply chain. Here's some guidance for modifications to COTS items.**

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What to Do with Fasteners?

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•The current broad DNAD for fasteners will expire for use on new contracts on 26 July 2008. Contracting Officers shall consider the following to determine the acceptance of a fastener:

-High performance fastener incorporated into a COTS end item, AF may accept the item.

-Commercial fastener not incorporated into COTS end item, manufacturer must certify in good faith to "market basket" approach (i.e., Manufacturer will purchase during the relevant calendar year, an amount of domestically produced specialty metals not less than 50% of the total amount of specialty metals to produce such fasteners for all its customers).

-If a non-compliant fastener falls under the 2% weight *de minimis* exception, it may be accepted.

-If the non-compliant fastener qualifies under any other exception, it may be accepted.

-If none of the above applies, the contractor must provide a compliant fastener, or the contracting officer shall determine if a DNAD is appropriate.

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What is considered Commercial Derivative Military Articles (CDMA)?

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"Commercially Derivative Military Article (CDMA)" is defined in ALTERNATE I (DEVIATION 2008-O0002) as an item procured by DoD that is or will be produced using the same production facilities, a common supply chain, and the same or similar production processes that are used for the production of articles predominantly used by the general public or by nongovernmental entities for purposes other than governmental purposes. The Secretary of the AF must determine that the item is a CDMA before using the rules for streamlined compliance for CDMA.

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The streamline compliance for Commercial Derivative Military Articles (CDMA) or Commercial Derivative Aircraft (CDA)

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The FY08 NDAA provides an alternative for streamline compliance for Commercial Derivative Military Articles (CDMA). This exception allows contractors to certify compliance based on equivalent purchases of domestic specialty metals. The contractor must certify that the contractor or subcontractor has agreed, based on good faith estimate, to purchase domestic metals for use during the contract period in an amount that is at least equivalent to the greater of:

(1) An amount equivalent to 120% of the amount of specialty metal that is required for the production of the CDMA; or

(2) An amount equivalent to 50% of the amount of specialty metal required to produce both the CDMA and the related commercial article, during the period of contract performance that is purchased by the contractor and its subcontractors.

- Contractors shall submit the certificate in ALTERNATE I (DEVIATION 2008-O0002) with their offer. The Contracting Officer shall develop a Determination and Finding (D&F) for approval by the SECAF. AFFARS Mandatory Procedure (MP) 5325.7002-2 is being revised to include a sample D&F and the procedures to follow.

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Show Me an Example

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Military Market	Combined Market
A good faith estimate of $20M is required for all Specialty Metal to manufacturer ten KC-10 Tankers (a Commercial Derivative Aircraft (CDA)	A total of $800M of Specialty Metal is required to manufacture KC-10 Tankers + all Boeing 707s for their Commercial Market during the same period
120% of $20M = $24M	50% of $800M = $400M

In order to certify, Boeing and its subcontractor must agree to purchase at least $400M of domestic Specialty Metals (the greater of the two).

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When do you include the Specialty Metal clause in the contract?

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Unless an exception applies, use DFARS Clause 252.225-7014, Preference for Domestic Specialty Metals (DEVIATION 2008-O0002) in solicitations and contracts exceeding the simplified acquisition threshold that require delivery of specialty metals as end products.

Alternate I (DEVIATION 2008-O0002) must be included in solicitations and contracts exceeding the simplified acquisition threshold that require delivery of any of the following items, or components*, if such items or components contain specialty metal.

(A) Aircraft
(B) Missile and space systems
(C) Ships
(D) Tank and automotive items
(E) Weapon systems
(F) Ammunition

If the solicitation and contract require delivery of a variety of contract line items containing specialty metals, but only some of the items are subject to domestic specialty metals restrictions, identify in the Schedule those items that are not subject to the restrictions.

* *The previous definition of Component with tier constraints no long applies. Alternate I (DEVIATION 2008-O0002) defines "Component" as any item supplied to the Government as part of an end item or of another component.*

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What is the rule for withholding on contracts awarded on or after 16 November 2006?

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Under 10 U.S.C. 2533b, for contracts awarded on or after 16 November 2006, DoD agencies can no longer continue the practice of withholding payment while conditionally accepting noncompliant items. The FY07 NDAA prohibited using funds to acquire end items and components containing non-compliant metals.

Can "withholds" still be used on contracts awarded prior to 16 November 2006?

Yes. Contracts awarded prior to 16 November 2006 are subject to 10 U.S.C. 2533a, and the focus of the restriction at that time was on using funds to acquire specialty metals. The "withhold" should be the value of the lowest auditable part that contains the specialty metal (plus burdens). Before the contract can be closed at least one of the following must occur: (1) contractor provides compliant parts, and replaces any non-compliant parts previously delivered; (2) government processes a one-time waiver under the authority granted in Section 842(b) of the FY07 Authorization Act; or (3) a DNAD is approved.

22

One-time Waivers. What should a CO do if they have non-compliance on contracts awarded prior to 16 November 2006?

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The Contracting Officer may accept an "inadvertently" non-compliant article, if—

Final acceptance takes place after 17 October 2006 and before 30 September 2010; and

Non-compliant specialty metals were incorporated into the items (whether end items, components, or parts) produced, manufactured, or assembled in the U.S. before 17 October 2006.

The contracting officer determines in writing that—

(1) It would not be practical or economical to remove or replace the specialty metals incorporated in such items or to substitute items containing compliant materials;

(2) The contractor and subcontractor responsible for providing items containing non-compliant specialty metals have in place an effective plan to ensure compliance for future items; and

(3) The non-compliance was not knowing or willful;

This determination must be approved by the Under Secretary of Defense for Acquisition, Technology, Logistics (USD(AT&L)) or the Service Acquisition Executive (SAE) of the Air Force.

Notification in FedBizOpps.gov within 15 days of the CO's determination is also required.

For these violations, the CO must determine whether the violation was inadvertent to use the one-time waiver. In such a situation, the CO should determine on a case by case basis the appropriate amount and form of consideration, if any, due to the Government. The CO should obtain and may rely on the contractor's representation that "the non-compliance is not knowing or willful." Basically, a one-time waiver is the same as a DNAD, except it can be signed at a lower level and requires FedBizOpps.gov notice.

23

What should the notification in the FedBizOpps.gov state for one-time waiver determinations?

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The notification in the FedBizOpps.gov should say something like this: "Per Public Law 109-364, Section 842(b), notification is made on *(insert date)* that the Air Force intends to grant a one-time waiver for the requirement to use specialty metals from domestic sources for *(state/describe items)* delivered pursuant to contract *(state contract number)* between *(contract issuing office)* and *(contractor)*, due to inadvertent use of non-compliant specialty metals."

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What should a CO do if they have non-compliance on contracts awarded on or after 16 November 2006?

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Unless the items were manufactured prior to 17 October 2006 and qualify for the one-time waiver, the items must be compliant, meet one of the exceptions, or have an approved DNAD. In the absence of these circumstances, if the contractor offers an item for inspection and acceptance and discloses that it is not compliant with 10 U.S.C. 2533b, you have few options. Also, if for any reason, you believe the contractor is in violation of the Berry Amendment or Specialty Metal laws, you must take action.

First, you should notify your lawyer, verify that the contract requires compliance and that the item falls under the restricted items in 10 U.S.C. 2533a or 2533b, notify DCMA to suspend acceptance of the non conforming items, notify DFAS to suspend payment, and get a list of the parts from the contractor.

The CO or contractor needs to conduct a market research for a domestic source of the item. If no domestic source is found, the CO must determine if a substitute item is available. If so, present the contractor with the substitute item options for acceptability. You can not accept the item until the contractor complies or you have a DNAD approved or in process

25

Can a contract be awarded before a DNAD is approved?

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Under certain situations, if a system/item specific DNAD that would cover non-compliant item(s) is in process, the CO may award the contract, which will include DFARS 252.225-7014 (DEVIATION 2008-O0002) and if applicable, Alternate I (DEVIATION 2008-O0002). "In process" means coordinate by SAF/AQCK and in process for approval by the SECAF. If the DNAD is not approved, the contractor must deliver compliant items. Prior to award of a contract that has a DNAD in process, the contract file must be documented to show that the contractor is aware of this requirement and concurs with it. The CO shall include applicable clauses in the contract until the DNAD is approved. (*reference AFFARS 5325.7002-2(b) and MP 5325.7002-2)*

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Can a CO use an existing approved DNAD or class waivers?

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OUSD(AT&L)/DPAP(DARS) memo dated 29 January 2008, provides guidance for using existing and class waivers DNADs. The broad DNADs for circuit card assemblies, fasteners, needle roller bearings, and diesel engines will expire for use on new contracts on 26 July 2008. Furthermore, Section 804 of the FY08 National Defense Authorization Act (NDAA) requires AF review previously approved DNADs and amend them to comply with the new statute by 26 July 2008. Furthermore, any class or broad based specialty metal DNAD (i.e., any DNAD to be applied to more than one contract) requires review and approval by the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)), as well as a FedBizOpps notice of intent to approve a DNAD at least 30 days prior to approval. AFFARS MP5325.7002-2 will include procedures for processing such a request. The Contracting Officer must prepare a D&F and obtain legal review, engineering analysis to support the determination, and coordination through SAF/AQCK.

27

Do CLS or repair contracts need to comply with the Specialty Metals requirement?

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Yes, services or repair contracts, including CLS contracts, must comply with DFARS 252.225-7014 (DEVIATION 2008-O0002), unless an exception applies or both of the following conditions exist:

The contract is for services (i.e., contractor receives an aircraft, services the aircraft, and returns the aircraft to the AF) and;

There are no CLINS requiring the delivery of end items or components covered by the specialty metals restrictions.

What about spare parts contracts under Specialty Metals, 10 U.S.C. 2533b?

Spares parts contracts must comply with basic DFARS 252.225-7014 (DEVIATION 2008-O0002), unless an exception applies. The clause shall be included in spare parts contracts.

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What about factory test equipment, ground support equipment, and simulators under Specialty Metals, 10 U.S.C. 2533b?

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Test equipment and ground support equipment must comply with basic DFARS 252.225-7014 (DEVIATION 2008-O0002) clause, unless an exception applies. Test equipment and ground support equipment do not have to comply with Alternate I.

What about Flight Simulators under Specialty Metals, 10 U.S.C. 2533b?

Flight Simulators must comply with basic DFARS 252.225-7014 (DEVIATION 2008-O0002) clause, unless an exception applies. Flight simulators do not have to comply with Alternate I.

What is the definition of weapon system?

A weapon system is defined as: "An item or set of items that is designed to kill or destroy the enemy." *(Reference: MP5325.7002-2, Addendum 2)*

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What about Delivery Orders issued on contracts issued prior to enactment of 10 U.S.C. 2533b?

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Within scope delivery orders will comply with the DFARS specialty metals clause issued with the basic contract. Contracting Officers may include the changes implemented by DEVATION 2008-O0002 in any existing contract with appropriate consideration. Out of scope modifications to these contracts must incorporate the requirements of FY08 NDAA and incorporate DFARS 252.225-7014 (DEVIATION 2008-O0002) clause.

Are Foreign Military Sales (FMS) contracts subject to Specialty Metals and Berry Amendment?

Yes. The Specialty Metal provisions apply to Foreign Military Sales, as well as purchases made with DoD funds sent for procurement to other agencies outside DoD.

30

What countries are qualifying countries?

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The specialty metals restrictions do not apply to specialty metals melted in a qualifying country or incorporated in an article manufactured in a qualifying country. Per DFARS 225.872-1, DoD has signed reciprocal defense procurement Memoranda of Understanding with the following countries. These are "qualifying countries."

Austria	Egypt	Israel	Portugal
Australia	Finland	Italy	Spain
Belgium	France	Luxembourg	Sweden
Canada	Germany	Netherlands	Switzerland
Denmark	Greece	Norway	Turkey

United Kingdom of Great Britain and Northern Ireland

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What are some other definitions under DEVIATION 2008-O0002?

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Alternate I (DEVIATION 2008-O0002) contains several definitions including:

"Assembly" means an item forming a portion of a system or subsystem that can be provisioned and replaced as an entity and which incorporates multiple, replaceable parts.

"Electronic component" means an item that operates by controlling the flow of electrons or other electrically charged particles in circuits, using interconnections of electrical devices such as resistors, inductors, capacitors, diodes, switches, transistors, or integrated circuits.

"End item" means the final production product when assembled or completed, and ready for issue, delivery, or deployment.

"Required form" means in the form of mill product, such as bar, billet, wire, slab, plate or sheet, and in the grade appropriate for the production of—

(i) A finished end item delivered to the Department of Defense; or

(ii) A finished component assembled into an end item delivered to the Department of Defense.

"Subsystem" means a functional grouping of items that combine to perform a major function within an end item, such as electrical power, attitude control, and propulsion.

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Who determines the applicability of the Berry Amendment/Specialty Metals to the specific procurement action?

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The application of the Berry Amendment and Specialty Metals clauses are determined for any acquisition on a case-by-case basis by the contracting officer. The CO may discuss with the program manager, legal advisor, or other technical experts the specific products (i.e., whether the end items contain specialty metals, fabrics, etc.), just as he/she would to determine the applicability of any clause to an acquisition. The contractor has the responsibility to report non-compliance with 10 U.S.C. 2533a and 2533b.

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What is required in a Domestic Non-Availability Determination (DNAD)?

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AFFARS MP5325.7002-2 includes, as an Addendum, a template for DNAD for Food, Clothing, Fabrics, and Hand or Measuring Tools. It also includes, as an Addendum, a template for DNAD for Specialty Metals. Basically, a DNAD Package will include:

a. Determination and Finding (D&F)—(prepared by the CO):
1) Identify noncompliant parts, assemblies or components.
2) Specify when compliant parts/components will be available.
3) Specify duration and scope (*e.g.*, month/year, covered lot numbers, contract numbers).
4) Discussion of circumstances that preclude acquisition of compliant items and alternative acquisition strategies.
5) Discussion of contractor's detailed market analysis and corrective action plan.
6) Impact on program's delivery schedule, program costs, and mission.
7) Alternatives/substitutes considered.
8) Based on above, a determination that waiver is required.
9) Certification by the requiring activity and approval by the SECAF.
b. Independent Government Verification/Validation of Contractor's Market Analysis. (This may not always be necessary if the contractor's market analysis includes Government validation.)
c. In-Depth Market Analysis—(prepared by the prime contractor):
1) Analysis of the current market and efforts required to obtain compliant parts.
2) Analysis of alternate acquisition strategies.
3) Submittal of a Corrective Action Plan (CAP).

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Do GSA purchases have to comply with the Berry Amendment or Specialty Metals?

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Since both of these acts are applicable to funds appropriated or otherwise made available to DoD, they apply even if another agency, such as GSA, is purchasing the item for DoD. Any purchase over the simplified acquisition threshold (SAT) must comply.

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What are some pre-award precautions?

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The time to deal with Berry Amendment and Specialty Metals restrictions is in the pre-award stage. If your contract contains or might contain any restricted item, it is imperative that you include appropriate clauses in your solicitation.

It is also imperative that COs ensure the contractor understands these clauses and can comply with them. If not, the CO needs to find another contractor or discuss alternative items that are available from a U.S. source. If the contractor can't comply, the Government's options are limited. Either find another contractor, find alternative domestic items that meet the AF needs, qualify another source, or if none of these are possible, process a DNAD.

Pre-award actions to minimize potential for violations include:
1. Consider the application of compliance for every procurement. Does the product contain Any restricted specialty metals, fabric, thread, or other items? If so, include the appropriated clause(s) in the solicitation in full text.
2. Make compliance a discussion item for Pre-proposal Conferences.
3. Pre-award survey can confirm contractor's ability to trace origin of materials.
4. Make compliance a negotiation discussion point to ensure contractor understands restriction requirements, especially flow down to subcontractors/ vendors/suppliers.

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What about an acquisition involving textiles and hand or measuring tools?

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The acquisition of textiles and hand or measuring tools still falls under the Berry Amendment Law 10 U.S.C. 2533a. DFARS 225.7002-1 includes textile specific rules and exceptions. The FY06 NDAA included several changes to the textiles portion of the Berry Amendment:

- Training of all acquisition workforce involved in buying textiles. If you are involved in buying textiles products such as upholstery on aircraft seats, parachutes, etc., you are required to take the DAU CLC 125, Berry Amendment training.
- Additional notification in the FedBizOps.gov within 7 days of award is required whenever a non-availability exception is used for any item containing textiles or the exception for chemical warfare protective clothing applies.
- Coverage of the Berry Amendment was expanded to all materials and components of clothing, such as zippers or steel toes in boots, that are normally associated with clothing. It does not apply to sensors or electronics or any like items not normally associated with clothing. Small arms protective inserts are not restricted under the Berry Amendment.

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Do aircraft seats need to comply with the Berry Amendment?

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DFARS 225.7002-2 does not exempt the fabric on upholstered seats (i.e. aircraft seats) from the Berry Amendment. However, fabric on seats are exempt when made of cotton, other natural fiber, or wool and is not more than 10% of the total price of the end product (end product would be defined as the CLIN item).

Synthetic fibers and threads must be wholly grown, reprocessed, reused, or produced in the U.S.—there is no *de minimis* exempt for synthetic fabric.

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There has been a problem with a certain non-compliant thread in parachutes, what should we do if the contractor tells us this is a problem on ejection seats?

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The Army has been investigating the need for a DNAD on non-compliant thread in parachutes. DCMA has issued Instruction Change Notice #08-010, dated 11 October 2007, for interim acceptance of noncompliant parachutes (including parachutes on ejection seats) that contain the same potentially non-compliant thread. ACOs may accept the item and apply a withhold or equitable adjustment of contract price if the noncompliance is not corrected or exempted within twelve (12) months of acceptance. This option should be very limited in application.

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