PERFORMANCE OF THE DEFENSE ACQUISITION SYSTEM

2013 ANNUAL REPORT

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FOREWORD

In God we trust; all others must bring data.

—Attributed to W. Edwards Deming

While the United States achieves its national security missions by equipping its military forces with the best weapons systems in the world, questions continue about the performance of the defense acquisition system. How effective is it? How can that effectiveness be objectively measured? Can we use those measures to affect behaviors with appropriate incentives or determine which policies and procedures improve results and which turn out to be misguided?

Answering these questions requires more than opinion. It requires analysis of unbiased data to discover insights into underlying effects. These, in turn, will inform better policy and programmatic decisions.

This is the first in a series of planned annual reports on the performance of the defense acquisition system—its programs, institutions, workforce, managers, executives, and industrial partners. By using objective data and analysis to measure performance, these reports will identify underlying drivers and inform future decisions on programs, policies, and processes.

This first report focuses primarily on performance related to Major Defense Acquisition Programs[1] (MDAPs). It will not delve into specifics of the individual programs but is intended to use aggregated data from these programs to shed light on macro-level performance indicators for the acquisition system as a whole. The report focuses on more in-depth indicators of system outcomes, particularly with respect to cost and schedule, and does so by looking at various institutional trends.

- How does the portfolio of major programs perform over time? What has changed, how, and by how much?
- Are there differences associated with leadership?
- Are there differences among DoD organizations?
- Are there differences among our industrial partners?

This report also reflects results to date from the compliance of the Department of Defense (DoD) with the Improve Acquisition Act of 2010 (Title VIII, Subtitle F, Public Law 111-383, Section 861 codified in 10 U.S.C. § 2548) on performance assessments of the defense

[1] 10 U.S.C. § 2430.

acquisition system. While similarly motivated, our efforts will go beyond the specifics of this act to seek additional insights for improving the performance of the defense acquisition system.

In addition, this study will be used in part to fulfill a recent request from the Office of Management and Budget for an evidence-based analytic study on acquisition performance.

Readily available data allowed us to provide historical baselines on acquisition performance and some initial insights into whether performance has, or has not, improved recently. They also demonstrate that it can take many years to see the results of new policies, making it even more important to test and inform those policies. Although existing data can be effectively leveraged to improve our understanding, a lesson learned is that gaps remain; therefore, I initiated a strategic initiative to identify those key data gaps and begin selective collection of new data for future analysis. That work will continue, and will inform future reports.

Since this initial report focuses primarily on analyzing MDAP development and early production information, it cannot be considered a complete picture of the entire acquisition system. Future reports will delve into areas such as contracting, acquisition of services, technology development, industrial base concerns, etc.

Value obtained in acquisition is a balance of costs, benefits, and prudent risks. Risks are a fact of life in acquiring the kinds of products our warfighters need, and these risks must be objectively managed. Additionally, demands and threats do change in both the short and long term, so the acquisition system must be able to respond. In some cases, cost growth results from prudent changes in quantity or capability of acquired systems. Our ultimate measure of performance is providing effective systems to the warfighter that are suitable for fielding, at costs that are affordable, while ensuring taxpayers' money is spent as productively as possible. Only through rigorous analysis and clear reporting will we be able to separate and account for acceptable and unacceptable types of cost growth, informing our discussions within DoD, with Congress, our Allies, and the American public.

The Honorable Frank Kendall
Under Secretary of Defense
Acquisition, Technology and Logistics

Contents

1. BACKGROUND

Our acquisition system—its institutions, offices, laboratories, workforce, managers, executives, and industrial partners—conducts research, provides a wide range of services, develops and produces new goods, and sustains their capabilities for warfighters and other operators. The performance of that system should be measured relative to its outputs and outcomes of interest. Identifying internal policies, processes, workforce, and management capabilities that bear positively or negatively on those measures requires data and analysis to avoid speculative or cyclical policy choices based on current conventional wisdom or untested hypotheses.

TRACKING AND DISSEMINATING ACQUISITION PERFORMANCE AND CORRELATES

Measuring performance is a key tool for improving performance. Fundamental to improving acquisition is to understand, in sufficient detail, how well we actually *are* performing: whether we are getting any better or worse, and, most importantly, understanding *why* any discernible trends exist. Without baselines and trends, it is impossible to know where to focus our efforts, what initiatives should be considered (or abandoned), and whether those initiatives are producing the desired results.

Determining whether we have improved our performance is a challenging task because many cost, schedule, and performance measures are lagging indicators that require years to reveal identifiable trends. Thus, the Department must continue to monitor performance closely and seek (whenever possible) more responsive or even leading indicators of performance.

At the direction of the Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]), the Department is establishing an expanded process for measuring and publishing the performance of the defense acquisition system, including the performance of both government and industry institutions under the tenures of primary decision makers. This reinforces accountability and responsibility throughout the acquisition system. The expanded process involves a three-pronged approach of ensuring objective data collection, rigorous analysis, and unbiased reporting of results. Data collection is a strategic project well under way. Rigorous analysis is supported by a new analysis cell in AT&L as well as the continued use of rigorous and objective internal and external analytic entities. Finally, this annual report is a key dissemination vehicle of our findings and begins a continuing process to improve our performance through data acquisition and analysis. Subsequent reports will extend and expand these findings as we continue to improve our ability to objectively measure and evaluate performance.

This document primarily reports on the results of our data-driven analysis. Interpretation of performance and the implication for policies are left largely to the reader. Some aid is given after the tables and figures to help the reader understand the analysis and to highlight key findings. Unless the analysis provides clear links to causes and policies, the document merely reports the facts to inform debates elsewhere.

FOCUS OF THE REPORT

The defense acquisition system acquires goods and services to support our military forces both now and in the future, while fulfilling our responsibility to be efficient and to avoid waste, fraud, and abuse of taxpayer dollars. The DoD's FY2014 base budget request for acquisition funding totals $166.8 billion, of which $99.3 billion is for Procurement, and $67.5 billion is for Research, Development, Test and Evaluation (RDT&E) programs. Of this amount, approximately 40 percent ($69.4 billion) is for Major Defense Acquisition Programs (MDAPs), which provide the bulk of the readily available data for analysis in this year's report.

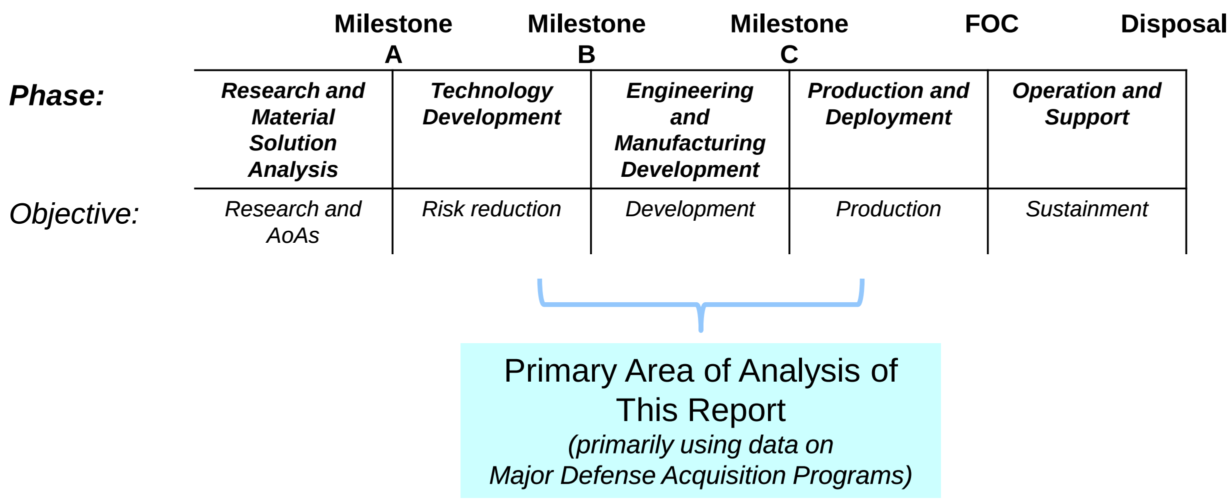
While using MDAP program- and contract-level data, we focus on how our institutions performed as evidenced by the collective outcomes of these MDAPs along various dimensions and acquisition approaches rather than on the individual performance of these programs.

This report provides improved insights into key aspects of total life-cycle cost performance to inform policy decisions about the overall acquisition system and institutions. There are important differences in how programs are managed depending on where they are in their life cycles.

Figure 1-1 depicts the entire defense acquisition system life cycle[2] and the portion where we currently have the best data for analysis, namely for development and early production. While we have some data that reflect partially on the performance in other phases (e.g., early research, analysis of alternatives [AoAs], early risk reduction, and sustainment), the phases subsequent to early production are reflected at best by early estimates. These other phases will be covered in subsequent versions of this report as we improve data access, quality, and availability.

[2] See https://dag.dau.mil/Pages/acqframework.aspx for a description of the life-cycle phases of the Defense Acquisition Management System framework.

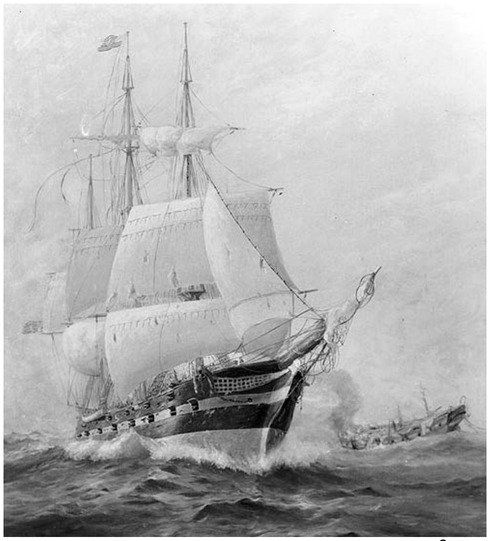
Figure 1-1. The Defense Acquisition System Life Cycle.



Judging Benefits Against Cost

This report seeks objective presentation of data and analysis, avoiding claims of whether the outcomes of technical performance and schedule are worth the cost (generally) and cost growth (specifically). It is important to note, however, that debates about value are important yet must be informed by facts.

The excerpt below from an article by Col. Mark F. Cancian (USMCR, ret.) illustrates these larger external debates. While the acquisition of the original six Navy frigates beginning in 1794 is a case where value can be argued, there certainly are others for which it cannot. We leave it to the reader to judge the cases in this report—informed in part by the analysis provided.



USS *Constitution* in the War of 1812[3]

> *Is Cost Growth Always Bad?*
>
> Discussions about cost growth presume that it is always bad and that policy makers should take drastic actions to prevent it. A cautionary tale from the early days of the Republic shows that the situation is more complicated than the usual morality play about shortsightedness and incompetence.

[3] This 1906 painting by G.T. Margeson depicts the USS *Constitution* sailing past the dismasted HMS *Guerriere* after action on August 19, 1812. Official U.S. Navy Photograph 428-N-1055208 (www.history.navy.mil).

In 1794, the young United States authorized the construction of six frigates (*United States*, *President*, *Congress*, *Constitution*, *Constellation*, and *Chesapeake*). Intended to be the major units of the new Navy, the ships represented the aspirations of an ambitious but inexperienced institution. In execution, all the pathologies of today's weapon systems acquisition were evident. Toll [in *"The Six Frigates"*] (2006) describes the history and construction of these ships.

- An innovative but unconventional design was criticized as "extravagant."
- A multi-mission requirement for irregular warfare (anti-piracy) and high-intensity warfare (against major powers such as Great Britain) put conflicting demands on the design.
- Use of exotic materials delayed construction and raised costs. (Key hull components required live oak, which had to be imported from inaccessible coastal areas in the South.)
- A divided political establishment argued over the need and cost.
- Contracts were spread around all the northeast states to ensure political support.
- Cost growth caused schedule slippage and program instability.
- Congress, alarmed at the costs and delays, conducted inquiries and railed against waste.

But the story did not end there. In service, the ships were spectacular successes. Over the course of their careers, they fought 11 combat actions, winning 8 and losing 3. The exploits of the *Constitution* particularly encouraged the young nation. These successes were achieved while badly outnumbered and fighting against the two best navies in the world—the British and French. How was this possible? The advanced design that caused so many problems during construction also gave the ships a decided advantage over other ships in their class. They could defeat any ship with comparable speed and outrun any ship that was more powerful. The unexpectedly high cost bought capabilities that proved important in war.

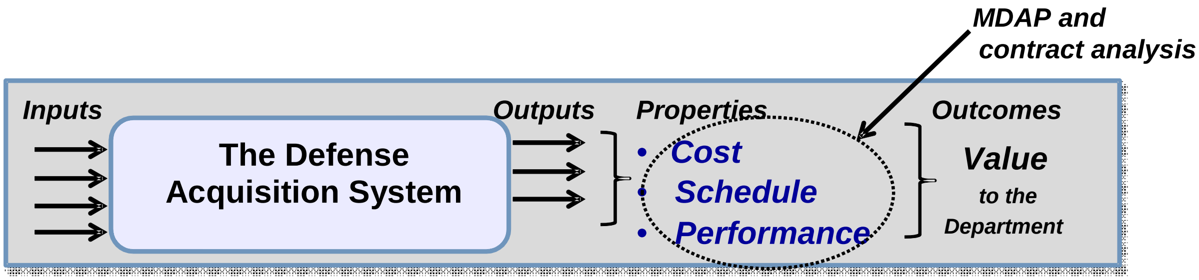
Substitute for frigates the M-1 tank, F-15 fighter, or Ohio-class submarine and the story moves forward two centuries. All of these programs had unexpectedly high costs, but proved world class in operation. The existence of cost growth therefore does not necessarily mean that the acquisition was a mistake.

[from Cancian, 2010]

ON MEASURING PERFORMANCE

Institutional performance is all about getting value. Value to the Department stems from the relative benefits (e.g., technical performance) of the goods and services acquired in a responsive time (schedule) compared to the costs to the taxpayer. Hence, measures of cost, schedule, and performance serve as the basis for measuring the effectiveness of the acquisition system in converting inputs to outputs (see Figure 1-2).

Figure 1-2. Output Measures for the Defense Acquisition System.



Integration of the DoD Decision Support Systems

While we focus on the defense acquisition system, it is important to remember that our acquisition system interacts with other systems that control the finances and requirements for the items being acquired. Moreover, all three of these systems are driven by broader policies and strategies created and evolved to meet the missions given to the Department by the country.

The Department of Defense has three principal decision-making support systems for meeting its policies and strategy, all of which have been significantly revised over the past few years. These systems are the following:

Planning, Programming, Budgeting and Execution System (PPBES): The Department's process for strategic planning, program development, and resource determination. The PPBES process is used to craft plans and programs that satisfy the demands of the National Security Strategy within resource constraints.

Joint Capabilities Integration and Development System (JCIDS): The systematic method established by the Chairman of the Joint Chiefs of Staff for identifying, assessing, and prioritizing gaps in joint warfighting capabilities and recommending potential solution approaches to resolve these gaps. CJCS Instruction 3170.01 and the *JCIDS Manual* describe the policies and procedures for the requirements process.

Defense Acquisition System: The management process by which the Department acquires weapon systems, automated information systems, and services. Although the system is based on centralized policies and principles, it allows for decentralized and streamlined execution of acquisition activities. This approach provides flexibility and encourages innovation, while maintaining strict emphasis on discipline and accountability. A significant revision to the DoD Instruction 5000.02, the governing policy on operation of the Defense Acquisition System, is nearing completion.

Understanding How Internal Functions and Processes Affect Performance

The acquisition system can be measured at two fundamental levels: (1) the major outputs and outcomes of the system, and (2) the key functions, responsible entities, and institutions accountable within the system to achieve those outputs and outcomes. The most readily available and measurable outcomes assessed throughout the report are cost and schedule growth, but some readily available information on technical performance also is analyzed.

Decomposing the acquisition system into major functional responsibilities enables analysis of how elements of the system affect the ultimate outcomes of interest. Intermediate outputs and outcomes of key institutional functions may correlate with cost, schedule, and performance outcomes, but others may be too small or difficult to discern from available data. Still, a functional decomposition helps to understand how well the defense acquisition system performs, based on management principles and intermediary outputs and outcomes. As this work moves forward, our greatest challenge will be to identify the relationships between and among the factors the Department can affect (policies, contract terms, incentives, workforce skills, etc.) and the outcomes we are trying to achieve. This report is a step in that process.

Scope of Outcomes: Programs or Their Constituent Contracts

Our analyses often examine two main types of performance data:

- **Program-level Data**—describing measurements across the entire program (e.g., estimated final total cost growth from Milestone B baseline for all units to be procured), and
- **Contract-level Data**—describing measurements on one of the many contracts that constitute a program (e.g., the total cost growth from original negotiated contract target cost for an early lot of units procured).

Program-level measures show how well the acquisition system developed the ability to produce the overall program against original estimated baselines despite quantity changes, while providing insight into whether cost growth may have been a factor in quantity changes.

Contract-level measures provide early indicators of potential program-level issues by examining performance when the Department contracts for specific work from industry. Nearly all the actual research, development, and production on weapon systems are performed by industry partners through contracts with the Department. Thus, examining performance at the contract level provides detailed and potentially useful indicators of performance that eventually will be seen at the more aggregate program level.

This report often switches between these types of data as we examine different types of institutions (e.g., DoD-wide to military departments to acquisition commands) and different phases of acquisition (e.g., development or early production).

While contracts are the key execution elements of a program (i.e., most goods and even services are provided by contractors), they have different baselines (e.g., contract cost targets) set at different times than the program's Milestone B baseline. Contract performance can be earlier, leading indicators of the larger program's performance but they do not necessarily reflect the performance revealed in program-level measurements. **Thus, it is *critically important* to recognize what type of data is being discussed at each point in the report.**

Also, care must be taken to note whether cost data have been adjusted for inflation. The available program-level budget data we used have been adjusted for inflation (i.e., is reported in "base-year" dollars), but the contract-level cost growth data have not (i.e., are only reported in "then-year" dollars, and insufficient temporal information was available for us to adjust the reported figures for inflation). Thus, partly because of inflation, the program-level cost growth figures in this report will be lower than those for contract-level analyses.

ORGANIZATION OF THE REPORT

The chapters that follow summarize analyses performed on MDAPs and their contracts, with the goal of identifying quantifiable and statistically significant correlations between cost and schedule growth, and other measurable factors. These analyses indicate areas that should be the focus of acquisition leadership to identify and address problems to improve the outcomes of the acquisition process.

Chapter 2 is a long presentation of analytic results. It begins by showing cost growth on major MDAP contracts with contract start dates plotted against government acquisition executive tenures when major reviews should have occurred. It then shows a view of acquisition productivity as measured by program cancellation or major curtailment. The report then discusses performance results by different organizational partitions from overall DoD performance through military departments, commands, and finally our industry partners. When available, analyses of the causes of performance differences are provided.

Chapter 3 briefly reviews the gaps in our analysis, important policies and processes we want to examine, and our efforts to fill data gaps and further our analyses.

Chapter 4 provides some comments on the analyses. However, this is not a comprehensive review of defense acquisition performance. Rather, the analytic results in Chapter 2 constitute the findings of the report. We leave it to the reader to draw his or her own conclusions and observations about the performance of the defense acquisition system, its sufficiency, and the degree of progress made to date. As you will see, there is room for improvement (as is always the case), and Chapter 4 does not purport to excuse weaknesses or claim victory for strengths but rather raises some observations for larger deliberations outside this report.

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2. Analysis of Acquisition Performance

A key to improving acquisition is to learn from our successes and failures. Without looking at results of past actions, we have no feedback to know whether hypotheses and beliefs pan out in the complicated world of defense acquisition. Objectively examining the relative effectiveness of acquisition components and institutions while attempting to distinguish which factors and variables affect outcomes not only allows us to identify successes and failures but also begins to lead us to specific lessons we can try to replicate and control points we can exploit.

The following analyses examine key outcome dimensions of cost, schedule, and technical performance of MDAPs across the DoD, Components, acquisition commands, commodities, and prime contractor spectrum, often measured at both the program and contract level. Combined, these analyses provide insight into key cause and effect relationships, focusing attention on problems as early as possible, clarifying misunderstandings, and informing assessments and learning.

These analyses, however, have limitations because they do not yet fully explain the underlying reasons *why* we found some factors to be significant contributors to cost or schedule growth. They also do not allow us to judge the merits of decisions that led to program or contract changes (e.g., whether changes were due to poor management or lack of discipline, or because of disciplined response to engineering challenges in advancing the state-of-the-art or changing missions and threats). Nevertheless, these measures provide insights and areas for further research that can be used by acquisition professionals as a part of management and oversight, as well as offering early insights of potential effects that may be realized at the program level.

For our analyses of program data, recognize that the MDAPs examined are in a varying state of maturity—from early programs that may or may not develop future problems, to mature programs adding new capabilities to existing systems, to completed programs.

For our analyses on contract data, we note that each MDAP may, and usually does, have more than one major contract in our datasets. These contracts may be for development or early production. No attempt was made to ignore outliers (examining extreme successes and failures are important for learning). These data are a readily available way to dig deeper into MDAP performance below the common program-level measures. We often report medians rather than averages (means), given the skewed distributions.[4] In such cases, medians are a better measure of central tendency across a collection of contracts while averages exaggerate the effect of extreme outliers.

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[4] Part of the skewing in the distribution of cost change is the mathematical boundary of cost change because cost cannot decrease more than 100 percent, but it can increase more than 100 percent.

CONTRACT COST GROWTH: POSSIBLE RELATIONSHIP TO ACQUISITION EXECUTIVE DECISIONS

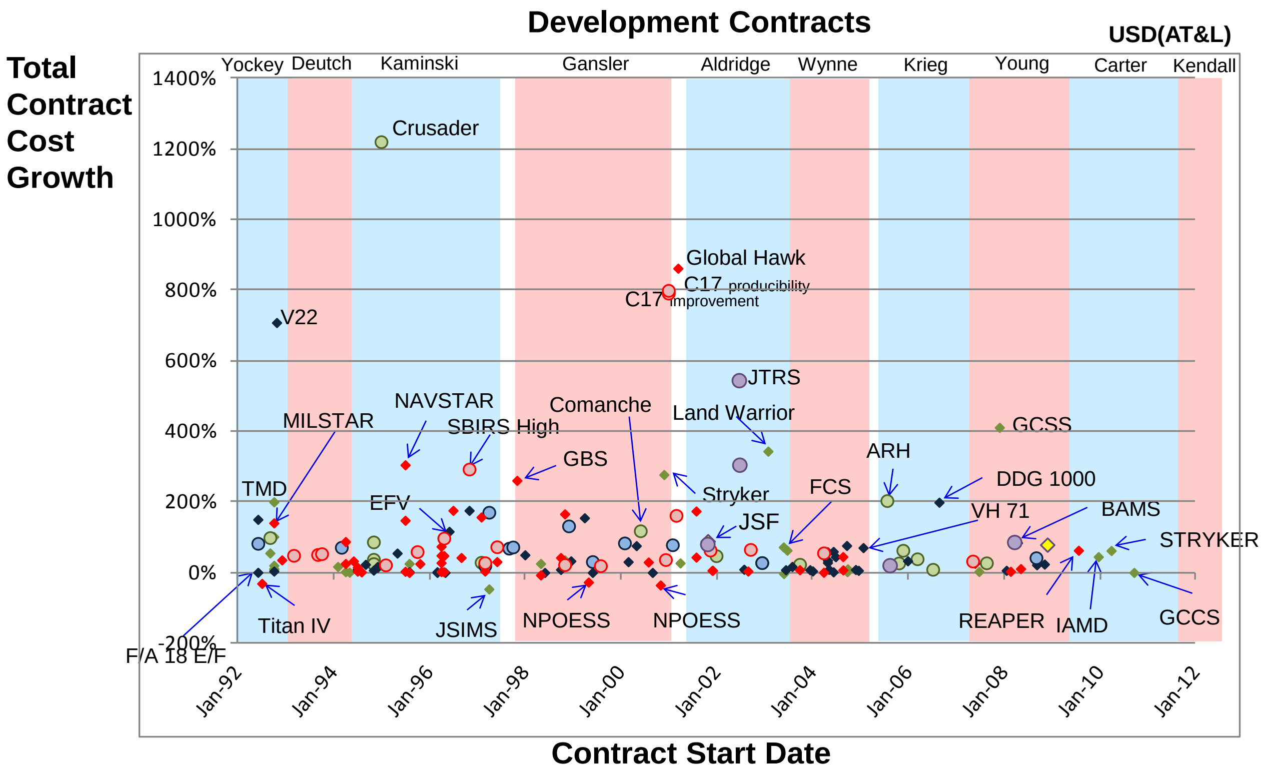
Let us begin by presenting cost growth on major MDAP contract over the last 20 years, plotting contract cost growth against the USD(AT&L) in office at each contract start date. These data allow us to introduce the magnitude and distributions of cost growths in defense acquisition and the challenges of trying to identify causes and motivate performance ownership.

Policy and execution decisions by DoD executives should bear (in part) on the effectiveness of the overall acquisition system during their tenures. Such decisions include changes to the defense acquisition system policies and procedures (e.g., through changes in Departmental regulations); approvals, certifications, and exemptions within that system; institutional organization, policies, and processes; incentives; personnel selection, training, and mentoring; guidance and execution on larger programs, including acquisition strategies and choices; and myriad other effects. More specifically, the acquisition executives chair the boards that review programs at major milestones, guiding both program directions and specific approaches to contracting. Thus, one way to reveal executive effectiveness is to measure the cost and schedule growth on major contracts.

Tracking effectiveness during the tenure of key executives may help baseline the effectiveness of the defense acquisition system overall and could offer clues for further research into broad policies and actions leading to improved practices. Note that programs started in the most recent tenures (e.g., USDs Frank Kendall and Dr. Ashton Carter) may have further changes in observed effectiveness due to the relative immaturity of these efforts.

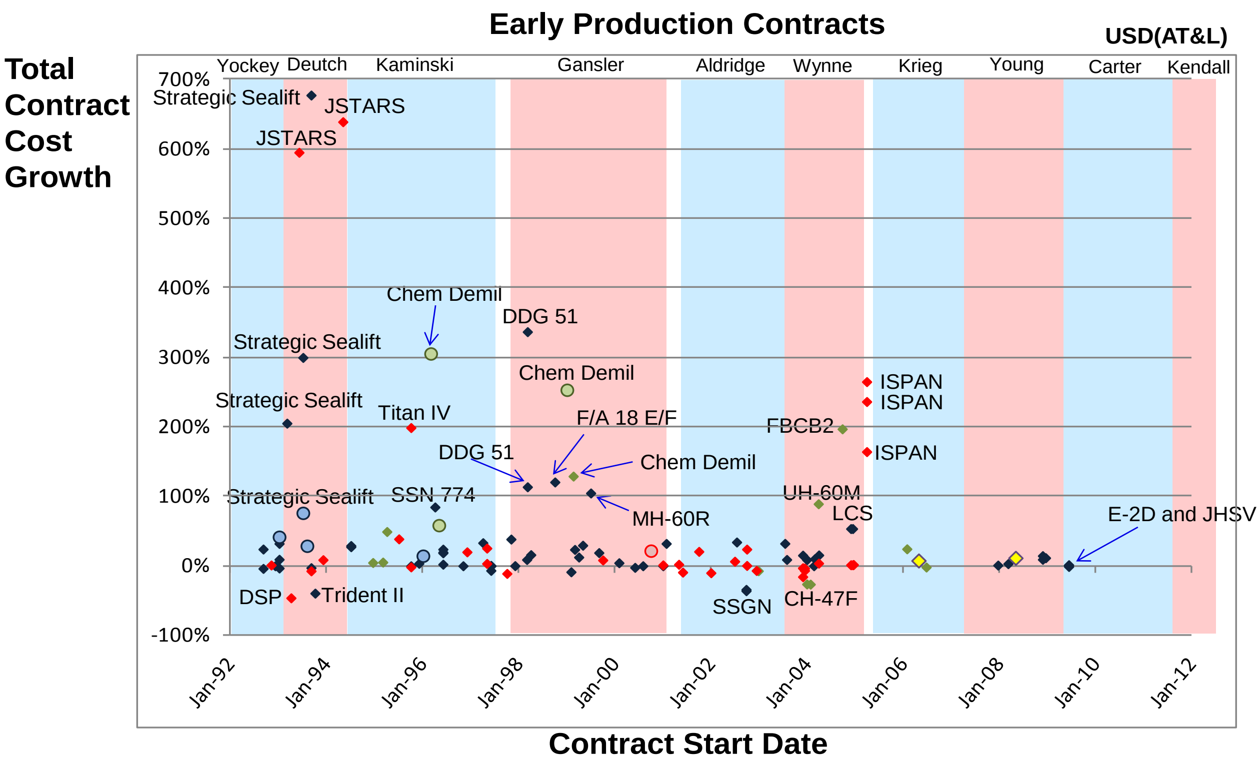
Figures 2-1 and 2-2 show approximately 20 years of contract data on total cost growth relative to initial contract cost targets for major MDAP development and early production contracts. Superimposed on the scatter charts are the tenures of Defense Acquisition Executives (DAEs) in place at the time of the contract start date. This was not a statistical analysis of correlation between DAE and contract but an exploratory examination that reveals the wide variation in cost growth of major contracts and possible relationships in time. An assumption was made that generally a contract start date closely follows a key review by the DAE for the programs to proceed with the contract (e.g., the Pre-EMD review or Milestone B decision), although there may be some situations where this was not the case and other factors also can be involved. Outliers and selected contracts for well-known programs are identified by program name (including some duplicates for multiple contracts for the same MDAP). The scatter plot reveals significant variation and skewing in total contract cost growth measured from original contract cost target.

Figure 2-1. DoD-Wide Development Contract Total Cost Growth and USD(AT&L) Tenures (1992–2011).



NOTE: Normally, contract start dates should be relatively close to prior major reviews (usually Milestone B decisions) by the MDA to approve contract award. Army programs are shown in green; Navy in blue, Air Force in red, DoD-wide in purple and yellow. Diamonds on the charts indicate growths mostly attributable to the start of the contract; circles represent significant work added later. Any white bars between Defense Acquisition Executive shaded regions represent periods where there was no confirmed executive. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Figure 2-2. DoD-Wide Early Production Contract Total Cost Growth and USD(AT&L) Tenures (1993–2011).



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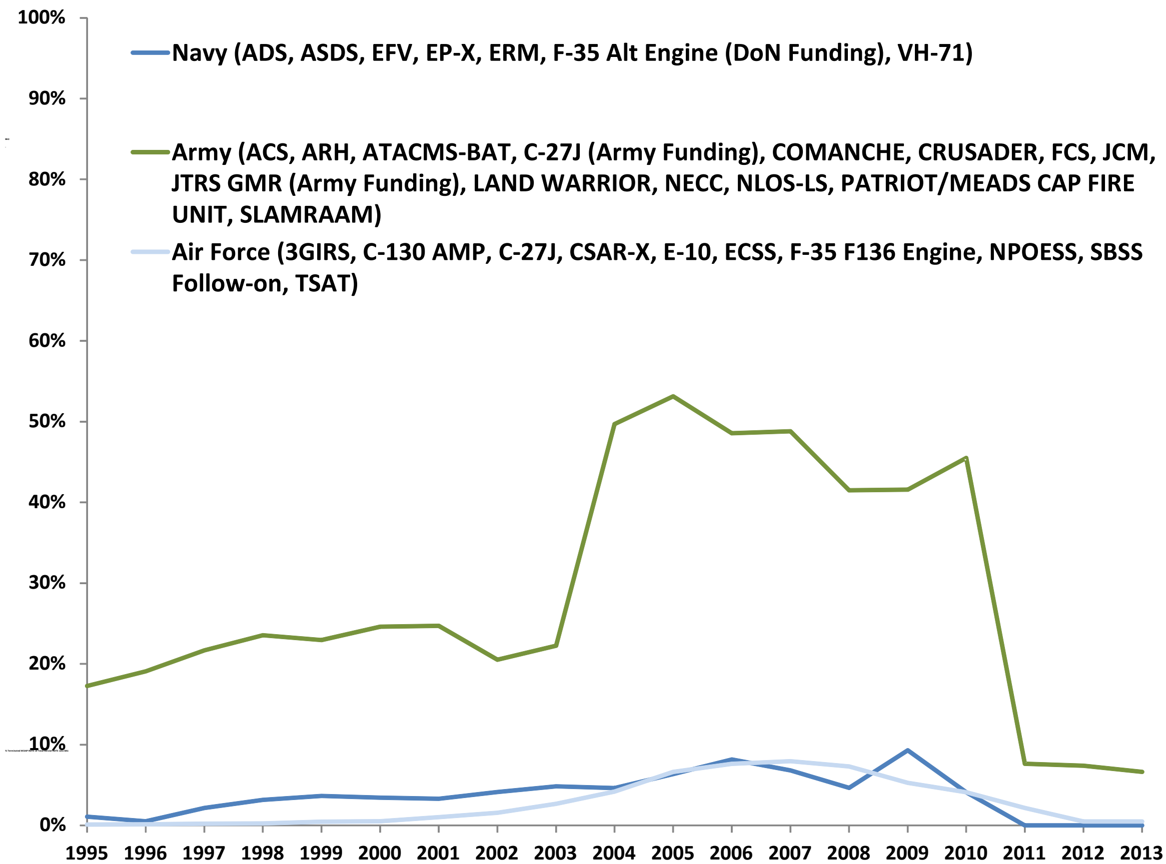
Productivity: Sunk Costs of Canceled Programs

One possible productivity measure is the amount of RDT&E funding spent on major programs that were canceled before producing any units and those that produced many fewer units than originally planned. Figure 2-3 shows the annual percentage of RDT&E funding (less earlier science and technology expenditures) by each Military Department on major weapon system development efforts with major curtailment or no operational units produced.

Figure 2-3. Major Programs Officially Canceled without Producing Any or Very Few Operational Units (1995–2013).



Source: DoD budget data.

Of note, the Army has both the largest number of canceled programs and the largest percentage of sunk RDT&E costs. The amount of funding lost was relatively constant for the Army from 2004 through 2010, coming down sharply thereafter. The majority of the Army's sunk funding problem through this period was due to the cancellation of the Future Combat System (FCS); however, every year from 1996 to 2010, the Army spent more than $1 billion annually on programs that ultimately were canceled (Decker 2011). The causes of these program cancellations and curtailments were not examined, but an overview of root-cause analyses of Nunn-McCurdy cost breaches is provided later in this chapter.

TECHNICAL PERFORMANCE OF MDAPS

While most of this report discusses outcome measures of cost and schedule, this section summarizes some readily available independent assessments of technical performance of weapon systems. Future reports will continue to expand this area.

Mission Effectiveness and Suitability of Acquired Systems by Organization

One measure of technical performance of acquisition programs is how they rate, as a group, in operational effectiveness and suitability as assessed by the DoD Director of Operational Test and Evaluation (DOT&E).[5]

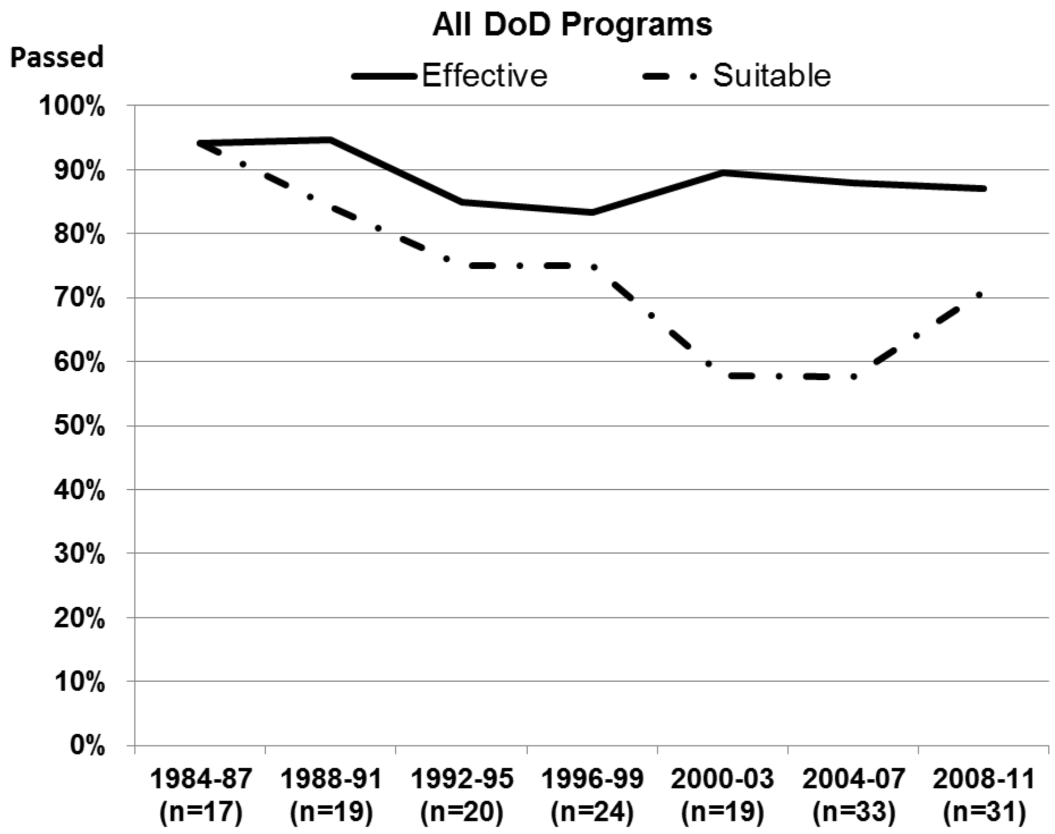
As a high-level indicator of the technical performance of major programs, this report uses "operational effectiveness" and "operational suitability." Operational effectiveness is defined in the *JCIDS Manual* as: "Measure of the overall ability of a system to accomplish a mission when used by representative personnel in the environment planned or expected for operational employment of the system considering organization, doctrine, tactics, supportability, survivability, vulnerability, and threat." Operational suitability is a composite evaluation that considers a system's safety, interoperability, availability, maintainability, and reliability. It should be noted that operational effectiveness and operational suitability are not measured solely on the basis of system technical performance parameters. Rather, measurements are accomplished through an evaluation that includes the system under test and all interrelated systems (its planned or expected environment in terms of weapons, sensors, command and control, and platforms, as appropriate) needed to accomplish a combat mission.

Robust developmental testing occurs throughout the earlier phases of a program's life cycle, intended to discover and correct significant issues so that, by the time operational testing is done, discovery of major technical performance issues should be rare.

The following table and graphs summarize DOT&E's assessments of technical performance of weapon systems grouped by Military Department, and how these have trended over time in 3-year increments. The percentage reported represents the number of MDAPs rated Effective or Suitable divided by the total MDAPs assessed by DOT&E. These results were taken from DOT&E's statutorily required Beyond Low Rate Initial Production (BLRIP) reports done prior to any decision to proceed to full-rate production of an MDAP. Each program is rated (or not) as a whole as Effective and Suitable.

[5] DOT&E is independent statutorily from the acquisition organizations and is responsible for, among other things, reporting the operational test results for all MDAPs to the Secretary of Defense, USD(AT&L), Service Secretaries, and Congress.

Figure 2-4. Percent of DoD MDAPs Rated as Operationally Effective and Suitable (1984–2011).



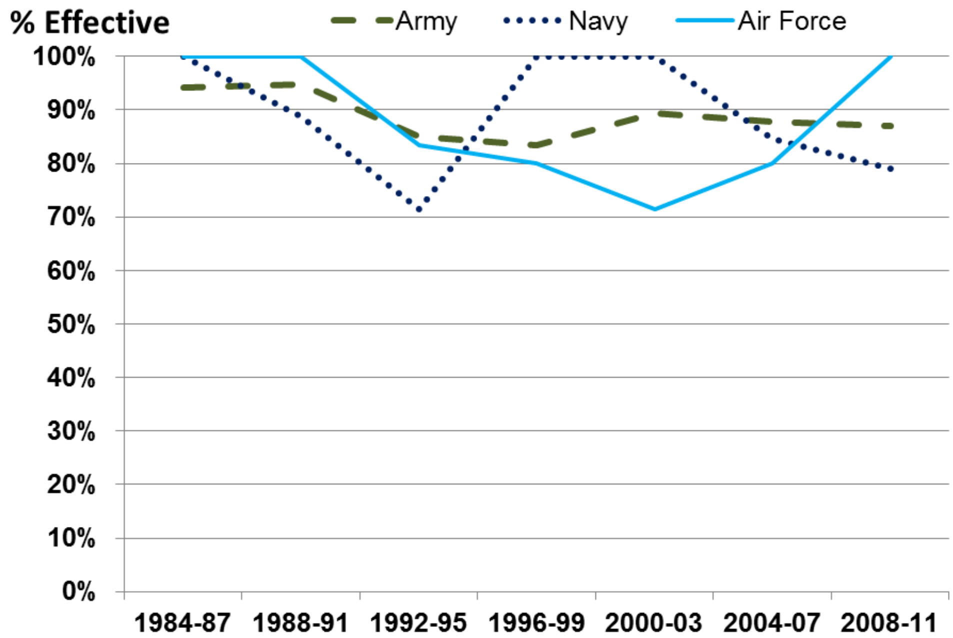
Source: DOT&E BLRIP reports.

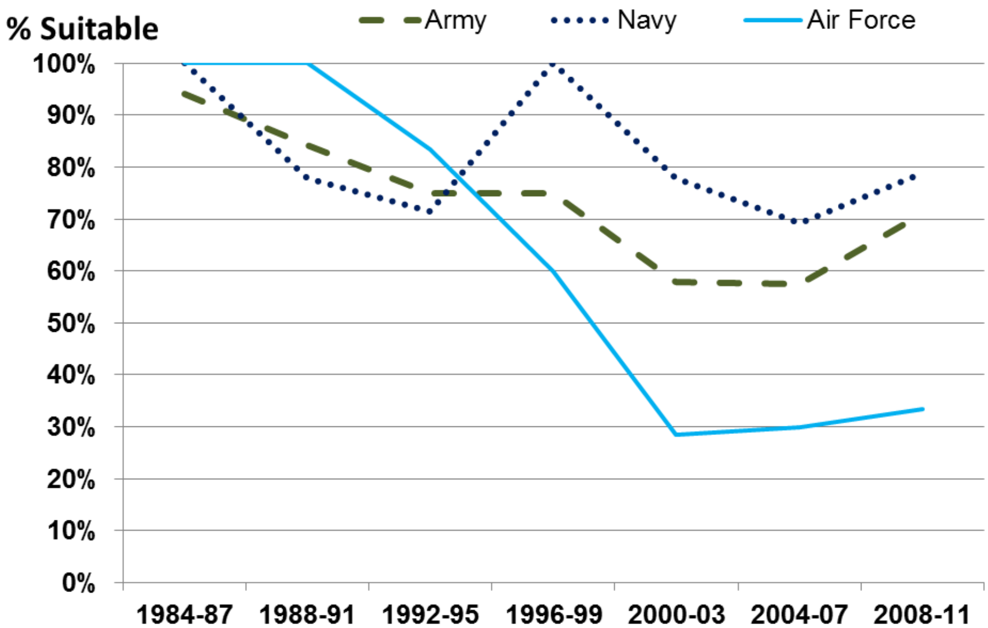
Table 2-1. Percent of MDAPs by Military Department Rated as Operationally Effective and Suitable (1984–2011).

	Army (n=47)	**Navy** (n=73)	**Air Force** (n=43)
Effective	**94%**	**88%**	**84%**
Suitable	**77%**	**81%**	**51%**

Source: DOT&E BLRIP reports.

Figure 2-5. Percent of Programs Rated Effective and Suitable by Military Department (1984–2011).



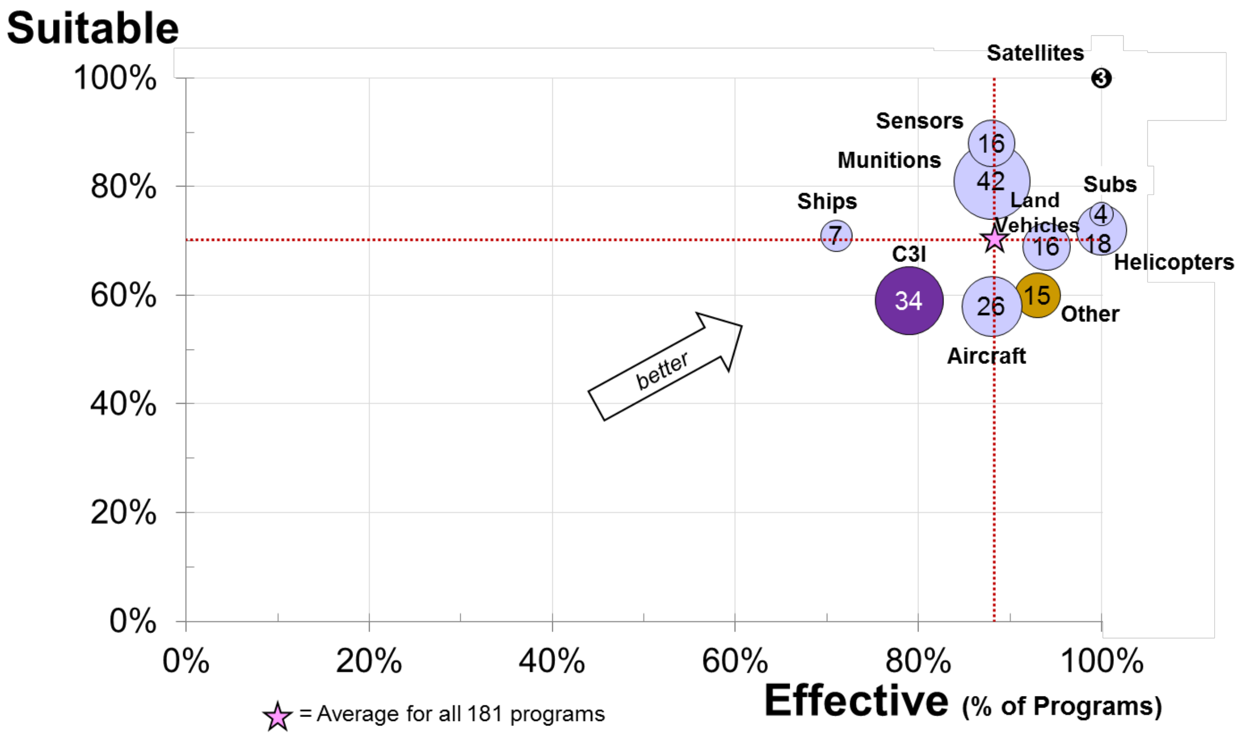


	n=	*n=*	*n=*	*n=*	*n=*	*n=*	*n=*
Army	5	8	7	8	3	10	6
Navy	10	9	7	6	9	13	19
Air Force	2	2	6	10	7	10	6

Mission Effectiveness and Suitability of MDAPs by Commodity Type

Figure 2-6 depicts aggregate data on operational test results since DOT&E was established in 1984 broken out by the type of systems (also referred to as a commodity within the DoD). Note that the chart includes a mix of programs by dollar value and is not limited solely to MDAP systems.

Figure 2-6. Program Ratings in Operational Testing by Commodity Type (1984–2011).



NOTE: Data include a mix of Acquisition Category (ACAT) I–III and special interest programs. The size of the circle indicates the number of programs evaluated, and the location is the average for each commodity type.
Source: DOT&E BLRIP reports.

When examining the overall ratings by commodity type, satellites were rated the best at 100-percent effective and suitable. Ships and command, control, communications and intelligence (C3I) systems, on the other hand, had the lowest ratings at about 70- to 80-percent rated initially as effective and 60- to 70-percent initially rated as suitable based on operational testing. Note that some of these categories have very small datasets and thus are less reliable to generalize (e.g., only three satellite systems are in the dataset).

Cost Growth: Nunn-McCurdy Program Breaches

Each MDAP is required by law to submit a Selected Acquisition Report (SAR) to the Congress 45 days after the President's annual budget submission and under various other circumstances (see 10 U.S.C. §2432). The SAR reflects what is included in the President's Budget as well as a comprehensive summary of MDAP cost, schedule, and technical performance measures. Historical SAR data serve as the primary sources for much of the program-level analysis in the report due to their relative availability and comprehensiveness.

Common cost measures such as Program Acquisition Unit Cost[6] (PAUC), which includes both RDT&E and procurement, and Average Procurement Unit Cost[7] (APUC), which includes only procurement) are codified in statute. Statute also requires that programs exceeding certain thresholds (measured by PAUC or APUC changes relative to their original and latest program baselines) must go through a rigorous reexamination and certification to Congress along a variety of specified criteria. This process commonly is referred to as the "Nunn-McCurdy" process, named for the two original sponsors of the legislation.

Two types of breaches are called out in the Nunn-McCurdy process: *significant* and *critical*. A "significant" breach is the lower threshold and is intended to warn Congress that a program is experiencing high unit cost growth. A "critical" breach signifies the cost growth is even higher, triggering the formal reexamination and certification process mentioned above. The criteria for a significant breach are 30 percent cost growth in APUC or PAUC from the original baseline or 15 percent from the current baseline reported in the previous SAR. A critical breach occurs when the program experiences 50 percent cost growth from the original baseline or 25 percent from the current baseline.

Figure 2-7 shows the number of Nunn-McCurdy breaches since 1997, including each individual breach for those programs that have breached multiple times (e.g., a significant breach followed by a critical breach). The National Defense Authorization Act (NDAA) for FY2006 made changes to the Nunn-McCurdy statute, adding the requirement to report unit cost growth from the original baseline; this additional requirement caused the large spike in 2005, where 11 programs had to report preexisting significant breaches. There have been 86 total breaches since 1997, and the most recent years reflect an apparent improving trend. However, it is too early to determine if this trend represents a systemic improvement in performance.

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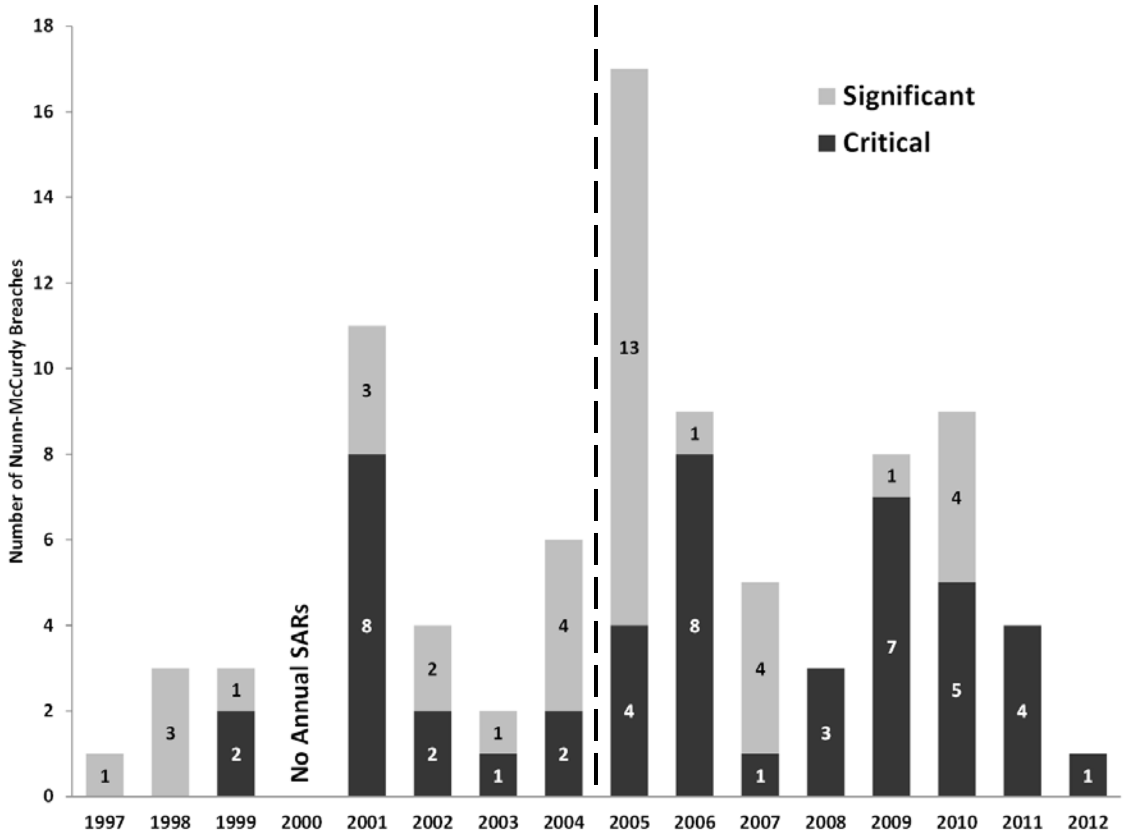
[6] Section 2432(a)(1), Title 10, U.S.C. defines program acquisition unit cost as "the amount equal to (A) the total cost for development and procurement of, and system-specific military construction for, the acquisition program, divided by (B) the number of fully configured end items to be produced for the acquisition program."

[7] Section 2432(a)(2), Title 10, U.S.C. defines procurement unit cost as "the amount equal to (A) the total of all funds programmed to be available for obligation for procurement for the program, divided by (B) the number of fully configured end items to be procured."

Figure 2-7. Nunn-McCurdy Breaches (with Multiple Breach Programs 1997–2012).



NOTE: The criteria for breaches were changed in NDAA 2006, affecting counts starting with 2005. Breaches are determined using "base-year" dollars (adjusted for inflation).

Table 2-2 below summarizes a different analysis of Nunn-McCurdy breaches by commodity. In this case, we do not "double count" programs that have breached multiple times, allowing us to compare the number of breached programs to those that have never breached and the total number of MDAPs during this period.

Table 2-2. Nunn-McCurdy MDAP Breaches and Rates by Commodity Type (Adjusted for Multiple Breach Programs 1997–2011).

	Total # Programs	# Breaches	Breach Rate
C3I	33	5	15%
Land Vehicle	9	2	22%
Missiles	22	5	23%
Munitions	12	3	25%
Ships	14	4	29%
Satellites	15	5	33%
Other	9	3	33%
Fixed Wing Aircraft	34	12	35%
Submersible	5	2	40%
Helicopters	13	10	77%
Chem Demil	4	4	100%
Total	170	55	31%

NOTE: Breaches are determined using “base-year” dollars (adjusted for inflation).

Thirty-one percent of all MDAPs since 1997 have had either a significant or critical breach. This analysis appears to show that all commodities are susceptible to breaches, with helicopter and the chemical weapons demilitarization (Chem Demil) programs having the highest breach rates. The Chem Demil programs historically had unique oversight and management that has recently been brought more in line with practices of the rest of the Department; the cost, schedule, and technical performance metrics were not mature, and were subject to somewhat unique factors in execution. Helicopter programs show a clear association with Nunn-McCurdy breaches, and this is an area that requires further investigation.

The Nunn-McCurdy process provides insights but only comes into play when programs already are having problems. Also, even though they are unit metrics, PAUC and APUC are sensitive to quantity changes, which can mask or confuse the real sources of cost growth or other acquisition problems. Explaining cost growth as simply a result of changing quantity, therefore, can be complicated and misleading without careful analysis. The SARs do contain cost variance discussions that provide some useful explanations of changes in individual programs, but inconsistencies in the variance concepts and process make it difficult to understand root causes of cost changes, especially across multiple programs and from the quantitative data in the cost variance reports. Recent efforts by the Department—especially the root-cause analyses summarized later in this report—are aimed at getting beyond mere characterization of “symptoms” and proximate causes to gain understanding of the underlying root causes and mechanisms leading to cost growth on programs.

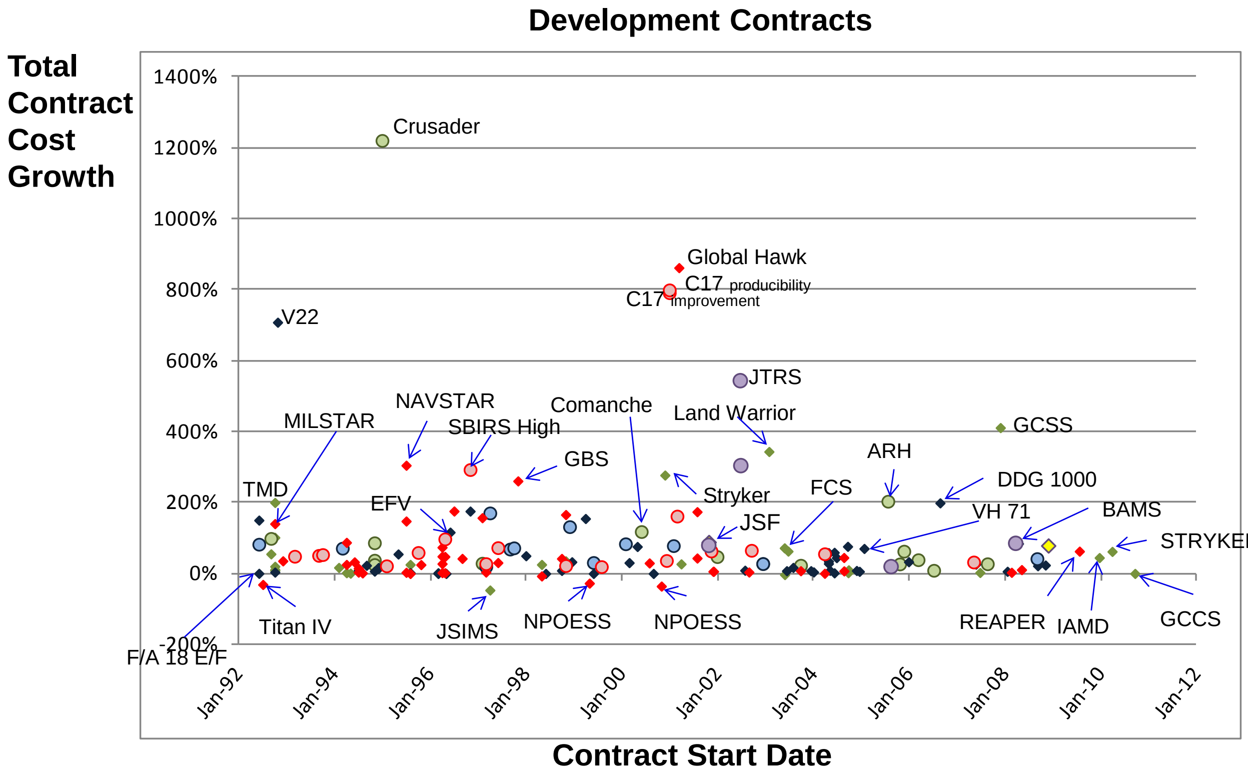
Cost Growth: Development

First, let us examine cost growth for MDAPs in development. MDAP contract data provides a valuable baseline of historical and relatively recent cost growth behavior to begin revealing any near-term and long-term trends as well as the implications of common practices. The long periods examined also are beneficial because they provide sufficient data for statistical analysis.

Contract-Level Development Cost Growth

First, let us revisit cost growth at the contract level on MDAPs for development. Figure 2-8 shows total cost growth since about FY1993 on MDAP contracts, measured from the originally negotiated contract target costs. (A similar chart for early production contracts will be discussed in the next section.) This figure identifies the program name for outliers plus selected programs with lower total cost growth. Note that contracts shown with open circles indicate significant cost growth well beyond the contract start date, which could indicate factors not attributable to the initial management of the contract.

Figure 2-8. Contract Level Total Cost Growth on MDAP Development Contracts (1992–2011).



NOTE: Army programs are shown in green, Navy are blue, Air Force are red, and DoD-wide are in purple and yellow; open circles indicate that there was significant cost growth well beyond the contract start date. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Program-Level Development Cost Growth

Generally, RDT&E costs must be paid regardless of how many units are produced. In that sense, they are a fixed cost for the Department to arrive at a point where we can actually procure and field a capability. Thus, for RDT&E, cost growth ideally should be tracked in total rather than by unit produced to avoid confusing the effects of quantity changes with RDT&E cost growth.

The following figures show total RDT&E cost growth by MDAP portfolio relative to the original program baseline and at 2-year intervals. These different views are useful because they show how the portfolio performed from inception compared to how it performed in its most recent periods. Differences that are statistically significant are indicated with asterisks.

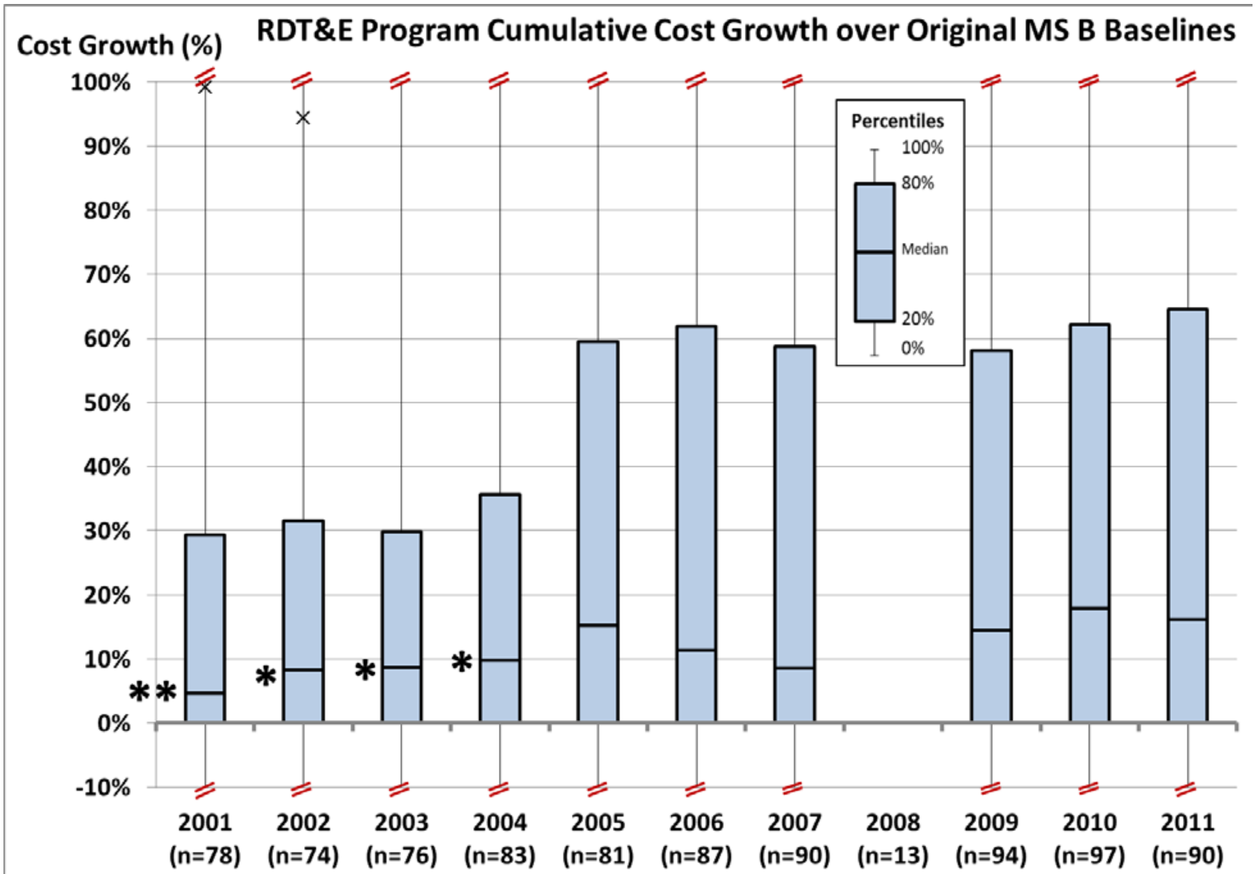
Examining RDT&E cost growth from each program's original baseline estimate is important to capture the overall growth since inception; however, it may not be the best choice to gain insight into recent cost growth management because MDAPs can have very long lives. When we analyze a program from inception, we are forced to carry all cost growth indefinitely. Programs that are currently executing well and that had a one-time cost increase in the distant past can appear to be long-term poor performers. Therefore, it is important that we look at both types of data.

Notably, the data show considerable (and sometimes seemingly conflicting) differences between the medians and the arithmetic means. This is because the data are highly skewed, and a single but very large outlier can have a large effect on the mean while not affecting the median.[8] Thus, we show the medians to provide a better sense of the central tendency of the population, and we provide the means for completeness and to show the effects of these outliers. Also, these values are not weighted by program dollar value, so they reflect program effectiveness generally regardless of size.

For each analysis, we first show the main portion of the cost growth distribution between -10 percent and 100 percent growth, followed by a separate figure showing all outliers (especially those with growth greater than 100 percent). The "Box-and-whisker" charts show the 20 percentile, median, and 80 percentile as the "box" with the minimum and maximum constituting the "whiskers." Gray-shaded columns in the table beneath each chart were periods with very low sample counts because full SAR reporting was not made in those years due to new Presidential administrations. The "x" markers above the box mark the five largest overruns (although outliers above 100 percent only appear on the outlier the graphs).

[8] Part of the skewing in the distribution of cost change is the mathematical boundary of cost change because cost cannot decrease more than 100 percent but can increase more than 100 percent.

Figure 2-9. RDT&E Program Cumulative Cost Growth over Original Milestone B Baseline (2001–2011).



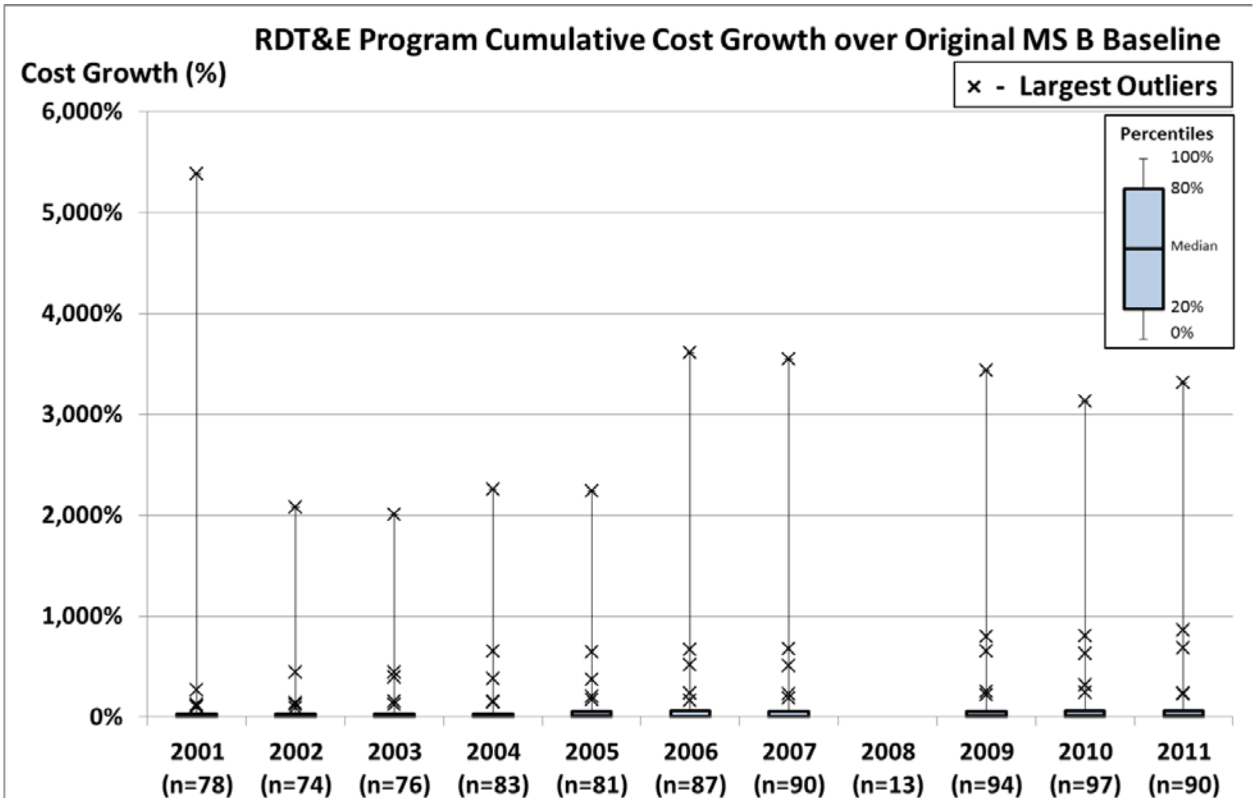
Median	** 5%	* 8%	* 9%	* 10%	15%	11%	9%	0%	14%	18%	16%
Mean	86%	51%	54%	58%	65%	81%	80%	75%	82%	80%	84%

** Statistically lower than 2010*
*** Statistically lower than 2005–2011*

NOTE: Source budgetary cost data were reported in "base-year" dollars (adjusted for inflation).

Figure 2-9 shows that RDT&E total cost growth has been statistically flat since 2005. Growth in 2001 was lower than in 2002–2004, and it increased after that. Thus, the median growths for 2010 and 2011 (18 percent and 16 percent, respectively) are not significantly higher than even the 9 percent in 2006. You can see that visually by comparing the boxes. This emphasizes the importance of statistically examining the population rather than just considering the median or mean.

Figure 2-10. RDT&E Program Cumulative Cost Growth Over Original Milestone B Baseline: Outliers (2001–2011).



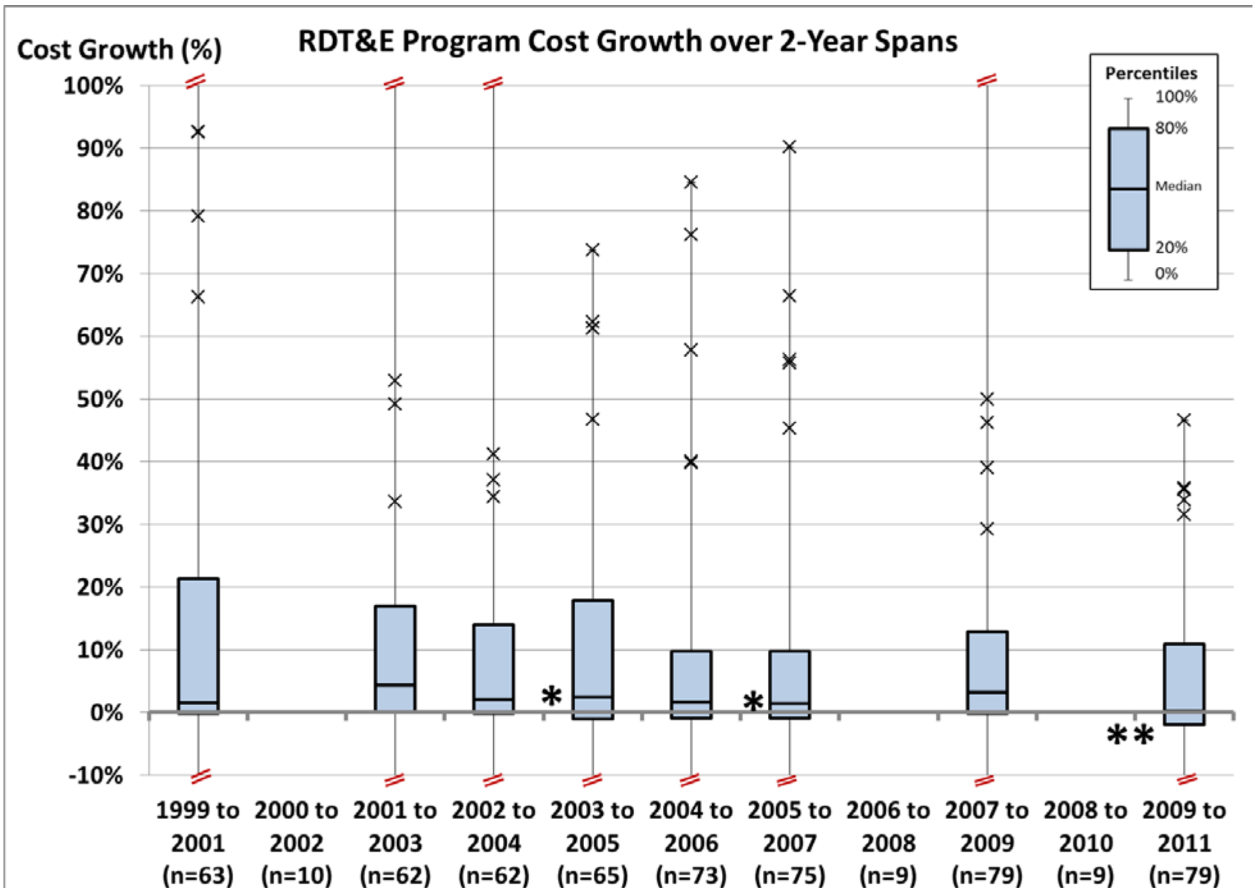
	2001 (n=78)	2002 (n=74)	2003 (n=76)	2004 (n=83)	2005 (n=81)	2006 (n=87)	2007 (n=90)	2008 (n=13)	2009 (n=94)	2010 (n=97)	2011 (n=90)
Largest outlier	GMLRS Launcher	C-130J							C-130J		
2nd Largest	MH-60S Knighthawk								MH-60S Knighthawk		
3rd Largest	Global Hawk		GMLRS						GMLRS		
4th Largest	CVN-77	SBIRS High	Global Hawk	SBIRS High	Global Hawk				Global Hawk		
5th Largest	SBIRS High	H-1 Upgrades	SBIRS High	UH-60M	SBIRS High				SBIRS High		

NOTE: Source budgetary cost data were reported in "base-year" dollars (adjusted for inflation).

Note that the maximum cost-growth percentages are very high due to a small number of outliers and are not statistically representative of the overall MDAP portfolio. These extreme growths are not due to measurement error so were not excluded from the analysis. Still, they do skew the aggregate data, which is an important fact for how to measure and discuss cost growth across a program population. Interestingly, similar skewing is observed in various complex commercial projects (see, for example, Flyvbjerg et al., 2002).

Understanding *why* a program may exhibit such a large percentage increase in RDT&E cost requires an individual examination of each case. For example, in Figure 2-10, the C-130J is the highest outlier from 2002 through 2011. The program originally was envisioned as a nondevelopmental aircraft acquisition with a negligible RDT&E effort planned. Several years into the program, the decision was made to install the Global Air Traffic Management system, adding several hundred million dollars to development and causing the total development cost growth to climb upward of 2,000 percent. This is an example of a major change in the program rather than poor planning or execution, although significant program changes like this are not necessarily the reason for all extreme cases of cost growth.

Figure 2-11. RDT&E Program Cost Growth Over 2-Year Spans (2001–2011).



Median	2%	22%	4%	2%	* 2%	2%	* 1%	7%	3%	4%	** 0%
Mean	86%	34%	42%	10%	10%	7%	6%	13%	8%	5%	4%

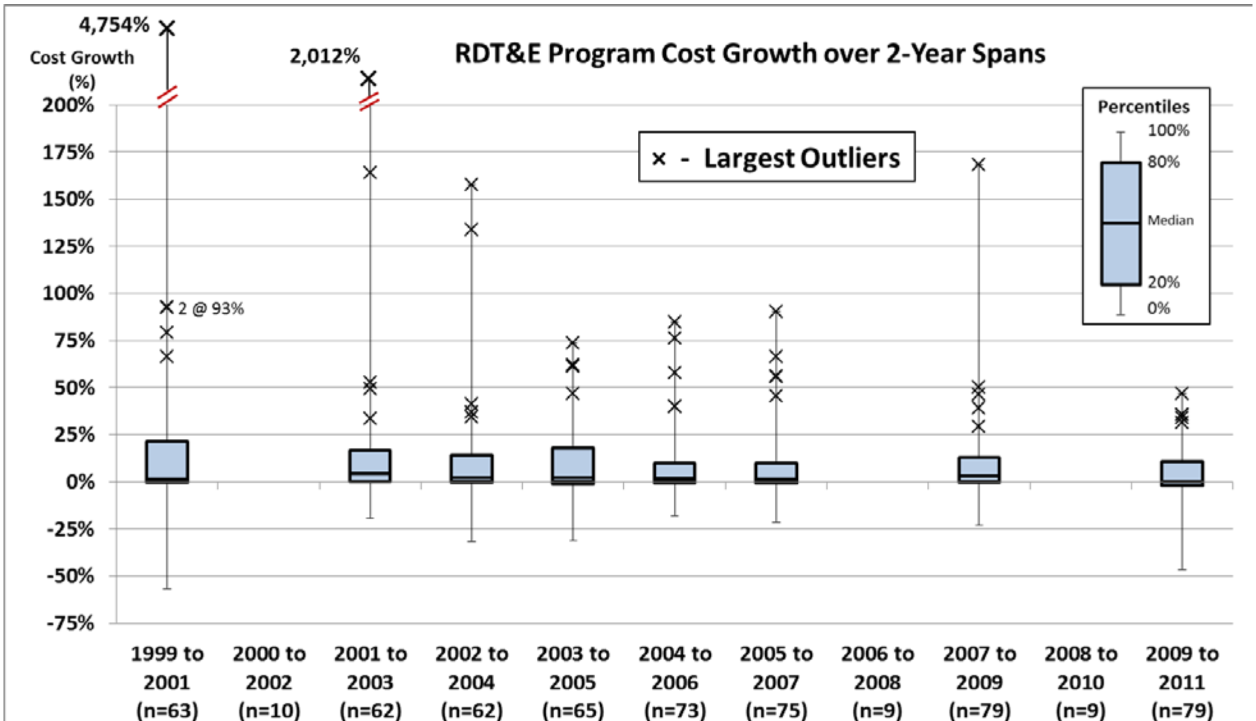
** Statistically lower than only the 2001–2003 span*

*** Statistically lower than all prior but 2004–2006 span*

NOTE: Source budgetary cost data were reported in "base-year" dollars (adjusted for inflation).

Comparing growth on a 2-year basis, the data show recent statistically significant improvement in the 2009-to-2011 period, but this is limited evidence of an improving trend. Further analysis of future years will be needed to see if this trend can be sustained.

Figure 2-12. RDT&E Program Cost Growth Over 2-Year Spans: Outliers (2001–2011).



	1999 to 2001	2000 to 2002	2001 to 2003	2002 to 2004	2003 to 2005	2004 to 2006	2005 to 2007	2006 to 2008	2007 to 2009	2008 to 2010	2009 to 2011
Largest outlier	GMLRS Launcher		C-130J	GMLRS	UH-60M	WIN -T	ARH		MRAP		AB3A Reman
2nd Largest	CVN-77		GMLRS	UH-60M	JTRS GMR	SSDS MK 2 P3I			WIN-T Inc 1		IAMD
3rde Largest	GMLRS		UH-60M	WGS	NPOESS	C-130J	NAVSTAR Equip-ment		MEADS Missile		STRYKER
4th Largest	CHEM-DEMIL CMA CSD		MH-60S Knighthawk		WIN -T	Global Hawk	C-130J		CH-53K		JTRS HMS
5th Largest	SBIRS High		NAVSTAR Equip-ment	JTRS GMR	FCS		CHEM-DEMIL CMA		LHA 6		Gray Eagle

NOTE: Source budgetary cost data were reported in "base-year" dollars (adjusted for inflation).

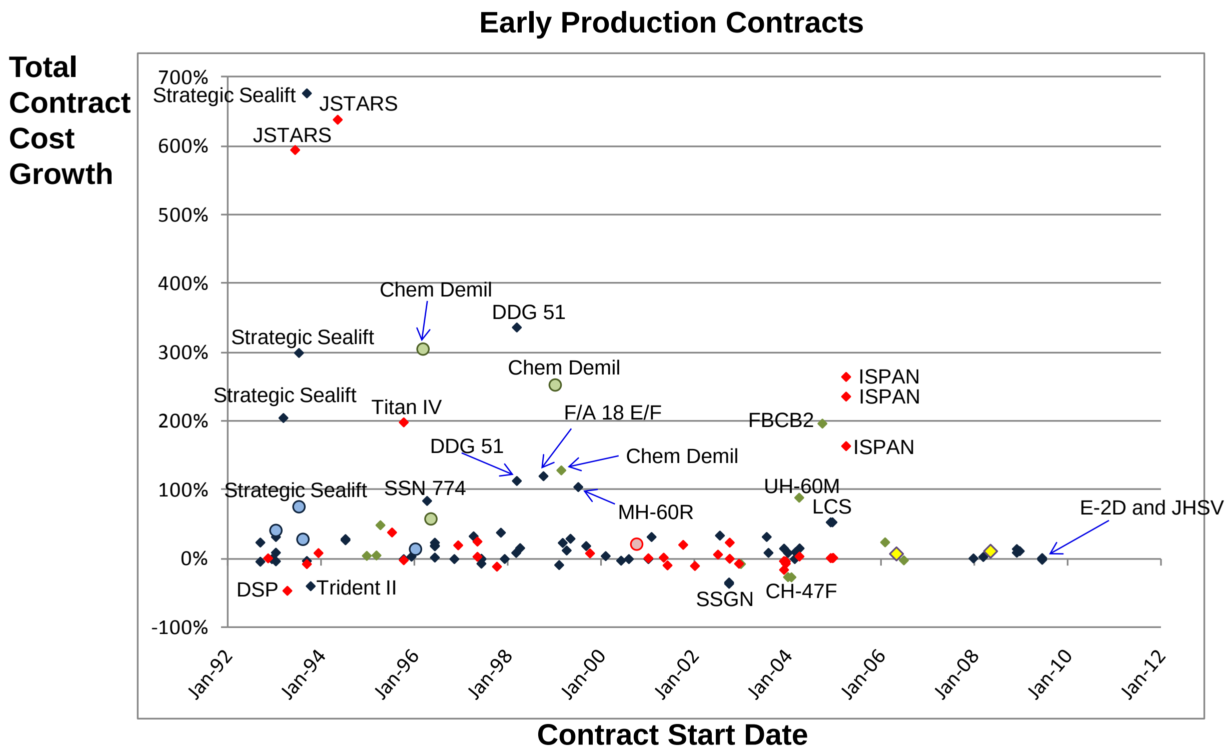
Cost Growth: Early Production

Now let us examine cost growth for MDAPs in early production. Again, MDAP contract data provide a valuable baseline of historical and relatively recent cost growth behavior to begin revealing any near-term and long-term trends as well as the implications of common practices. The long periods examined also are beneficial because they provide sufficient data for statistical analysis.

Contract-Level Early Production Cost Growth

First, let us revisit cost growth at the contract level on MDAP—now for early production. Figure 2-13 shows total cost growth since about FY1993 on MDAP contracts, measured from the originally negotiated contract target costs. This figure identifies the program name for outliers plus selected programs with lower total cost growth. Note that contracts shown with open circles indicate they had significant cost growth well beyond their start dates, which could indicate factors not attributable to the initial management of the contracts.

Figure 2-13. DoD Total Cost Growth on MDAP Early Production Contracts (1992–2011).



NOTE: Army programs are shown in green, Navy are blue, Air Force are red, and DoD-wide are in purple and yellow; open circles indicate that there was significant cost growth well beyond the contract start date. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

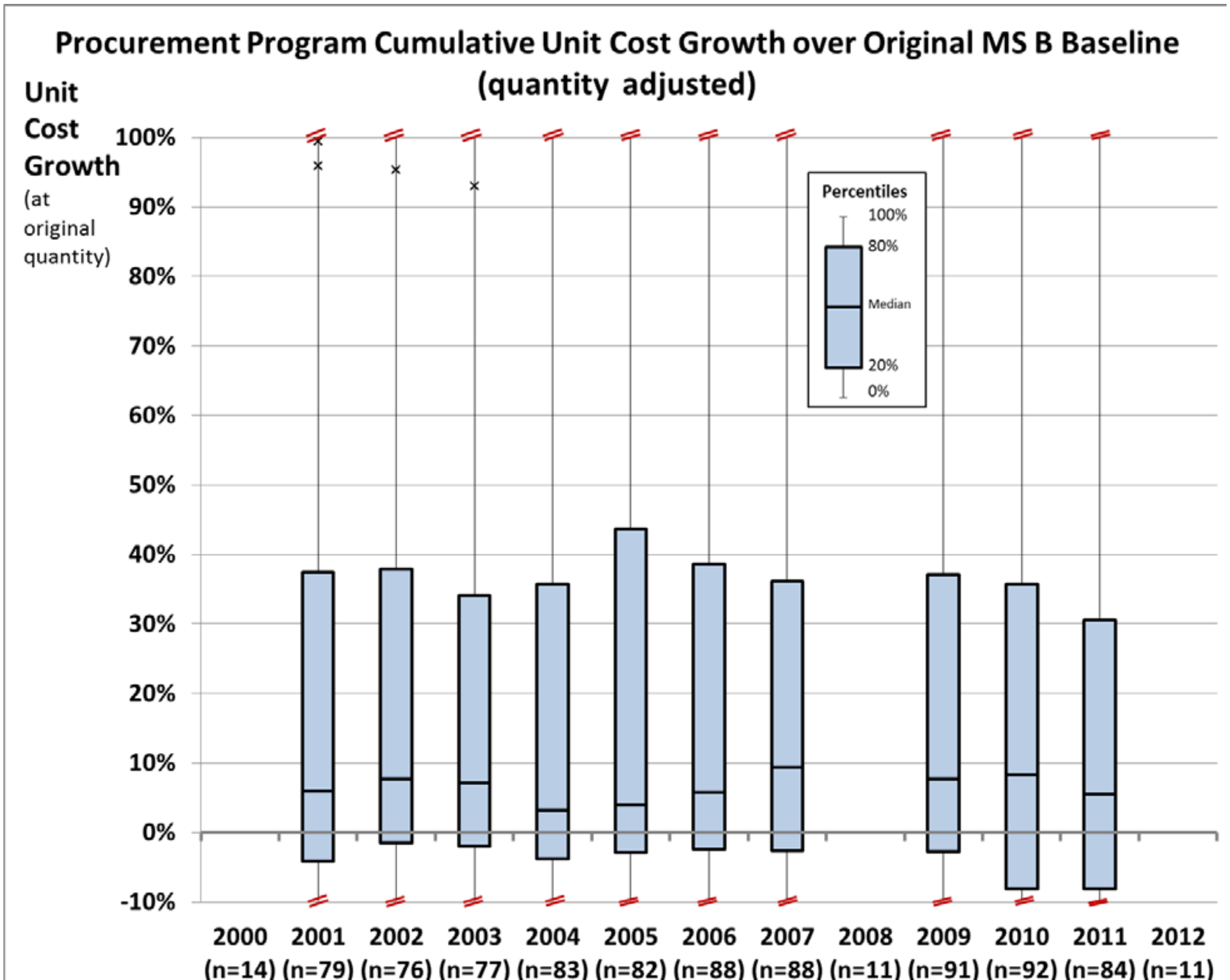
Comparing these results to those for development (e.g., Figure 2-8), this analysis is further evidence that we are much better at executing to planned costs for early production than we are for development. For some perspective, historically, since 1993, total contract cost growth for development contracts had a median of about 32 percent (unadjusted for inflation). The total contract cost growth for early production had about a 9 percent median (unadjusted for inflation).

Program-Level Early Production Cost Growth (Quantity-Adjusted)

Now at the program level, the following figures summarize the unit procurement cost growth across the MDAP portfolio from the original MS B baseline and in 2-year increments. Again, box-and-whisker charts are provided for both the main portion of the distribution and for outliers.

These program-level data are for unit costs and (unlike PAUC and APUC) are adjusted for any changes in procurement quantity. These results compare recurring procurement unit costs at the initially estimated quantities, extrapolating data if quantities have been reduced. This approach provides a superior way of comparing what the units would have cost if we had not changed quantities by, essentially, measuring the shift in the cost-vs.-quantity procurement cost curve from planned to actual. In other words, we measure changes in procurement cost at the currently planned quantity to be purchased (usually lower than the initial) *and* assume that the original planned quantity still was being purchased. This approach allows us to examine on a unit basis the cost of the capability to acquire those units regardless of whether we increased or decreased quantity. Of course, quantity decreases may be due to unit cost increases, and this approach will show such cost increases clearly.

Figure 2-14. Program Procurement Cumulative Unit Cost Growth (Quantity Adjusted) Over Original Milestone B Baseline (2001–2011).

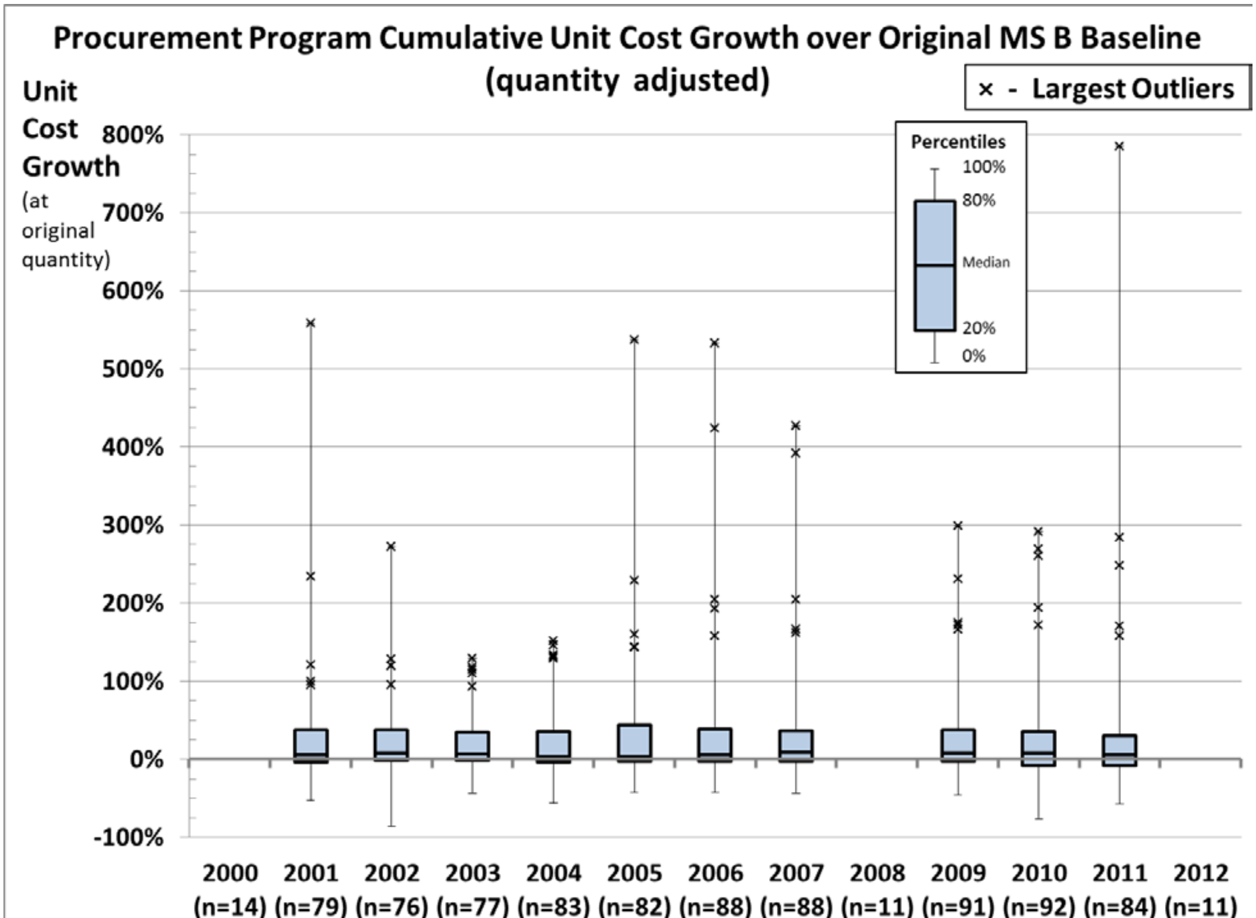


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Median	**1%**	**6%**	**8%**	**7%**	**3%**	**4%**	**6%**	**9%**	**5%**	**8%**	**8%**	**5%**	**0%**
Mean	3%	24%	21%	18%	18%	26%	30%	29%	49%	25%	27%	28%	40%

(differences are not statistically significant)

NOTE: The analysis only includes data through the September 2012 Selective Acquisition Report (i.e., the annual 2012 SAR was not yet available at the time of this analysis). Source budgetary cost data were reported in "base-year" dollars (adjusted for inflation).

Figure 2-15. Program Procurement Cumulative Unit Cost Growth (Quantity Adjusted) Over Original Milestone B Baseline: Outliers (2001–2011).

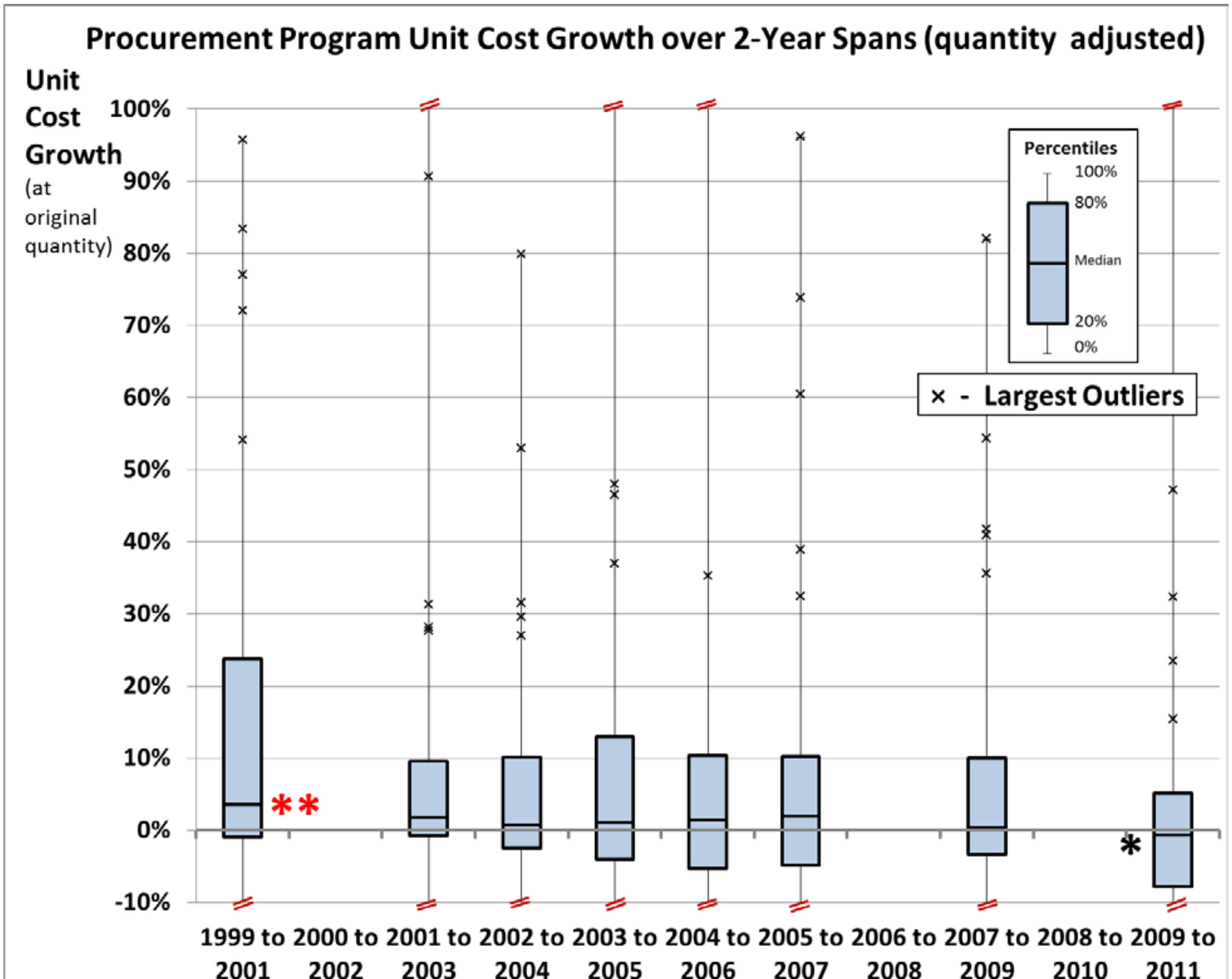


	2000 (n=14)	2001 (n=79)	2002 (n=76)	2003 (n=77)	2004 (n=83)	2005 (n=82)	2006 (n=88)	2007 (n=88)	2008 (n=11)	2009 (n=91)	2010 (n=92)	2011 (n=84)	2012 (n=11)
Largest outlier		SADARM Projectile	ATACMS BLK II/IIA	PAC-3 Fire Unit	SBIRS High			NPOESS		SBIRS High	ATIRCM QRC	C-130 AMP	
2nd Largest		ATIRCM CMWS	PAC-3 Fire Unit	GMLRS AW	EELV	NPOESS		SBIRS High		AEHF SV 1-4	SBIRS High		
3rd Largest		PAC-3 Fire Unit	ATACMS BAT P3I	CH-47F	CH-47F	GMLRS AW	EELV			H-1 Upgrades	AEHF SV 1-4		
4th Largest		GMLRS AW		EELV	GMLRS AW	EELV	GMLRS AW			C-130 AMP		GMLRS AW	
5th Largest		CH-47F	H-1 Upgrades	SBIRS High	PAC-3 Fire Unit	CH-47F		C-130 AMP		GMLRS AW	EFV	CH-47F	

NOTE: The analysis only includes data through the September 2012 SAR (i.e., the annual 2012 SAR was not yet available at the time of this analysis). Source budgetary cost data were reported in "base-year" dollars (adjusted for inflation).

Similar to the prior RDT&E results, cost growths are highly skewed upward, with arithmetic means higher than the medians. As noted above for the contract-level data, the overall magnitudes of the cost growths are not nearly as large as those for RDT&E. Also, there is considerable variability in the production cost growth across the MDAP portfolio.

Figure 2-16. Program Procurement Cumulative Unit Cost Growth (Quantity Adjusted) Over 2-Year Spans (2001–2011).



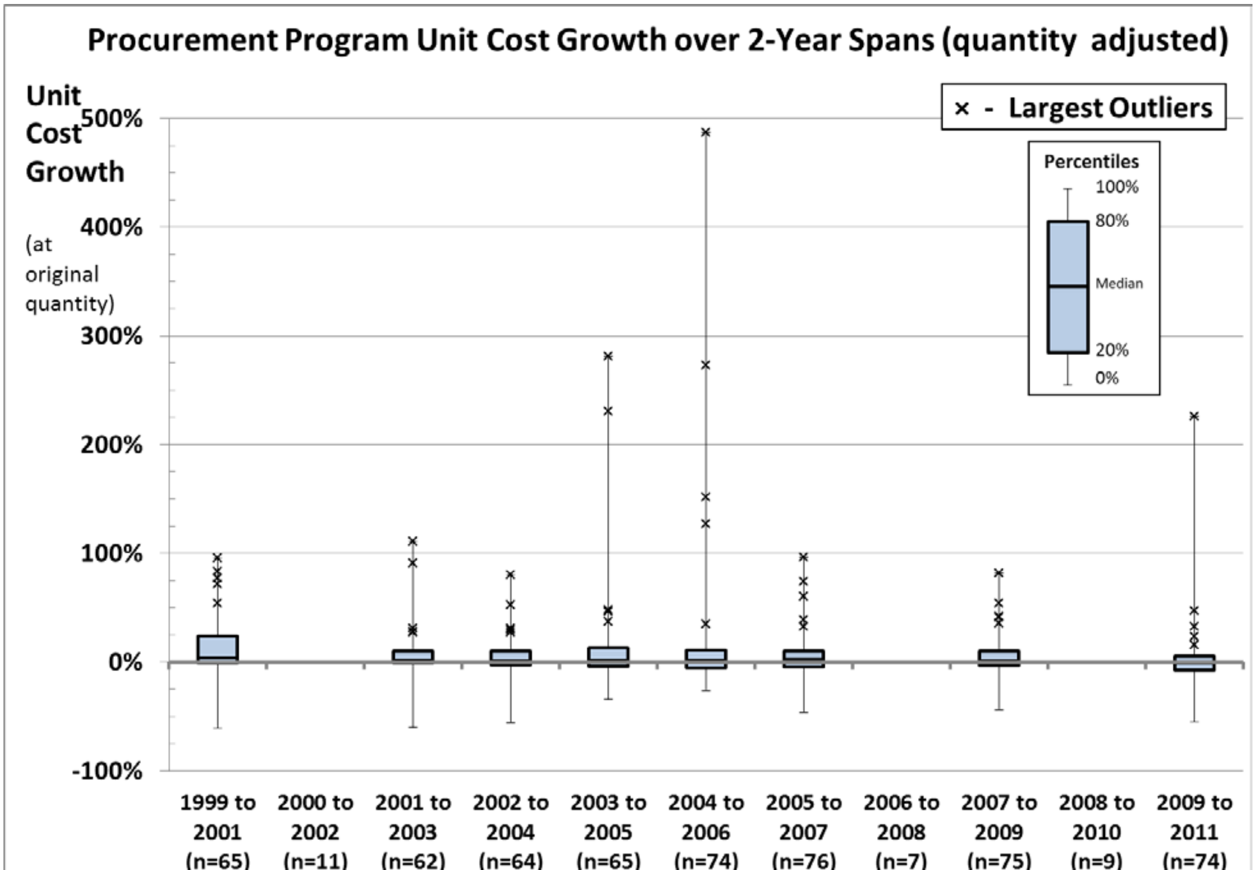
	1999 to 2001	2000 to 2002	2001 to 2003	2002 to 2004	2003 to 2005	2004 to 2006	2005 to 2007	2006 to 2008	2007 to 2009	2008 to 2010	2009 to 2011
Median	** 4%	12%	2%	1%	1%	1%	2%	4%	0%	2%	* -1%
Mean	12%	14%	5%	3%	11%	15%	4%	28%	5%	2%	1%

** Statistically lower than all prior two-year periods*
*** Statistically higher than all periods starting 2002 and later*

NOTE: Source budgetary cost data were reported in "base-year" dollars (adjusted for inflation).

Here the median cost growth from 2009 to 2011 is lower statistically than all prior 2-year periods, again highlighting a recent improvement. The earliest period (1999–2001) was statistically higher than all (unshaded) periods.

Figure 2-17. Procurement Program Cumulative Unit Cost Growth (Quantity Adjusted) Over 2-Year Spans: Outliers (2001–2011).



	1999 to 2001	2000 to 2002	2001 to 2003	2002 to 2004	2003 to 2005	2004 to 2006	2005 to 2007	2006 to 2008	2007 to 2009	2008 to 2010	2009 to 2011
Largest outlier	CH-47F		SBIRS High	EELV	NPOESS		C-130 AMP		B-2 RMP		C-130 AMP
2nd Largest	ATIRCM CMWS		EELV	CH-47F	SBIRS High	Land Warrior	EFV		AEHF SV 1-4		JTRS HMS
3rd Largest	GMLRS AW		AEHF SV 1-4	SBIRS High	UH-60M	SBIRS High	NPOESS		VTUAV		Excalibur
4th Largest	MH-60R		Tactical Tomahawk	AEHF SV 1-4	FCS	C-130 AMP	AEHF SV 1-4		AB3A Reman		FAB-T
5th Largest	H-1 Upgrades		B-1B CMUP Computer	UH-60M	Land Warrior	EFV	LHA 6		H-1 Upgrades		WGS

NOTE: Source budgetary cost data were reported in “base-year” dollars (adjusted for inflation).

Causes of Growth

Let us now review existing analysis and approaches that begin to indicate major causes and components of cost growth on MDAPs. Independently assessing the root causes behind significant cost growth on a program (or even a single contract) requires significant effort beyond the data readily available across the MDAP portfolio. Efforts to date include the work of the Office of Performance Assessments and Root Cause Analyses (PARCA) (especially on Nunn-McCurdy breached programs), case studies of individual programs, and analyses that identify variables that correlate statistically with cost growth. Cost growths often are examined relative to original program baselines or original contract cost targets. Conversely, costs could be compared to those for legacy weapon systems of similar types to obtain an absolute measure of the cost we pay, independent of acquisition baselines.

First, we will review trends in the root-cause analyses performed since 2010 by the PARCA in AT&L of program Nunn-McCurdy breaches.

Second, we will review findings from in-depth analyses of all contracts on six selected space system programs. This analysis breaks contract cost growth into major categories of work-content growth and cost-over-target, then into subcategories that help show what constitutes these major categories.

Third, we will discuss higher-level analytic results that use readily available contract data to measure work-content growth and cost-over-target across all major MDAP contracts from 1970–2011.

Finally, analyses have been conducted that examine a range of contract parameters to see which parameters correlate statistically with cost and schedule growth. Some of these variables begin to give insights into the causes of growth—at least at a high level. Combining this with analyses that compare performance between institutions can start to explain causes of cost growth as exhibited by these institutions.

PARCA Root-Cause Analyses of Program Cost Growth

By law, AT&L PARCA must perform a statutory root-cause analysis for all “critical” Nunn-McCurdy breaches as well as discretionary root-cause analyses requested by the Secretary of Defense (see 10 U.S.C., Section 2438). Table 2-3 summarizes the common root causes in the 18 analyses conducted by PARCA over the last 3 years (see Bliss, 2012a; Bliss, 2013).

Table 2-3. PARCA Root Causes Analyses (Statutory and Discretionary; 2010–2012).

	Dominant
10 of 18 (56%)	**Poor management performance** • Systems engineering • Contractual incentives • Risk management • Situational awareness
5 of 18 (28%)	**Baseline cost and schedule estimates** • Framing assumptions
4 of 18 (22%)	**Change in procurement quantity**
	Infrequent
1 of 18	**Immature technology, excessive manufacturing, or integration risk**
2 of 18	**Unrealistic performance expectations**
1 of 18	**Unanticipated design, engineering, manufacturing or technology issues**
None	**Funding inadequacy or instability**

Currently Dominant Root Causes

Poor Management Effectiveness. The broad category of *poor management effectiveness* was a root cause in just over half of the cases. Problem areas included:

- **Poor systems engineering to translate user requirements into testable specifications**. This includes the flow down of requirements, interface/environmental management, and management of holistic performance attributes such as reliability or weight. These largely are systems engineering functions.
- **Ineffective use of contractual incentives.** This includes whether the acquisition strategy selected satisfies the conditions necessary for its success, whether it is consistent with corporate environment (including long- and short-term objectives), whether it is aligned with program goals, whether there are perverse effects, and whether it was enforced.
- **Poor risk management.** This includes the identification, quantification, evaluation, and mitigation of risks.
- **Poor situational awareness.** Deficiencies have been identified in program office, contractor, and oversight awareness, and the timeliness and effectiveness of responses, related to the cost, schedule, and technical performance of DoD programs.

Baseline Cost and Schedule Estimates. Baseline cost and schedule estimates were unrealistic in just over one-fourth of the cases. The primary underlying reason was invalid framing assumptions (Arena et al., 2012; Bliss, 2012b). Framing assumptions are any explicit or implicit assumptions central in shaping cost, schedule, and/or technical performance expectations. A prototypical example of a framing assumption was the original space shuttle processing concept of minimal preparation of the orbiter between launches whereas the actual processing involved extensive facilities and refurbishment (e.g., individual testing of each heat tile). Below are illustrative examples of framing assumptions that may be made on defense systems:

- The design is very similar to the prototype or demonstration design.
- Modular construction will result in significant cost savings.
- Arbitrating joint requirements will be straightforward.
- The satellite bus will have substantial commercial market for the duration of program.

A recurring problem identified in the PARCA root-cause analyses of Nunn-McCurdy breaches is a lack of consideration and monitoring of program framing assumptions. AT&L is working with the acquisition community to establish practices that explicitly identify, consider, and monitor key framing assumptions upon which strategies and estimates are based. This effort should enable earlier detection and adjustment for problems that lead to poor cost, schedule, and technical performance of MDAPs.

Quantity Changes. Quantity changes for reasons outside the acquisition community’s control caused breaches on only about one-fifth of the cases.

Currently Infrequent Root Causes

Although often cited as common acquisition problems, the following were each found in only one case each (to date):

- Immature technology; excessive manufacturing risk; or excessive integration risk.
- Unrealistic performance expectations.
- Unanticipated design, engineering, manufacturing or technology issues.

Funding inadequacy or instability never caused a breach in the set of 18 programs examined to date, which is contrary to conventional wisdom, but warrants additional analysis.

These results provide objective insights into the major causes of cost growth, but they are only performed after programs have problems. Still, some lessons learned (e.g., the framing assumption process discussed above) have already been implemented, but more work is needed on the underlying issues and on other root causes.

In-Depth Case Studies of Contract Cost Growth on Selected Space Programs

Table 2-4 summarizes the results of a case study of six space-related MDAPs. This in-depth analysis examined all contract actions on the six programs, using expert judgment to assign cost growth to the categories identified.

Table 2-4. Comparing Manual Analysis with Contract Cost Growth Analysis.

	Share of Total Cost Growth				
	Six Space Programs		All Space Development Contracts	All DoD Development Contracts	All DoD Development Contracts
Analysis: / Cost Categories	In-depth	High-Level	High-Level (1970–2011) (37 contracts)	High-Level (1970–2011) (433 contracts)	High-Level (1992–2011) (176 contracts)
Work content changes	**0.25***	**0.27**	**0.40**	**0.55**	**0.69**
New sub-tier requirements	*0.08*				
Additional testing	*0.14*				
Requirements clarification	*0.04*				
Requirements descope	*-0.02*				
Key Performance Parameter (KPP)[9] changes	*0.00*				
Cost-over-target	**0.75**	**0.73**	**0.60**	**0.45**	**0.31**
Technology development	0.18				
Delays/rework	*0.13*				
Engineering studies	*0.02*				
Additional testing	*0.02*				
Design changes	*0.01*				
Integration	0.23				
Payload	*0.08*				
Vehicle	*0.07*				
Command/Control	*0.07*				
Contractor execution	0.34				
Rework	*0.14*				
Design flaws	*0.18*				
Obsolescence	*0.01*				
Supplier delays	*0.01*				

*Accounts for rounding error of breakdown categories below.

NOTE: Analysis of the six space programs used data through February 2011. Analysis of high-level data used medians to determine the share of work-content-change and cost-over-target, whereas the six in-depth case studies were based on aggregating total dollars.

While these studies partition costs in detail to lower-level cost categories, they are very time consuming and costly. This analysis involved deep review of all program contracts and consultation with program and contract personnel.

Also, the PARCA root-cause analyses mentioned earlier have the benefit of avoiding attribution to proximate causes and focus on the largest root causes. Their focus and time constraints, however, do not allow for the kind of complete contract change allocation of small portions of cost growth in the way other case studies can.

Primary Elements of Contract Cost Growth

In addition to summarizing the case studies, Table 2-4 summarizes analysis of high-level contract and PM cost-estimate data readily available on major MDAP contracts.

The comparison in the table shows that the analysis of high-level DoD data matches well at the total levels with each of the six in-depth space program case studies. Thus, these six space programs case studies provide valuable insight into what constitutes work content changes and costs-over-target. They also provide some evidence to support the anecdotal assertions that Key Performance Parameter (KPP)[9] changes are very infrequent.

Note, however, that the split of total cost growth between work-content growth and cost-over-target in these six case studies is different than those found historically going back to 1970 and very different from the median behaviors across all types of DoD contracts. These six programs had about a quarter of their cost growth from work content changes and three-quarters from cost growth over the contract target cost. All space system contracts since 1970 showed a split of about 40 and 60 percent, respectively, while across all DoD contracts we found work content to be the larger contributor (55 percent since 1970 rising to 69 percent in the last 2 decades). Thus, these six space programs are not exemplars of the split of cost growth between work content growth and cost-over target DoD-wide, showing yet again the wide range of outliers in our dataset.

Approach. Figure 2-18 illustrates how the two components of total cost growth—work content growth and cost-over-target—relate to the contract cost target and the program manager's estimate at completion (PM-EAC). All the contract cost data used in our analyses are reported in "then-year" dollars and are thus *not* adjusted for inflation. This is in contract to the program-level budget data for which "base-year" (inflation-adjusted) data are available and used in our analyses.

Note that the target cost and PM's EAC can be above or below each other or the initial target cost. Thus, work content growth and cost-over-target can be positive, zero, or negative. The

[9] Key Performance Parameters (KPPs) are key system attributes or characteristics that *must* be meet in order for a system to meet its operational goals.

four most common examples of these seen in our dataset of MDAP development contracts from 1970–2011 are shown on the right side of Figure 2-18. Note also that work content growth and cost-over-target are shown as positive but can also be individually or both negative (as can total cost growth).

Figure 2-18. Contract Cost-Growth Measures.

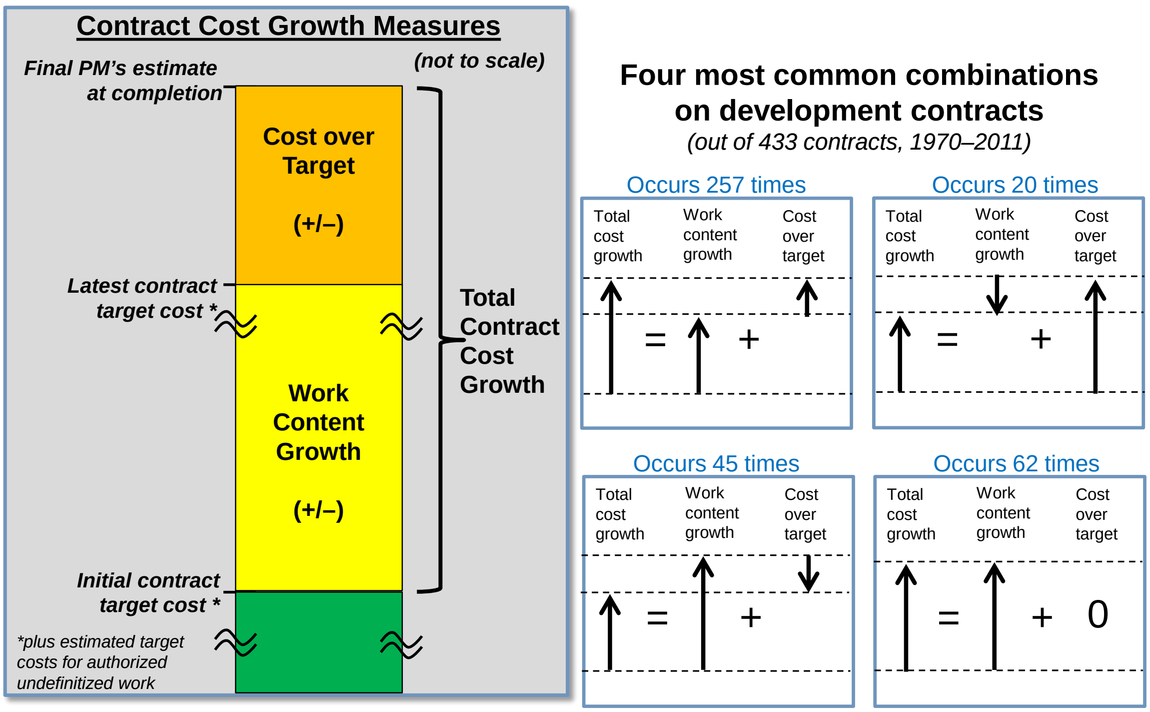


Table 2-5 provides the equations used to calculate these three cost growth metrics. The contract budget base (CBB) provides the target cost (plus the estimated cost of any authorized unpriced work) at a given time (*t)*. To avoid confusion with other baselines used in acquisition management, we simply refer to these as the contract target cost instead of the contract budget base.

Also, Table 2-5 provides a description and the *possible* causes of changes in these measures. The case-study analysis in Table 2-4 provides analytic support for this decomposition. As the table shows, these are a mixture of causes that could stem from planning poorly, executing poorly, or consciously choosing to alter the contract to respond to changes in requirements. For example, if the government needs to change deliverables on a contract to reflect normal engineering design changes, the negotiated costs for those changes are added to the contract target. If, however, a contractor finds that added labor is needed to deliver the items sufficiently specified in the contract (and thus reflected in the existing, negotiated target cost for those items), then those costs are reflected as the cost-over-target. Program management guidance explicitly precludes adding costs-over-target into the target cost, and our analysis of target cost and PM EAC profiles indicates such ill-advised practices, if occurring, may only be happening in a very small (single digit) percentage of MDAP contracts (see last bar titled "Poor contract management" in Figure 2-28 and Figure 2-43).

Table 2-5. Contract Cost Measure Definitions and Example Causes.

Contract cost measures	Definitions	Description	Possible Causes (unordered)
Total cost growth (%)	$\equiv \dfrac{PM\ EAC(t) - Target(0)}{Target(0)}$	Total cost growth from original contract cost target (plus any original authorized unpriced work). It is the sum of work content growth plus cost-over-target growth.	Any additional cost, planned or unplanned, that increases the current contract cost from the original cost.
Work content growth (%)	$\equiv \dfrac{Target(t) - Target(0)}{Target(0)}$	Portion of total cost growth due to negotiated contract work content changes as reflected by increases in the contract target cost.	• Planned additional work options exercised • System specification changes • Unforeseen engineering changes needed to meet requirements • Quantity changes • Poor understanding of technical maturity • Requirement changes[10]
Cost-over-target (%)	$\equiv Total\ cost\ growth - Work\ content\ growth$ $= \dfrac{PM\ EAC(t) - Target(t)}{Target(0)}$	Remainder of the total cost growth, which is due to costs over current target.	• Unrealized assumptions • External factors (e.g., higher than anticipated labor or material costs) • Poor contractor performance

Table 2-6 summarizes an analysis of the relative contributions of the two elements (work-content growth and cost-over-target) to total cost growth help us to understand the magnitude of their relative contributions. A limitation of the available data is that while we can, by inference, determine that a change in work content and cost-over-target *did* happen, *the data*

[10] Some analysis to date (e.g., see Table 2-4) supports the assertions that changes to KPPs are infrequent, but further quantitative analysis is warranted.

do not offer visibility into what specific underlying change actually happened, nor why it happened on each individual case, like the case study analysis provides. Detailed case studies would be necessary to examine these factors in more detail.

Table 2-6. Frequency of Observed Contract Cost Growth Metrics (1970–2011).

433 development contracts

Metric	Number of contracts <0	Number of contracts =0	Number of contracts >0
Work content growth	39	21	373
Cost over target	61	83	289
Total cost growth	29	11	393

440 early production contracts

Metric	Number of contracts <0	Number of contracts =0	Number of contracts >0
Work content growth	66	39	335
Cost over target	146	59	235
Total cost growth	94	11	335

NOTE: These figures show any cost growth (negative or positive) as reported to the precision in our data.

Factors Tested for Correlation with Contract Cost and Schedule Growth

Finally, when data were available and sufficient for statistical analysis, we examined what variables or factors correlate with cost and schedule growth on major MDAP contracts. This analysis allows us to control for a fairly wide range of possible factors, reporting only those that correlate with the growth in question. It also allows us to measure how much of the variation in the data can be explained by the variables we examined and how much is due either to other variables on which we do not have data or to random noise. These analyses are reported throughout the remainder of the report.

Table 2-7 lists the variables that are generally available in our MDAP contract dataset (i.e., we have information on cost, schedule, system complexity, size, definitization, contract type, system commodity type, Military Department, and prime contractor for each in the dataset). Nearly all analyses examined all variables except prime contractor, which were only examined for analysis related to industry institutional performance.

Table 2-7. Variables Examined in Statistical Analyses.

General Category	Variables
Cost	• Total cost growth • Work content growth • Cost growth over target • Major work content growth timing (early or later) • Major cost growth over target
Schedule	• Schedule growth • Cycle time • Percent complete • Start date • Trends
System complexity	• Complex (binary)
Size	• Size
Definitization	• UCA (binary)
Contract type	• Cost-plus – CPAF – CPFF – CPIF • Fixed-price – FPIF – FFP • Hybrid
System commodity type	• Aircraft (including rotary wing and UAVs) • Ships • Space • Engines • Missiles • Bombs • Ground tactical vehicles • Weapons • Other
Military Department	• Army • Navy • Air Force • DoD (joint)
Prime Contractor	• Contractor (see Table 2-24 for groupings)

TRENDS AND CORRELATES OF CONTRACT COST GROWTH: DEVELOPMENT

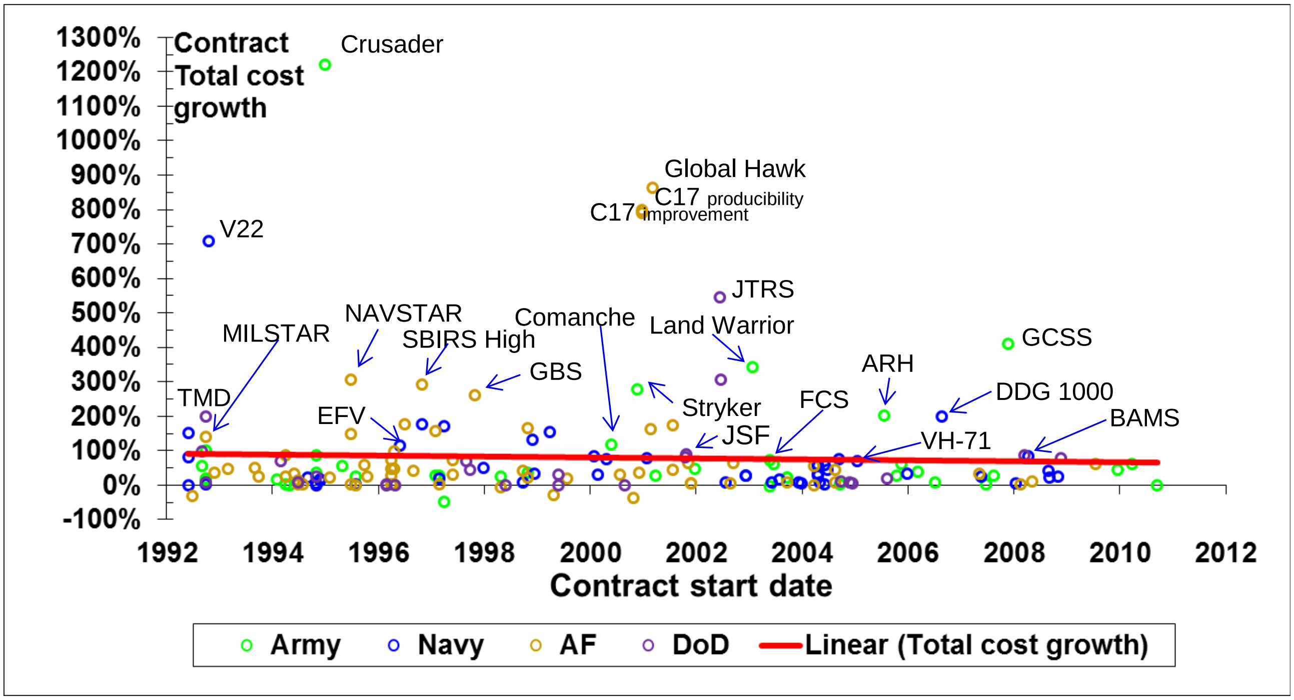
Contract Cost Growth Trends: Development

Analysis found modest but statistically significant improvement trends in contract total cost growth. Comparing the decade before and since the start of FY2002, total cost growth for development contracts has been 10 percentage-points lower and appears to be trending favorably. Comparing contract total cost growth from 1992–2005 to 2005–2011, the reduction was 18 percentage points.

Although all these contracts had completed at least about 30 percent of original contract dollar amount (55 percent of original schedule), some caution should be observed because many of the more recent contracts have not completed and may yet end with cost growths higher than currently estimated.

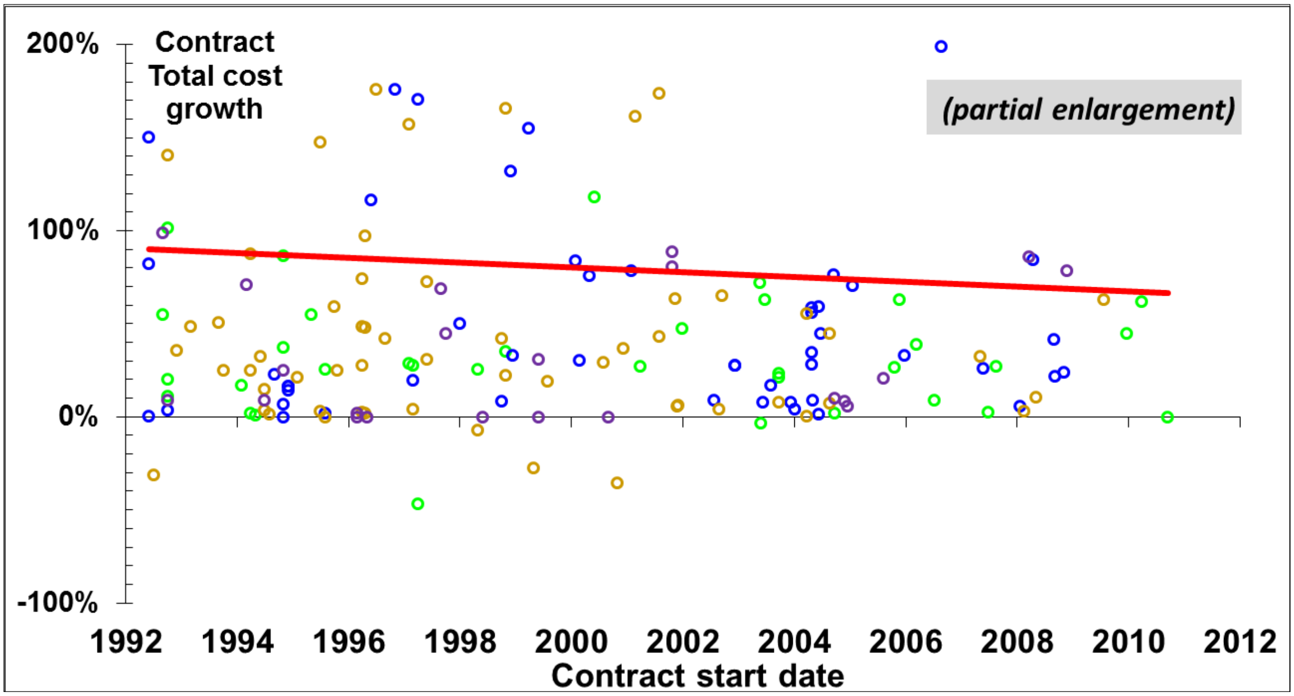
Figure 2-19 graphically depicts this modest downward trend, with Figure 2-20 providing an enlarged view of the dominant portions of the distribution. The trend line on these figures is a simple linear regression through all the cost growth points.

Figure 2-19. DoD Total Cost Growth: Development Contracts (1992–2011).



NOTE: Source cost data were reported in “then-year” dollars (unadjusted for inflation).

Figure 2-20. Enlarged view of DoD Total Cost Growth: Development Contracts (1992–2011).



NOTE: Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Contract Cost Growth Correlates: Development

The following analyses identify and quantify the performance differences between Military Departments, weapon system commodity types, contracting practices, contract size, and schedule effects. These analyses examine whether any of these variables correlate with total cost growth—or whether the variation in cost growth is confined to the two primary cost growth measures independent of these other variables. We tested all these variables for statistical correlation with total cost growth first for all DoD development contracts from 1970 to 2011, then conducted separate tests for contracts to develop aircraft, missiles, munitions, space systems, and ships.

We know from earlier analyses that we can quickly break down total contract cost growth into two primary measures: work content growth (increased work added to a contract and reflected in changes to the contract's target cost) and cost-over-target (as reflected by the PM EAC; see Figure 2-18). We also know generally what constitutes these two measures (even if more analysis is needed on each contract to quantify the breakdown) and that normally (but not always) work content growth is the larger of the two constituents (see Table 2-4).

Because work content is a constituent of total cost growth, we should find that it always correlates positively with total cost growth. The following regression analyses control for that effect (and thus the effect of the complementary cost measure of cost-over-target), allowing us to test which noncost variables (if any) correlate with total cost growth while controlling for cost elements. The regressions also tell us how large the contributions are from each variable when the other variables are held constant (i.e., all other things being equal). Thus, we have a much better ability to test for and measure the separate institutional and process performance differences while controlling for other variable effects.

Table 2-8 summarizes the significant variables that contribute to total cost growth on all DoD development contracts. It is important to note that the other variables listed in Table 2-7 (contract type, other commodity types, and Military Departments) were examined and found to have no significant contribution statistically to total cost growth.

Table 2-8. Contributors to Total Contract Cost Growth on DoD-Wide Development Contracts (1970–2011).

Significant variables	Corresponding effect on Total contract cost growth
Work content: each +1 percentage-point	+1.03 percentage-points
Aircraft contract	+22 percentage-points
UCA at any time	+7 percentage-points

NOTE: Work content, Aircraft, and UCAs in this regression explain 94 percent of the observed variation in total contract cost growth (i.e., only 7 percent of the variation in the data is due to variables we do not have data for, or is random noise). Level of significance is 5 percent (only 5 percent chance we cannot reject the value is actually zero). Source cost data were reported in “then-year” dollars (unadjusted for inflation).

As expected, the effect of work content growth is statistically significant, but we also found that aircraft contracts also exhibited significantly higher total cost growth historically (generally 22 percentage-points, all other things being equal) and were the only commodity type that had a measurable effect. Undefinitized contract actions (UCAs) also had a smaller but measurable increase on total cost growth (7 percentage points) historically.

Correlates by Commodity Type. Table 2-9 summarizes the significant variables that contribute to total cost growth on development contracts for five different system commodity types: aircraft, missiles, munitions, space systems, and ships.

Table 2-9. Contributors to Total Contract Cost Growth on Development Contracts by Commodity Type (1970–2011).

	Significant variables	Total contract cost growth corresponding effect
Aircraft *(n=41)*	**Work content:** each +1 percentage-point	+1.08 percentage-points
Missiles *(n=157)*	**Work content:** each +1 percentage-point	+0.93 percentage-points
	Schedule growth: each +1 percentage-point	+0.19 percentage-points
	Army contract	+30 percentage-points
Munitions *(n=20)*	**Work content:** each +1 percentage-point	+0.79 percentage-points
Space systems *(n=37)*	**Work content:** each +1 percentage-point	+1.13 percentage-points
Ships *(n=28)*	**Work content:** each +1 percentage-point	+0.86 percentage-points
	UCA at any time	+41 percentage-points

NOTE: The variable in these five regressions explain 96 percent, 93 percent, 69 percent, 91 percent, and 39 percent of the observed variation in total contract cost growth, respectively. Other variables listed in Table 2-7 (schedule, size, definitization, contract type, other system commodity types, and other Military Departments) were examined but found to have no significant contribution statistically to total cost growth. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

As expected, the effect of work content growth is statistically significant on all regressions, but some had a stronger relationship than others. We also found other variables for some commodity types that also exhibited significantly higher total cost growth historically.

For missile development contracts, we found a small but statistically significant correlation between schedule growth and total cost growth (each percentage-point increase in schedule generally correlated with a higher total cost by about 0.19 percentage points). Also, total cost growth was generally 30 points higher (all other things equal) on Army missile development contracts. This was the only Military Department with a statistically significant correlate at the commodity level, and only for missile development contracts.

For ship development contracts, we found a statistically significant UCA effect. Thirty-nine percent of the ship development contracts had a UCA, and they generally add 41 percentage-points to total cost growth. This UCA effect was larger than the other UCA effects identified in this report, and it could indicate an area of caution and attention for the Navy.

Temporal Patterns of Cost Growth: Development

We examined the temporal patterns of contract cost growth on 176 large development contracts in MDAPs from 1993 to 2011 to look for clues to problem behaviors and possible causes or predictors of contract cost and schedule growth.

Interestingly, we found seven general types of cost growth patterns when looking at MDAP contract data (see the following figures, showing an illustrative example MDAP for each pattern).[11] Each pattern is suggestive of underlying behaviors in how the contracts were planned or managed: well-managed, premature start, premature start with poor estimate, work added later, work added later with poor estimate, poor estimate only, and poor contract management.

Note that the labels for each pattern are a general interpretation of the shape of the pattern and indicate a potential cause that could lead to the pattern. Further analysis would be needed on each program to determine whether the label applies to each category. For example, the "Poor contract management" profile indicates a suspicious pattern that could indicate poor contract management wherein cost increases may be rolled into the target or where the work content is suspiciously unstable. Further analysis is needed to determine the underlying causes, but this kind of pattern analysis is one way to quickly categorize contract behavior and focus attention on contracts that indicate a possible concern.

Also, each program selected to be shown as the exemplar was not selected for any particular reason from the others that could have been shown. Still, it is informative to name the program from which the contract came. For example, the F-35 EMD airframe contract example shows that the cost growth for JSF development is coming mostly from cost-over-target growth rather than work added to the contract by the government.

[11] Note that the difference between work content growth and total cost growth is, by definition, cost-over-target.

Figure 2-21. Example Development Contract Cost-Growth Profiles: "Well Managed."

Well-Managed (F/A-18E/F EMD)

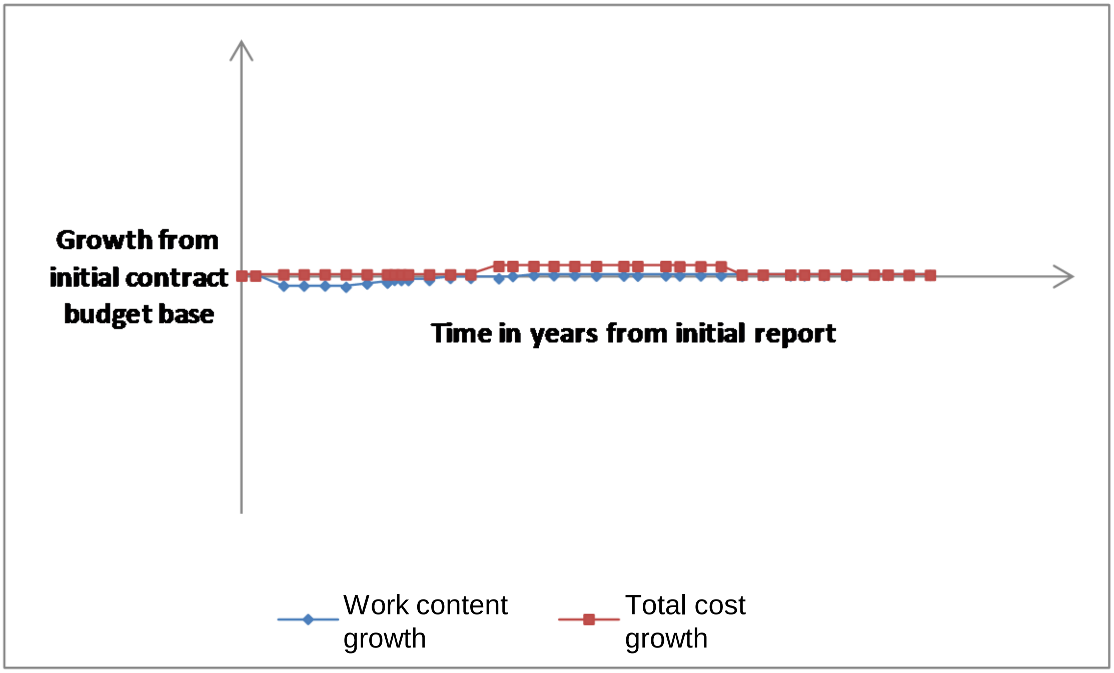


Figure 2-22. Example development contract cost-growth profiles: "Premature Start."

Premature start (DDG-1000: First two lead-ship awards)

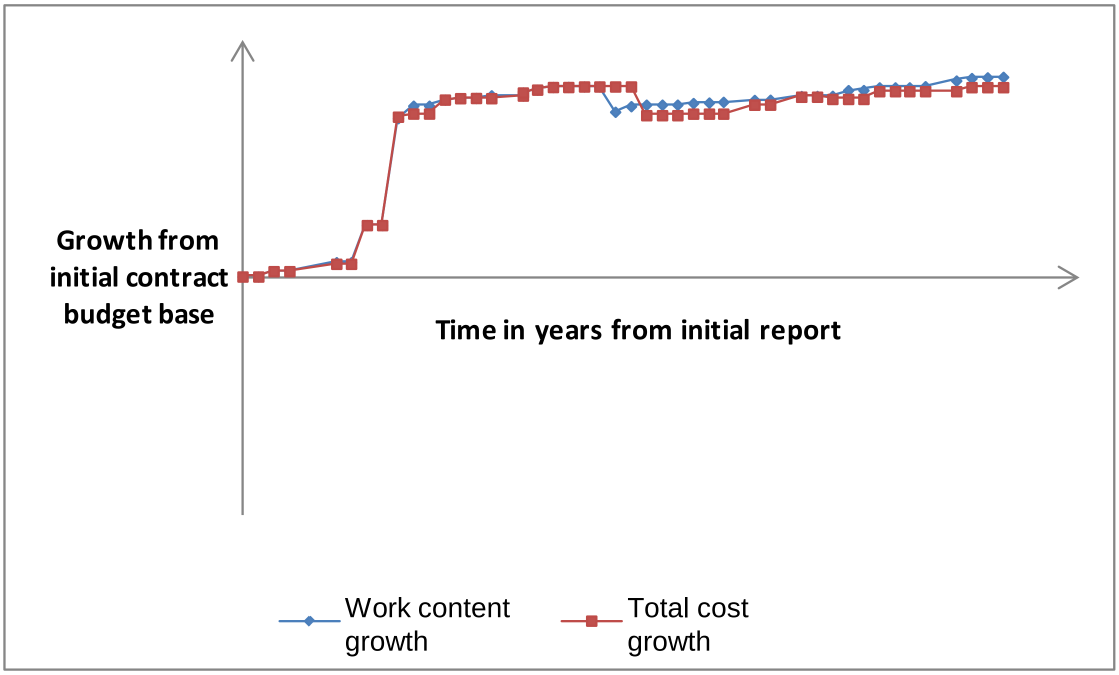


Figure 2-23. Example Development Contract Cost-Growth Profiles: "Premature Start + Poor Estimate."

Premature start; poor estimate (V-22 EMD)

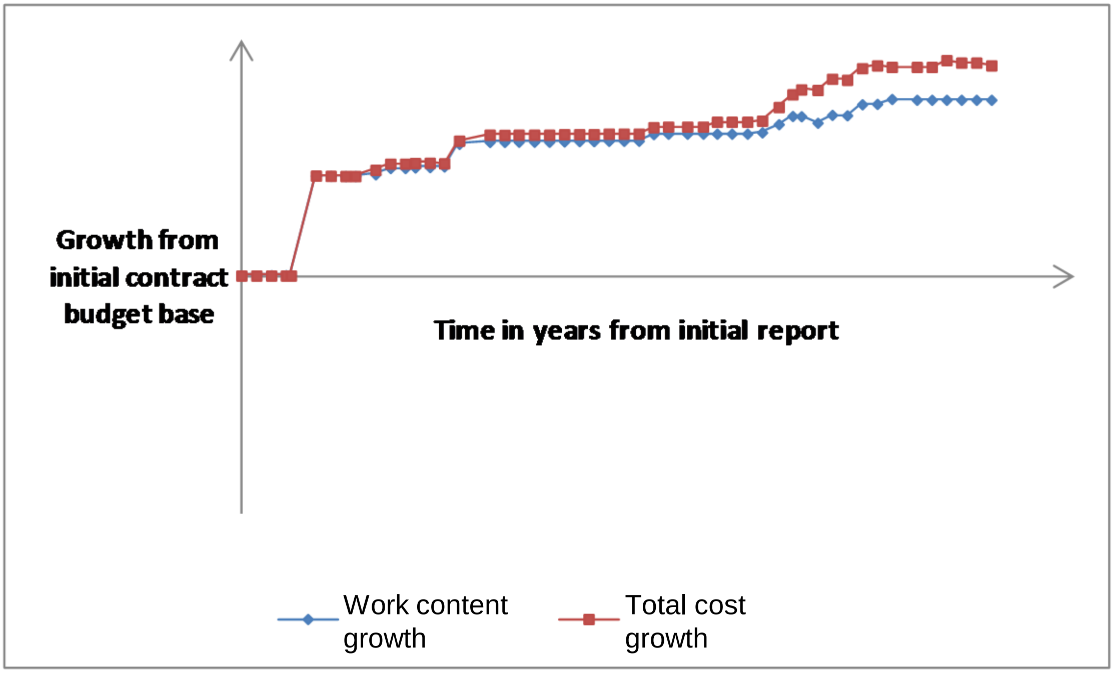


Figure 2-24. Example Development Contract Cost-Growth Profiles: "Work Added Later."

Work added later (C-17 improvement started 2001)

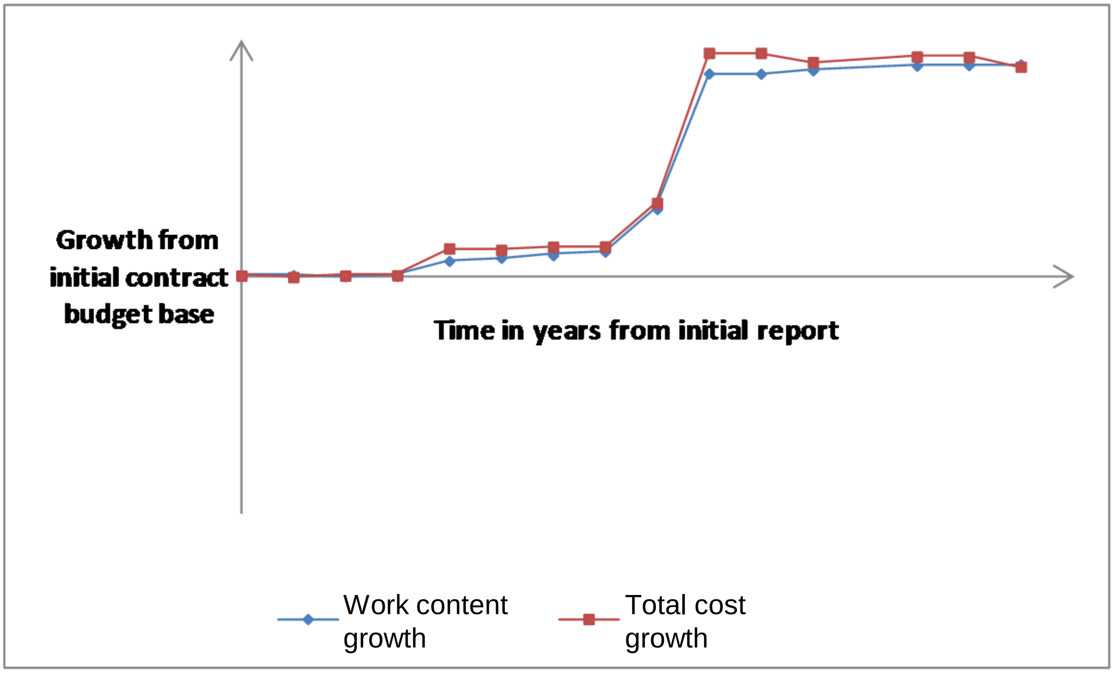


Figure 2-25. Example Development Contract Cost-Growth Profiles: "Work Added Later + Poor Estimate."

Work added later; poor estimate (JSOW EMD)

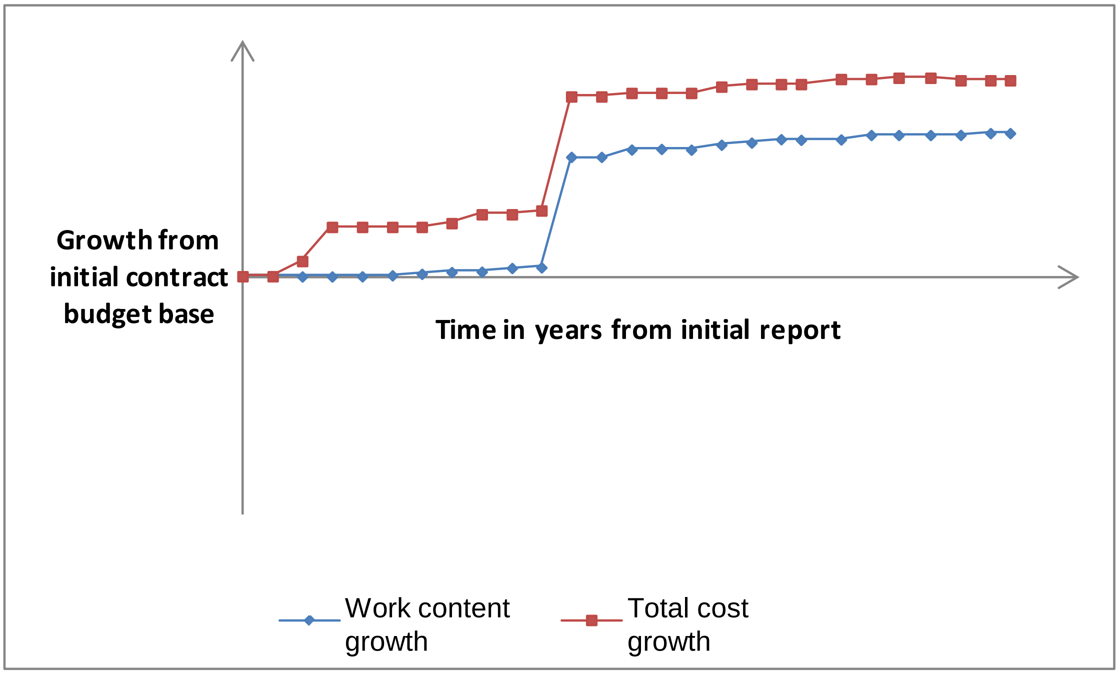


Figure 2-26. Example Development Contract Cost-Growth Profiles: "Poor Estimate."

Poor estimate only (F-35 airframe EMD)

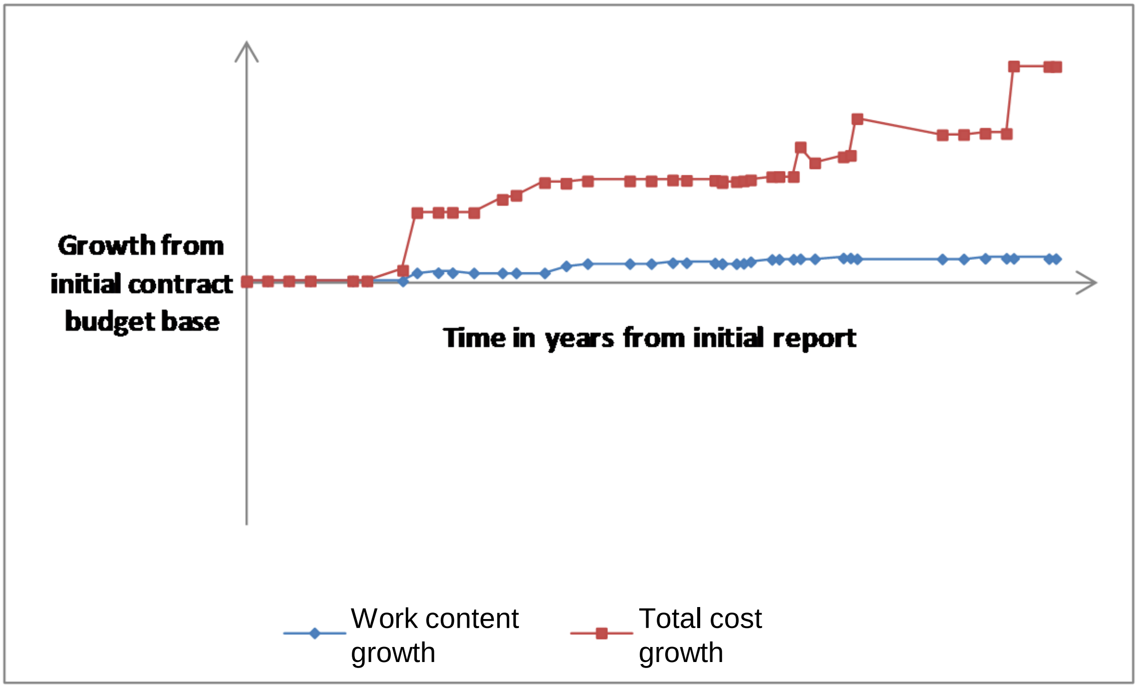


Figure 2-27. Example Development Contract Cost-Growth Profiles: "Apparently Poor Management."

Apparent Poor Contract Management (Stryker EMD)

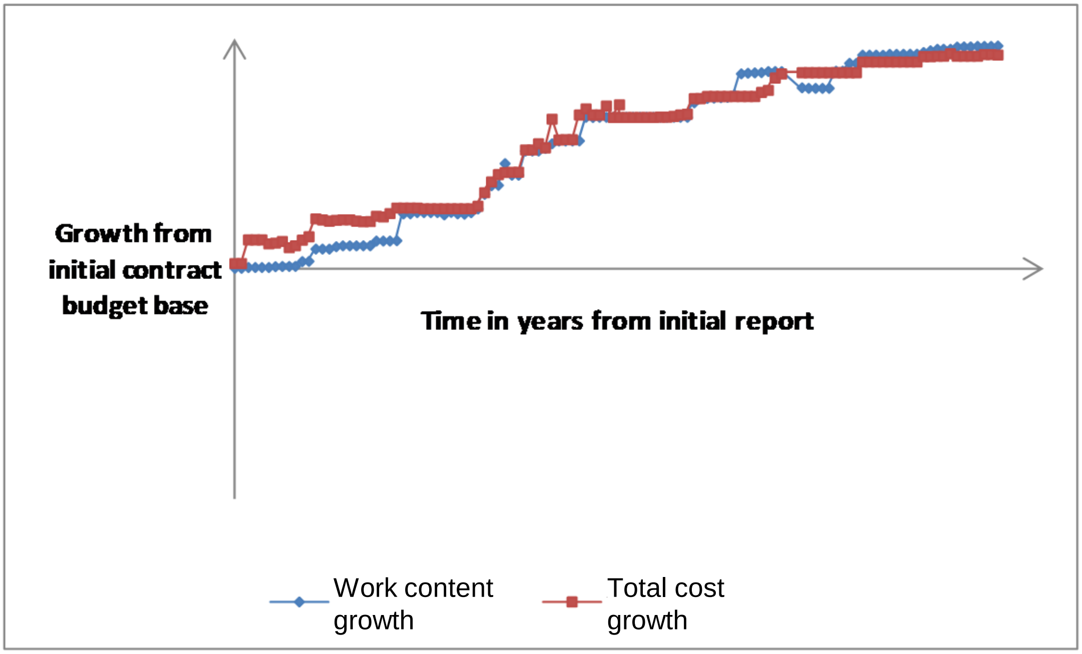
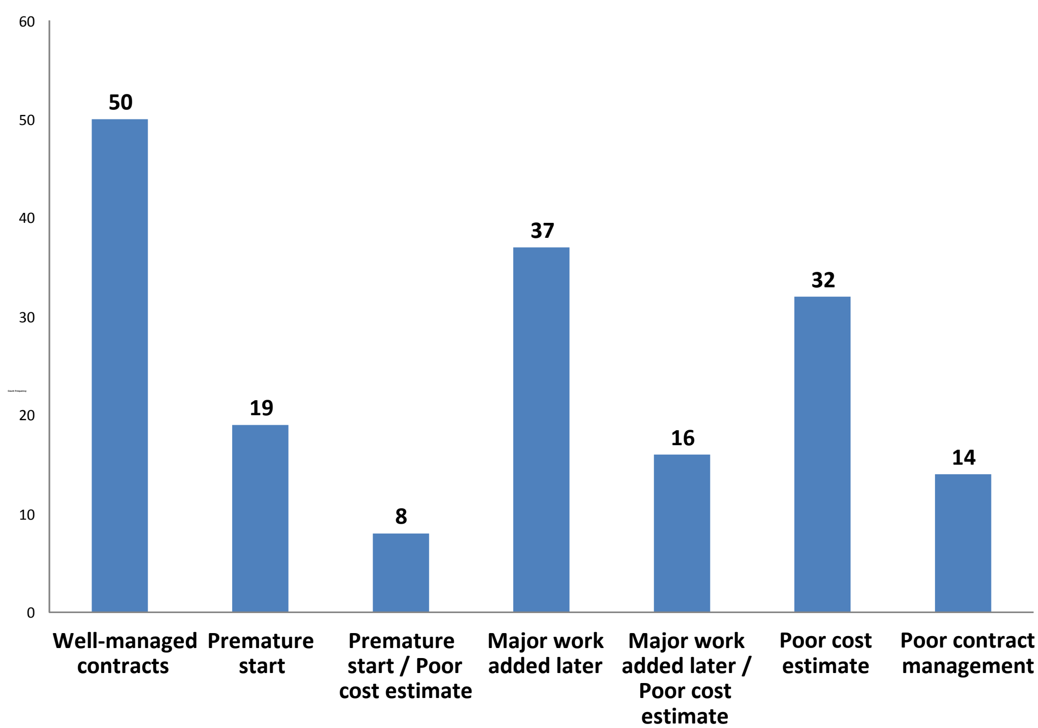


Figure 2-28. Summary of Development Contract Cost-Growth Profiles.



NOTE: n=176 total development contracts.

The frequency of each pattern in Figure 2-43 reveals how common these problems appear historically across MDAPs. Just over a quarter of the major contracts (50 out of 176, or 28 percent) were well managed with minimal cost growth of any kind. The remaining contracts had some type of large cost growth in one of the six categories.

The largest cost-growth patterns by count were the addition of major work to 37 contracts later in contract execution (21 percent), and 32 contracts (18 percent) solely experiencing cost-over-target (interpreted as poor cost estimates). Fourteen contracts (8 percent) exhibited cost-growth patterns that may indicate poor contract management.

Early Contract Work Content Stability: Development

For those patterns discussed above where work content was stable in the first year, we found that cost and schedule growth also were more stable. The following are the statistical results of examining MDAP development contracts from June 1992 through December 2011.

- *Development* contracts with early work content stability exhibited significantly lower:
    - Total cost growth *–61 percentage points*
    - Work content growth *–82 percentage points*
    - Schedule growth *–31 percentage points*

  (all at the median and all other things equal; costs unadjusted for inflation).

This helps confirm the view that a well-understood and -defined contract at the outset tends to perform better in the long term. Note that we found no statistically significant difference in costs-over-target on development contracts between stable and unstable work content in the first year of the contract. Also remember that it can take some time for problems on such contracts to be revealed.

For this analysis, we only included data on contracts that spent about a third of their original cost target (nominally about 55 percent of their original schedule). Analysts generally find that the cost estimates for the completed project become reliable at this point.

Effect of Contract Type Contract Cost and Schedule Growth: Development

Analysis of historical MDAP contracts revealed no statistical correlation between the use of contract type (e.g., cost-plus and fixed-price types) and lower cost or schedule growth. In other words, the type of contract used in each case did not result in a statistically significant difference in cost growth. No differences were found in contract type in 433 MDAP development contracts from 1970–2011. (We found and discuss similar results later in the report for 440 MDAP early production contracts.) This analysis is depicted in the following tables and charts.

Table 2-10. Fixed-Price and Cost-Type Contract Effects on Total Development Contract Cost Growth (1970–2011).

Significant variables		Corresponding effect on Total contract cost growth
Work content: each +1 percentage point		+1.03 percentage points
Aircraft contract		+22 percentage points
UCA at any time		+7 percentage points
Insignificant variables (no statistical significant effects on total contract cost growth)		
Contract type	• Cost-plus – CPAF – CPFF – CPIF • Fixed-price – FPIF – FFP • Hybrid	*Controlling for the three variables above, fixed-price contracts did not exhibit a significantly different cost growth than cost-reimbursable contracts.*
System commodity type	• Ships • Space • Engines • Missiles • Bombs • Ground tactical vehicles • Weapons • Other	
Military Department	• Army • Navy • Air Force • DoD (joint)	

NOTE: The three statistically significant variables in the regression (work content, aircraft, and UCAs) explain 94 percent of the observed variation in total contract cost growth. The level of significance is 5 percent (i.e., there is only a 5 percent chance we cannot reject the value is actually zero). Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Table 2-10 shows the three variables that are statistically correlated with total contract cost growth along with the other variables we tested. Note that contract type did not correlate with total contract cost growth.

Figure 2-29. Contract-Type Effects on Development Contract Cost Growth (1970–2011).

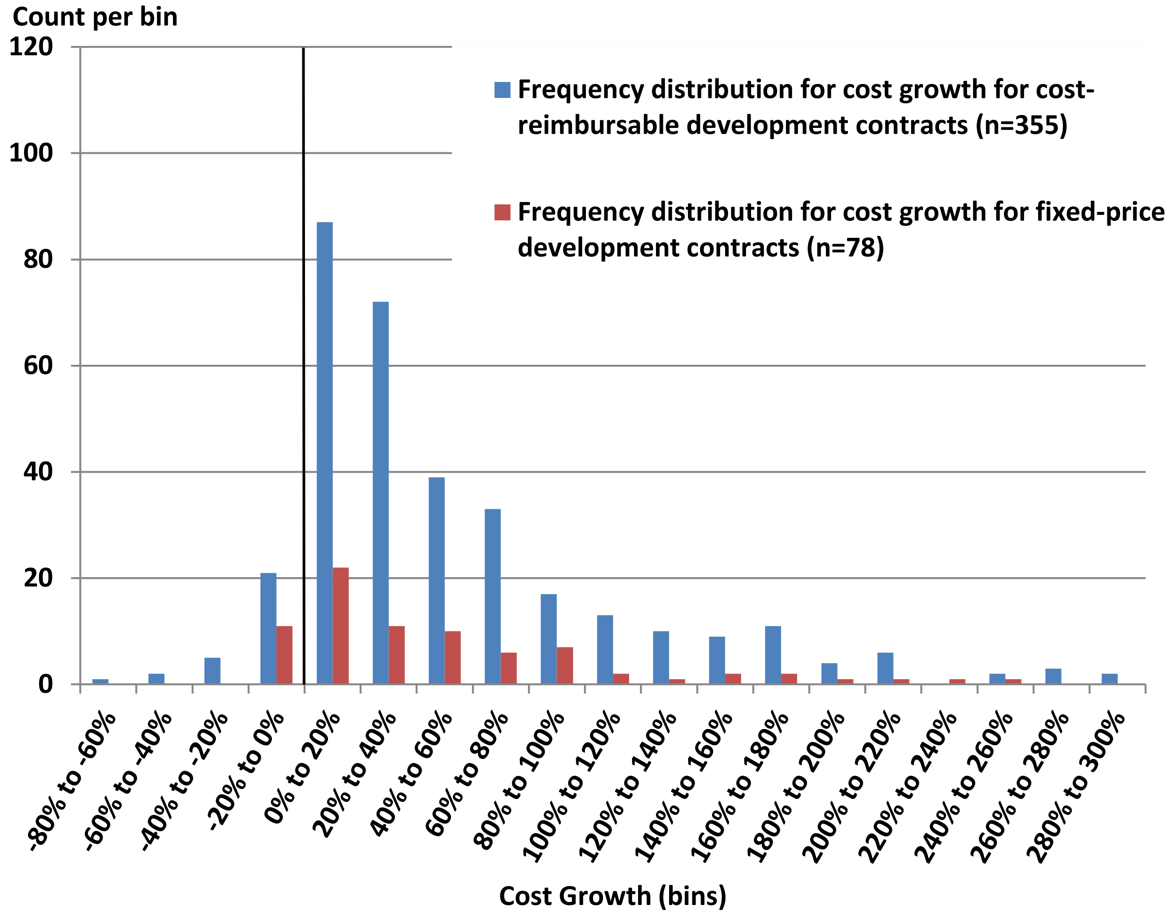


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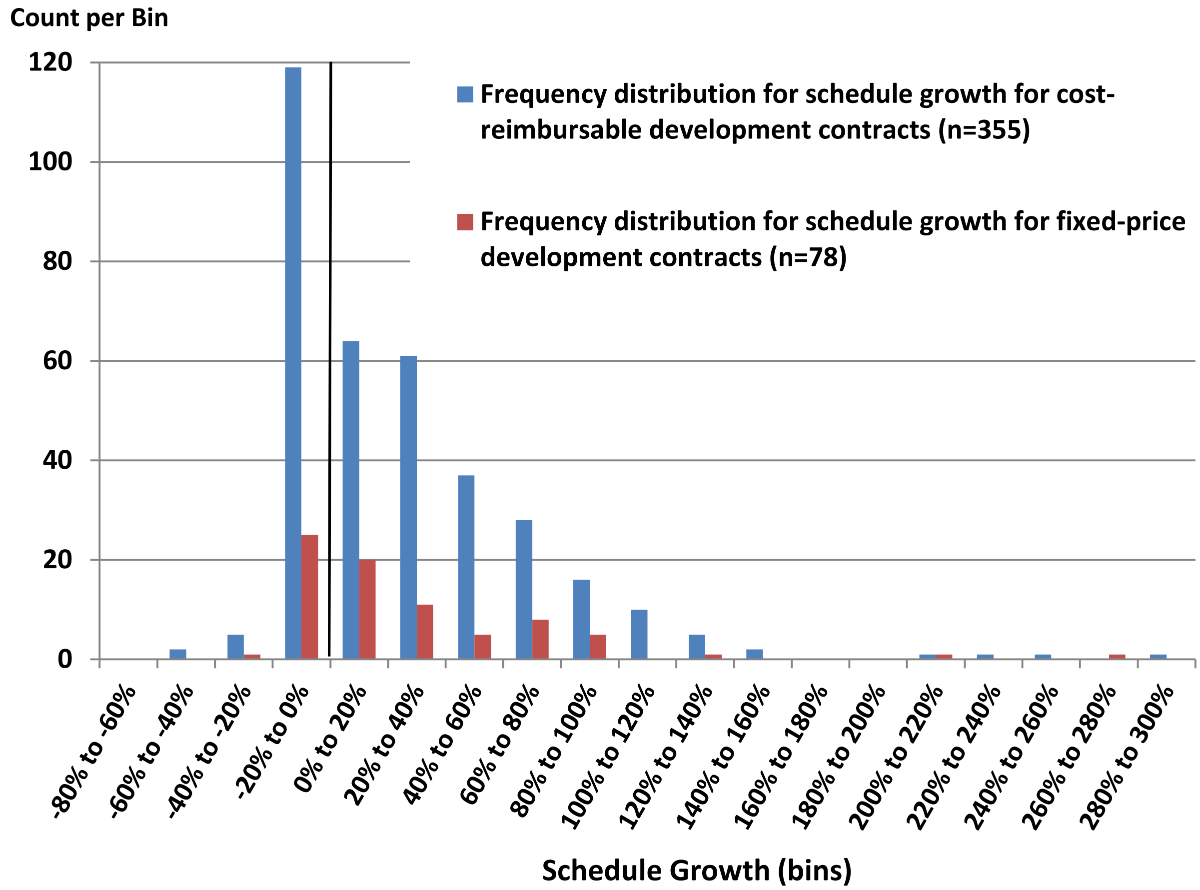
Figure 2-30. Contract-Type Effects on Development Contract Schedule Growth (1970–2011).



Statistical analysis also confirmed that there is no statistically significant difference in Figure 2-29 between cost-reimbursable and fixed-price contracts with respect to schedule growth on development contracts.

Effect of UCAs on Cost Growth: Development

Undefinitized contract actions (UCAs) had a measurable increase on total contract cost growth and also on cycle time in development. Using a binary flag for whether a major MDAP contract had a UCA, analyses found that a contract with a UCA would be expected to have 7 percentage points higher total cost growth (all other things being equal) as measured across all DoD contracts from 1970–2011. UCAs effects on ship development contracts were much larger: 41 percentage points higher total cost growth (again, all other things being equal) as measured across all DoD ship development contracts from 1970 to 2011. UCAs effects were not statistically significant on aircraft, missile, munitions, or space systems development contracts.

As we will see shortly, a contract with a UCA generally lasted 0.3 years longer (all other things being equal), as measured across all DoD contracts from 1970–2011. Thus, UCAs increase development cycle time by increasing schedule growth.

CYCLE TIMES: DEVELOPMENT

We are examining whether it is taking longer to develop new systems and why. Statistical analysis of the length of development contracts for 433 major development MDAP contracts between 1970 and 2011 is summarized in the following figures and tables.

First, Figure 2-31 shows the individual factors from an analysis of multiple variables and the size of their independent contributions. The individual contributions can be added together to yield the expected cycle time of a contract based on historical data and trends. In other words, given a certain contract, you can add the cycle time contributions of these individual factors based on whether these factors are present in the contract and (in the case of the two cost-growth factors) by how much.

All other things equal, development cycle time on contracts after 1980 took an average of 0.9 years longer than contracts before 1980—an increase of about one-sixth over the base of 5.2 years.

This analysis also found some smaller but still statistically significant correlations between cycle time increases and cost growth on MDAP contracts. Every 10 percentage-point increase in work-content cost growth generally added 0.066 years, and every 10 percentage-point increase in cost-over-target generally added 0.16 years.

Also, contracts with UCAs were about 0.3 years longer generally.

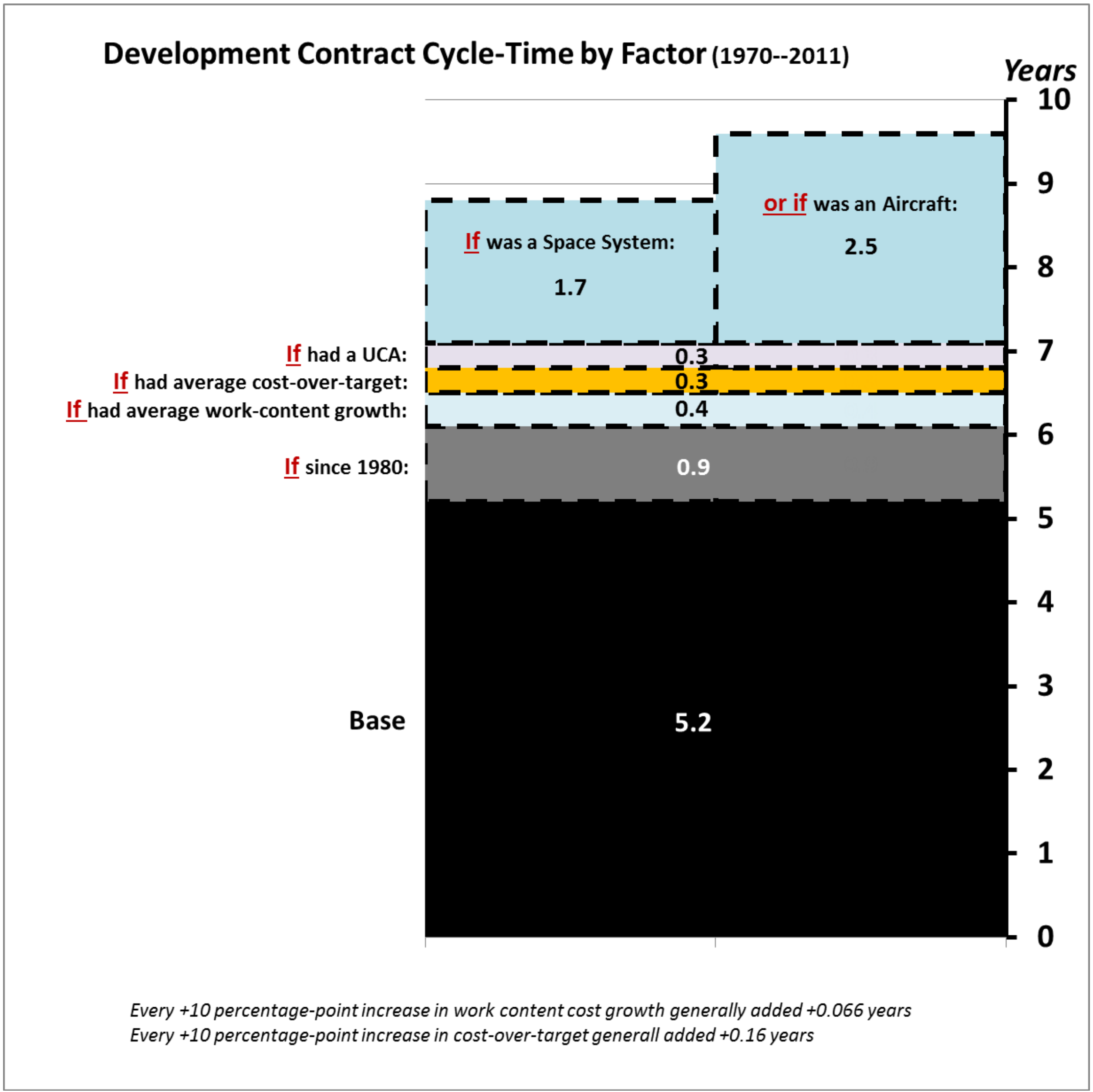
Contracts for space systems were an additional 1.7 years longer, whereas contracts for aircraft were 2.5 years longer. No other commodity types had significantly longer cycle times.

Thus, for example, a contract started before 1980 with a UCA, 10 percentage points increase in work content, 90 percentage points increase in cost-over-target, and for a space system would statistically be expected to have a cycle time (contract length) of 8.7 years.[12] Conversely, a contract started after 1980 without a UCA, with 120 percentage points increase in work content, 15 percentage points increase in cost-over-target, and which was not for a space system or aircraft statistically would be expected to have a cycle time (contract length) of 7.1 years.[13]

[12] 5.2 + 0.3 + 0.066 + (9*0.16) + 1.7 = 8.7

[13] 5.2 + 0 + 0.9 + (12*0.066) + (1.5*0.16) + 0 = 7.1

Figure 2-31. Contributors to Development Contract Cycle Time (Length) DoD-Wide (1970–2011).



NOTE: This analysis used the length of 433 MDAP development contracts as contract cycle time. The regression of two simultaneous equations examined the indirect effect of schedule growth on cycle time. Other variables examined (see Table 2-10) were not statistically significant contributors to cycle time and are not shown here. The level of significance for each variable was <=5% (i.e., there is at most a 5 percent chance we cannot reject that the value actually is zero).

Figure 2-32 shows a simpler before/after 1980 analysis of cycle time that did not control for other variables but shows the medians, percentiles, and frequency distributions of these development contracts. Here the median difference of 1 year is very close to the 0.9 years in the first analysis.

Additional sensitivity analysis on the before/after date for different commodity types and Military Departments yielded some additional statistically significant results.

- Aircraft development cycle times also increased significantly after 1980 (see Figure 2-33).
- Space system development cycle times increased at the 1995 point instead (see Figure 2-34).
- “Other” commodity types (including include electronics, avionics, and communication systems) *decreased* significantly after 1995 (see Figure 2-35).

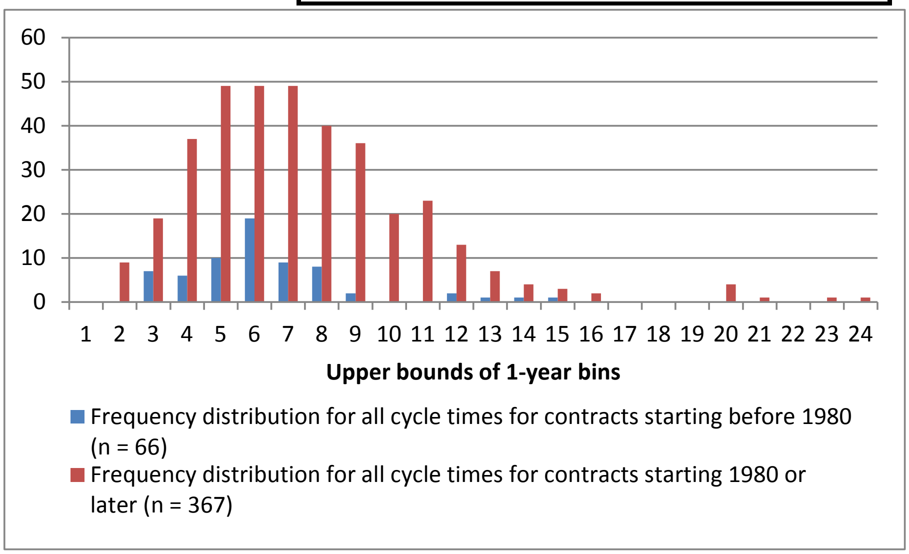
All other differences in cycle times were not statistically significant (e.g., some due to insufficient sample size), and remaining variation in the data is due to variables outside our dataset, or random noise.

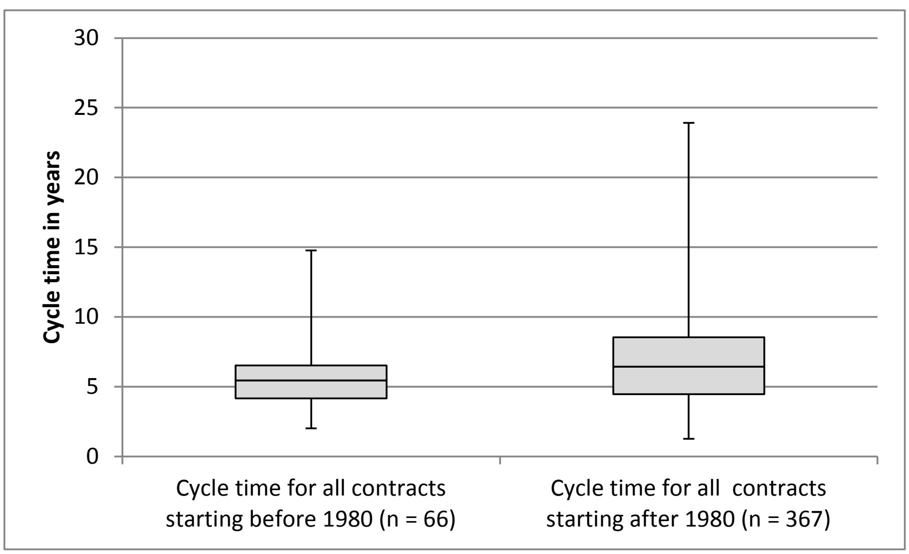
Additional analysis of cycle times by Military Department are discusses later in this chapter.

Figure 2-32. All Development Contract Cycle Time Trends (1970–2011).

<u>All</u> development contract cycle times *increased* significantly *after* 1980

	Cycle time for all contracts starting before 1980 (n = 66)	Cycle time for all contracts starting after 1980 (n = 367)
Minimum	2.0	1.3
25th percentile	4.2	4.5
Median	5.4	6.4
75th percentile	6.5	8.5
Maximum	14.8	23.9



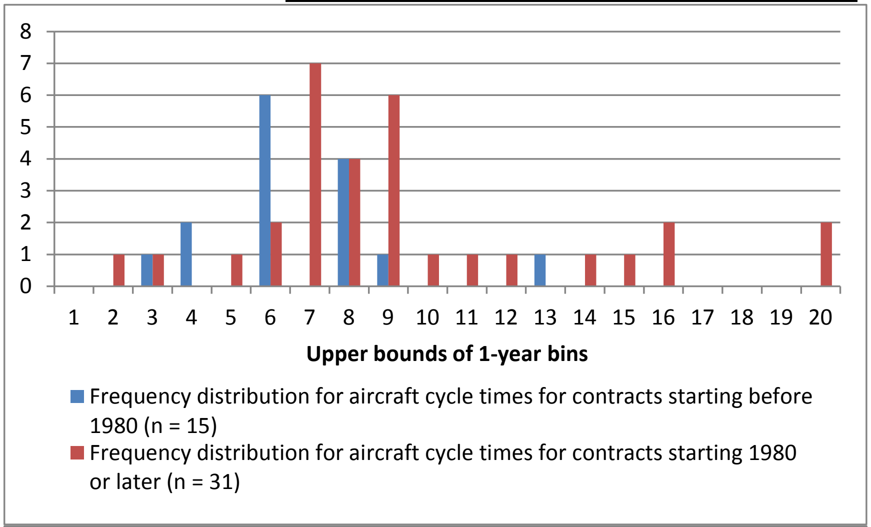


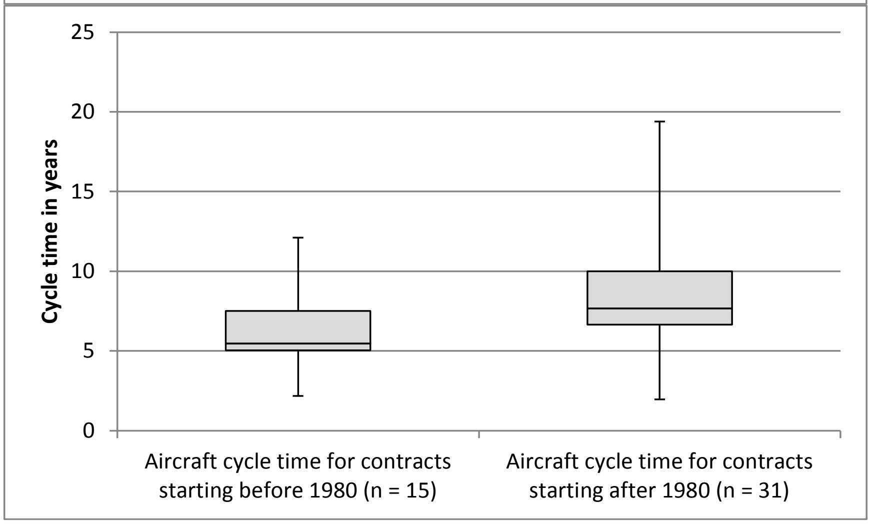
NOTE: The bottom "box and whisker" chart shows the middle two quartiles in the box with the median. The "whiskers" show the maximum and minimum values in the table at the top of the figure.

Figure 2-33. Aircraft Development Contract Cycle Time Trends (1970–2011).

Aircraft **development contract cycle times** ***increased*** **significantly** ***after*** **1980**

	Aircraft cycle time for contracts starting before 1980 (n = 15)	Aircraft cycle time for contracts starting after 1980 (n = 31)
Minimum	2.2	2.0
25th percentile	5.0	6.7
Median	5.5	7.7
75th percentile	7.5	10.0
Maximum	12.1	19.4



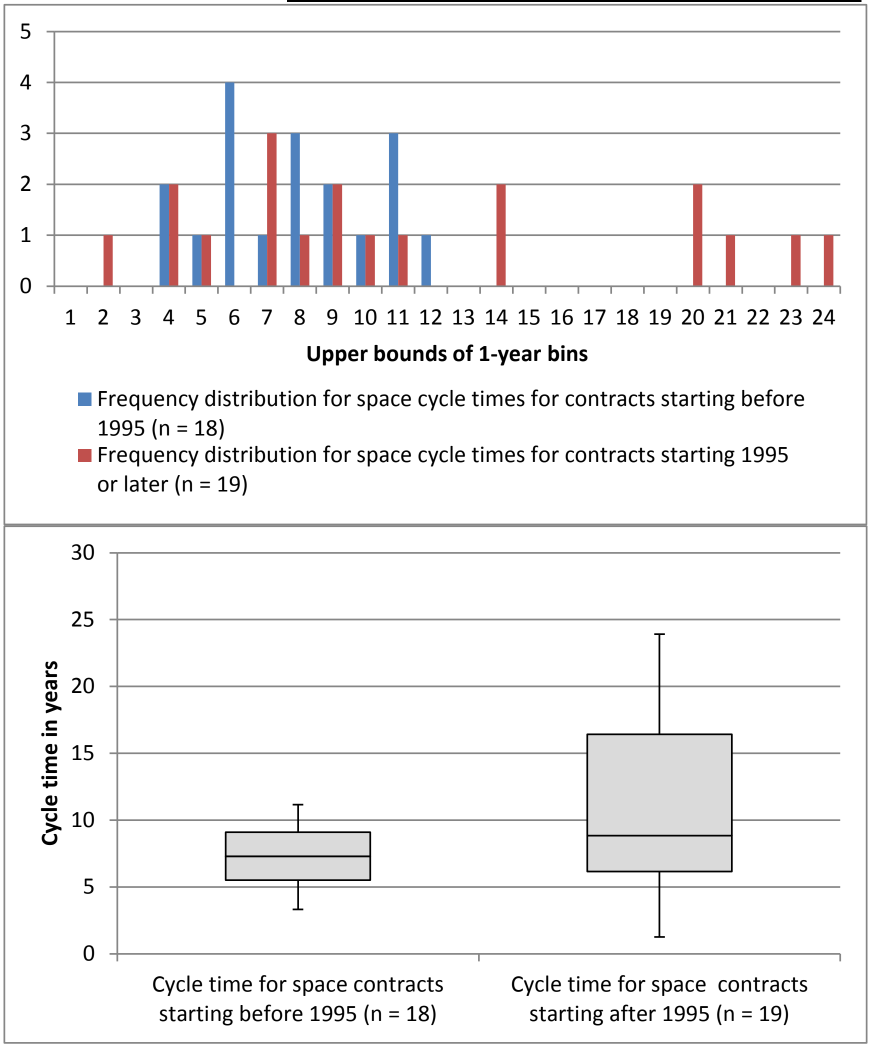


NOTE: Aircraft contracts after 1980 included B-2, C-17, A-12, F-22, V-22, F-35, Global Hawk, and Comanche, among others. The bottom "box and whisker" chart shows the middle two quartiles in the box with the median. The "whiskers" show the maximum and minimum values in the table at the top of the figure.

Figure 2-34. Space Development Contract Cycle Time Trends (1970–2011).

Space **development contract cycle times** ***increased*** **significantly** ***after 1995***

	Space cycle time for contracts starting before 1995 (n = 18)	Space cycle time for contracts starting after 1995 (n = 19)
Minimum	3.3	1.3
25th percentile	5.5	6.2
Median	7.3	8.8
75th percentile	9.1	16.4
Maximum	11.2	23.9

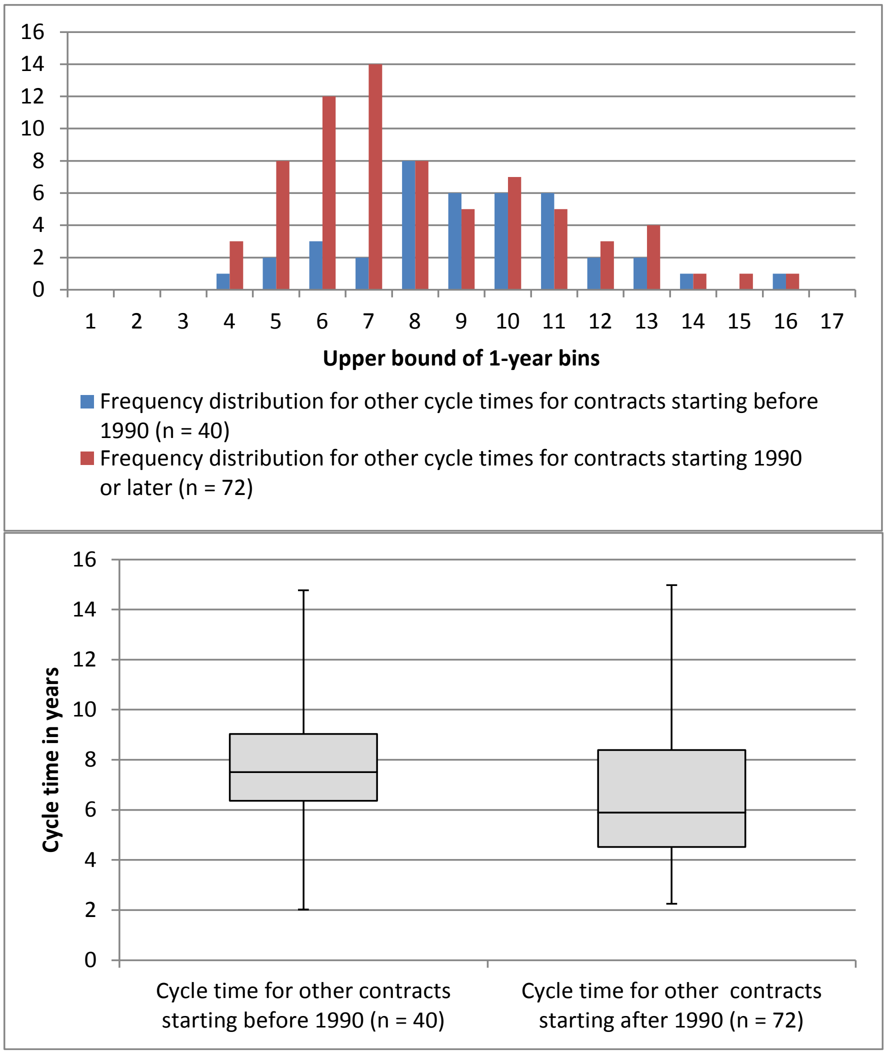


NOTE: Space contracts after 1995 included GPS IIF, SBIRS High, NPOESS, FAB-T, and MUOS. The bottom "box and whisker" chart shows the middle two quartiles in the box with the median. The "whiskers" show the maximum and minimum values in the table at the top of the figure.

Figure 2-35. "Other" Commodity Type Development Contract Cycle Time Trends (1970–2011).

"Other" commodity type development contract cycle times *decreased* significantly *after 1995*

	"Other" cycle time for contracts starting before 1990 (n = 40)	"Other" cycle time for contracts starting after 1990 (n = 72)
Minimum	2.0	2.3
25th percentile	6.4	4.5
Median	7.5	5.9
75th percentile	9.0	8.4
Maximum	14.8	15.0



NOTE: "Other" commodity types include electronics, avionics, and communication systems. The bottom "box and whisker" chart shows the middle two quartiles in the box with the median. The "whiskers" show the maximum and minimum values in the table at the top of the figure.

Trends and Correlates of Contract Cost Growth: Early Production

Contract Cost Growth Correlates: Early Production

As we did for development contracts, we also identified and quantified early production contracts performance differences between Military Departments, weapon system commodity types, contracting practices, contract size, and schedule effects. These analyses examine whether any of these variables correlate statistically with total cost growth—or whether the variation in cost growth is confined to the two primary cost growth measures independent of these other variables. We tested all these variables for statistical correlation with total cost growth first for all DoD development contracts from 1970 to 2011, then conducted separate tests for early production contracts for aircraft, missiles, munitions, space systems, and ships.

Table 2-11 summarizes the significant variables that contribute to total cost growth on early production contracts. It is important to note that other variables listed in Table 2-7 (contract type, other commodity types, and Military Departments) were examined and found to have no significant contribution statistically to total cost growth.

Table 2-11. Contributors to Total Cost Growth on DoD-Wide Early Production Contracts (1970–2011).

Significant variables	Corresponding effect on total contract cost growth
Work content: each +1 percentage-point	+1.07 percentage-points
Schedule growth: each +1 percentage-point	+0.09 percentage-points
Army contract	+12 percentage-points

NOTE: Work content, schedule growth, and Army contracts in this regression explain 92 percent of the observed variation in total contract cost growth (i.e., only 8 percent of the variation in the data is due to variables we do not have data for, or is random noise). Level of significance is 5 percent (only 5 percent chance we cannot reject the value is actually zero). Source cost data were reported in "then-year" dollars (unadjusted for inflation).

As expected and discussed earlier on development contracts, the effect of work content growth dwarfed all others, but unlike on DoD-wide development contracts now there is a small but measurable schedule effect, and Army contracts now have a statistically significant effect. Interestingly, UCAs did not correlate with total cost growth in early production as they did on development contracts.

Correlates by Commodity Type. Table 2-12 summarizes the significant variables that contribute to total cost growth on early production contracts for five different system commodity types: aircraft, missiles, munitions, space systems, and ships. Again, it is important to note that other variables listed in Table 2-7 (contract type, definitization, and Military Departments) were examined and found to have no significant contribution statistically to total cost growth.

Table 2-12. Contributors to Total Contract Cost Growth on Early Production Contracts by Commodity Type (1970–2011).

	Significant variables	Total contract cost growth corresponding effect
Aircraft *(n=73)*	**Work content:** each +1 percentage-point	+1.08 percentage-points
Missiles *(n=136)*	**Work content:** each +1 percentage-point	+1.12 percentage-points
	Army contracts	+10 percentage-points
Munitions	*[insufficient data]*	
Space systems *(n=36)*	**Work content:** each +1 percentage-point	+0.92 percentage-points
Ships *(n=86)*	**Work content:** each +1 percentage-point	+1.04 percentage-points
	Schedule growth: each +1 percentage-point	+0.61 percentage-points

NOTE: The variable in these four regressions explain 97 percent, 91 percent, 90 percent, and 96 percent of the observed variation in total contract cost growth, respectively. Other variables listed in Table 2-7 (schedule, size, definitization, contract type, other system commodity types, and other Military Departments) were examined but found to have no significant contribution statistically to total cost growth. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

As expected, the effect of work content growth is statistically significant on all regressions, but some had a stronger relationship than others. We also found other variables for some commodity types that also exhibited significantly higher total cost growth historically.

In missile production, Army early production contracts generally were 10 percentage-points higher on total cost growth (all other things equal).

There were insufficient data to test for correlates of total cost growth on early production munitions contracts.

For ship production, schedule growth is now a large contributor to total cost growth. Each percentage-point increase in schedule generally correlated with a higher total cost by about 0.61 percentage points. This correlation only showed for ship production, and recall that the only other commodity for which schedule growth was a factor was for missile production contracts (discussed earlier).

Interestingly, there was no UCA correlation with total cost growth for ship production (recall there was a large UCA effect on development contracts). This result is in line with the other UCA findings in the report: We found no instances where UCAs (as used by the DoD historically) correlated statistically with cost growth on these MDAP contracts.

Temporal Patterns of Cost Growth: Early Production

As with development contracts, we also examined temporal cost data on 119 large early production MDAP contracts programs from 1993–2011. We found that the same seven cost growth profiles from development contracts covered the general patterns for early production contracts. Examples from each pattern are shown in the following figures.

Figure 2-36. Example Early Production Contract Cost-Growth Profiles: "Well Managed."

Well-managed **(a Trident II D-5 contract)**

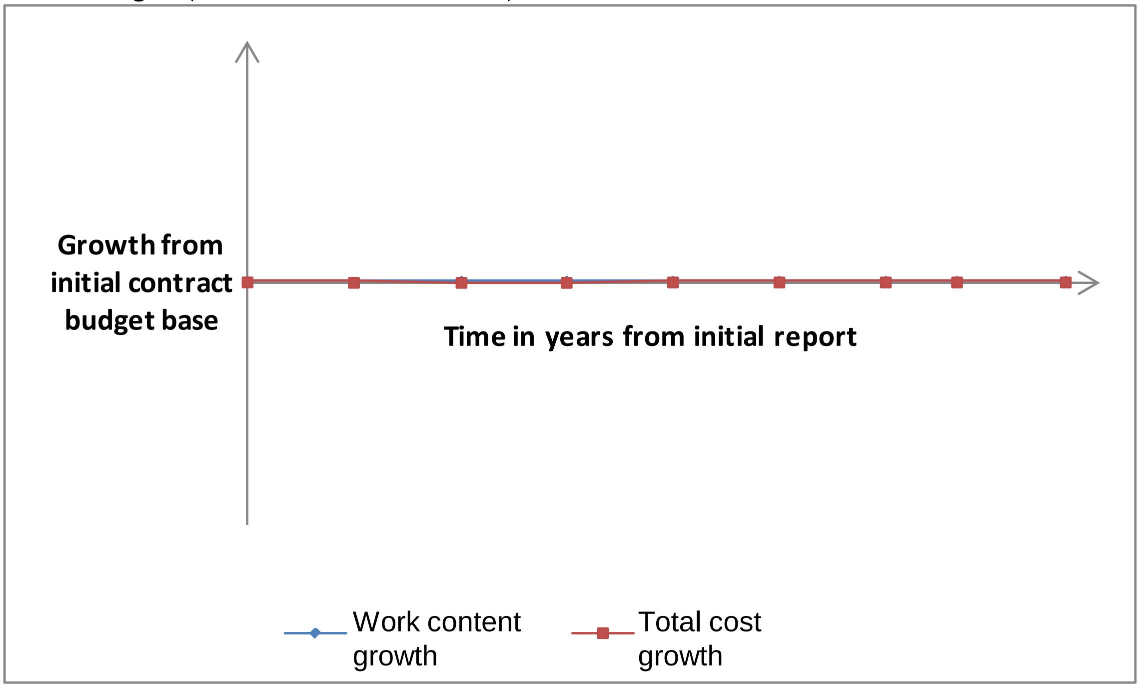


Figure 2-37. Example Development Contract Cost-Growth Profiles: "Premature Start."

Premature start **(a Titan IV contract)**

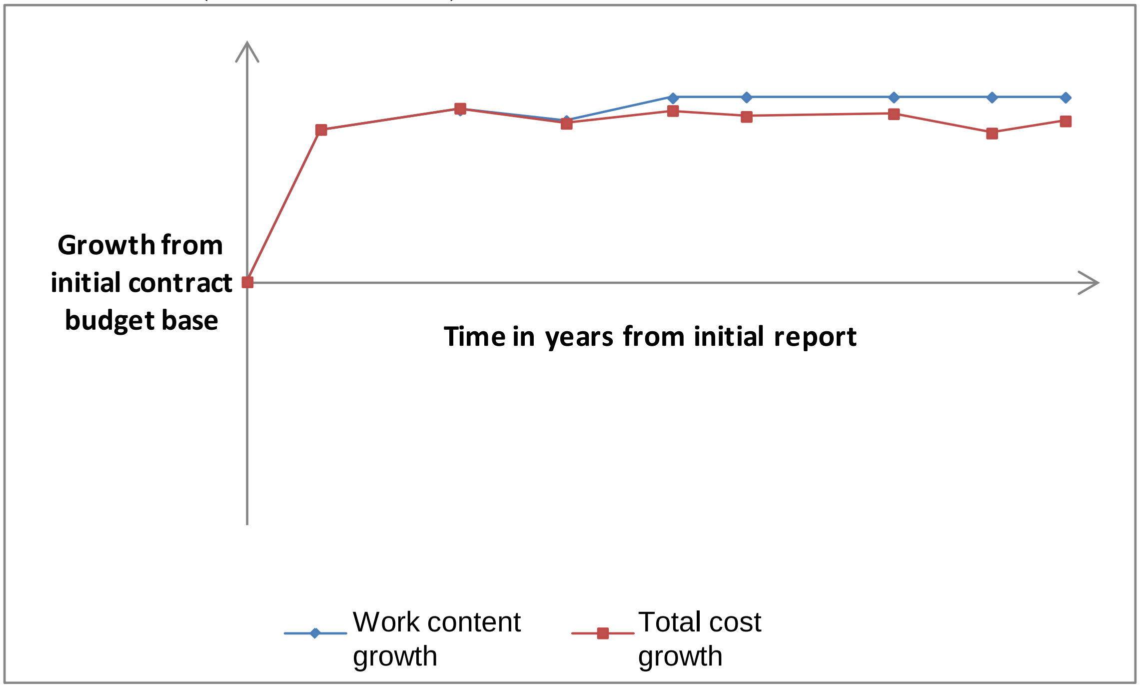


Figure 2-38. Example Development Contract Cost-Growth Profiles: "Premature Start + Poor Estimate."

Premature start; poor estimate (a JSTARS contract)

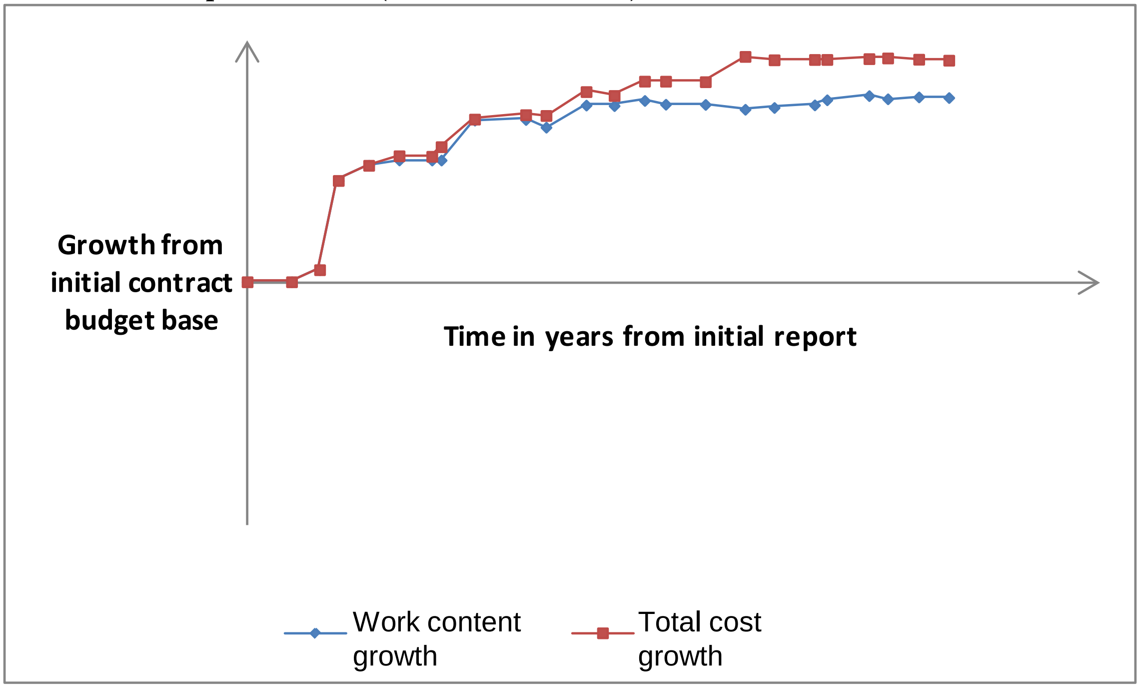


Figure 2-39. Example Development Contract Cost-Growth Profiles: "Work Added Later."

Work added later (a DDG-51 contract)

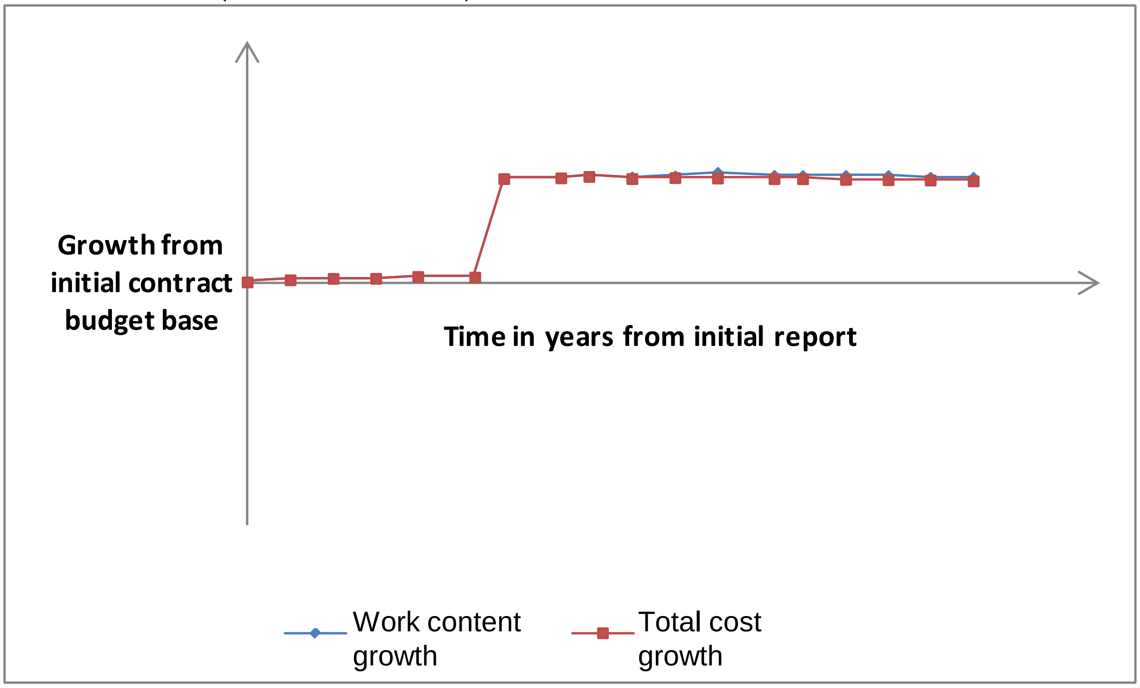


Figure 2-40. Example Development Contract Cost-Growth Profiles: "Work Added Later + Poor Estimate."

***Work added later; poor estimate*(a ChemDemil CMA contract)**

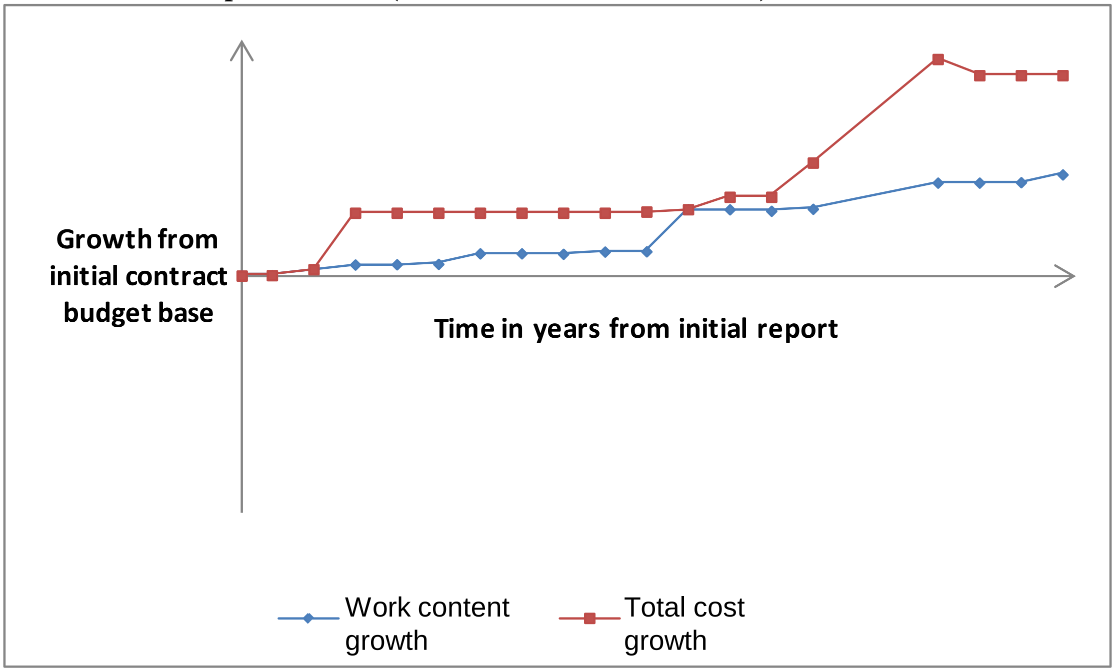


Figure 2-41. Example Development Contract Cost-Growth Profiles: "Poor Estimate."

***Poor estimate only* (a SADARM airframe contract)**

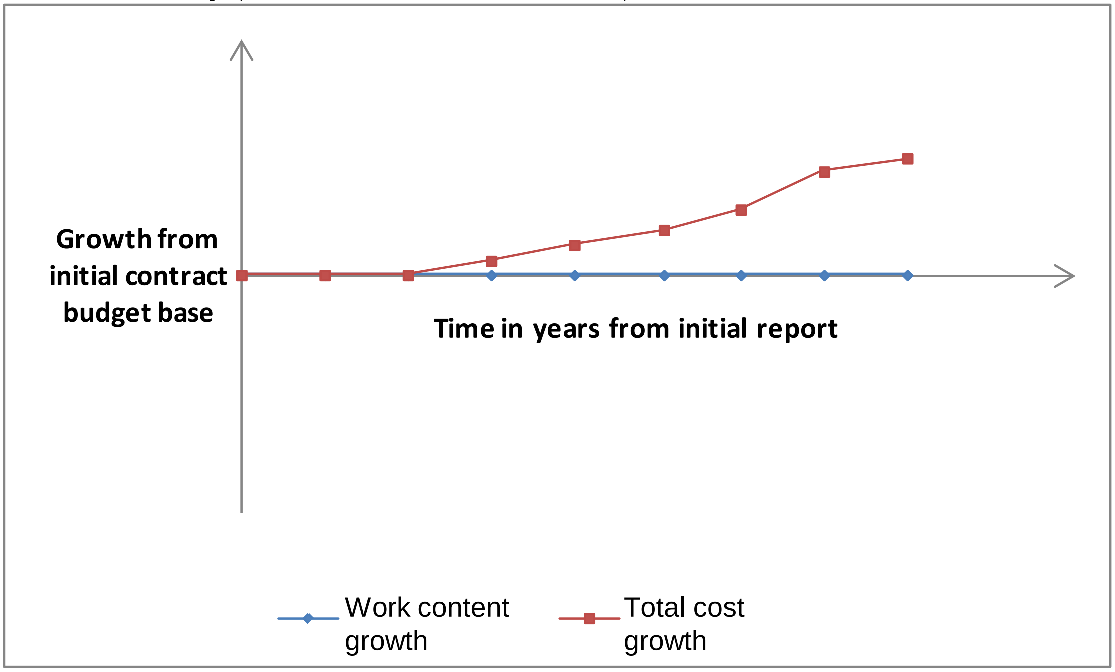


Figure 2-42. Example Development Contract Cost-Growth Profiles: "Apparent Poor Management."

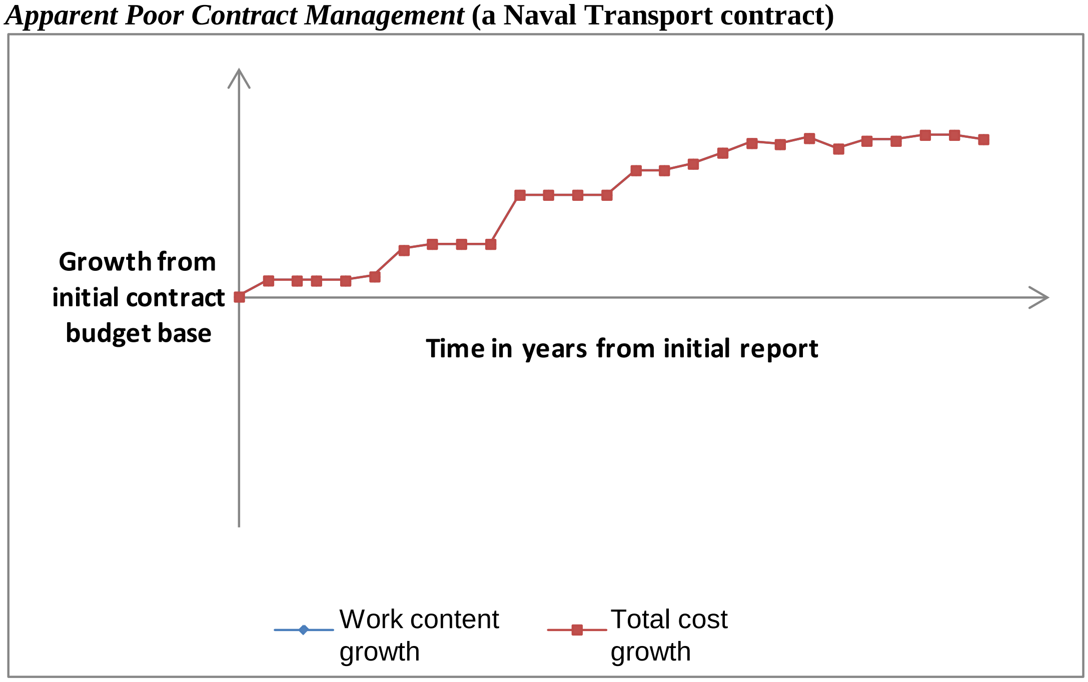
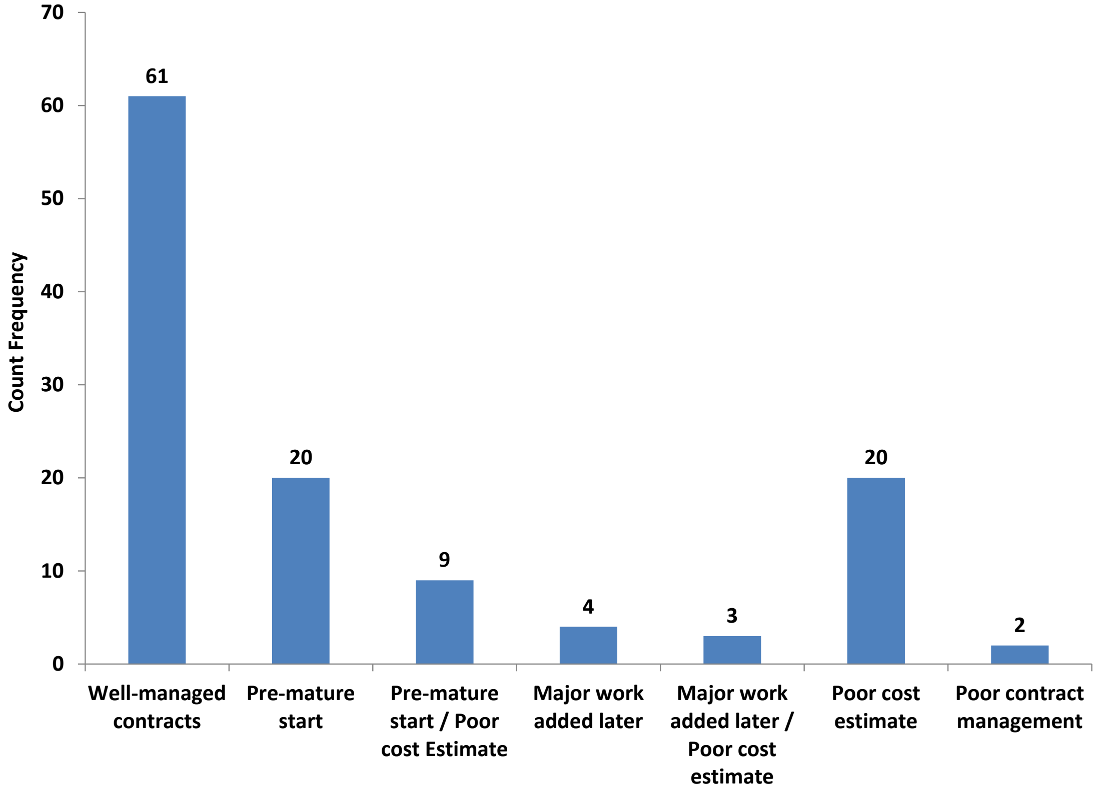


Figure 2-43. Summary of Early Production Contract Cost-Growth Profiles.



NOTE: n=119 total early production contracts.

In production, half of the major contracts (61 out of 119, or 51 percent) were well managed with minimal cost growth of any kind (the ratio was lower at 28 percent for development contracts). The remaining contracts had some type of large cost growth in one of the six categories.

As in development contracts, cost-over-target (interpreted as poor cost estimates) was a dominant pattern (20 out of 119 contracts, or 35 percent), but now large work content added early in the contract (interpreted as a premature start) also was dominant at the same level (20 contracts; 35 percent).

Interestingly, work content more often was added earlier ("premature start," with or without cost-over target growth) for production contracts, whereas in development work content was more often added later.

Moreover, only 2 of 119 contracts (less than 2 percent) exhibited cost growth patterns that may indicate poor contract management (this is a decrease from the 8 percent for development contract patterns).

Early Contract Work Content Stability: Production

As with the development contract discussion above, we examined the effects of early work content stability on long-term cost and schedule growth. The following are the statistical results of examining major MDAP development contracts from June 1992 through December 2011.

- *Early production* contracts with early work content stability had significantly lower
  - Total cost growth *–85 percentage -points*
  - Work content growth *–51 percentage points*
  - Schedule growth *–17 percentage -points*

(all at the median and all other things equal; cost data unadjusted for inflation).

For those patterns where work content was stable in the first year, we found that cost and schedule growth also were more stable. This supports the view that a well-understood and -defined contract at the outset tends to perform better in the long term. We found no statistically significant difference in costs-over-target on early production contracts between stable and unstable work content in the first year of the contract.

Effect of Contract Type Contract Cost and Schedule Growth: Early Production

As with development, our statistical analyses checked whether contract type correlated with cost growth on early production contracts. Statistical analysis of the effect of contract type on early production for 440 MDAP contracts between 1970 and 2011 is summarized in the following figures and tables.

Unlike the results for development contracts, Aircraft and UCA variables did not statistically increase cost growth historically, and schedule growth now correlates with total cost growth (at about one-tenth the rate that work-content cost growth does); if the early production contract was for the Army, there is a measurable correlation of a 12 percentage-points increase.

Again, no statistically significant differences were found in contract type in 433 MDAP development contracts or 440 MDAP early production contracts in 1970–2011.

Table 2-13. Fixed-Price and Cost-Type Contract Effects on Early Production Total Contract Cost Growth (1970–2011).

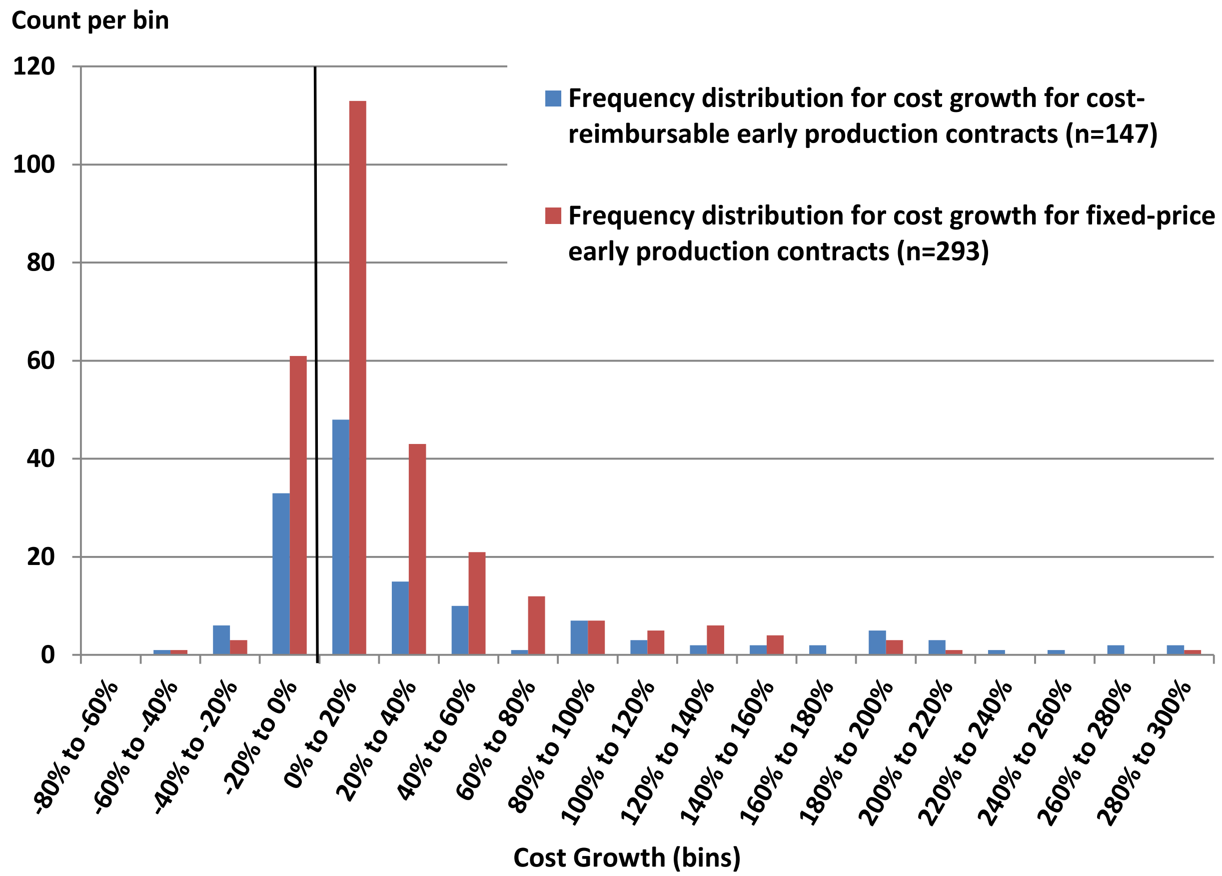
Significant variables		Corresponding effect on Total contract cost growth
Work content: each +1 percentage-point		+1.07 percentage-points
Schedule growth: each +1 percentage-point		+0.095 percentage-points
If is an **Army** contract		+12 percentage-points
Insignificant variables (*no* statistical significant effects on total contract cost growth)		
Contract type	• Cost-plus – CPAF – CPFF – CPIF • Fixed-price – FPIF – FFP • Hybrid	
Definitization	• UCA	
System commodity type	• Aircraft • Ships • Space • Engines • Missiles • Bombs • Ground tactical vehicles • Weapons • Other	
Military Department	• Army • Navy • Air Force • DoD (joint)	

Controlling for the three variables above, fixed-price contracts did not exhibit a significantly different cost growth than cost-reimbursable contracts.

NOTE: The three statistically significant variables in this regression explain 92 percent of the observed variation in total contract cost growth for early production. Level of significance is 5 percent (i.e., there is only a 5 percent chance we cannot reject the value is actually zero). Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Table 2-13 shows the three variables that are statistically correlated with total contract cost growth along with the other variables we tested. Note that contract type did not correlate with total contract cost growth.

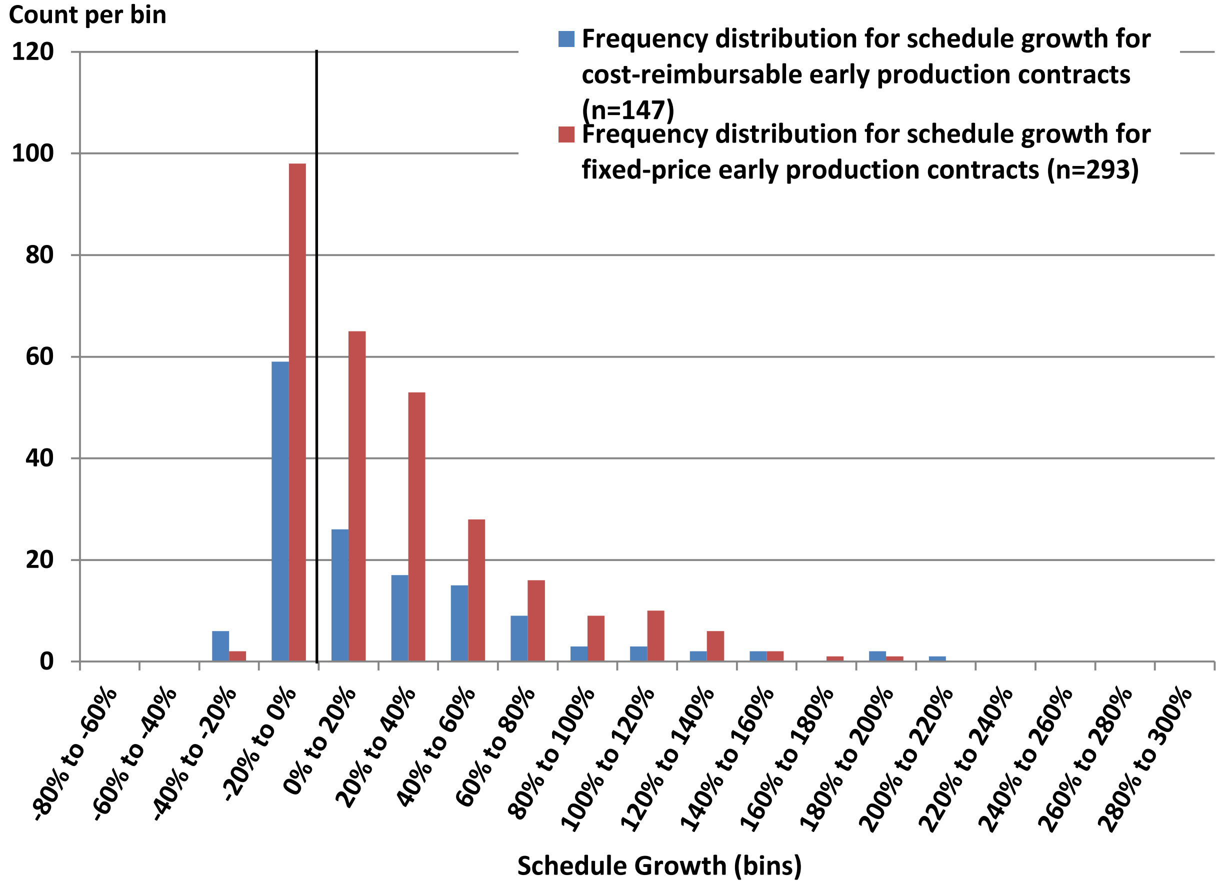
Figure 2-44. Contract-Type Effects on Early Production Contract Cost Growth (1970–2011).



NOTE: Source cost data were reported in "then-year" dollars (unadjusted for inflation).

The statistical analysis verifies that there is no statistically significant difference in Figure 2-44 between cost-reimbursable and fixed-price contracts with respect to cost growth on early production contracts.

Figure 2-45. Contract-type effects on early production contract schedule growth (1970–2011).



The statistical analysis verifies that there is no statistically significant difference in Figure 2-45 between cost-reimbursable and fixed-price contracts with respect to schedule growth on early production contracts.

UCA Effects on Cost Growth: Early Production

In all our analyses of contracts in 1970–2011 (in total and the more recent subset since June 1992). UCAs did not correlate with total cost grown on early production. Recall that there were some correlates on development contracts.

Institutional Analyses: Military Departments

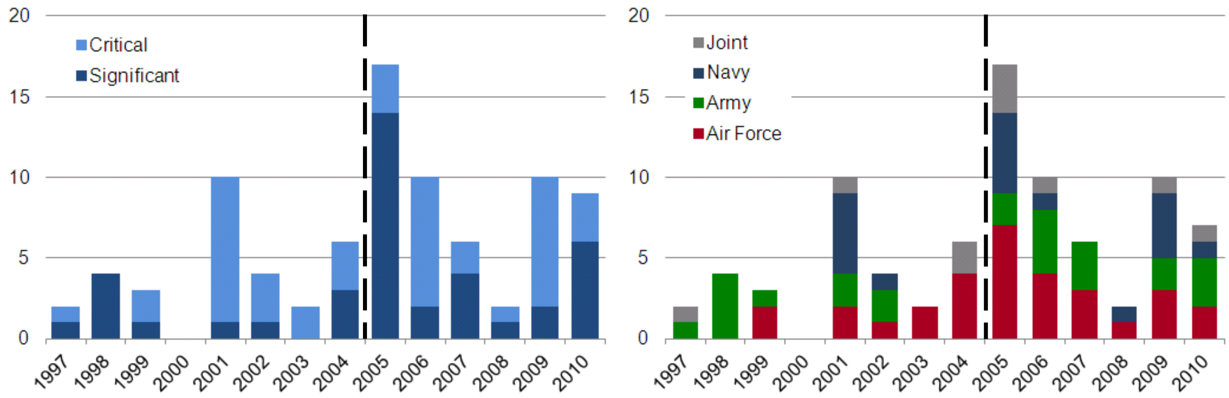
This section summarizes various acquisition performance metrics analyzed by Component, predominantly as measured by contract cost and schedule growth.

Not all of the many defense acquisition functions performed by the Components show statistically significant effects on cost and schedule. However, measuring them at the macro level and comparing their performance may provide useful indicators of performance and their possible causes.

Nunn-McCurdy Cost Breaches

Again, we can get a proxy measure of acquisition performance by looking at Nunn-McCurdy breach rates by Component. Figure 2-46 shows Nunn-McCurdy breach counts by year from 1997 to 2010. Table 2-14 provides a different analysis counting the number of programs that never breach against those that have at least one breach.

Figure 2-46. Annual SAR Nunn-McCurdy Breaches (1997–2010).



NOTE: The criteria for breaches were changed in NDAA 2006, affecting counts starting with 2005. These plots include multiple breaches on a single program if cost changed from prior year. “Joint” programs in this plot are those identified as “DoD” in AT&L’s database. Breaches are determined using “base-year” dollars (adjusted for inflation).

The graphs in Figure 2-46 reflect the data printed in the SAR and may differ slightly from breaches reported individually to Congress. For example, in December 2010, the Global Hawk program only experienced a significant Nunn-McCurdy breach of 22.8 percent, which is reflected in graph, but Congress was notified of a critical breach since the draft Program Office Estimate was signaling increased cost above the 25 percent threshold. Similarly, the December 1998 SAR for the SADARM program indicated a significant breach, which is included in the graph, but the program did not report a breach since it attributed the breach to rounding errors in the unit cost calculation.

Table 2-14. Nunn-McCurdy MDAP Breach Rates by Component (1997–2011).

	Total # of Programs	# of Programs that Breached	Breach Rate	# of Programs with at Most a Significant Breach	Significant Breach Rate	# of Programs with a Critical Breach	Critical Breach Rate
Air Force	51	15	29%	2	4%	13	25%
Army	45	18	40%	8	18%	10	22%
Joint	14	7	50%	1	7%	6	43%
Navy	60	14	23%	5	8%	9	15%
Total	170	54	32%	16	9%	38	22%

NOTE: Analyzed data on active programs from the 1997 SAR to the September 2012 SAR. Some programs breach because of cancellation (e.g., Land Warrior) and some programs canceled before Nunn-McCurdy (e.g., VH-71). If program had both a significant and critical breaches, it was only included in the "programs with critical breach" column. Not adjusted for quantity or other variances. "Joint" programs in this table are those identified as "DoD" in AT&L's database. Breaches are determined using "base-year" dollars (adjusted for inflation).

Historically, most Air Force and joint MDAPs that breach go critical (i.e., very few remain at the significant level).[14] Only half of Army breaches are critical, but Army MDAPs breach at a higher rate. Overall, Navy MDAPs have the lowest breach rate and about two-fifths of those remain below the critical level.

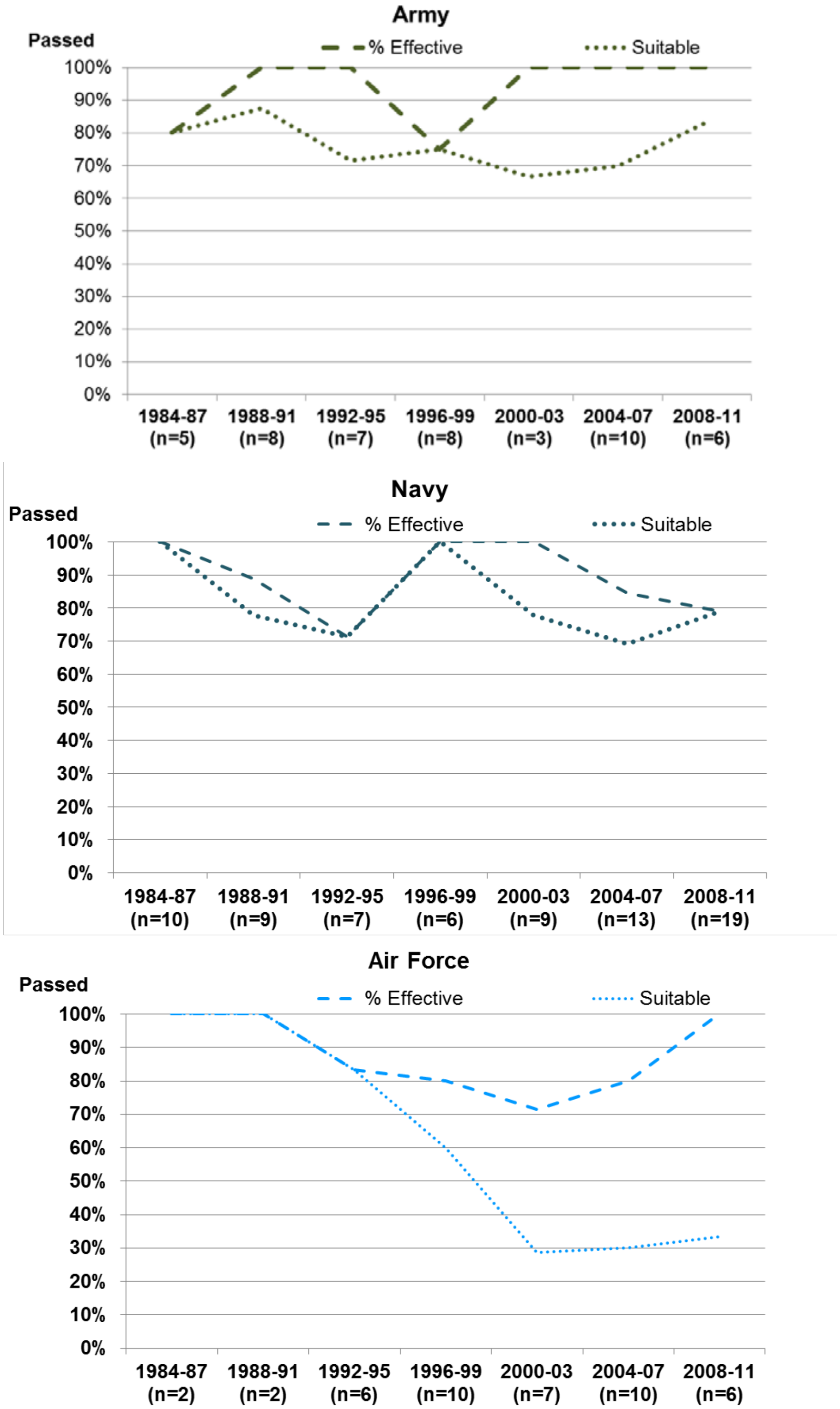
No attempt was made to identify or remove program breaches based on cause. Some programs may breach because of cancellation (e.g., Land Warrior) and some programs may have been canceled before their breach (e.g., VH-71). If program had both a significant and critical breaches, it was only included in the "programs with critical breach" column.

Mission Effectiveness and Suitability of Acquired Systems: Military Departments

Figure 2-47 plots the operational effectiveness and suitability of the systems acquired by the Military Departments as assessed by the DoD Director of Operational Test and Evaluation (DOT&E) in 3-year increments.

[14] Note that there is a small sample set of only 13 Joint programs in this dataset.

Figure 2-47. Percent of MDAPs by Military Department Rated as Effective and Suitable for Operation (1984–2011).



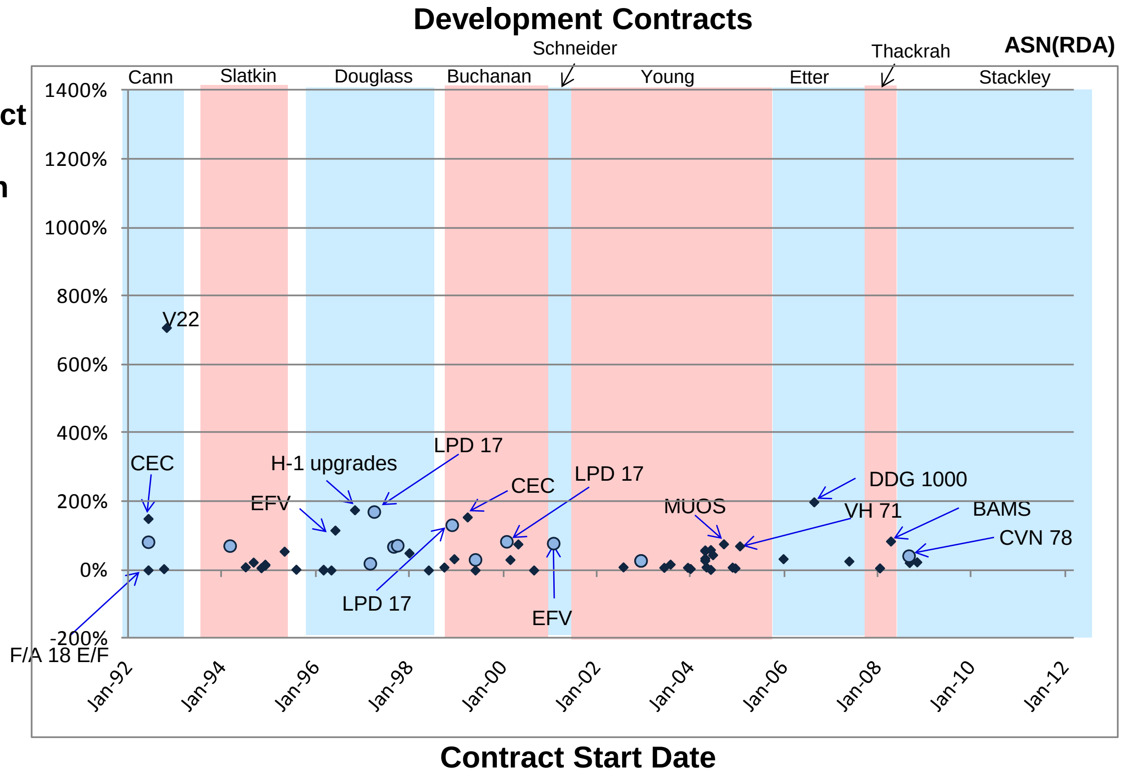
Source: DOT&E BLRIP reports.

Contract Cost Growth and Service Acquisition Executives: Development

As with the earlier plots for the USD(AT&L), we conducted a number of nonstatistical examinations looking at various dimensions of cost and schedule growth, for both development and production contracts within each Military Department and showing Service Acquisition Executive (SAE) tenures. The charts for development are included below; early production results are included later in this section.

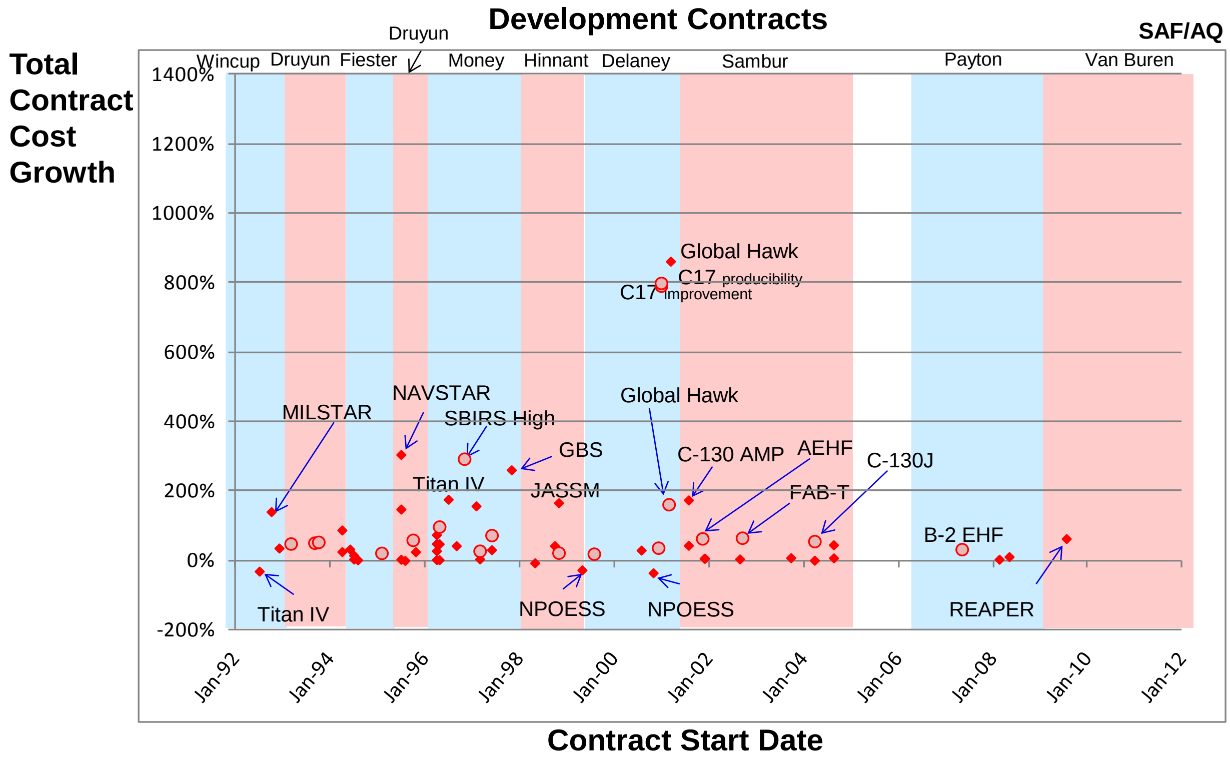
Some isolated patterns of interest emerged from prior analyses that are apparent in the following charts, but none are statistically significant unless they are explicitly as such.

Figure 2-48. Navy Development Contract Total Cost Growth and SAE Tenures (1992–2011).



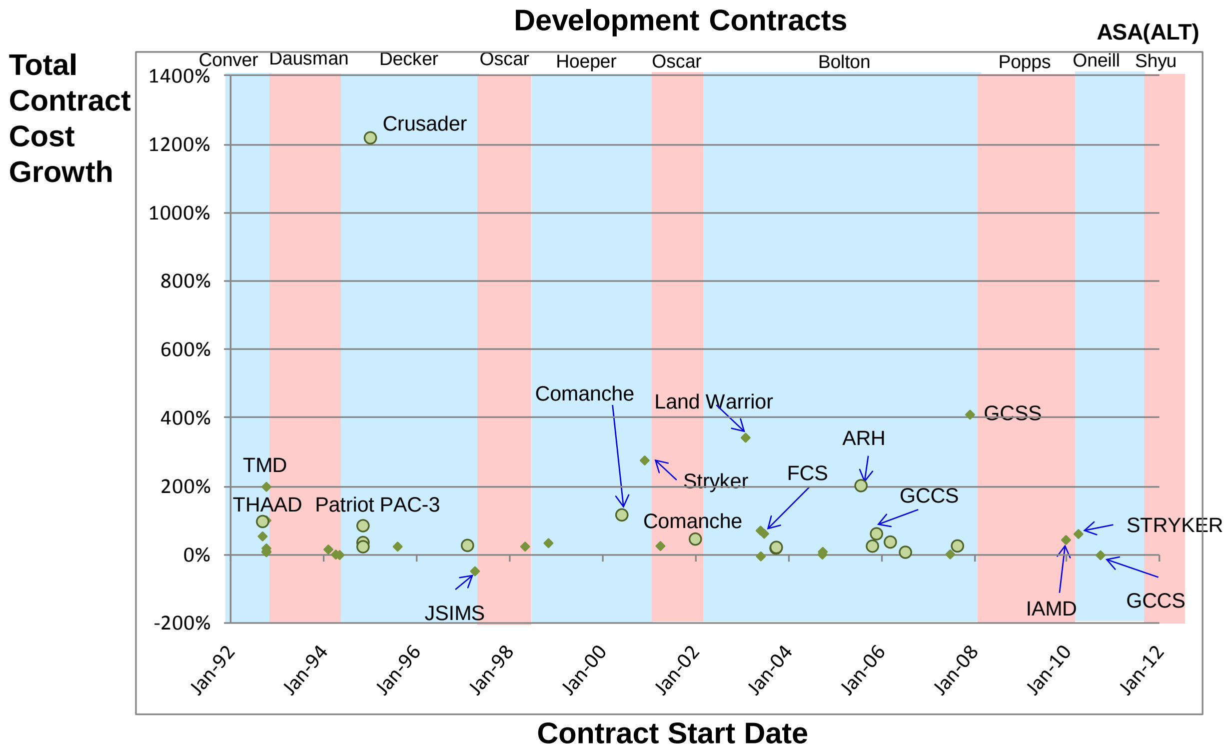
NOTE: Normally, contract start dates should be relatively close to prior major reviews (usually Milestone B decisions) by the SAE and MDA to approve contract award. Diamonds on the charts indicate growths mostly attributable to the start of the contract; circles represent significant work added later. Any white bars between SAE shaded regions represent periods where there was no confirmed executive. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Figure 2-49. Air Force Development Contract Total Cost Growth and SAE Tenures (1992–2011).



NOTE: Normally, contract start dates should be relatively close to prior major reviews (usually Milestone B decisions) by the SAE and MDA to approve contract award. Diamonds on the charts indicate growths mostly attributable to the start of the contract; circles represent significant work added later. Any white bars between SAE shaded regions represent periods where there was no confirmed executive. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Figure 2-50. Army Development Contract Total Cost Growth and SAE Tenures (1992–2011).



NOTE: Normally, contract start dates should be relatively close to prior major reviews (usually Milestone B decisions) by the SAE and MDA to approve contract award. Diamonds on the charts indicate growths mostly attributable to the start of the contract; circles represent significant work added later. Any white bars between SAE shaded regions represent periods where there was no confirmed executive. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

These figures seem to imply visually some relationships between sitting SAE for major reviews before these contracts and the eventual performance of those contracts. For example, development contract schedule growth analysis shows that Navy growths appear to be better controlled since 2006 (Etter, Thackrah, and Stackley eras). However, such visual observations are subjective at this point rather than tested statistically, especially because these plots do not control for other variables that may be the dominate factors that affect cost growth on contracts.

However, while many visual observations of these figures are only apparent, some of our other statistical analyses are evident in these charts. For example, other analysis that found total cost growth for Air Force development contracts are lower by a statistically significant amount since 2002 can be seen visually in these charts (i.e., since the Sambur era).

Cycle Times: Development

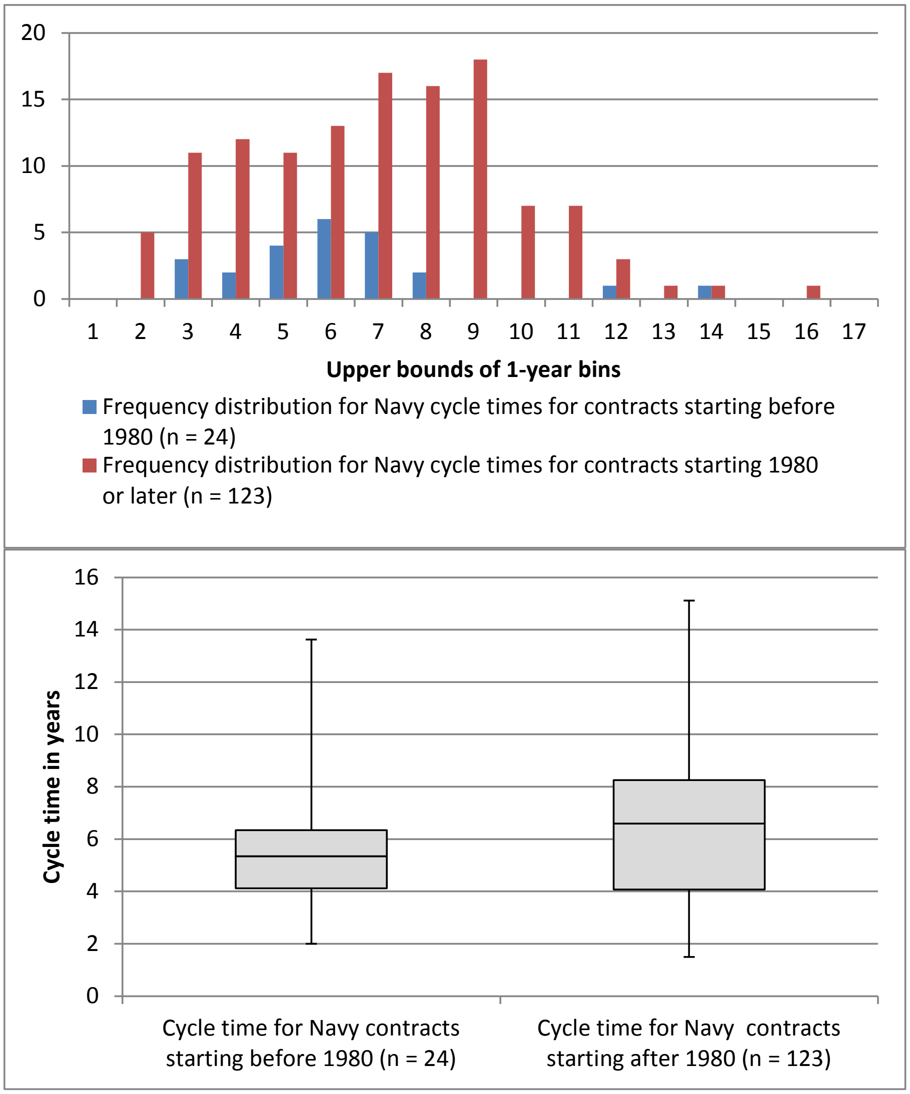
In this section, we report contract cycle times by Military Department. We only found two significant before/after period splits: Navy before/after 1980, and Air Force before/after 1995. There were no statistically significant before/after period splits in which Army cycle times were significantly different.

Analysis of development cycle time across the Department and by commodity types was discussed earlier in this report.

Figure 2-51. Navy Development Contract Cycle Time Trends (1970–2011).

Navy development contract cycle times *increased* significantly *after* 1980

	Navy cycle time for contracts starting before 1980 (n = 24)	Navy cycle time for contracts starting after 1980 (n = 123)
Minimum	2.0	1.5
25th percentile	4.1	4.1
Median	5.3	6.6
75th percentile	6.3	8.2
Maximum	13.6	15.1

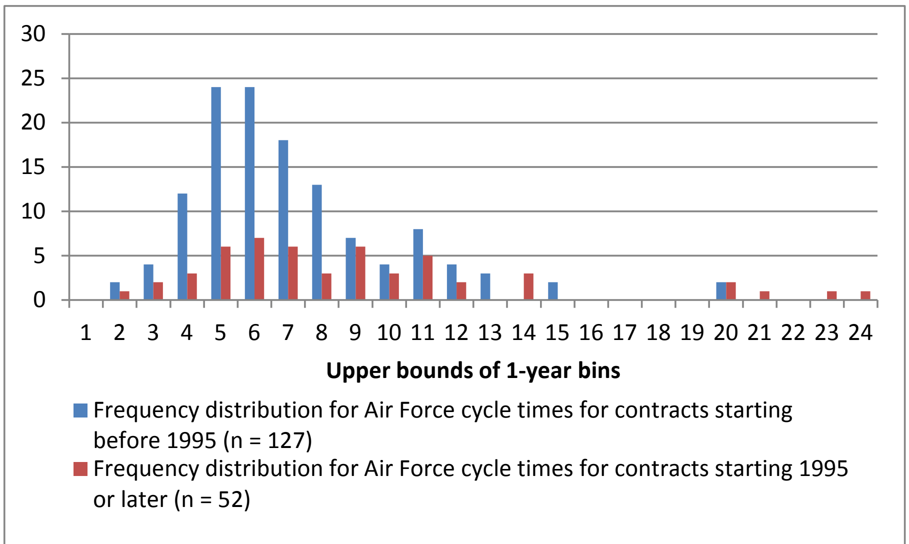


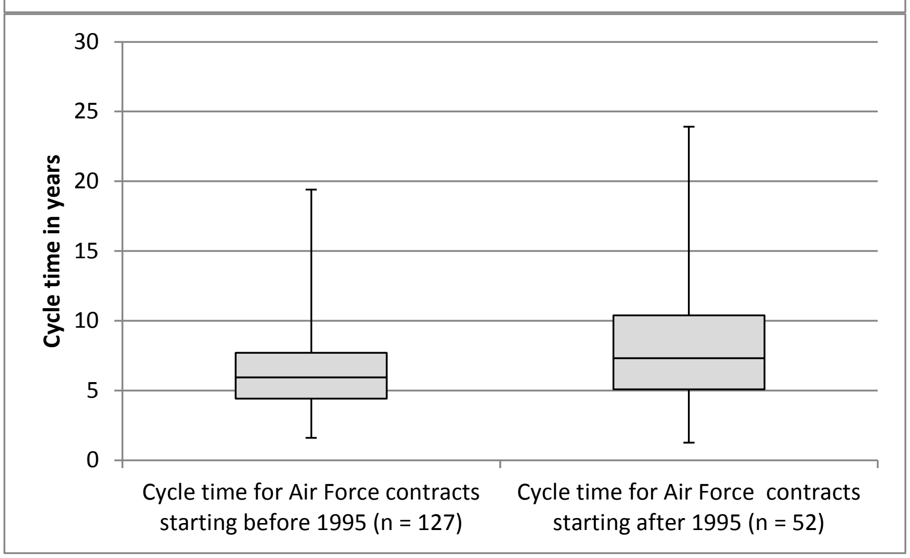
NOTE: Navy contracts after 1980 included DDG 51, Sea Wolf, A-12, V-22, LPD 17, EFV, MUOS, and DDG 1000. "Box-and-whisker" charts (lower-right) show minimum, median, maximum, and quartiles.

Figure 2-52. Air Force Development Contract Cycle Time Trends (1970–2011).

Air Force* development contract cycle times *increased* significantly *after 1995

	Air Force cycle time for contracts starting before 1995 (n = 127)	Air Force cycle time for contracts starting after 1995 (n = 52)
Minimum	1.6	1.3
25th percentile	4.4	5.1
Median	5.9	7.3
75th percentile	7.7	10.4
Maximum	19.4	23.9





NOTE: Air Force contracts after 1995 included Global Hawk, GPS IIF, SBIRS High, NPOESS, C17 mods, C-130 AMP, FAB-T; they also executed under acquisition concepts such as Total System Performance Responsibility (TSPR).

Cost Growth: Development

This section summarizes contract-level data associated with Military Department development cost growth. All indicated distinctions are statistically significant.

Historical Contract Results (1970–2011). Table 2-15 compares the total cost growth outcomes on 429 MDAP development contracts from 1970 through 2011.

Table 2-15. Military Department Performance on Development MDAP Contracts (1970–2011).

Variables (medians):	Army (n = 97)	Navy (n = 146)	Air Force (n = 179)	DoD (n = 7)
Total cost growth	* 44%	30%	31%	* 86%
Work content growth	* 26%	9%	* 19%	* 27%
Costs-over-target	* 9%	* 8%	2%	* 54%
Schedule growth	* 23%	9%	12%	* 23%
UCA rate	41%	39%	39%	43%
Duration (years)	5.7	6.2	6.2	10.0

**Statistically higher than unmarked values for this variable.*

Trends	Army (n = 97)	Navy (n = 146)	Air Force (n = 179)
Total cost growth			Upward
Work content growth			Upward
Costs-over-target	Downward		
Schedule growth		Downward	
Duration (years)			Upward

Blank cells had no measurable trends.

NOTE: All these contracts had completed at least about 30 percent of original contract dollar amount (55 percent of original schedule). Identified trends are those that are statistically measurable (with at least a 10 percent level of significance). Source cost data were reported in “then-year” dollars (unadjusted for inflation).

Historically, the Navy and Air Force had significant lower total cost and schedule growths statistically than the Army and Joint programs (see **Table** 2-15). The Navy controlled work content the most, while the Air Force had lower costs-over-target. Trend analysis showed the Air Force was increasing total cost growth and work content growth, the Navy was decreasing schedule growth, and the Army was decreasing costs-over-target.

Recent Contract Results. Table 2-16 compares the total cost growth outcomes on 170 MDAP development contracts from June 1992 to December 2011.

Table 2-16. Contract Total Cost Growth by Military Department in Development (FY1993–2011).

Total Cost Growth (Development Contracts)

	Army (n = 42)	Navy (n = 64)	Air Force (n = 64)
Median	**28%**	**28%**	**34%**
Mean	92%	54%	91%

NOTE: Differences were tested and are *not* statistically significant. Medians are the better measure of central tendency for this skewed distribution. Source cost data were reported in “then-year” dollars (unadjusted for inflation).

The three Military Departments had statistically similar total cost growths since June 1992.

The distributions are skewed to the high side, so medians provide a better measure of central tendency of the population while the means give a sense of the effect of outliers. The apparent differences from examining the arithmetic means are due to effects of higher outliers for the Army and Navy. For example, the highest growths for the Army and Air Force were 1,221 percent and 862 percent, compared to 708 percent for the Navy. Interestingly, the lowest cost growths for the Army and Air Force were both negative at -47 percent and -36 percent, respectively, compared to 0 percent for Navy. These calculations were not weighted by contract size.

Recent Contract Trends. In a different regression analysis, we found a small but measurable trend of reducing total cost growth for the Army and Air Force. All other things equal (i.e., controlling for other variables), Army and Air Force contracts from June 1992 through December 2011 were dropping (-4 percentage-points and -3 percentage points every 10 years, respectively); however, these trends only explained 0.1 percent each of the variation in the data when controlling for the other variables in Table 2-7, including schedule growth, size, definitization, contract type, commodity type, and the remaining Military Departments (the Army). The dominant statistical correlate of total cost growth was work content growth (as reflected in a higher contract target cost), which explained 96 percent of the variation in the data. The remaining 3.4 percent of the variation is not explained by the variables examined and is due to other variables outside our dataset or random noise.

In another (less sophisticated) analysis comparing the decades before and since 2002, the Army and Air Force total cost growths were lower by 24 and 21 percentage points, respectively, and exhibited decreasing trends compared to the prior decade. Army reduced costs-over-target and has a decreasing trend; Air Force lowered schedule growth and has a decreasing trend. Navy showed no significant changes between the two decades. Air Force aircraft development total cost growth on contracts since 2002 were significantly higher by 103 percentage-points than those in the prior decade. Note that these values indicate the expected change in percentage-points in total cost with all other things being equal (i.e., holding fixed other variables in our data).

Schedule Growth

Table 2-17 compares schedule growth outcomes on 170 MDAP development contracts from June 1992 to December 2011.

Table 2-17. Military Department Schedule Growth on MDAP Development Contracts (FY1993–2011).

Schedule Growth (Development Contracts)

	Army (n = 42)	Navy (n = 64)	Air Force (n = 64)
Median	*** 20%**	**6%**	**3%**
Mean	87%	35%	77%

* Statistically higher than unmarked values for this variable.
NOTE: Medians are the better measure of central tendency for this skewed distribution.

The Air Force and Navy each had significantly lower schedule growth compared to the Army when tested statistically across the population of contracts.

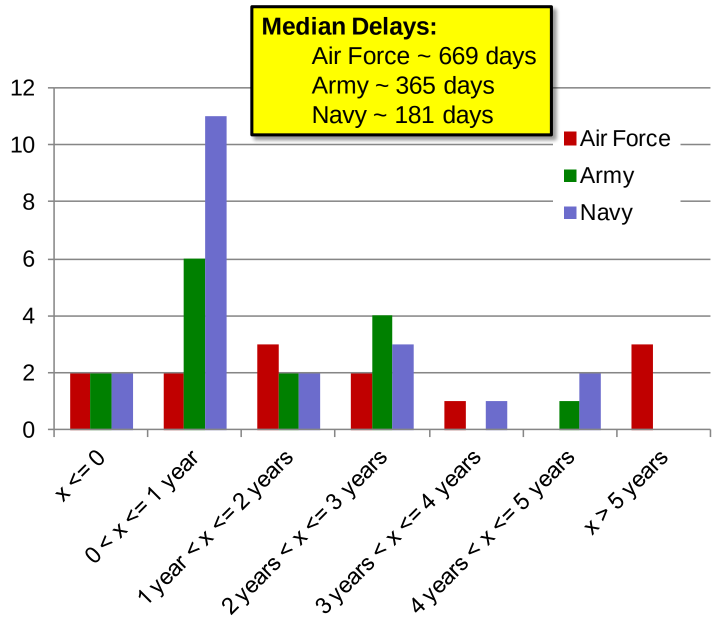
In a different regression analysis, we found that 30 percent of the variation in schedule growth is due to work content growth, where schedule growth rose by 2.2 percentage-points for every 10 percentage-point increase in work content cost (all other things being equal). A very small but measurable 2 percent of the variation in schedule growth is explained by Army contracts being 26 percentage points higher (again, all other things being equal). Still, 68 percent of the variation in schedule growth is unexplained by examining the variables in Table 2-7, including size, definitization, contract type, commodity type, and the other two Military Departments (Navy and Air Force).

As with cost growth generally, schedule growth distributions were skewed to the high side, so medians provide a better measure of central tendency while the means give a sense of the effect of outliers. The apparent differences from examining the arithmetic means are due to effects of higher outliers for the Army and Navy. For example, the highest growths for the Army and Air Force were 582 percent and 459 percent, compared to 238 percent for the Navy. All three departments had at least one contract with negative schedule growth, although their first quartile was at 0 percent. These calculations were not weighted by contract size.

Program Schedules. Finally, Figure 2-53 shows preliminary analysis of program delays of their Milestone C (MS C), comparing actual dates to the estimate made at the original Milestone B development baseline. Milestone C is the review at which approval is made for a program to enter the Production and Deployment phase. Note that the data were incomplete: Not all MDAPs reported forecasts of their MS C dates at MS B, and many MDAPs have yet to have their MS C. Further analysis is needed.

Figure 2-53. Milestone C Delays from Development Baseline (1997–2011).

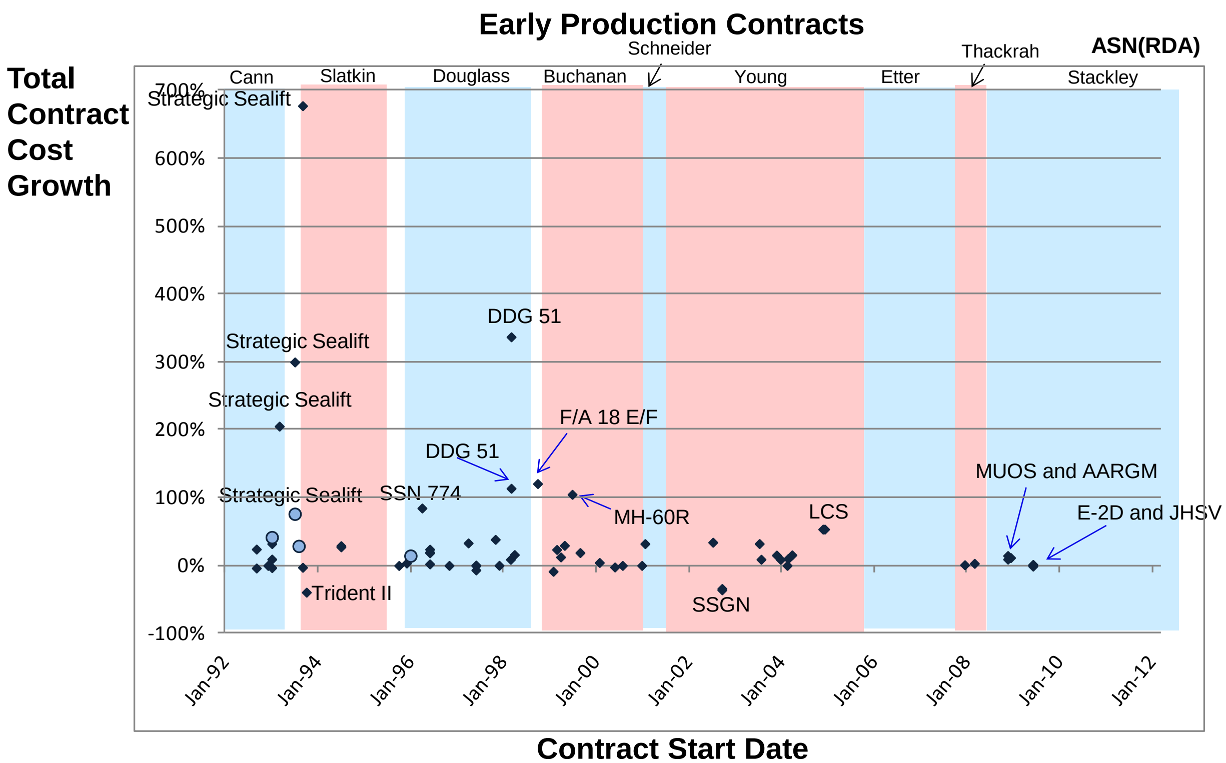
	Total Programs	# past MS C Reporting Schedule Data	
Air Force	48	13	27%
Army	45	15	33%
Joint	13	0	0%
Navy	58	21	36%
Total	164	49	30%



Contract Cost Growth and Service Acquisition Executives: Early Production

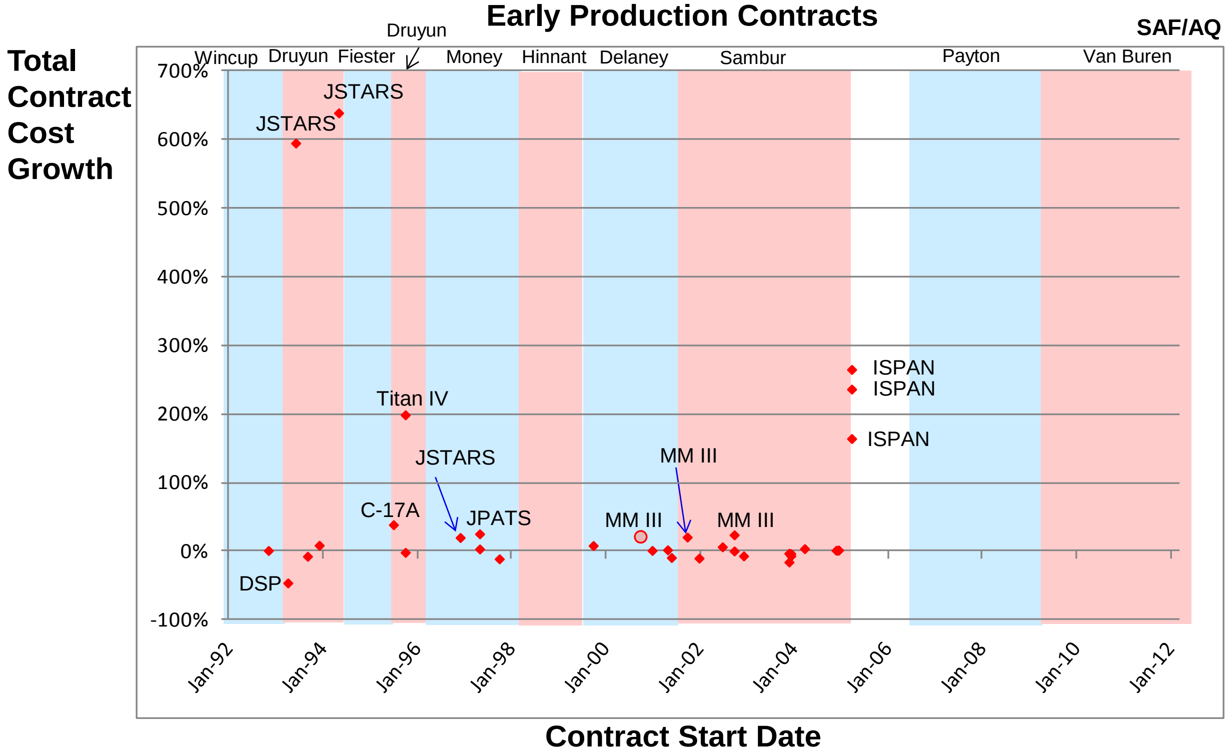
Below are the early production charts looking at various dimensions of cost and schedule growth, for both development and production contracts within each Military Department and Service Acquisition Executive (SAE). Some isolated patterns of interest emerged from prior analyses that are apparent in the following charts. Unless shown, there was no noteworthy pattern observed.

Figure 2-54. Navy Early Production Contract Total Cost Growth and SAE Tenures (1992–2011).



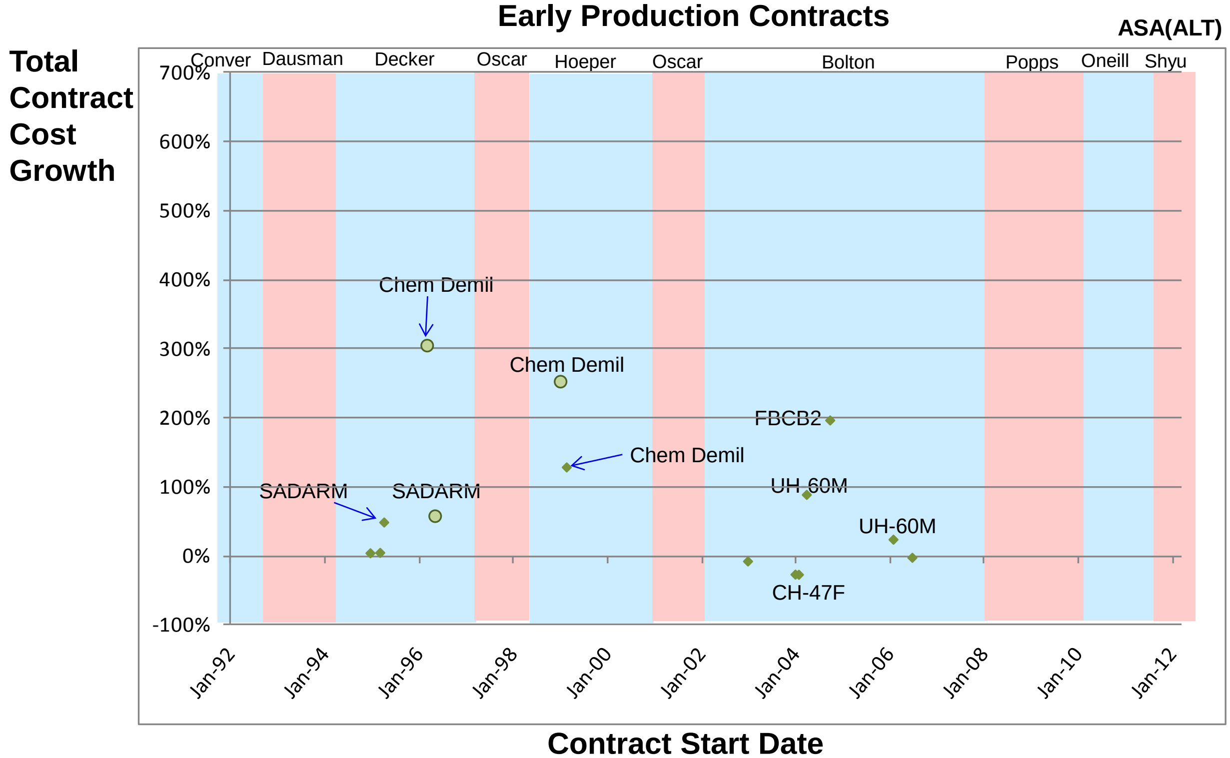
NOTE: Normally, contract start dates should be relatively close to prior major reviews (usually Milestone B decisions) by the SAE and MDA to approve contract award. Diamonds on the charts indicate growths mostly attributable to the start of the contract; circles represent significant work added later. Any white bars between SAE shaded regions represent periods where there was no confirmed executive. Source cost data were reported in “then-year” dollars (unadjusted for inflation).

Figure 2-55. Air Force Early Production Contract Total Cost Growth and SAE Tenures (1992–2011).



NOTE: Normally, contract start dates should be relatively close to prior major reviews (usually Milestone B decisions) by the SAE and MDA to approve contract award. Diamonds on the charts indicate growths mostly attributable to the start of the contract; circles represent significant work added later. Any white bars between SAE shaded regions represent periods where there was no confirmed executive. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Figure 2-56. Army Early Production Contract Total Cost Growth and SAE Tenures (1992–2011).



NOTE: Normally, contract start dates should be relatively close to prior major reviews (usually Milestone B decisions) by the SAE and MDA to approve contract award. Diamonds on the charts indicate growths mostly attributable to the start of the contract; circles represent significant work added later. Any white bars between SAE shaded regions represent periods where there was no confirmed executive. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

These figures seem to imply visually some relationships between SAE in place for major reviews before these contracts and the eventual performance of those contracts. For example, since 2008 (Thackrah and Stackley eras), Navy production total cost growth appears better controlled than earlier Navy contracts. However, all such visual observations are subjective at this point rather than tested statistically, especially because these plots do not control for other variables that may be the dominate factors that affect cost growth on contracts.

Cost Growth: Early Production

This section summarizes contract-level data associated with Military Department early production cost growth. All cited distinctions are statistically significant.

Historical Contract Results (1970–2011). Table 2-18 compares the total cost growth outcomes on 429 MDAP early production contracts from 1970 through 2011.

Table 2-18. Military Department Performance on Early Production MDAP Contracts (1970–2011).

Variables (medians):	Army (n = 71)	Navy (n = 199)	Air Force (n = 168)
Total cost growth	* 14%	13%	9%
Work content growth	5%	4%	4%
Costs-over-target	* 2%	* 4%	0%
Schedule growth	* 20%	8%	* 20%
UCA rate	7%	38%	22%
Duration (years)	3.8	* 5.3	* 4.5

**Statistically higher than unmarked values for this variable.*

Trends	Army (n = 71)	Navy (n = 199)	Air Force (n = 168)
Total cost growth			
Work content growth			
Costs-over-target			
Schedule growth			
Duration (years)	Upward		

Blank cells had no measurable trends.

NOTE: Regression explains 92 percent of the observed variation in total cost growth. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

From 1970–2011, the Navy and Air Force had significantly lower total cost growth than the Army programs (see Table 2-18). The Air Force had lower costs-over-target, and there was no difference in controlling work content. The Navy controlled schedule growth the most. No statistically significant historical trends were observed in cost and schedule growth.

Recent Contract Results and Trends. In a different regression analysis, we found that with all other things equal (i.e., controlling for other variables), Army contracts from June 1992 through December 2011 were 53 percentage-points higher; however, this Army effect only explains 1 percent of the variation in the data. In other words, the effect is large and measurable, but nearly all the differences between cost growth on different contracts in the data are due to variables other than whether this was an Army contract. This comparison is important because we are trying to look for performance differences between institutions and processes as we search for lessons learned. The statistics tell us that even if we were able to eliminate this Army contract effect, the other dominant factors that cause variation in cost growth still would be present and lead to increases from the central tendency unless they also were eliminated.

Also, we found an even smaller but measurable trend of increasing total cost growth for the Navy. Navy contract total cost growths were increasing 4 percentage-points every 10 years, respectively; however, this trend only explained an even smaller 0.1 percent of the variation in the data. This analysis controlled for the other variables in Table 2-7, including schedule growth, size, definitization, contract type, commodity type, and the remaining Military Departments (the Army). The dominant statistical correlate of total cost growth was work content growth (as reflected in a higher contract target cost), which explained 95 percent of the variation in the data. The remaining 3 percent of the variation is not explained by the variables examined and is due to other variables outside our dataset or random noise.

Institutional Analyses: Acquisition Commands by Commodity Type

We also conducted analyses of the outcomes on contracts by the Military Departments' acquisition commands. Our data do not identify acquisition commands directly, so we used a combination of commodity type and Military Department identifiers to infer acquisition commands. Thus, in some cases we had insufficient sample size and therefore are not discussed.

Aircraft: Development

Table 2-19 compares the relative outcomes of contracts nominally by the U.S. Naval Air Systems Command (NAVAIR) and the Air Force's Aeronautical Systems Center (ASC) on 41 MDAP development contracts from 1970 to 2011.

Table 2-19. Relative Performance of NAVAIR and ASC on Aircraft Development MDAP Contracts (1970–2011).

Variables (medians):	NAVAIR (n = 21)	ASC (n = 20)
Total cost growth	40%	* 67%
Work content growth	9%	* 37%
Costs-over-target	16%	19%
Schedule growth	5%	* 29%
UCA rate	29%	35%
Duration (years)	6.7	7.7

**Statistically higher than unmarked values for this variable.*

Trends	NAVAIR (n = 21)	ASC (n = 20)
Total cost growth		
Work content growth		
Costs-over-target		
Schedule growth		Downward
Duration (years)	Upward	

Blank cells had no measurable trends.

NOTE: Source cost data were reported in "then-year" dollars (unadjusted for inflation).

NAVAIR controlled total cost growth better than the ASC by controlling work content better, though costs-over-target were similar. NAVAIR controlled schedule growth better, and ASC has a long-term trend of decreasing schedule growth on aircraft contracts.

This highlights a difference at the acquisition command level that was not apparent in the Military Department level data. NAVAIR shows more favorable results because it controls work content better than ASC. This is one instance where we are beginning to use data analysis to explain why some institutions perform better than others. We still do not know *how* NAVAIR controlled work content more, but that control is *why* NAVAIR performs better on aircraft developments.

Missiles: Development

The Army Aviation and Missile Life Cycle Management Command (AMCOM), NAVAIR, and the Air Force's Air Armament Center (AAC) were analyzed next.

Table 2-20. Relative Performance of AMCOM, NAVAIR, and AAC on Missile Development MDAP Contracts (1970–2011).

Variables (medians):	AMCOM (n = 32)	NAVAIR (n = 51)	AAC (n = 74)
Total cost growth	** 86%	* 26%	21%
Work content growth	** 25%	9%	15%
Costs-over-target	** 21%	* 4%	0%
Schedule growth	** 34%	4%	* 11%
UCA rate	47%	31%	22%
Duration (years)	6.7	5.0	5.4

***Statistically higher than all other values for this variable.*
** Statistically higher than unmarked values for this variable.*

Trends	AMCOM (n = 32)	NAVAIR (n = 51)	AAC (n = 74)
Total cost growth	Downward		
Work content growth	Downward		
Costs-over-target	Downward		
Schedule growth		Downward	
Duration (years)			

Blank cells had no measurable trends.

NOTE: Source cost data were reported in "then-year" dollars (unadjusted for inflation).

AAC controlled total cost growth the most, followed by NAVAIR; AAC and NAVAIR both controlled work content better than AMCOM. NAVAIR controlled schedule growth the most, followed by AAC. AAC controlled costs-over-target the most, followed by NAVAIR. Despite being higher, AMCOM showed improving trends in total cost growth, work content growth, and cost-over-target. NAVAIR had an improving trend in schedule growth. Also, recall that in the prior analysis of missile development contracts (see Table 2-9, wherein Army (AMCOM) total cost growth generally was 30 points higher, all other things equal [i.e., Army's median total cost growth was higher still for other reasons]).

Again, this level of analysis highlights a difference at the acquisition command level that was not apparent in the Military Department level data. AAC and (to a lesser extent) NAVAIR show more favorable results mostly because they control work content (and, to a lesser extent, schedule growth) better than AMCOM. This is another instance where we are beginning to use data analysis to explain why some institutions perform better than others. We still do not know *how* AAC and NAVAIR controlled work content more, but that control is *why* they perform better on missile developments.

Munitions: Development

Munitions included the Army's Joint Munitions and Lethality Life Cycle Management Command (JM&LLCMC), NAVAIR, and the Air Force's AAC.

Table 2-21. Relative Performance of JM&LLCMC, NAVSEA, and AAC on Munitions Development MDAP Contracts (1970–2011).

Variables (medians):	JM&LLCMC (n = 7)	NAVSEA (n = 2)	AAC (n = 11)
Total cost growth	33%	*N/A*	31%
Work content growth	* 55%	*N/A*	25%
Costs-over-target	0%	*N/A*	0%
Schedule growth	23%	*N/A*	38%
UCA rate	43%	*N/A*	64%
Duration (years)	7.4	*N/A*	5.6

**Statistically higher than AAC's values for this variable.*

Trends	JM&LLCMC (n = 7)	NAVSEA (n = 2)	AAC (n = 11)
Total cost growth		*N/A*	
Work content growth		*N/A*	
Costs-over-target		*N/A*	Downward
Schedule growth		*N/A*	
Duration (years)		*N/A*	

Blank cells had no measurable trends.

NOTE: Source cost data were reported in "then-year" dollars (unadjusted for inflation).

AAC controlled work content more than the Army's JM&LLCMC. Also, AAC showed an improving trend on costs-over-target. NAVSEA did not have a large enough sample size to analyze.

This highlights a further difference at the acquisition command level that was not apparent in the Military Department level data. Here the effect is somewhat weaker in that work content only explained 69 percent of the variation in the cost growth data, but it still indicates that AAC showed a more favorable result mostly because it controls work content better than

JM&LLCMC. Again, data analysis is helping us to begin explaining why some institutions perform better than others. We still do not know *how* AAC controlled work content more, but that control is *why* they perform better on munitions developments.

Aircraft: Early Production

Table 2-22 compares the relative outcomes of contracts nominally by NAVAIR and ASC on 73 MDAP early production contracts from June 1992 to December 2011.

Table 2-22. Relative Performance of NAVAIR and ASC on Aircraft Early Production MDAP Contracts (1970–2011).

Aircraft Early Production (n = 73)		
Variables (medians):	NAVAIR (n = 29)	ASC (n = 44)
Total cost growth	2%	* 8%
Work content growth	1%	* 4%
Costs-over-target	* 0%	0%
Schedule growth	7%	* 38%
UCA rate	55%	27%
Duration (years)	4.3	4.5

**Statistically higher than unmarked values for this variable.*

Aircraft Early Production (n = 73)		
Trends	NAVAIR (n = 29)	ASC (n = 44)
Total cost growth		
Work content growth		
Costs-over-target		Upward
Schedule growth		
Duration (years)	Upward	

Blank cells had no measurable trends.

NOTE: Source cost data were reported in “then-year” dollars (unadjusted for inflation).

NAVAIR controlled total cost growth better than ASC by controlling work content better, although costs-over-target were measurably higher on NAVAIR aircraft contracts. As in development, NAVAIR controlled schedule growth better. ASC has a statistically significant long-term trend of larger costs-over-target on aircraft contracts.

As we found in analyzing development contracts, this highlights a difference at the acquisition command level that was not apparent in the Military Department level data. NAVAIR showed a more favorable result because it controls work content better than ASC.

Missiles: Early Production

The Army Aviation and Missile Life Cycle Management Command (AMCOM), NAVAIR, and the Air Force's Air Armament Center (AAC) were analyzed next.

Table 2-23. Relative Performance of JM&LLCMC, NAVSEA, and AAC on Missile Early Production MDAP Contracts (1970–2011).

Missile Early Production (n = 136)

Variables (medians):	AMCOM (n = 30)	NAVAIR (n = 42)	AAC (n = 64)
Total cost growth	* 10%	2%	7%
Work content growth	* 8%	1%	2%
Costs-over-target	* 1%	* 0%	-2%
Schedule growth	* 20%	7%	0%
UCA rate	3%	24%	16%
Duration (years)	4.1	3.8	4.0

**Statistically higher than unmarked values for this variable.*

Missile Early Production (n = 136)

Trends	AMCOM (n = 30)	NAVAIR (n = 42)	AAC (n = 64)
Total cost growth		Downward	
Work content growth		Downward	
Costs-over-target			
Schedule growth	Downward		
Duration (years)			

Blank cells had no measurable trends.

NOTE: Source cost data were reported in "then-year" dollars (unadjusted for inflation).

NAVAIR and AAC both were lower than AMCOM in total cost and work content; AAC was lower than both AMCOM and NAVAIR on costs-over-target. NAVAIR and AAC were both lower than AMCOM in schedule growth. NAVAIR had an improving trend in total cost and work content growth and AMCOM showed an improving trend in schedule growth. Again, this level of analysis indicates that NAVAIR and AAC show more favorable results predominantly because they control work content better than AMCOM.

INSTITUTIONAL ANALYSES: PRIME CONTRACTORS

This section summarizes a comparison of cost and schedule growth among the major prime defense contractors on development and early production MDAP contracts. Table 2-24 shows the groupings employed to deal with consolidation of legacy companies into the current defense prime contractors cited. Here we broke out five major primes and grouped the others into a single set.

Table 2-25 and Table 2-26 show a breakout of the number of MDAP development and early production contracts, respectively, including the share (fraction) by number and by dollar value.

Table 2-24. Major Prime Contractor Groupings after Consolidation.

"**Lockheed Martin**" included contracts with the following companies:		
Gould	Marinette (for shipbuilding)	
Lockheed	Martin Marietta	
Longbow LLC (joint venture with Northrop Grumman)	MEADs International	
	Sperry	
"**Boeing**" included contracts with the following companies:		
Hughes Helicopter		
McDonnell Douglas		
Rockwell		
"**Northrop Grumman**" included contracts with the following companies:		
Avondale (shipbuilding)	Litton	
Grumman	Newport News	
Huntington Ingalls (spin-off for ship construction)	Northrop	
Intermarine (shipbuilding)	Tenneco (shipbuilding)	
"**General Dynamics**" included contracts with the following companies:		
Bath Iron Works	GMGDLS	
Electric Boat	NASSCO (shipbuilding)	
"**Raytheon**" included contracts with the following company:		
Hughes Aircraft (missiles)		
"**Others**" included contracts with the following companies:		
Aerojet	Garrett	LTV
Alliant (including Honeywell propulsion)	General Atomics	MDTT
AT&T	General Electric	Texas Instruments
Austal	GTE	Thiokol
Autonetics	Honeywell (engines)	TRW
AVCO	Hercules	Unisys
Bell Textron	IBM	United Technologies (including Sikorsky and Pratt & Whitney)
Eaton	Interstate Electronics	
Fairchild	LHTEC	Vought
FMC	Logicon	Westinghouse
Ford Communications and Aerospace	Loral	Williams International

Table 2-25. Data on Prime Contractor Shares of Development Contracts (1994–2011).

Development Shares (1994-2011), n = 157

Company	Number of MDAP contracts	Share of MDAP contracts (by number)	Share of MDAP contracts by $ value
Lockheed Martin	40	25% ↑	42% ↑
Boeing	28	18%	19% ↓
Northrop Grumman	26	17%	19% ↓
General Dynamics	14	9%	4% ↓
Raytheon	21	13%	5% ↑
All others	28	18%	12% ↓
Total	157	100%	100%

NOTE: Red arrows indicate direction of change in share value since 1994.

Table 2-26. Data on Prime Contractor Shares of Early Production Contracts (1994-2011).

Early Production Shares (1994-2011), n = 100

Company	Number of MDAP contracts	Share of MDAP contracts (by number)	Share of MDAP contracts by $ value
Lockheed Martin	14	14% ↑	18% ↑
Boeing	20	20%	22% ↓
Northrop Grumman	31	31%	26% ↑
General Dynamics	12	12%	21%
Raytheon	5	5%	1% ↓
All others	18	18%	12%
Total	100	100%	100%

NOTE: Red arrows indicate direction of change in share value since 1994.

We used FY1994 as the start point for this analysis because it began a new period of industry consolidation.[15] We analyzed 157 development contracts and 100 early production contracts from FY1994–2011. Additional analysis was conducted to assess relative performance among prime contractors for various commodity types.

The only two breakdowns that contained sufficient data for statistical analysis after partitioning by both commodity type and prime contractors were aircraft (development and early production) and ships (early production only. No difference was found in ship development contracts due to the small sample size).

[15] Deputy Secretary of Defense William Perry told industry in the fall of 1993 that budget cutbacks will require major consolidations. Thus, 1994 would be an appropriate starting point when examining industry performance.

Cost and Schedule: Development Contracts

Table 2-27 shows the cost and schedule outcomes by prime contractor for all development contracts from FY1994 to December 2011.

Table 2-27. Cost and Schedule Growth by Primes on DoD-Wide Development Contracts (1994–2011).

	Development Contracts (medians)						
Variables:	Lockheed Martin	Boeing	Northrop Grumman	General Dynamics	Raytheon	All Others	*Total sample*
Total cost growth	** 42%	** 46%	** 31%	** 36%	* 25%	16%	*28%*
Schedule growth	1%	** 17%	* 6%	* 6%	0.0%	0.0%	*4%*

***Statistically higher than all other values for this variable (not considering total sample column).*
** Statistically higher than unmarked values for this variable (not considering total sample column).*
NOTE: Source cost data were reported in “then-year” dollars (unadjusted for inflation).

Most of the major primes except Raytheon (Lockheed Martin, Boeing, Northrop Grumman, and General Dynamics) had statistically similarly total cost growth on development contracts. Raytheon was lower, and the remaining primes (as a group) were lower than Raytheon. All values shown are medians.

For schedule growth, Boeing had the highest statistically, followed by Northrop Grumman and General Dynamics. Lockheed, Raytheon, and all others (as a group) were the lowest. All values shown are medians.

Table 2-28 now examines just contracts for aircraft development by the three prime contractors.

Table 2-28. Cost and Schedule Growth by Primes on Aircraft Developments (1994–2011).

	Aircraft Development Contracts (medians)			
Variables:	Lockheed Martin	Boeing	Northrop Grumman	*Total sample*
Total cost growth	56%	52%	* 162%	*72%*
Schedule growth	–9%	* 39%	4%	7%

Program	Contractor
F35	Lockheed Martin
C-130J Block Upgrade	Lockheed Martin
MH-60R	Lockheed Martin
MV-22	Boeing
Apache Block 3	Boeing
P8A	Boeing
Comanche	Boeing
UAS BAMS	Northrop Grumman
Global Hawk	Northrop Grumman

**Statistically higher than all other values for this type of growth (not considering total sample column).*
NOTE: The table on the right lists the programs by name and contractor. Source cost data were reported in “then-year” dollars (unadjusted for inflation).

Analyzing just aircraft development contracts, Northrop Grumman had significantly higher total cost growth than Lockheed Martin and Boeing.

As for schedule growth, Boeing had the highest. Lockheed Martin's median schedule growth, while negative, is not significantly different that Northrop Grumman's value.

Table 2-29 now examines just contracts for ship development by the two prime contractors.

Table 2-29. Cost and Schedule Growth by Primes on Ship Development (1994–2011).

Ship Development Contracts (medians)

Variables:	**Northrop Grumman**	**General Dynamics**	***Total sample***
Total cost growth	42%	45%	*49%*
Schedule growth	22%	47%	*27%*

Whether the differences in these values are statistically significance could not be tested due to low sample size.

Program	Contractor
CVN 78	Northrop Grumman
LHA 6	Northrop Grumman
CVN 21 CP FY05	Northrop Grumman
LPD	Northrop Grumman
LPD	Northrop Grumman
LPD	Northrop Grumman
LPD	Northrop Grumman
LPD	Northrop Grumman
LPD	Northrop Grumman
LCS	General Dynamics
LCS	General Dynamics
DDG 1000	General Dynamics
DD(X)	General Dynamics

NOTE: The table on the right lists the programs by name and contractor. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

As mentioned above, for ship development, we found no statistically significant differences among the major primes due to the small sample size.

Cost and Schedule: Early Production Contracts

As compared to the analysis for development contracts, the production data shows a partial shift in total cost growth to the pool of non-major primes and shifts in abilities to meet schedules (see Table 2-30).

Table 2-30. Cost and Schedule Growth by Primes on DoD-Wide Early Productions (1994–2011).

	Early Production Contracts (medians)						
Variables:	Lockheed Martin	Boeing	Northrop Grumman	General Dynamics	Raytheon	All Others	*Total sample*
Total cost growth	* 8%	0.3%	2%	** 15%	** 16%	** 37%	*9%*
Schedule growth	3%	* 15%	0.0%	2%	** 29%	1%	0.0%

***Statistically higher than all other values for this variable (not considering total sample column).*
** Statistically higher than unmarked values for this variable (not considering total sample column).*
NOTE: Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Three of the five major primes had lower total cost growth than the pool of remaining contractors along with General Dynamics and Raytheon. Lockheed Martin was better; Boeing and Northrop Grumman were better still.

Breaking down total cost growth into its constituents, the pool of "All Other" prime contractors had the highest work content growth. Lockheed Martin and Northrop Grumman were lower and statistically similar; Boeing, General Dynamics, and Raytheon's levels were similar among themselves. On cost-over-target, General Dynamics and the "All Other" group were the highest, followed by Lockheed Martin. Boeing, Northrop Grumman, and Raytheon were lower at statistically similar values.

As for schedule growth, Raytheon was the highest, followed by Boeing. Differences between the lower Lockheed Martin, General Dynamics, and "All Others" medians were not significant.

Table 2-31 now examines just contracts for early production aircraft by the three prime contractors.

Table 2-31. Cost and Schedule Growth by Primes on Early Production Aircraft (1994-2011).

Aircraft Early Production Contracts (medians)

Variables:	Lockheed Martin	Boeing	Northrop Grumman	*Total sample*
Total cost growth	* 9.5%	0.0%	2%	*4%*
Schedule growth	0.0%	17%	39%	*14%*

**Statistically higher than all other values for this variable (not considering total sample column).*

NOTE: The table on the right lists the programs by name and contractor. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Program	Contractor
F35	Lockheed Martin
F35	Lockheed Martin
V22	Boeing
V22	Boeing
V22	Boeing
V22	Boeing
V22	Boeing
V22	Boeing
V22	Boeing
V22	Boeing
V22	Boeing
V22	Boeing
V22	Boeing
CH47	Boeing
Ch47	Boeing
F/A18	Boeing
F/A18	Boeing
F/A18	Boeing
F/A18	Boeing
E2D	Northrop Grumman
E2D	Northrop Grumman
Global Hawk	Northrop Grumman
Global Hawk	Northrop Grumman
Global Hawk	Northrop Grumman
Global Hawk	Northrop Grumman
Global Hawk	Northrop Grumman
Global Hawk	Northrop Grumman
Global Hawk	Northrop Grumman

For aircraft early production, Lockheed Martin had higher total cost growth than Boeing and Northrop Grumman, driven by costs-over-target on the first two F-35 low-rate initial production (LRIP) contracts. In this case, further analysis revealed that cost-over-target was the major contributor to total cost growth on LRIP 1 and 2. Work content on these two contracts was stable (and, in fact, slightly negative), as it was on the Boeing and Northrop Grumman aircraft early production contracts.

Differences in schedule growth are not statistically significant for aircraft early production.

Table 2-32 now examines just contracts for early production ships by the two prime contractors.

Table 2-32. Cost and Schedule Growth by Primes on Early Production Ships (1994-2011).

Ship Development Contracts (medians)

Variables:	Northrop Grumman	General Dynamics	*Total sample*
Total cost growth	27%	24%	27%
Schedule growth	0.0%	5%	0.0%

Differences are not statistically significant.

NOTE: The table on the right lists the programs by name and contractor. Source cost data were reported in "then-year" dollars (unadjusted for inflation).

Program	Contractor
Arleigh Burke	Northrop Grumman
Arleigh Burke	Northrop Grumman
Arleigh Burke	Northrop Grumman
CVN 77	Northrop Grumman
LHD 7	Northrop Grumman
Arleigh Burke	General Dynamics
Arleigh Burke	General Dynamics
Arleigh Burke	General Dynamics
T-AKE	General Dynamics
T-AKE	General Dynamics
T-AKE	General Dynamics
SSN 778	General Dynamics
SSN 779	General Dynamics

For ship early production, the total cost growth and schedule growth differences are not statistically significant.

This analysis will be extended and expanded in subsequent reports.

3. Needs for Additional Analysis

Policies and Processes for Further Analysis

This report is just the beginning. We do not have all the answers, but it is important to share what we do know and start down the road for further progress toward understanding performance and answering those questions.

Many policies and processes have changed in past attempts to improve acquisition. Our efforts to pursue data-driven analysis are building a capacity to more clearly understand the effectiveness of these policy changes so we can keep those that work and replace those that do not. We recognize the need to focus further efforts on candidates that we hypothesize may be major contributors for change. The following list illustrates some candidates for which the Department is pursuing data and analytic approaches:

- Cost growth on MDAP sustainment costs
- Cycle time trends and effects on decision quality and meeting mission needs
- Meeting key system performance requirements
- Setting Preliminary Design Review (PDR) before Milestone B
- Competitive Prototyping for Risk Reduction, not Proof of Concept
- Reducing technical risks during Technology Development phase
- Cost and schedule growth relationships between contract-level and program-level
- Better Buying Power (e.g., should-cost; see below)

Better Buying Power

AT&L is instituting a series of continuous improvement initiatives under the Better Buying Power (BBP) effort[16] to improve the performance of the defense acquisition system to improve efficiency and cost-saving processes. Implementation of these efforts continues, and we are pursuing data collection activities to enable analysis of whether and to what degree these initiatives improve acquisition performance. Version 2.0 of Better Buying Power was implemented in April 2013 and continues and expands upon initiatives begun in 2010. Version 2.0 has seven focus areas, including a new one on the importance of our acquisition workforce.

[16] See http://bbp.dau.mil/.

Further, Better Buying Power includes a strong emphasis on data collection and analysis to understand the effectiveness of the policies and processes addressed both within the BBP initiatives, and more generally across the entire acquisition enterprise.

For example, a key effort begun as part of the 2010 Better Buying Power initiative was the implementation of “should cost” based management, which is fundamental to controlling costs through the acquisition life cycle. Managers have been tasked to establish “should cost” goals by scrutinizing each element of cost, then taking action to purse these potential cost savings. In FY2012 approximately one-third of all Acquisition Category (ACAT) I/II/III programs within the Military Departments had implemented should-cost; and reporting on program should-cost execution savings in FY2012 showed roughly 2 percent to 3 percent savings realized in FY2012 in these programs, as compared to budget levels. These savings typically have been plowed back into the programs to gain higher productivity.

Gaps in Existing Analysis

The analysis in this report evolved through exploration of data and analytic approaches over the last 2 years. As a result, earlier analyses such as the DOT&E assessments of weapon system performance do not have the latest results and thus could be updated in subsequent reports when considered worthwhile.

Other gaps result from either insufficient data (i.e., low sample count) or nonexistent data to address a particular performance area. Even with the large set of MDAP contracts we used, for example, splitting between Military Departments in recent periods (e.g., 2005–2011) and especially when also splitting by commodity type (as in our analysis of acquisition commands) can result in insufficient data to reach statistical conclusions.

Even more importantly, perhaps, this stream of MDAP contract data requires a long time before we can attempt to measure the effects of major policies (e.g., measuring whether cost growth was lower after 2009 when the Weapon Systems Acquisition Reform Act became law and the effects will take). Similarly, at the program level, 1 or 2 years of lower cost growth may or may not indicate a long-term trend.

Finally, the data must have relevant variables or parameters at the transaction level (e.g., per contract) that relate to a topic of interest. If our data only show, for example, that an entire Military Department follows a certain process that makes it difficult to test the implications of that process because the result will correlate to the Department rather than the process. We need data on cases in all Military Departments when they followed the common process and when they did not to attempt measurement of that process’ effectiveness.

In addition to identifying data, different analytic approaches and models were created over the last 2 years. Some are more sophisticated than others, and some merely partition the data in different ways. While multiple analytic results can be confusing, examining the data in different ways helps to validate findings and ensure that they are robust. For example, different analyses identified measurable improvement trends in controlling total contract cost growth. Although the magnitude of the improvements vary somewhat, they are similar and thus support the robustness of the finding. Likewise, different analyses show that UCAs tend to contribute to cost growth only on development contracts (although to different degrees in different sets of data). The consistency of these observation helps to instill confidence in the analysis and any lessons we conclude. Our efforts will continue to seek and adjust analytic methods to the available data and question.

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4. CONCLUDING COMMENTS

Taken together, measuring the performance of defense acquisition provides objective, quantitative information on our current performance. The following insights provide some broader perspectives and considerations. These should inform and enable stable improvement in our overall acquisition performance.

Acquisition as an Endeavor

Competing measures of performance. Contextually, we note that the time required to acquire next-generation capabilities is often longer than the strategic threat and technology cycles these capabilities are meant to address. Performance (good or bad) in planned defense acquisition is intertwined with cost and schedule implications from unplanned responses to these external demands. This is not an excuse for cost and schedule growth, but an observation from first principles that changing threats and needs can add costs and delays relative to original baselines as ongoing acquisitions are adjusted.

Acquisition is about risk management—not certainties. Especially for major weapons systems acquisitions (which almost always involve research and development), uncertainties imply cost, schedule, and performance risks relative to early estimates. These risks diminish as we move from research to development through production to sustainment, but their realization may result in cost and schedule growth. These risks also require use of different management tools (such as the right contract types and incentives) at different stages to mitigate risks and motivate industry to achieve the lowest possible total price to the government. We must monitor and explain risks, but it is important to remember that developing technologically superior military capability is not a risk-free endeavor.

Intelligent acquisition is key. Analysis confirms many acquisition fundamentals and the need for informed judgments. For example, analysis is revealing that UCAs can be successfully employed in early production but are concerns for developmental work. In another example, no single contract type (e.g., fixed price or cost-reimbursed) yields better cost control; thus, we need to rely on best practices to select the most appropriate contract type and incentive structure given the maturity, system type, and acquisition strategy for each system.

Beyond analysis, experience also leads us to assert that basic acquisition fundamentals work. Premature contracting without a clear and stable understanding of engineering and design issues greatly affects contract work content stability and cost growth. In addition, first principles indicate that concurrent production when designs are unstable can impose added retrofit costs for early production products. Further analysis of past performance will provide an objective foundation for informing future policies and acquisition decisions.

Programs with bad starts often continue to have problems. Early work content stability on a contract predicts lower total cost, work content, and schedule growths (but not costs-over-target) on development and early production contracts. Also, cost growth on development contracts correlates strongly with cost growth on subsequent early production contracts. Independent analysis compared RDT&E program-level cost growth from SARs to growth in procurement unit costs; regression analysis showed that each 10 percentage-point increase in RDT&E would be expected to produce an increase of 6 points in APUC (Davis, 2011).

No single contract type is best. Analysis of past acquisitions shows that, when controlling for other factors that contribute to contract cost performance, contract type alone (e.g., fixed price or cost-reimbursable) does not predict lower cost growth in development or early production contracts. This suggests that relying on contract type alone to achieve better affordability outcomes will not likely be successful. This does not absolve us from the need to carefully consider and select the most appropriate contract type given the maturity, system type, and business strategy for each system.

On Measuring Performance

Institutional differences are informative. Performance differences between Military Departments, acquisition commands, prime contractors (and even acquisition executives) reveal clues for improvement and potential areas ripe for analysis. However, more needs to be done to understand the causes of these differences and identify transferable shared practices. For example, NAVAIR controlled total contract cost growth better than ASC by controlling contract work content better, but how NAVAIR controlled work content relative to changing needs is not yet clear, nor how much of that added work content was unavoidable.

Institutional differences are not always decisive. A major shift in our analytic approach is the examination of *institutional* performance as opposed to the performance of individual *programs*. Significant insights have been made, especially in comparing the performance of acquisition commands when acquiring the same types of systems. In many cases, however, the analysis found that institutional differences—while statistically significant—are not large nor do they explain much of the variation in performance. In these cases, focusing on reducing these performance differences will return little for our effort.

Performance relative to original baselines does not guarantee lowest end cost to the taxpayers. Baselines at Milestone B are static yet help to control appetites and provide valuable triggers to explain substantial changes. Original baselines at Milestone B provide a useful reference point for subsequent cost and schedule performance, but developmental uncertainties, changing operational needs, and other mechanisms for controlling costs make such baselines somewhat arbitrary and misleading if used as absolute reference points. Techniques to control immediate costs and moderate capability appetite (e.g., block upgrades; taking content out of a program; postponing fixes until sustainment) can control cost relative to certain baselines yet delay capabilities and push added costs into (monitored or unmonitored) future activities. Still, baselines are useful tools to help monitor costs and ground agreements within the Department and with Congress on what we are acquiring and at what cost. Moreover, in-depth monitoring of cost growth at different levels and in different ways helps to increase transparency and the Department's cost consciousness in balancing timely acquisition of warfighter capabilities while being responsible to the taxpayers.

Contract measures help inform causes of cost and schedule growth. For example, total contract cost growth can be split between work content purposely added to a contract and costs-over-target. Contract work content growth dominates total cost growth statistically, but costs-over-target also are significant and worrisome. Cost-over-target reflects poor performance, poor estimation, or faulty framing assumptions and generally is bad. Work content growth, on the other hand, may (in part) reflect normal, necessary additions that resolve and reduce problems from technical and engineering uncertainties. Still, requirements creep can be a factor in work content growth and needs to be recognized and subject to affordability constraints.

Current Acquisition Performance

Current execution performance is mixed. Performance across all MDAPs at the *program* level is highly skewed, with a few outliers with extremely high cost growth, a large population with moderate cost growth, and a small number with negative or negligible cost growth. Over the last 10 years analyzed, median program RDT&E cost growths have ranged from 5 percent to 18 percent (inflation adjusted), while median quantity-adjusted program unit costs have ranged from 3 percent to 9 percent (inflation adjusted), measured against original Milestone B baselines. While unacceptable, problems on some programs such as the F-35 mask the fact that some DoD programs perform relatively well, raising the question of how the Department can be more consistent in its performance.

Performance at the MDAP *contract* level also is highly skewed, but the cost growth is higher than measured at the program level. Twenty-year median total cost growth has been about 31 percent (unadjusted for inflation) on development contracts and 10 percent (unadjusted for inflation) on early production contracts, measured against original contract cost targets. Between organizations, performance varies significantly between Military Departments, acquisition commands, and commercial companies in measurable ways, suggesting questions of why and whether lessons learned can be shared to improve performance. While not excusing poor performance, large commercial projects also exhibit significant and skewed cost growths similar to those in the DoD. This helps to support the hypothesis that technical and engineering risks on complex, state-of-the-art systems are somewhat unpredictable, contributing to cost and schedule growth.

Performance is improving. Some program and organizational performances are better in some measures, but more progress is needed. Very recent data show statistically significant improvement, but only further analysis will tell if these trends continue into the future. For example, comparing the last 2 decades, the Army and Air Force have reduced total cost growth on contracts, and the Army has reduced contract costs-over-target. The Air Forcealso has lowered contract schedule growth. Despite such trends, the magnitude of absolute performance issues leaves considerable room for additional improvement.

Affordability will be a major challenge in the next few years. While most cost growth measures are improving, median cost growth across the MDAP portfolio is not zero and will likely lead to near-term affordability challenges given flat or declining fiscal resources. Achieving affordability by removing capability or requirements may help reduce cost growth, and SAR reports at the program level, and work content measures at the contract level should reveal whether such actions are being taken.

A. Abbreviations

AAC–Air Armament Center [Air Force]

AEHF–Advanced Extremely High Frequency

AFATDS–Advanced Field Artillery Tactical Data System

AFMC–Air Force Materiel Command

AMC–Army Material Command

AMCOM–Aviation and Missile Command [Army]

AMP – Avionics Modernization Program

AoA–Analysis of Alternatives

APUC — Average Procurement Unit Cost

ARH–Armed Reconnaissance Helicopter

ASC–Aeronautical Systems Center [Air Force]

AT&L–Acquisition, Technology, and Logistics

BAMS–Broad Area Maritime Surveillance

CBB—Contract Budget Base

CEDD–Continuing Engineering Design/ Development

CJR–Cobra Judy Replacement

CPAF—Cost Plus Award Fee

CPFF—Cost Plus Fixed Fee

CPIF—Cost Plus Incentive Fee

DDS–Dry Dock Shelter

DoD–Department of Defense

DOT&E—Director, Operational Test and Evaluation

DSUP–Defense System Upgrade Program

DVH–Double-V Hull

EFV–Expeditionary Fighting Vehicle

EMD—Engineering, Manufacturing and Development

FAB-T–Family of Advanced Beyond-line-of-sight Terminals

FCS–Future Combat Systems

FPIF—Fixed Price Incentive Firm

FFP—Firm Fixed Price

FY—Fiscal Year

Granite Sentry–aircraft tracking system

GBR–Ground Based Radar

GBS–Global Broadcast Service

GCCS–Global Command and Control System

GCSS–Global Combat Support System

GPS–Global Positioning System

IAMD–Integrated Air and Missile Defense

JASSM–Joint Air-to-Surface Stand-off Missile

JDAM–Joint Direct Attack Munitions

JHSV–Joint High Speed Vessel

JLENS–Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System

JM&LLCMC—Joint Munitions and Lethality Life Cycle Management Command

JSF–Joint Strike Fighter

JSOW–Joint Stand-off Weapon

JSTARS–Joint Surveillance Target Attack Radar System

JTRS–Joint Tactical Radio System

KPP—Key Performance Parameter

LADS–Laser Area Defense System

LRIP–Low-Rate Initial Production

MDA–Milestone Decision Authority

MDAP—Major Defense Acquisition Program

MDD–Materiel Development Decision

MEADS–Medium Extended Air Defense System

MIDS-LVT–Multi-functional Information Distribution System–Low Volume Terminal

MRAP–Mine Resistant Ambush Protected

MS–Milestone

MUOS–Mobile User Objective System

NAVAIR–Naval Air Systems Command

NAVSEA—Naval Sea Systems Command

PAC-3–Patriot Advanced Capability– 3

PARCA—Performance Assessments and Root Cause Analysis

PAUC—Program Acquisition Unit Cost

PM EAC—Program Manager Estimate at Completion

RDT&E—Research Development Test and Evaluation

SAE–Service Acquisition Executive

SAR—Selected Acquisition Report

SBIRS–Space-based Infrared System

SCAMP–Single-channel Anti-jam Man-portable

TMD–Theater Missile Defense

UCA—Undefinitized Contract Action

U.S.C.—United States Code

USD–Under Secretary of Defense

WIN-T–Warfighter Information Network – Tactical

B. Indices

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C. References

Arena, Mark V., Abby Doll, and Megan McKernan, Santa Monica, Calif.: RAND Corporation, unpublished research on framing assumptions, 2012.

Arena, Mark V., Robert S. Leonard, Sheila E. Murray, and Obaid Younossi, *Historical Cost Growth of Completed Weapon System Programs*, Santa Monica, CA: RAND Corporation, TR-343-AF, 2006. http://www.rand.org/pubs/technical_reports/TR343.html

Augustine, Norman R. "The Last Supper, Revisited: Meeting Ignited Inevitable Consolidation," *Defense News*, June 26, 2006.

Bliss, Gary R., *Performance Assessments and Root Cause Analyses: 2012 Annual Report*, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Washington, D.C.: U.S. Department of Defense, March 2012a.

Bliss, Gary R., "Observations from AT&L/PARCA's Root Cause Analyses," briefing to NDIA ICPA, February 29, 2012b.

Bliss, Gary R., *Report to Congress on Performance Assessments and Root Cause Analyses*, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Washington, D.C.: U.S. Department of Defense, 2013.

Cancian, Col Mark F., USMCR (Ret.), "Cost Growth: Perception and Reality," *Acquisition Research Journal*, Defense Acquisition University, July, 2010. http://www.dau.mil/pubscats/PubsCats/AR%20Journal/arj55/Cancian_55.pdf

Davis, Dan, *Pay Me Now and Pay Me Later: The Effect of R&D Cost Growth on Subsequent Procurment Costs*, Alexandria, VA: CNA, CRM D0024982.A1/Final, May 2011.

Decker, Gilbert and Louis Wagner. "Army Strong: Equipped, Trained and Ready, Final Report of the 2010 Army Acquisition Review." January 2011.

Deutch, John, "Consolidation of the U.S. Defense Industrial Base," *Acquisition Review Quarterly*, Fall 2001.

Flyvbjerg, Bent, Mette Skamris Holm, and Søren Buhl. "Underestimating Costs in Public Works Projects: Error or lie?" *Journal of the American Planning Association* (Chicago: American Planning Association) 68(3): 279–295, 2002.

Merrow, Edward W., Kenneth E. Phillips, and Christopher W. Myers, *Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants*, Santa Monica, Calif.: RAND Corporation, R-2569-DOE, 1981. http://www.rand.org/pubs/reports/R2569/

Reeves, L. S. (1996). *The Ghost of Acquistion Reform: Past, Present, and Future.* The Industrial College of the Armed Forces. Washington, D.C.: National Defense University.

Toll, Ian W., *Six Frigates*, New York, NY: W. W. Norton & Company, Inc., 2006.

U.S. Department of Defense, Office of the Under Secretary of Defense (Comptroller) / Chief Financial Officer, *Program Acquisition Costs by Weapon System*, February 2012. http://comptroller.defense.gov/defbudget/fy2013/FY2013_Weapons.pdf

U.S. General Accounting Office (now U.S. Government Accountability Office), *NASA Program Costs: Space Missions Require Substantially More Funding Than Initially Estimated*, Washington, D.C., GAO/NSIAD-93-97, December 1992. As of January 16, 2007: http://archive.gao.gov/d36t11/148471.pdf

———, NASA: Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management, Washington, D.C., GAO-04-642, May 2004. As of January 16, 2007: http://www.gao.gov/new.items/d04642.pdf

Younossi, Obaid, Mark V. Arena, Robert S. Leonard, Charles Robert Roll, Jr., Arvind Jain, Jerry M. Sollinger, *Is Weapon System Cost Growth Increasing? A Quantitative Assessment of Completed and Ongoing Programs*, Santa Monica, Calif.: RAND Corporation, MG-588-AF, 2007. http://www.rand.org/pubs/monographs/MG588.html