Approved for public release; distribution unlimited.

Cost Growth in Major Weapon Procurement Programs

David L. McNicol

DATE: OCT 04
PNumber: NSP-3832
Log Number: H03-002170
Cy: 10

INSTITUTE FOR DEFENSE ANALYSES
5 0598 00233337 7

Institute for Defense Analyses
IDA

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Copyright 2004
Institute for Defense Analyses
ISBN 0-9762550-0-6

Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, Virginia 22311-1882

Phone: 703-845-2000

Approved for public release; distribution unlimited.

Copyright IDA/Scanned June 2007

Approved for public release; distribution unlimited.

Cost Growth in Major Weapon Procurement Programs

David L. McNicol

Institute for Defense Analyses

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Preface

The Institute for Defense Analyses (IDA) prepared this publication, IDA Paper P-3832 (Nonstandard), under IDA's Independent Research Program. It provides a detailed analysis of the causes of growth in the procurement costs of major acquisition programs from those estimated when the programs entered into the Engineering and Manufacturing Development phase.

David R. Graham, Michael Leonard, J. Richard Nelson, and Karen W. Tyson of IDA were the technical reviewers for this paper.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Acknowledgements

This study had its origins in the occasional lectures on cost growth on major weapon acquisition programs that I gave at the Defense Systems Management College (DSMC) from the early 1990s through my retirement from the Department of Defense (DoD) in September 2002. I learned a great deal from the men and women, all seasoned acquisition professionals, who took part in those sessions. The shortcomings of this study are entirely my responsibility, but the point of view that it embodies owes a great deal to conversations over many years with my former colleagues in the Resource Analysis deputate of the Office of Program Analysis and Evaluation. I am especially indebted to Gary Bliss, who worked with me on the DSMC lectures (and delivered a few of them), the late Bryan Jack, Jerry Pannullo, Mark Daley, and John McCrillis. During her tenure as a summer intern at the Institute for Defense Analyses (IDA), Kristel Adler did the hard work with DoD reports reflected in Chapter 4, and she helped out on other parts of the study (particularly Appendix E). As is suggested by citations that appear throughout the study, I have also profited from prior work on the topic done at IDA and from conversations with IDA colleagues about it. I owe particular debts to Gen. Larry Welch, USAF (Ret.), former President of IDA, and Steve Balut, Director, Cost Analysis and Research Division, for providing me with the support required to complete this project.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Table of Contents

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

List of Figures

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

List of Tables

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Summary

The root question behind this study is whether, as a matter of public policy, the cost growth experienced on those systems constitutes a substantial case for strengthening the process the Defense Department uses to avoid instances of large cost growth on weapon system procurements. This is a question about DoD management practices. It encompasses not only the process used to forecast the likely cost of proposed systems, but also the processes used to establish, fund, and manage system acquisition programs. IDA examined growth in the costs of procuring 138 weapon systems undertaken by the Department of Defense (DoD) during 1970 through 1997, measured against an initial forecast of what those costs would be.

Point of Departure

Throughout the 25 to 50 years of a major weapon system's life, many estimates of its costs are made for a variety of purposes by different organizations inside and outside the Government. This study was concerned with the cost estimates for major weapon systems made by offices within the Defense Department as a basis for budgeting. More specifically, it was concerned with the procurement (and not the development) portion of the cost estimate made at the point that the Defense Department commits to acquiring a system. During the years 1970–1997, this ordinarily was at Milestone II. At that point, a system typically had been in development for several years and, in some cases, a prototype had been built. The Milestone II decision authorized the detailed design of the system and the means used to manufacture it, construct a number of test articles, and conduct extensive testing. Since the mid-1980s, this phase has been called Engineering and Manufacturing Development (EMD). Production of the system ordinarily requires a separate approval, which usually would come towards the end of EMD.

In 1972, the Defense Department adopted the basic elements of the process still used today to ensure that the budgets for weapon system acquisition programs are informed by realistic cost estimates—cost estimates made by an independent office and informed by historical experience. There have since been two major and many minor changes in the process. Several studies have considered whether instituting independent costing in the Defense Department had the intended effect of improving the initial cost estimates for major systems and, hence, in reducing cost growth. All found that it did so to a marked extent.

Nevertheless, for many the point of entry into a discussion of cost growth on DoD procurement programs often must be the following question: If the Defense Department is budgeting for major weapon systems on the basis of

Approved for public release; distribution unlimited.

unbiased and professionally competent cost estimates, why does the Defense Department never overestimate resource requirements? The answer is that it does. But the only systematic data on weapon system cost growth that the Defense Department collects makes this fact difficult to see.

To be usable, the data collected must be normalized in two respects. First, all of the dollar values should be stated in the same year's dollars. Second, it is necessary to account for the fact that the actual cost observed reflects both cost growth and the actual number of the systems acquired, which may be quite different from the number assumed in the Milestone II cost estimate. Hence, to isolate cost growth, it is necessary to restate actual costs based on the number of systems the Defense Department planned to acquire at Milestone II. Once the data are normalized, it becomes clear that about 30 percent of the major systems the Defense Department acquired over the period 1970–1997 showed negative cost growth—that is, the actual costs of procuring the number of systems assumed at Milestone II proved to be less than forecasted.

This study used data that attempts one further refinement. This is the exclusion of growth in procurement cost due to unforced changes in the capabilities of the system procured, or other aspects of program content. It remains true for these more refined data that about 30 percent of the 138 systems in the sample showed negative cost growth. Moreover, the cost growth for about 80 percent of the 138 systems in the sample fall into a roughly bell-shaped distribution, with a maximum procurement cost growth of 30 percent and an average of only about 3 percent. An average error of 3 percent seems very creditable for cost estimates made at a point when the systems will remain in development for 6 to 10 years and then be bought over an additional 10 to 20 years.

The DoD process is noticeably imperfect, however. About one out of five systems experienced cost growth of more than 30 percent. This subset of the sample had an average growth in procurement cost of about 70 percent.

Is There Still a Problem?

It is necessary in the light of these facts to start with the question of whether growth in the costs of major defense acquisition programs (MDAPs) remains enough of a problem to warrant further corrective action.

Providing a clear answer to that question requires an explicit criterion for determining the damage growth in procurement cost causes. One relevant criterion is suggested by characterization of the budget established for a major acquisition program as a contract between the Defense Department and the Congress. The issue this criterion points to is not in any straightforward sense one of damage, but of control. The decisions that the Congress makes on the budgets for weapon system procurement programs must be reopened later to

Approved for public release; distribution unlimited.

the extent that they rested on seriously flawed cost estimates. Substantial errors in forecasts of weapon system costs thus entail political costs, and they tend to reduce the Congress's effective authority over the allocation of defense resources.

Cost growth clearly was a problem by this political criterion in the late 1960s and early 1970s. It again became a political problem in the late 1970s and early 1980s. Since then, the correct answer to the question of whether growth in the costs of weapon system procurements has been a political problem probably is "no," although there have been a few instances in which it very nearly became one.

The other relevant criterion is an economic test. A reasonable standard is the total cost of procuring the program approved at Milestone II for a set of major acquisition programs. This is not measured simply by the amount of cost growth because, in terms of a familiar metaphor, the cost of acquiring a Rolls Royce isn't any less because someone promised it for the price of a Ford. Rather, the relevant measure is the amount by which the cost of the Rolls Royce the Defense Department decided to develop and pr™ocure increased because the Defense Department initially based the program on the false assumption that it could be acquired for the price of a Ford.

Errors in the amount of funding reserved for a program may be accommodated by a transfer of resources from other parts of the defense program, or by the addition of funds to the Defense Department. Alternatively, the resources required can be reduced by procuring fewer or less capable systems. Typically, the required funds are found in neither of these ways, but in the procurement accounts, by stretching the program that experienced the cost growth or stretching other acquisition programs. Stretching programs means that they are produced at a lower annual rate for more years and, hence, incur additional years of overhead costs. Through this mechanism, underestimation of funding requirements at Milestone II tends to increase the total cost attributed to the program.

This study presents a rough computation of the magnitude of this effect given the average growth in procurement costs over about the past 30 years due to forecasting errors and flaws in the Defense Department's execution of the program. The effect appears to be about equivalent to an annual tax of 2 to 8 percent on the procurement program. It is also relevant that about three-quarters of the 2 to 8 percent tax is due to the one system in five that experienced procurement cost growth of at least 30 percent. There has been no apparent tendency for the proportion of MDAPs that fall into this extreme cost growth tier to decline. In fact, the proportion was higher in the 1990s than it had been in the 1980s, although the average procurement cost growth shown by these systems did not return to pre-independent costing levels.

Approved for public release; distribution unlimited.

A tax of even 2 percent on a magnitude as large as the DoD budget for major weapon system procurement represents a sobering amount of resources. This is to say that growth in procurement cost, in particular the comparatively uncommon instances of extreme growth in procurement cost, remains a problem.

Importance of Various Causes of Cost Growth

The path from this conclusion to suggestions for ways to reduce cost growth leads directly to the decisionmaking processes in the Department of Defense. To identify what needs to be "fixed," we need to know what mechanisms generated the cost growth, or at least permitted it to occur, and the importance of each.

Identifying the mechanisms of cost growth is relatively simple. In broad terms, growth in procurement cost can occur in the following three ways within the Defense Department's management processes:

1. *Increased system capabilities.* A decision not forced by adverse events within the program is made to increase the capabilities of the system beyond what was approved at Milestone II and captured in the Milestone II procurement cost estimate.
2. *Unrealistic procurement cost estimates adopted at Milestone II.* The decision maker at Milestone II, for whatever reason, adopts an unrealistic estimate of procurement cost.
3. *Poor program execution or exceptional budget instability.* Cost growth in such cases would have been avoided with better program management or more budget stability.

The hard part of the study was finding ways of evaluating how much cost growth can be attributed to each of these mechanisms. The study did not tackle this problem in its entirety. Rather, the inquiry was directed largely to the 35 systems that showed extreme cost growth. As noted, these 35 systems account for about three-quarters of the damage done by growth in procurement cost over the period 1970–1997.

A statistical approach was used to explore the correlation between measured growth in procurement cost and a number of factors that would be expected to influence it. The results obtained are interesting and provide some help in understanding the causes of cost growth. For example, the statistical analysis is consistent with the well-established presumption that the military services (especially the Army) tend to prefer reasonably optimistic procurement cost estimates. The statistical results also indicate that growth in procurement cost tends to be greater on systems that have few precedents that can be used in projecting their costs. Nevertheless, the statistical results fall well short of explaining instances of extreme cost growth. Consequently, the study found it

Approved for public release; distribution unlimited.

necessary to draw on a variety of other sources of information, from case studies to patterns of cost growth in various groupings of major systems.

The study's main conclusions on the mechanisms of cost growth are as follows:

1. *Increased system capabilities.* Substantial increases in capability were introduced during EMD for 7 of the 35 systems showing extreme procurement cost growth. Patterns of cost growth also suggest that this was the case for the 7 systems that were modification programs adopted after 1988. It is likely that in these 14 cases, much of the extreme cost growth was due to a change in what was procured rather than to adoption of an unrealistic cost estimate at Milestone II.

   The pivotal question about the 14 systems in this category is whether the changes apparently introduced during EMD were unforced decisions to procure a more capable system or whether they were necessary to meet the requirements the system approved at Milestone II. Direct evidence for two systems indicates that the changes were unforced. This study inclines to the conclusion that at least most of the others were as well, in which case they fall under the first of the three cost growth mechanisms listed previously. This conclusion, however, rests entirely on circumstantial evidence.

2. *Unrealistic procurement cost estimates adopted at Milestone II.* The evidence presented does not rule out the adoption of an unrealistic cost estimate at Milestone II as the main cause of the extreme cost growth in 15 of the 35 instances of extreme procurement cost growth. The statistical results do tend to reject the popular notion that cost growth can be explained by the deliberate adoption at Milestone II of an unrealistic cost estimate. This conclusion leaves two possible explanations: (1) a straightforward, inadvertent costing error and (2) one of the major program assumptions on which the cost estimate rested proved to be unrealistic.

   Unfortunately, this study provides only a blurry picture of the relative importance of these two ways to arrive at an unrealistic cost estimate at Milestone II. The only general evidence we have on this point is that the mistakes component of procurement cost growth tends to be larger on systems with fewer precedents useful in cost estimation. This correlation points in the direction of inadvertent error and uncertainty in the independent cost estimate developed for the Milestone II review.

3. *Poor program execution or exceptional budget instability.* The study had only very limited means of gauging the effects of program management and budget instability. Budget instability certainly causes growth in procurement cost, and the study found fairly clear evidence that changes in acquisition management structure adopted in the late 1980s were associated with increased growth in procurement cost growth. As a general rule,

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

however, budget instability and ineffective program management do not seem to explain instances of extreme growth in procurement cost.

The exceptions to this rule are the six cases in the sample in which contractually binding commitments for the early stages of production were obtained through a competition for the development work authorized at Milestone II. This contractual strategy was a limited form of Total Package Procurement (TPP) used (almost always unsuccessfully) for a number of major weapon system acquisition programs in the 1960s. Each of the six systems for which a TPP-like procurement strategy was used was in the top cost growth tier, and there is no real doubt that the TPP-like contract was the problem that led to the growth in procurement cost experienced. Although the rationale for doing so may not be obvious, this study treats TPP-like contracts as an example of the third of the mechanisms of cost growth listed above.

How Might Procurement Cost Growth Be Reduced?

The following list pairs the main mechanisms of procurement cost growth with ways for reducing the number of programs that exhibit extreme cost growth due to those mechanisms:

1. *Employ spiral development.* Use of spiral development as specified in the new DoD acquisition process ordinarily precludes baseline changes while a system is in EMD. Thus, rigorous use of spiral development would block one of the main processes that resulted in extreme instances of procurement cost growth during the period considered in this study.
2. *Identify difficult-to-cost systems early in development.* An appropriate mix of data collection, demonstrations, and studies should be directed to provide adequate foundations for making a sound cost estimate when the system's sponsor seeks approval to proceed to the later stages of development.
3. *Limit TPP-like arrangements.* Such arrangements should be used, if at all, only for technologically undemanding systems with firm requirements and excellent prospects for stable funding.

Adoption of these recommendations would not entirely eliminate growth in procurement costs due to inadvertently poor forecasts of procurement cost, more or less deliberate acceptance of unrealistic Milestone II estimates, cost growth due to budget instability, use of a flawed contract mechanism, poor program execution, or decisions to increase capability that are not fully funded when they are made. It would not even eliminate all extreme instances of growth in procurement cost from these causes, since the recommendations made would not provide any additional means for precluding extreme cost growth from unique constellations of circumstances. However, adoption of these recommen-

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

dations could be expected to significantly reduce instances of extreme cost growth and, hence, the damage they do to the DoD program as a whole.

Broader Implications for DoD Processes

Some of the intermediate results of this study provide a commentary on DoD processes that may be more interesting and important than the recommendations in the previous section. Two of these warrant particular mention.

The first result concerns the role of budget strategy in the cost estimates—and, hence, the budgets—adopted at Milestone II. It is a safe bet that those outside the Defense Department assume that the dominant influence on weapon system costing is a desire on the part of the service sponsoring the program to ensure that it will be started. Advocates of a program may adopt a "camel's nose" strategy—that is, adopt an optimistic cost estimate in the hope of increasing the chances that the program will be approved by the Congress.

As noted previously, the statistical evidence indicates that the services prefer optimistic costing. There is no indication, however, that changes in the budget climate led the services to adopt more optimistic costing, which is what a camel's nose approach seems to suggest. In fact, the estimated correlation (although statistically insignificant) suggests more conservative costing in periods when the DoD budget is tight. This aspect of the statistical results may seem surprising, as there are incentives for the services to adopt a camel's nose approach to procurement pricing. The explanation presumably rests with another aspect of the statistical results. The introduction of independent parametric weapon system costing in 1972 appears to have had a continuing, marked effect in reducing growth in procurement costs from the Milestone II baseline. The evidence also less strongly indicates that the subsequent strengthening of the independent costing process has further reduced cost growth, and that observed cost growth is influenced by the stringency with which policy on realistic costing is enforced. Thus, the Milestone II procurement cost estimates from which cost growth is measured are at least to a significant degree constrained by the DoD policy of budgeting for major weapon systems on the basis of realistic cost estimates.

The second interesting result concerns the effect on cost growth of the acquisition reform efforts of the past 20 years. Reduction of cost growth was sometimes offered as one reason for these reforms and, even when it was not, there is a widespread expectation that the reforms undertaken had a major effect on cost growth. This study leaves entirely open the possibility that acquisition reform reduced growth in development costs of major weapon system programs. It provides no indication, however, that acquisition reform significantly reduced the growth in procurement costs. In fact, as noted above, a management change introduced in 1986 as an acquisition reform is associated with higher cost growth.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

This feature of the statistical results is plausibly explained by the fact that the acquisition reforms in question were only partially implemented, and the part not implemented was designed to provide both program managers and defense contractors with a strong incentive to avoid unrealistic costing and hold cost growth in check. The broader result probably reflects the fact that the acquisition reforms are most likely to have a strong, direct effect on program procurement costs and to be quickly reflected in the cost estimates made at Milestone II. Consequently, data on *cost growth* will not provide a reliable indication of the effects of acquisition reform on *cost*.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

1. Is There a Case for "Doing Something" About Cost Growth?

In the early 1970s, the Defense Department adopted the basic elements of the process still used to ensure that decisions on the budgets for weapon system acquisition programs are informed by realistic cost estimates. There have since been two major and many smaller changes in the process, and also many changes in the DoD budget and acquisition processes, which exercise their own influence on weapon system cost growth.

There is room for debate about whether the net result of the Defense Department's efforts to limit cost growth on major weapon systems gets a passing grade. On the one hand, instances of large cost growth are not as frequent as is commonly supposed, and most DoD weapon system cost estimates are judged by senior DoD officials and the Congress to be satisfactory. On the other hand, a significant number of the major weapon system procurement programs undertaken by the Defense Department over the past 30 years have exhibited cost growth large enough to cause sustained criticism of the Department.

The overall impression conveyed by the record is that growth in the cost of weapon acquisition programs is held in check uneasily and imperfectly. It is not surprising, then, that cost growth has maintained a position relatively high on the list of problems concerning the Defense Department's management of resources.[1]

The bulk of this study is concerned with evaluation of the importance of the main pathways through which growth in the costs of major procurement programs occurs. Chapter 2 introduces the cost growth data used in the study. This is followed (in Chapter 3) by a fuller description of the ways in which procurement cost growth occurs, together with some illustrative examples. Chapters 4 through 6 take up the task of relating observed cost growth to the different ways in which it can occur. Chapter 7 summarizes the main conclusions of those chapters and sketches some recommendations for ways in which DoD processes could be changed to reduce cost growth.

This chapter serves to provide a policy foundation for the study by examining whether there is a case for "doing something" about cost growth on weapon system procurements beyond what the Defense Department has done over the past three decades. This is not an easy or straightforward question. To make sense of it, it is necessary to identify what cost estimates are under consideration and what role or roles they play. That is the task addressed in the first section of this chapter. The second section sketches the process the Defense Department uses to guard against adoption of unrealistic cost estimates and

Approved for public release; distribution unlimited.

budgets for major acquisition programs, and the third section turns directly to the question of whether the Defense Department needs to do more about cost growth than cope with the problem using more or less the tools currently available. The final section outlines the plan of the study, the purpose of which is to evaluate how much cost growth can be attributed to identifiable mechanisms of cost growth.

Scope and Context

The term *cost growth* is sometimes used to refer to the increase in unit cost from one generation of weapon system to the next generation; for example, from the 637 class of attack submarines to the 688 class to the SSN-21 class. Studies of cost growth so defined tend to be about whether the added capability provided by the newer systems is worth the increased cost.

This study, in contrast, examines growth in the costs of individual weapon system procurement programs, measured against an initial forecast of what those costs would be. During the 25 to 50 years of a major weapon system's life, many estimates of its costs are made by different organizations, inside and outside the Government, for a variety of purposes. This study is concerned with the cost estimates for major weapon systems made by offices within the Defense Department as a basis for budgeting, as explained in the paragraphs that follow.

Framing the study in this way places in the foreground two of the Defense Department's main decision processes—the management of weapon system acquisitions and the allocation of resources. In the background is a process, separate from the acquisition process, through which the requirements for each major acquisition program were established. With a few exceptions during the period covered by this study (1970–1997), it was accepted that the task of the acquisition process was to deliver on time and within budget a system that met the established requirements.

The Congress also is placed in the background of this study's picture of cost growth. There is undoubtedly an excellent study to be done of the role of cost in the Congress's decisions on whether to approve new weapon system acquisitions and its subsequent decisions on their funding. But this is not that study; the focus of the work reported here is, again, on decisionmaking in the Defense Department.

For about four decades, senior DoD management has used a milestone decision process to oversee major defense acquisition programs (MDAPs).[2] There have been many changes in the definitions of the milestones through the years. Laying aside differences in terminology and some real but, for present pur-

poses, not crucial differences in the definitions, the process was made up of five main stages during the years included in this study:[3]

1. Concept Exploration (Milestone 0)
2. Program Definition/Risk Reduction (Milestone I)
3. Engineering and Manufacturing Development (Milestone II)
4. Low-Rate Initial Production (Milestone IIIa)
5. Full-Rate Production (Milestone IIIb)

Concept Exploration typically lasted only a year or two and usually was limited to "paper studies;" that is, engineering analyses that did not entail substantial experimentation or physical testing. The second phase, Program Definition/Risk Reduction, was longer and usually involved significant expenditures on development of subsystems at least. Sometimes, it included development of a prototype of the system. Any invention required by the contemplated system was to take place during Program Definition/Risk Reduction. The third phase, Engineering and Manufacturing Development (EMD), was then intended to be a matter of working out the detailed design of the system and, from the late 1980s, the means used to manufacture it. Production was divided into two phases, an early phase, Low-Rate Initial Production, during which bugs were still being worked out of the system and the manufacturing process, and a later phase, Full-Rate Production.

Perhaps the fundamental rule of the milestone decision process was (and still is) that an MDAP cannot proceed from one phase to the next—that is, spend funds for activities of the next phase—without an affirmative decision by the Milestone Decision Authority (MDA). The MDA for most large weapon system acquisition programs is the Under Secretary of Defense (Acquisition, Technology and Logistics), or USD(AT&L).[4] The Defense Acquisition Board (DAB), which is chaired by USD(AT&L), provides a forum for the involvement in the review process of the military departments (not just the military service sponsoring the procurement), the Joint Staff, and a number of offices within the Office of the Secretary of Defense (OSD). The DAB is the successor to the Defense Systems Acquisition Review Council (DSARC), which was created in 1969 to serve essentially the same purpose as the DAB. The DAB and the DSARC (before 1987) were the mechanisms that the MDAPs in this study typically used to gain milestone approval.

The cost estimates made to support DAB or DSARC reviews bear two different sorts of weight at different milestones. First, cost estimates play a role in selecting the system to acquire. The point of departure in the acquisition process was (and still is) a determination that a new or increased military capability is required. Milestone 0 approval launched largely "paper studies" of vari-

Approved for public release; distribution unlimited.

ous alternatives for providing the new capability; in addition to alternative new systems, these were to include such possibilities as an upgrade to an existing platform, improved munitions or subsystems (e.g., the radar on a tactical aircraft), adaptation to a new role of an existing platform, or a change in doctrine. DAB procedures required that the alternatives be evaluated through an Analysis of Alternatives (AoA)—that is, an extensive cost-effectiveness analysis.[5]

The key decision at Milestone I for the systems considered in this study was about which of the alternatives (if any) would proceed to Program Definition/Risk Reduction. Cost was almost never the sole factor considered in these decisions, and it is not clear that it was often a decisive factor. To the extent that cost considerations did enter into the decision, however, they were illuminated by the cost estimates made in support of the AoA and the Milestone I review.

The potential role of cost estimates in the AoA and Milestone I decisions is the most important that they play within the Defense Department. In the current state of the data, however, evaluating the realism of the cost estimates in Milestone I decisions (much less in AoAs) is a virtually impossible challenge that this study does not attempt.

The second function of cost estimates in the acquisition process is to provide a basis for budgeting for individual procurement programs, each of which is a separate line item in the budget. *Budget* is used broadly to include the following: funding requested for the upcoming year in the DoD budget submitted to the Congress, funding requirements for the years beyond the budget year in the Future Years Defense Program (FYDP), and funding requirements for the years beyond the FYDP over which the program will be executed. Typically, budget requests for MDAPs are initiated by the military department sponsoring the program. The amounts budgeted for development and procurement, however, are supposed to be consistent with cost estimates approved by the MDA.[6]

Operating and support (O&S) costs typically account for about 50 percent of an MDAP's life-cycle cost. While there is considerable variation from one program to the next, procurement typically accounts for about 40 percent of life-cycle cost and development, for about 10 percent.

O&S costs are excluded from the study because the data required to evaluate them could be assembled, if at all, only with great difficulty.[7] Resource constraints required that the study be narrowed further, and it was focused on procurement costs because they are, after O&S costs, by far the largest element of total cost.

Approved for public release; distribution unlimited.

The procurement cost estimates made at Milestone II are important for two distinct reasons. First, the Milestone II estimate of unit cost is a standard by which the Congress gauges the performance of a program. For that reason, acceptance at Milestone II of a procurement cost estimate that proves to be unrealistic is likely to eventually cause potentially serious congressional criticism, even if the program is otherwise proceeding normally. Second, adoption of unrealistic procurement cost estimates at Milestone II leads to "overprogramming" by creating the illusion that the Defense Department has more resources available in the future years for procurement than it actually does. Looking forward at any point in time, some MDAPs are expected to go out of production or drop to low levels of procurement. Therefore, as illustrated in Figure 1, there is room for new starts even if the total funding allocated to procurement of weapon systems is not expected to grow. To the extent that cost estimating for MDAPs in the program is unreasonably optimistic, there appears to be more room in the out-years for new starts than there actually is. Overprogramming results to the extent that that appearance is acted upon; that is, the Defense Department decides to undertake a set of programs that will cost more in the out-years than the funds anticipated to be available can cover (making due allowance for the small amount of slack provided by the glitches that inevitably delay some programs).[8]

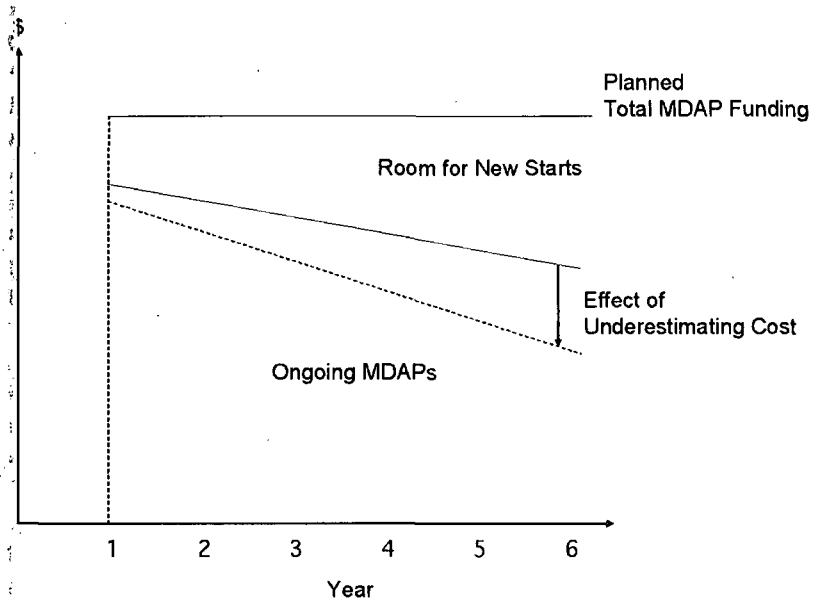


Figure 1. Underestimation of Cost and Apparent Scope for New Starts

The relevant decisions are not tentative plans for future years that can be easily reversed in later budgets. To the contrary, a decision to start a new major

Approved for public release; distribution unlimited.

program, or permit a program to enter EMD, implies near-term contractual commitments and spending. These commitments to a program carry with them requirements for spending in later years. When the Defense Department systematically understates at Milestone II the out-year procurement funding that major acquisition programs will require, funds will not be sufficient to do all that was planned as the out-years approach, and programs will have to be cancelled (and the value of the investments made to that point largely lost) or stretched.

That is the nub of the problem considered in this study. Underestimation of procurement cost leads to overprogramming, which increases the costs of the procurement program. Overprogramming should therefore be avoided, and one requirement for doing so is realistic costing at Milestone II.

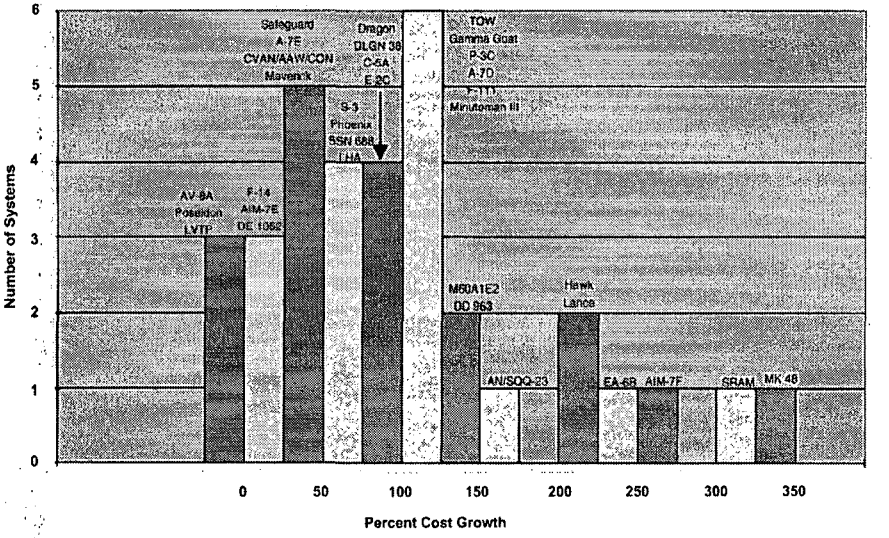
Introduction of Independent Parametric Costing

The case for realistic costing looks different viewed from within the Defense Department than it does from within the Congress. One of the founders of cost estimation in the OSD pointed out that "the cost of a Rolls Royce has not 'grown' simply because someone promised it would cost less than a Ford."[9] Those in the Congress might well disagree, taking the position that the controlling decision is that of the Congress, often made on the Defense Department's recommendation, to authorize and appropriate funds sufficient for acquisition of a Ford. They would then see the growth in the cost of the program (i.e., the budget) as a matter of buying more capability (a Rolls Royce) than was approved and, hence, an implicit challenge of congressional authority.

Cost growth on major acquisition programs first became a major issue with the Congress in 1969. Melvin Laird and David Packard had recently become Secretary and Deputy Secretary of Defense, respectively. They found when they assumed office that it had become necessary to "do something" about cost growth.

The magnitude of the cost growth exhibited by weapon acquisition programs around that time is indicated by the data in Figure 2, a reconstruction of a chart from a briefing given in December 1971 to David Packard by Gardiner Tucker, then the Assistant Secretary of Defense (Systems Analysis) or ASD(SA).[10] It shows the growth in acquisition cost experienced on 34 major weapon procurement programs. (Acquisition cost is the sum of development cost and procurement cost.) Cost growth was measured from the cost estimate made when the system begins development but was restated on the basis of the then most recent assumption on the number of units the Defense Department planned to buy.[11] Of the 34 systems, 23 showed cost growth of more than 50 percent; the modal system showed cost growth of more than 100 percent (i.e., its cost more than doubled); and the cost more than tripled for 6 of the 34 systems.

Approved for public release; distribution unlimited.



Source: ASD(SA) December 2, 1971, briefing to the Deputy Secretary of Defense, December 2, 1971.

Figure 2. Cost Growth in Weapon Systems

In April 1969, the Defense Department acceded to a request from the Senate Armed Services Committee that the Selected Acquisition Reports (SARs), which provide information on the costs of individual MDAPs, be provided to the Congress.[12] A month later, David Packard established the DSARC to advise the Secretary and Deputy Secretary of Defense on decisions about major system acquisition programs. He also introduced "fly-before-you buy" and several changes in acquisition policy. These steps were apparently not sufficient to resolve congressional concerns:[13]

> Mr. Packard had recently [late 1970] come under severe criticism from Congress because of continuing major cost growth problems....[The SAR] data, along with a stream of well-publicized weapon system technical problems, schedule slippages, and massive cost overruns were raising questions about DoD's ability to effectively manage its major system developments.

A way forward on the problem was suggested by Gardiner Tucker's briefing. That briefing contained two key insights, both of which David Packard accepted. The first of these was that the large cost growth that the Defense Department had been experiencing was primarily due to poor initial cost estimates. This is not an obvious point, and it is one that was (and to some degree still is) contentious. There is a tendency in the acquisition community to see cost growth as the result of some feature of the program, or simply as a fairly

Approved for public release; distribution unlimited.

routine problem to be overcome by more vigorous management.[14] Gardiner Tucker presented evidence for several systems showing, to the contrary, that the large cost growth experienced on them was plausibly explained by initial estimates that were unreasonably optimistic.

The second insight was that much-better initial estimates could be made by employing "parametric" cost-estimating methods. In the broadest sense of the term, a parametric estimate is one that makes systematic use of the costs actually incurred on previous programs when estimating either the costs of a prospective program or the future costs of an existing program. Such estimates are not ordinarily made at the level of a "whole-up" system; they are built up of estimates made at a lower level (for example, the wing of a tactical aircraft whose cost is to be estimated). A parametric cost estimator would look at the costs of the wings of past tactical aircraft procurements and scale them for such factors as size of the wing, the materials from which it is made, any particular features of how it is manufactured, and so on.[15]

The prime virtue of parametric cost estimates is that, by working from costs actually incurred, they automatically build in a degree of realism. In contrast, the detailed engineering buildups that are the alternative to parametric estimates ordinarily do not include an allowance for the sorts of misfortunes and missteps that are a feature of all development programs.[16]

On December 7, 1971, David Packard issued to the secretaries of the military departments a memorandum, "Use of Parametric Cost Estimates." (The memorandum is reproduced in Appendix A.) Although the memorandum did not refer explicitly to the ASD(SA) briefing of December 2,[17] it summarized its main points and directed the service secretaries to "perform an independent parametric cost analysis on each major system at key decision points and...make that analysis available for each DSARC review."

David Packard concluded the memorandum with a request that the service secretaries inform him of their efforts to improve their "capability to perform independent parametric cost analyses and to make use of them in acquisition management."

On January 25, 1972, Secretary of Defense Melvin Laird signed a memorandum to the secretaries of the military departments, "Cost Estimating for Major Defense Systems." This memorandum (also in Appendix A) announced the creation of the OSD Cost Analysis Improvement Group (CAIG). The CAIG was made responsible for (1) reviewing the independent parametric cost estimates brought to the DSARC by the services and (2) developing uniform criteria to be used by all OSD groups in making parametric cost estimates. Secretary Laird's memorandum also made explicit the guidance implicit in David Packard's December 7 memorandum that each of the military departments should have

Approved for public release; distribution unlimited.

"a staff component capable of preparing independent parametric cost estimates."

In summary, three things followed the December 7, 1971, and the January 25, 1972, memoranda:

1. A unit within each of the military departments but outside the acquisition organizations was designated to perform parametric cost estimates of weapon system procurements.
2. The military departments included these estimates in the materials they prepared to support DSARC reviews.
3. The OSD CAIG began providing the DSARC its reviews of both the services' independent parametric cost estimates and the program offices' estimates.

Each of the military departments assigned the independent parametric cost estimation role to an existing unit in its comptroller's office. From its inception, the Systems Analysis Group had included a small unit that did parametric weapon system cost estimating.[18] This group was assigned the task of preparing the cost estimates vetted through the CAIG and then presented to the DSARC. Thus, the new system began functioning in the spring of 1972.

Several studies have considered whether instituting independent parametric costing in the Defense Department in 1972 had the intended effect of improving the initial cost estimates for major systems and, hence, in reducing cost growth. All found that it did so to a marked extent.[19] The most straightforward connection with the evidence presented in Figure 2 is provided by a Defense Science Board (DSB) study.[20] According to the Congressional Budget Office (CBO):[21]

> [T]he Defense Science Board concluded that weapon systems developed during the 1960s averaged approximately 200 percent real growth from start to finish, compared with only 50 percent for similar systems developed a decade later.

The other studies surveyed by the CBO were not all readily comparable to the DSB study, or to one another, but the studies agreed that cost growth was considerably lower after the introduction of parametric cost estimating in the early 1970s.

In summary, the Defense Department had a severe problem with procurement cost growth in the late 1960s and early 1970s; steps to solve the problem were adopted; and the solution apparently was at least partially successful. Moreover, as is discussed in Chapter 5, the independent cost-estimating process was significantly strengthened twice after it was established, once in 1983

Approved for public release; distribution unlimited.

and a second time in 1992. It is, therefore, necessary to ask if there is still a problem with cost growth on major weapon system programs.

Is There Still a Problem?

The introduction of independent parametric costing did not eliminate cost growth. As is discussed in more detail in the following chapter, after 1973 the average procurement cost growth was at least 16 percent, and about one system in five experienced cost growth of more than 30 percent.

Providing a clear answer to the question of whether this much cost growth is a problem requires an explicit criterion for determining the damage it causes. One relevant criterion is suggested by the characterization of the budget established for an MDAP as a contract between the Defense Department and the Congress.[22] The issue this criterion points to is not one of damage in any straightforward sense, but of control. The Congress has the last word on the allocation of U.S. Government budgetary resources. But if the decisions the Congress makes on the budgets for weapon system procurement programs (or, more broadly, the DoD budget) are based on seriously flawed cost estimates, they must be revisited later. Substantial errors in forecasts of weapon system costs thus entail political costs, and they tend to reduce the Congress's effective authority over the allocation of defense resources. It is not surprising, then, to find that the Congress has been concerned enough with realistic estimation of weapon system cost to legislate on the subject, and it is plausible to suggest that congressional concern with cost growth has colored a considerable range of statutory provisions governing acquisition of major systems.

As discussed in the preceding section, cost growth clearly was a problem by this political criterion in the late 1960s and early 1970s. It again became a political problem in the late 1970s and early 1980s. Since then, the correct answer to the question of whether growth in the costs of weapon system procurements has been a political problem probably is "no," although there have been a few instances in which it nearly became one.[23]

The alternative to this political criterion is an economic test. A reasonable standard is the total cost of procuring the program approved at Milestone II for a set of MDAPs. Note that this is not measured simply by the amount of cost growth because, in terms of the metaphor cited earlier, the cost of a Rolls Royce isn't less because someone promised it for the price of a Ford. Rather, the relevant measure is the amount by which the cost of the Rolls Royce the Defense Department decided to develop and procure increased because the Defense Department initially based the program on the (false) assumption that it could be acquired for the price of a Ford.

Approved for public release; distribution unlimited.

Errors in forecasting procurement costs may be funded by a transfer of resources from other parts of the defense program, or by the addition of funds to the Defense Department. Typically, however, the required funds are found in the procurement accounts by stretching the program that experienced the cost growth or stretching other programs. For example, suppose 300 aircraft were to be bought during Full-Rate Production over a period of 10 years at a rate of 30 per year. To accommodate a cost increase, the annual lot size might be reduced to 25, and the 300 aircraft bought over 12 years. Reducing the annual production rate from 30 to 25 and increasing the production period from 10 to 12 years adds 2 years worth of overhead to the program. Hence, through this mechanism, underestimation of unit procurement cost at Milestone II tends to increase the total cost attributed to the program.

Appendix B presents a rough computation of the magnitude of this effect given the average growth in procurement costs over about the past 30 years due to forecasting errors and flaws in the Defense Department's execution of the program. The errors appear to be about equivalent in their effects to an annual tax on the procurement program of 2 percent to 8 percent. A tax of even 2 percent on a magnitude as large as the DoD budget for major weapon system procurement represents a sobering amount of resources.

The 2 percent to 8 percent tax does not imply that avoiding cost growth and the program stretches it causes would have permitted more procurement programs to be accommodated in any given period of a few years. In fact, the opposite is true. More realistic cost estimates at Milestone II would imply fewer programs at any point in time. These programs would be procured more rapidly, however, and over a span of years a given total amount of procurement funding could buy 2 to 8 percent more program.[24] Alternatively, if the industrial base could be adjusted downward, a given set of programs could be produced at roughly 2 to 8 percent less funding.

The following chapter shows that three-quarters of procurement cost growth (by the most relevant available measure) is accounted for by the approximately one system in five that exhibited growth in its procurement cost from the Milestone II baseline of more than 30 percent. (The average procurement cost growth of these MDAPs was 70 percent.) Thus, the bulk of the 2 percent to 8 percent tax is due to the comparatively small number of systems that experience extreme cost growth. Moreover, there has been no apparent tendency for the proportion of MDAPs that fall into this extreme cost growth tier to decline. In fact, the proportion was higher in the 1990s than it had been in the 1980s, although the average procurement cost growth shown by these systems did not return to pre-independent costing levels.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

In summary, by the economic criterion, there still is a problem with cost growth. This problem stems from the comparative small number of systems (about one in five) that exhibit extreme cost growth (an average of 70 percent from the Milestone II baseline.)

Plan of the Study

The path from this conclusion to suggestions for ways to reduce cost growth leads directly to the decisionmaking processes in the Department of Defense. To identify what needs to be "fixed," we need to know what mechanisms generated the cost growth, or at least permitted it to occur, and the importance of each.

Identifying the mechanisms of cost growth is comparatively simple. In broad terms, growth in procurement cost can occur within the Defense Department's management processes in three ways:

1. A decision is made to increase the capabilities of the system beyond what was approved at Milestone II and captured in the Milestone II procurement cost estimate.
2. The decision maker at Milestone II, for whatever reason, adopts an unrealistic estimate of procurement cost.
3. Poor program execution or exceptional budget instability cause cost growth avoidable by better program management or more budget stability.

   The difficult part of the study is finding ways of evaluating how much cost growth can be attributed to each of these mechanisms.

Case studies of cost growth are far too labor-intensive to be of much help in categorizing procurement cost growth for a sample of more than a few systems. The only practical approach is to use statistical techniques and comparisons with cost growth and other data for a reasonably large sample of MDAPs. The rationale for this approach is that the historical record provides the results of "experiments" that indicate the importance of the various mechanisms of cost growth. One straightforward example of this has already been mentioned—the introduction of independent parametric cost estimation, which invited "before" and "after" comparisons of cost growth. Careful examination of the mechanisms of cost growth points to several additional differences between time periods and MDAPs that we would expect to be reflected in the record of growth in procurement costs.

What can be learned from this approach is limited by the "experiments" available in the historical record. This study uses data on 138 MDAPs that passed Milestone II from 1970 to 1997 inclusive. These include systems of each of the major categories of major weapon systems the Defense Department purchased

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

and include the full range of acquisition strategies. Some were dual sourced and some were not; in some cases, the early phase of the development program included construction of a prototype, and in other cases, it did not; and so on. The period takes in one and one-half "feast and famine" cycles in the DoD budget, three notable changes in the process used to estimate MDAP cost, the introduction of a set of reforms to the acquisition process in 1987, and a number of other changes that plausibly influence cost growth. In short, the record is rich enough to suggest a reasonable prospect that it will yield useful results.

This promise is partially borne out, as the statistical analysis does yield interesting and useful conclusions. It falls well short of identifying the causes of extreme cost growth, however, and a variety of other information must therefore be used in pursuing this study's objective.

Chapter 2 introduces the cost growth data used in the study. This is followed (in Chapter 3) by a fuller description of the ways in which procurement cost growth occurs, together with some illustrative examples. Chapters 4 through 6 take up the task of relating observed cost growth to the different ways in which it can occur. The final chapter summarizes the main conclusions of those chapters and sketches some recommendations for ways in which DoD processes could be changed to reduce cost growth.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

2. Introduction to the Data

Growth in the costs of major weapon acquisition programs has been a recurrent source of criticism of the Defense Department for 40 years. Accordingly, there is a reasonable expectation that the Defense Department's record in forecasting the costs of weapon system procurements is well understood. In fact, in important respects, it is not. This is so in part because of shortcomings in the data, which, moreover, are not available in a form that is easy to use and, hence, are not widely understood.

It is appropriate for this reason to begin with the data on cost growth. The discussion of these data also provides interesting and somewhat unexpected perspectives on growth of the costs of major weapon system acquisition programs.

PA&E's SAR Database

This study uses a cost growth database prepared by the Office of the Director, Program Analysis and Evaluation (PA&E). It includes data drawn from the Selected Acquisition Reports (SARs) for 138 systems that passed Milestone II between 1970 and 1997 inclusive.[25] Systems that had not completed at least 3 years of Engineering and Manufacturing Development (EMD) during that period were excluded, as were systems that entered the acquisition process at Milestone IIIa or Milestone III.

This is a fairly large sample but, unfortunately, one that is probably not representative in all respects. Table 1 provides the basic data that serve to frame this concern. SAR data are available for approximately 260 systems. The sample includes a little more than half of these. It could eventually include an additional 31 systems with usable data. These 31 systems are potentially an issue because the 18 systems "in process" are disproportionately from the years 1970–1975. About two-thirds of the remaining systems with SAR data were excluded from the sample because:

- The SARs for the MDAP were of such poor quality that it was not possible to extract coherent data; or
- The MDAP passed Milestone II before SAR reporting began.

Exclusion of systems that passed Milestone II before 1970 is a matter of what the study attempts, not of bias in the sample. Again, however, there is reason to believe that the systems from the early years are under-represented in the sample.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Table 1. Comparison of Sample Systems to Total Number of Systems for Which SARs Have Been Filed

Total MDAPs	254
Total systems	260
Systems included in the sample	138
Systems excluded from the sample	
Useable data	
Not yet 3 years past Milestone II	13
In process	18
Unusable data	
Poor quality data or Milestone II passed before SAR reporting	60
Programs merged for SAR reporting or cancelled early in EMD or before	31

Source: Preliminary DoD data adjusted by the author from a table for a sample of 131 systems, of which 25 were shown as "in progress." It is assumed that the additional 7 systems included in the 138 on which data have been made available came from the 25 that had been "in progress."

Note: For reasons stated in the text, the total number of systems with SARs is 6 more than the total number of MDAPs.

The more serious problem is presented by the remaining one-third of the systems excluded—approximately 30 systems. These were excluded for the following reasons:

- The MDAP was merged with another for SAR reporting;
- The MDAP passed Milestone II but was cancelled before completing three years of EMD; and
- One or more SARs were filed before the system passed Milestone II, and the system was cancelled before it entered EMD.[26]

It is highly likely that most of these were troubled programs, and cost estimates probably were bound up with the problems they experienced.

In summary, the sample used in this study is not fully representative of all MDAPs that passed Milestone II during the years 1970–1997 in two respects. First, a smaller portion of the total population of MDAPs included the early years of the period, especially those before 1975. Second, the sample is made up of systems that proceeded more or less normally from development into production.

Approved for public release; distribution unlimited.

PA&E normalized the SAR data in two ways. First, in the version of the database used in this study, all of the dollar values are stated in FY 2002 constant dollars. Second, the actual cost growth observed is restated on the assumption that the quantity of the system the Defense Department planned to buy at the Milestone II decision is actually bought.

Figure 3 illustrates the definition of cost growth used in the PA&E database. What is actually observed is, first, the procurement cost the Defense Department forecasted at Milestone II and the number of units the Defense Department then planned to acquire and, second, the quantity actually bought and what that quantity cost to procure.[27] What cost growth would have been had the Milestone II quantity been bought is an estimated value. Appendix C describes the approach PA&E took to the normalization of cost growth for quantity. For this discussion, keep in mind that the cost growth figures used measure what cost growth would have been had the Milestone II quantity been bought.[28]

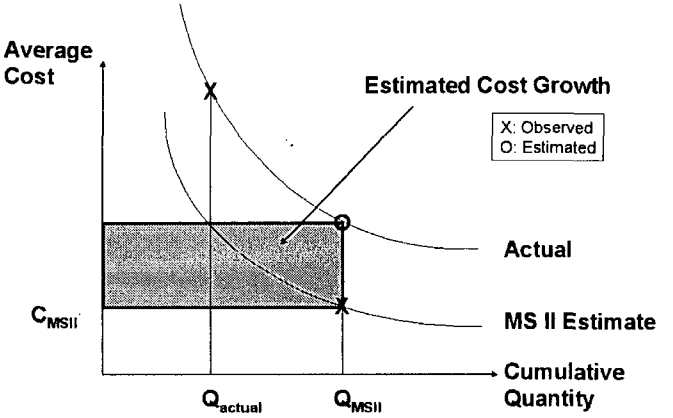


Figure 3. Definition of Procurement Cost Growth

Figure 4 is the histogram of the normalized growth in procurement cost for the 138 systems in the sample. As noted, these data exclude the effects of inflation and changes in the total quantity purchased, but they include cost growth from all other causes.

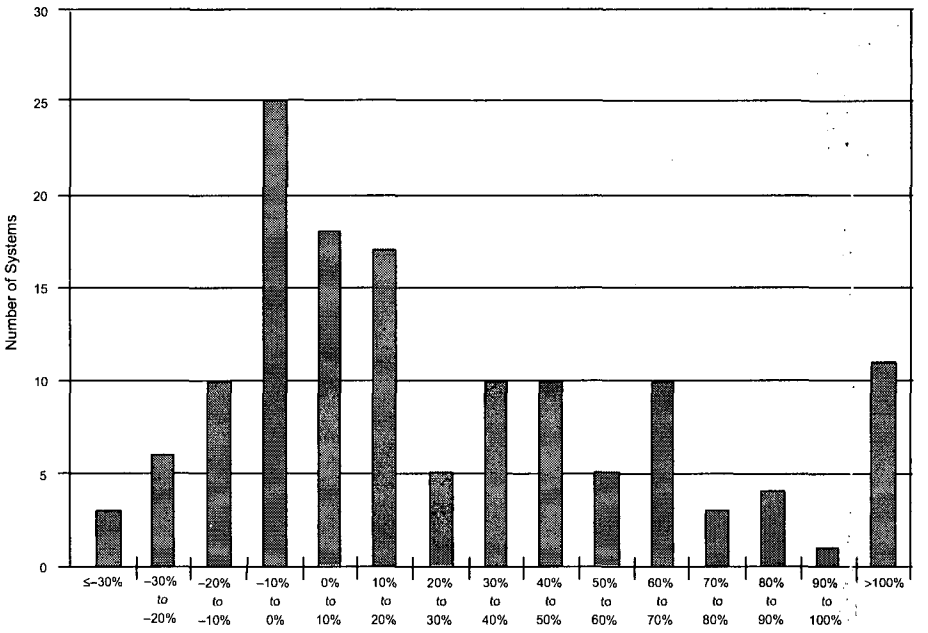


Figure 4. Distribution of Procurement Cost Growth from the Milestone II Baseline for 138 Major Weapon Acquisition Programs

Mistakes and *Decisions*

A long-standing criticism of the SAR variance categories is that they do little to reveal the underlying causes of the cost growth recorded in them. For example, procurement cost may have increased because at Milestone II the military service made (and placed on contract) an unrealistic assumption about what physical attributes the system needed to have to satisfy the requirements that had been established for it. Alternatively, the increase might be explained by a decision to buy a more capable system or to upgrade a system that had been in the field for years. Similarly, a quantity variance can occur when some change in circumstances—the threat the system is to meet, for example—leads to a reduction in the quantity the service decides to buy. A quantity variance may reflect a return to the original quantity decision in light of a considerably higher cost, which in turn may reflect the adoption of an unrealistic cost estimate at Milestone II.

PA&E took a first, limited step towards correcting this shortcoming of the SARs by separating the amount of cost growth due to *mistakes* from the amount due to *decisions* for each system in the PA&E data. These labels are italicized because they stand for the criteria for categorizing the data. In general terms, the *decisions* bin is intended to capture the costs of changes made for reasons

exogenous to the program itself. The *mistakes* bin is intended to capture the growth in the cost of obtaining the program approved at Milestone II. (Note that by these criteria, the costs of changes in a system needed to meet Milestone II requirements should be classified as *mistakes*, not *decisions*.)

The definitions of *mistakes* and, especially, *decisions* are discussed further below. Before turning to that, however, it is useful to describe briefly what is involved in sorting the SAR data into these two bins.

The categorization is based on details of cost growth reported in the SARs. The SARs report cost growth attributed by the program manager to each of seven categories of change, defined as follows:[29]

1. Economic—change in price level
2. Quantity—change in the number of units acquired
3. Schedule—change in procurement or delivery schedule, completion date, or intermediate milestone for development or production
4. Engineering—change in the physical or functional characteristics of a system or item delivered
5. Estimating—change due to correction of previous estimating errors or refinements of a current estimate
6. Other—change due to unforeseen events or not covered in any other category (e.g., natural disaster, strike)
7. Support—change associated with support equipment for the major item of hardware

Over the life of a major system, several dozen to several hundred variances typically will be posted. Some of these are explained in the SAR text; others are posted in one of the SAR categories without specific explanation. PA&E had each of these examined and classified as the result of a *decision* or a *mistake*.[30] The rule used in classifying the individual elements of cost growth was that anything not clearly a *decision* was counted as a *mistake*. Ordinarily, the classification was based only on information reported in the SAR. Thus, only cost variances described in the SARs in a way that clearly identified them as exogenous changes in the content approved at Milestone II would be included in *decisions*.

The distinction between *decisions* and *mistakes* is of pivotal importance in assessing the amount of damage done by cost growth and gauging the importance of its various causes. The label itself tells us the general cause of cost growth due to *decisions*; the question in this case is whether out-year procurement funds were put into the budget at about the same time as the decision to change the system was made. To the extent that the answer to that question is

Approved for public release; distribution unlimited.

"yes," cost growth due to *decisions* is not a source of overprogramming. The *mistakes* component of cost growth presents the opposite case—we do not know the underlying causes of the *mistakes* component of cost growth, but we know that whatever their cause, they lead to overprogramming.

Table 2. Average Growth in MDAP Cost from Milestone II Due to *Decisions* and *Mistakes*

	Percentage	
	Development	Procurement
Decisions	21	10
Mistakes	24	18
Total	45	28

Source: Preliminary DoD data.

Table 2 reports the *decisions* and *mistakes* components of cost growth for the 138 systems in the sample. The average *mistakes* component of cost growth is 18 percent for procurement; the estimated *decisions* component is 10 percent. The table also reports the *decisions* and *mistakes* components of development cost growth. Although development cost growth is not examined in this study, it is interesting to note that both components of cost growth are higher for development than they are for procurement.

The estimates in Table 2 should be taken more as a point of departure than a conclusion because some problems are still present in the data. The next two subsections point to reasons why the *mistakes* component of procurement cost growth is understated by the estimates in Table 2 and the *decisions* component overstated. Chapter 4 identifies a set of cases—quantitatively much more important in terms of cost growth—that go in the opposite direction, i.e., in which cost growth due to unforced program changes appears to have been misclassified (that is, included with *mistakes*).

Characteristics of the *Mistakes* Component of Cost Growth

General features of the data on the *mistakes* component of procurement cost growth say little directly about its underlying causes. They do point, however, to a set of systems that are the main source of damage due to procurement cost growth.

Figure 5 is a histogram of the *mistakes* component of procurement cost growth. Notable are the three bars on the left that show negative forecasting errors, that is, systems for which at Milestone II the funding required for procurement was overestimated (when adjusted for quantity and *decisions*). One common rhetorical question about cost growth is: If the Defense Department is budgeting

Approved for public release; distribution unlimited.

for MDAPs on the basis of unbiased and professionally competent cost estimates, why is cost never overestimated? As Figure 5 shows, there are such overestimates. In fact, the *mistakes* component of procurement cost growth was negative for 42 of the 138 systems in the sample.

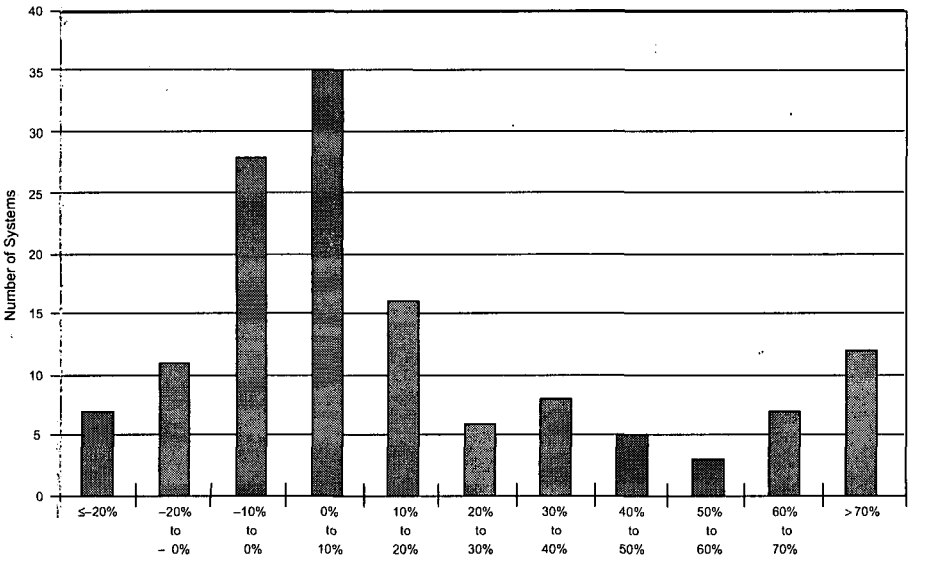


Figure 5. Distribution of the *Mistakes* Component of Procurement Cost Growth from the Milestone II Baseline for 138 Major Weapon Acquisition Programs

Also notable in Figure 5 is the long right tail: 35 of the 138 systems in the sample—about 1 in 5—experienced more than 30 percent *mistakes* procurement cost growth, and several more had forecasting errors of between 20 percent and 30 percent. While an 18 to 24 percent average *mistakes* component of cost growth might be judged small enough not to be a problem, cost growth for most of the systems in the far right tail of the distribution definitely was a problem.

The average *mistakes* component of procurement cost growth of the 35 systems in the right tail of Figure 5 is 70 percent. (See Table 3.) In sharp contrast, the 96 systems in the middle tier of Table 3 had a *mistakes* procurement cost growth of only 3 percent. On average, the Milestone II procurement cost estimate of the 7 systems in the bottom tier overestimated cost by about 35 percent, after taking out *decisions*.

Approved for public release; distribution unlimited.

Table 3. Average *Mistakes* Component of Procurement Cost Growth—High, Middle, and Low Tiers

	Number of Systems	Average Mistakes Component of Procurement Cost Growth
Greater than 30%	35	70%
–20% to 30%	96	3%
Less than –20%	7	–35%
Total	138	18%

As noted above, cost growth is a problem in the efficient use of resources to the extent that it usually results in program stretches. In practice, the Defense Department has only a limited ability to offset overestimates of cost with underestimates. Hence, the best base for measuring the size of the problem probably is systems that had at least some cost growth due to *mistakes*. In total, these 96 systems had *mistakes* cost growth of about $130 billion (in constant FY 2002 dollars). The 35 systems with cost growth of 30 percent or more account for nearly three-quarters of this total.

Table 4 lists the systems with a *mistakes* component of cost growth of 30 percent or more. Army systems are over-represented, as they account for a little over half of the systems in the top *mistakes* cost growth tier, while the Army was the sponsor of less than one-third of the systems in the sample. Apart from that, there is no pattern apparent in Table 4. Instances of extreme cost growth occur for each of the services in all time periods and all commodity groups, and the list does not seem to be weighted towards especially high-technology systems.

Characteristics of the *Decisions* Component of Cost Growth

The *decisions* component of procurement cost growth includes five subcategories. Figure 6 indicates the portion of the total of the *decisions* component accounted for by each of these. The Requirements/Configuration/Variants subcategory includes new models and major upgrades. The Integrated Logistics Support, Spares, and Support subcategory is intended to sweep up the effects of such actions as an enforced post-Milestone II change from three-level to two-level maintenance. The External Program Factors subcategory includes such events as strikes. The Other Decisions subcategory takes in a variety of other *decisions* not readily included in one of the other subcategories. Together, these three subcategories account for about 60 percent of the estimated cost growth due to *decisions*.

Table 4. Systems in the Sample with *Mistakes* Procurement Cost Growth of at Least 30 Percent

System Name	Milestone II	Mistakes Component of Procurement Cost Growth
Army		
SADARM 155mm Projectile	1988	260%
FIM-92 Stinger Missile	1973	142%
USQ-84(V) SOTAS	1978	99%
M2/M3 Bradley FVS	1978	95%
MIM-104 Patriot PAC-3	1994	86%
AH-64D Apache Helicopter Airframe	1990	81%
FMTV	1988	78%
FGM-148A Javelin AAW Missile	1989	76%
UH-60A Blackhawk Helicopter	1972	67%
Hunter Short-Range JTUAV	1991	64%
AH-64 Apache Helicopter	1976	64%
M1 Abrams Tank	1976	62%
ATACMS P3I (BAT)	1991	61%
M712 CLGP (Copperhead)	1975	60%
ATCCS ASAS Block II/III	1993	56%
ALQ-212(V) ATIRCM/CMWS	1995	46%
ATCCS FAAD C2I	1990	36%
ATACMS Block II/IIA	1995	36%
M2/M3 Bradley FVS Upgrade	1994	36%
Navy		
NATO Pegasus-Class PHM	1973	144%
T-45 Goshawk Training System	1984	55%
AGM-84A Harpoon Missile	1973	44%
AN/SQR-19 TACTAS	1977	38%
NATBMD	1997	37%
Air Force		
E-3 Sentry AWACS RSIP	1989	109%
JSTARS	1985	77%
DSCS-III	1977	72%
BGM-109G Tomahawk GLCM	1977	63%
AIM-9L Sidewinder Missile	1973	51%
T-6A JPATS	1995	49%
GBS	1997	47%
C-17A Globemaster Aircraft	1984	47%
C-130J Hercules Aircraft	1996	39%
LGM-30 Minuteman III GRP	1993	33%
F-15 Eagle Aircraft	1970	30%

Note: See the list of abbreviations at the end of this paper for the meanings of abbreviations used here.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

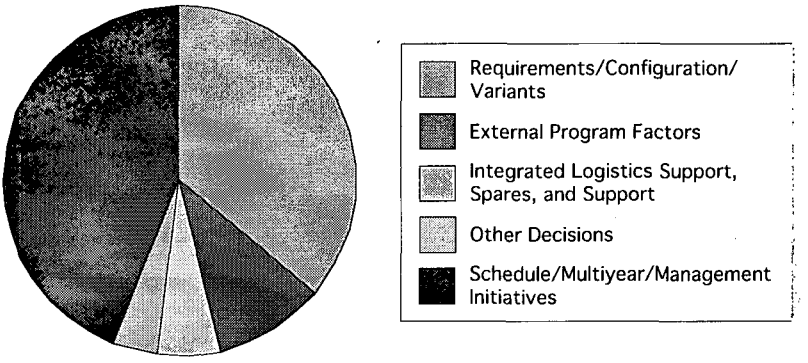


Figure 6. Composition of the *Decisions* Component of Cost Growth

The Schedule/Multiyear/Management Initiatives subcategory, which accounts for the roughly 40 percent remaining, is a problem. Part of it belongs in *decisions*. For example, the cost of a stretch is properly classified as a *decision* if it is required to accommodate an MDAP's share of an across-the-board budget cut. The cost of the stretch should be counted with *mistakes*, however, if it is required because the cost estimate adopted at Milestone II was unrealistically low. Nonetheless, the PA&E data count the costs of almost all schedule changes as *decisions*. On this score, the *decisions* category is overstated and the *mistakes* category, understated.

The total of the Schedule/Multiyear/Management Initiatives is about 4 percentage points. The data do not indicate how much of this is due to schedule slips, but it is likely to be the largest part. If the entire category is shifted to *mistakes*, the *mistakes* component of procurement cost growth increases to 22 percentage points, and the *decisions* component decreases to 6 percentage points.

Concluding Comment

Taken at face value, the estimates presented above imply that the *decisions* component of procurement cost growth is of comparatively minor importance. Information developed in Chapter 4, however, identifies a number of systems in which cost growth classified as due to *mistakes* appears to have been due in substantial part to unforced decisions to develop and acquire a more capable system than that approved at Milestone II. Consequently, discussion of cost growth due to *decisions* is relevant to this study's governing concern with overprogramming.

Before pursuing this point, we turn to a general exploration of the mechanisms of cost growth. The three chapters that follow provide more detailed, quantitative discussions of the main mechanisms of cost growth. Chapter 4

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

examines the *decisions* component of procurement cost growth. The *mistakes* component of procurement cost growth is taken up in Chapter 5 (cost growth due to the adoption of an unrealistic cost estimate at Milestone II) and Chapter 6 (cost growth from poor program execution or budget instability.)

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

3. Mechanisms of Cost Growth

The preceding chapter identified two large categories of cost growth—*decisions* and *mistakes*. A decision to increase the capabilities of a weapon system being developed can be made in several ways, but they all involve both the acquisition and resource allocation processes. There are two main pathways in which cost growth due to mistakes can occur. First, substantial procurement cost growth is nearly certain to occur to the extent that the cost estimate adopted at Milestone II is unrealistic. Second, even if the estimate adopted is realistic, poor program execution or an unusual degree of instability in the program's budget will result in cost growth.

Figure 7 shows how the main mechanisms of cost growth due to both decisions and mistakes can be grouped into "families." There are two points to note about this taxonomy. First, each of the nodes is associated with particular DoD decisionmaking processes. Second, to be recorded in the Selected Acquisition Report (SAR), procurement cost growth ordinarily will have to pass through one of the "gates" shown in Figure 7.

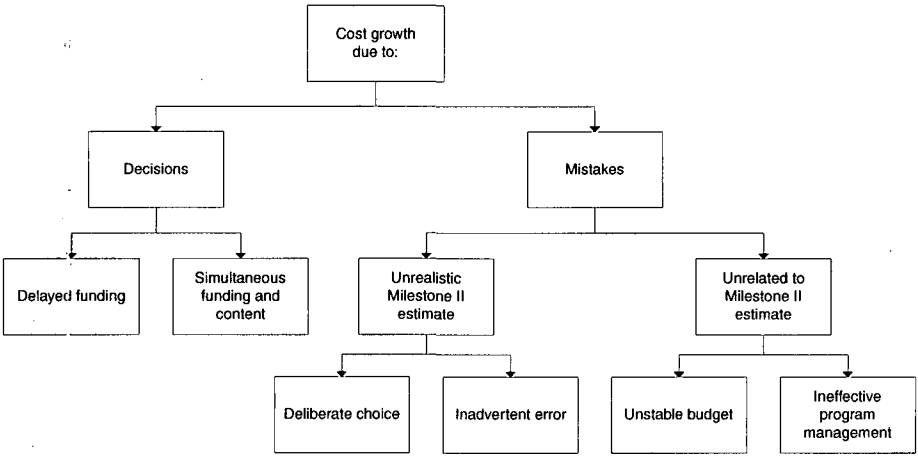


Figure 7. Mechanisms of Cost Growth

Each family of cost growth mechanisms involves some sub-cases and complications, which are explained briefly in the following sections.

Mistakes Due to Unrealistic Cost Estimates at Milestone II

Although the Defense Department never characterizes cost estimates adopted at Milestone II as unrealistic, unrealistic estimates are sometimes adopted.

Approved for public release; distribution unlimited.

Deliberate Choice

One way this can occur is the acceptance by the Milestone Decision Authority (MDA) of a cost estimate in the face of creditable evidence that the estimate is, in fact, unrealistic. It seems reasonable to assume that such a decision would reflect the adoption of a "camel's nose" strategy; that is, it was made in the expectation that the low cost estimate would make the program more attractive to the Congress.[31] This probably is the most popular explanation outside the Defense Department of underfunding of weapon system acquisition programs.

The record does not contain any clear-cut examples of this case (because the Defense Department doesn't label cost estimates it adopts as unrealistic and there is never any shortage of competing explanations for the cost growth experienced.) The clearest example is the case in which a program manager's cost estimate exceeds the budget established for the program. In this case, the difference between the cost estimate and the budget ordinarily is referred to as a "management challenge." The sense of this label is that it is up to the program manager (PM) to find a way to get the cost of the program down to the budget without compromising the ability of the system to meet established performance requirements. Accordingly, the PM will bring forward with his presentation to the DAB (or promise to develop and implement) a set of steps to achieve the indicated cost reductions. If an estimate of this sort is adopted, it probably would be characterized as "optimistic" (and the cost reductions required to achieve it noted.)

It is awkward to include under *mistakes* a deliberate choice to adopt an unrealistic estimate at Milestone II. Such choices are, however, *mistakes* in the sense that they run counter to stated DoD policy.

Inadvertent Error

Alternatively, an unrealistic cost estimate might have been adopted because the MDA was poorly advised—that is, neither the service sponsoring the program nor the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) provided a realistic cost estimate. The CAIG has no stake in the programs it estimates. Its only job is to make accurate estimates of program cost, and it is criticized at least as vigorously for an estimate that proves to be too high as for one that proves to be too low. Hence, if in retrospect the CAIG estimate proves to have been unrealistic, the explanation is either that the CAIG inadvertently made a cost-estimating error, or that its estimate was based on an unrealistic program assumption.

The Family of Medium Tactical Vehicles (FMTV) provides a ready example of cost growth due in significant part to an inadvertent cost-estimating error.

The FMTV came to the DAB in 1988. The program involved only a limited amount of development and therefore requested combined Milestone II and Milestone IIIa authority. The FMTV PM stated that his procurement cost estimate was based on the actual cost of a vehicle that had recently entered production and was closely analogous to the core FMTV vehicle. A few months after the DAB, the PM reported that he was not able to negotiate a contract for the FMTV in the ballpark of his estimate, and the price eventually negotiated was considerably above the Milestone II/IIIa estimate.

The error in this case started with terminological imprecision. What the PM had labeled an "actual cost" was the price in a firm fixed-price contract that the Army had for the analogous system, not the cost that the manufacturer of the vehicle had incurred in its production. The producer of the analogous system (not the same firm with which the PM was trying to negotiate an FMTV contract) was losing a substantial amount of money on the contract. The FMTV estimate rested on the false assumption that the contract price for the analogous system was an accurate measure of the cost that would be incurred in its production. In substantial part because of that error, FMTV has the ninth highest cost growth of the 138 major weapon system acquisition programs in the sample used in this study. [32]

The P-7 Long Range Air ASW Capable Aircraft (LRAACA) provides a dramatic example of a cost estimate based on an unrealistic program assumption. The LRAACA program was to develop and procure a replacement for the P-3 aircraft. As approved at its Milestone II DAB in late 1988, the P-7 was to be simply a stretched P-3 with updated electronics and mission equipment. The Milestone II cost estimate was based on the assumption that the P-7 would be 60 percent common with the P-3. It was further assumed that the P-7 design could be based on the P-3 drawings, and could be produced on the same production line, using much of the same tooling.

It was discovered as the development work went along that poor configuration control had been maintained on the P-3 and that the aircraft produced differed significantly from one another. Consequently, plans to base the P-7 on P-3 drawings and to use P-3 tooling had to be abandoned. Commonality fell from the assumed 60 percent to near zero, which is to say that the P-7 effectively became a new design, with costs of development and procurement well above those estimated at Milestone II. The program was cancelled in 1990 before completing EMD.

The LRAACA is a case in which an unrealistic program assumption clearly could and should have been corrected before the program came to the DAB for Milestone II approval. This subcategory also includes program assumptions that prove to be unrealistic due to unanticipated technical problems. Some might question the reasonableness of assigning to the *mistakes* category cost growth

Approved for public release; distribution unlimited.

due to unanticipated technical problems. The basis for doing so lies in the DoD policy in effect since about 1970 that the technologies taken into EMD should have been demonstrated. Hence, when major technological surprises do occur during EMD, the cost growth associated with them is properly counted as a *mistake*, although it will usually be chargeable to the program manager, not to the cost estimators.[33]

Mistakes Unrelated to Milestone II Estimates

Unstable Budget

Understood literally, "budget instability" implies that the budget fluctuates over time in an unplanned way, and it suggests uncertainty about the level of funding that will be provided to the program. In practice, the term mainly refers to situations in which the budget is insufficient to procure the system at the annual rates assumed at Milestone II. This can happen either because the cost estimate adopted at Milestone II was unrealistically low or because the program's budget was cut. The likely result in either case is a stretch of the program, which extends the period over which the program bears at least a portion of the overhead costs of the system's producers.

This aspect of the connection between budget instability and cost growth is straightforward. It is experienced by virtually all programs, and it is segregated, although imperfectly, in the data used in this study. (As noted in the preceding chapter, most of the cost growth for this purpose was classified as due to *decisions*, although much of it was not caused by exogenous budget changes and, therefore, should have been classified with *mistakes*.)

This is not the only or necessarily the most important link between budget instability and cost growth. Another link often posited is between the steepness of the learning curve and program stability, which means reasonable stability in planned budgets and production profiles as well as in requirements. This conjecture is plausible since program instability tends to discourage the investments that play a predominant role in moving costs down the learning curve. Previous studies do not provide an estimate of how large this effect is.

Ineffective Program Management

Ineffective program management can cause cost growth in many ways. To take a simple example, suppose that the Milestone II cost estimate assumed that during the procurement phase the system's producer would receive an annual fee of 13 percent of cost. It could be that the producer would have settled for a profit rate (on cost) of 13 percent, but that the PM negotiated a rate of 15 percent. The result would be growth on the total cost to the Government (the

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

producer's cost plus fee) of a bit less than 2 percent. As this example suggests, identifying cost growth due to ineffective program management is in many cases not something that can be done with the sort of information available to researchers.

Cases in which the Defense Department obtained contractually binding commitments to early procurement lots in connection with the competitive award of an EMD contract may provide an instance in which cost growth due to ineffective management can be readily observed. This acquisition strategy was a less ambitious form of Total Package Procurement (TPP), which was used on several major acquisition programs during the 1960s. Under TPP, the contract awarded after the competition covered EMD, the entire quantity to be procured and, usually, contractor support for Operations and Maintenance (O&M) once the system was in the field. The versions of TPP attempted after the 1960s covered procurement only of the early lots and included little or no provision by the contractor of O&M.

This acquisition strategy was employed in the hope that it would avoid the fatal flaws evident from earlier experience with TPP and yet provide substantial benefits from competition. Like the full TPP, however, the less ambitious form gave bidders a strong economic incentive to "buy in," that is, to make a bid for less than the likely cost of executing the program.[34] Eventually, these contracts had to be restructured, and the restructured contracts executed at a cost substantially above the Milestone II baseline. Each of the six post-1960s major acquisition programs that used a TPP-like acquisition strategy is on the list of systems that experienced procurement cost growth due to *mistakes* of at least 30 percent.

TPP-like contracts are discussed at greater length in Chapters 6 and 7. The question in this chapter is whether the cost growth due to TPP-like arrangements is properly classified as a consequence of ineffective program management. Some would argue that the unsatisfactory results obtained in these cases were due to factors such as a failure of the Defense Department to make a strong commitment to the program; the persistent, if individually small, increases in the performance required of the system; and budget instability. From that perspective, the TPP-like approach could have been effective, and its failure reflects poor execution of the program, mainly at levels above the PM. It is on that basis that the cost growth associated with TPP-like contracts is classified as a *mistake* due to ineffective program management. An alternative view is that TPP-like contracts are intrinsically flawed, and cannot be made to work successfully. At least in retrospect, then, their adoption reflects not poor execution but ineffective high-level management when the acquisition strategy was adopted. On that premise, cost growth due to the use of TPP-like contracts would still be classified with *mistakes*, but it would be classified as another way of adopting an unrealistic cost estimate at Milestone II.

Approved for public release; distribution unlimited.

Decisions

The *mistakes* component of cost growth causes overprogramming by creating the illusion that the portion of resources actually committed to ongoing systems is smaller than it really is. The *decisions* component presents a more complicated situation. The key question is as follows: Was the required funding committed at substantially the same time as the decision was made to increase capability, or did the procurement funding decision lag by several years? If the capability decision and funding commitment are matched, there is (by definition) no overprogramming. But a decision to increase capability that is not matched by a commitment of funds creates the same illusion on resources uncommitted as the *mistakes* component, causing overprogramming. It is for that reason that the *decisions* branch of Figure 7 has the two sub-branches shown.

Timely Funding of Content Changes

The F/A-18 aircraft program provides a good example of a decision that was funded in a timely way. The F/A-18A/B began EMD in 1976. The F/A-18C/D began EMD in 1987, after 400 of the A and B models had been procured. The two models are on the same SAR, however. (The Navy decided to put on its own SAR the F/A-18E/F, which went into EMD in 1992.) The F/A-18A/B/C/D had a total growth in procurement cost of 48 percent, of which 44.8 percent were due to variant changes.[35] It seems clear simply from the sequence of events that, in the F/A-18B/C case, the funding was committed in a timely way. In fact, the inclusion of the funding in the budget probably was the vehicle for the decision.

Delayed Funding

The M2/M3 Bradley Fighting Vehicle System (FVS) is an example in which commitment of funding lagged a decision to procure a more capable system. The Bradley, which has the sixth highest *mistakes* procurement cost growth among the systems in the sample, grew out of the earlier Mechanized Infantry Combat Vehicle (MICV). The MICV got Milestone II approval in 1972. In 1976, the Secretary of Defense approved the Bradley, which had considerably greater capability. For example, the Bradley's armaments included a 25-mm gun, where the MICV mounted a 20-mm gun, and the Tube-Launched, Optically Tracked, Wire Guided (TOW) missile system, which was not on the MICV. The MICV was cancelled in 1977.[36] For the purposes of SAR reporting, however, the Bradley was tracked against the MICV Milestone II baseline until at least through 1980, at which point the Bradley was in Low-Rate Initial Production.[37] Given that the SARs must match the budget submitted to the Congress, it was apparently at that point that the Bradley procurement cost estimate was updated.

Approval of the Bradley seems to have reflected a decision to purchase a system more capable than the MIVC. Hence, the associated cost increases should have been posted as due to *decisions*, although they appear not to have been. Further, there seems to be no doubt that the adjustments to procurement funding came 3 to 4 years after the decision to procure the Bradley rather than the MIVC.[38]

Uncertainty and Extreme Cost Growth

The taxonomy outlined in this chapter is used in this study to structure an analysis of the 35 systems in the sample that had a *mistakes* component of procurement cost growth of at least 30 percent. The assumption entertained is that there are systematic explanations of this cost growth. Of course, the accuracy that any cost estimate eventually proves to have is determined in part by random factors—factors that the cost estimator cannot hope to model and incorporate in the cost estimate. Hence, it seems necessary to ask whether the cases of large cost growth simply reflect extreme bad luck—situations in which all of the random factors that could go wrong did.

The importance of this possibility turns on how big a random element is typical of a careful Milestone II procurement estimate that attempts to be realistic. There is no established, well-grounded answer to this question. A conventional and probably reasonable guess is that 90 percent of such estimates will be within ±20 percent of the actual procurement cost (adjusted for inflation, quantity change, and exogenous changes in program content.) If this position is accepted, only less two cases in 100 (averaged over many samples) would be expected to have a cost growth of as much as 30 percent due to random factors,[39] 9 and it is reasonable to think in terms of the systematic causes of instances of extreme cost growth.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

4. *Decisions*

As noted in the previous chapter, the Office of the Director, Program Analysis and Evaluation (PA&E) intented to classify in *decisions* only those cost variances that clearly were the result of exogenous decisions to change program content. It was also noted that much of the *decisions* component of cost growth due to stretches probably should have been classified with *mistakes*. Hence, with this one exception, we can be fairly confident that the *decisions* component of cost growth identified in the database is due to changes in program content that were not forced by adoption at Milestone II of an unrealistic cost estimate or poor program execution.

We can be much less certain that these decisions on the program typically were funded at about the time the change in program content was adopted, or whether the funding decisions lagged significantly. Beyond that question, there are some major instances in which there is evidence that cost growth due to unforced changes in the system was misclassified as *mistakes*.

Indications from the Selected Acquisition Reports (SARs)

It is appropriate to start with the part of procurement cost growth tagged in the PA&E database as due to *decisions*. There is no simple statistical marker of the instances in which these decisions were matched with timely commitments of funds or the instances in which the commitments of funds lagged. In the absence of detailed budget data, about all there is to go on is the fact that these changes were clearly labeled in the SARs. The changes were, then, substantial and there was no reluctance on the part of the program manger (PM) or the service to call attention to them. There is a weak presumption on these grounds that the changes in content were funded in a timely way. That is the assumption made in computing the 2 percent to 8 percent tax from cost growth discussed in Chapter 1. To the extent that the assumption is incorrect, the tax would, of course, be larger.

Another set of programs among those with extreme *mistakes* cost growth present a more important problem. The SARs and other readily available materials (mainly General Accounting Office reports) were examined for the high-cost-growth Army and Navy systems in the hope that they might provide an explanation of the extreme *mistakes* component of cost growth observed. (Resource constraints precluded doing this for the Air Force systems as well.) What stood out in this review were seven major Army acquisition programs in which major changes were made after Milestone II but before the system went into production. The following systems had this characteristic:

- Sense and Destroy Armor (SADARM) 155mm Projectile
- FIM-92 Stinger Missile

Approved for public release; distribution unlimited.

- USQ-84(V) Stand-off Target Acquisition System (SOTAS)
- M2/M3 Bradley Fighting Vehicle System (FVS)
- MIM-104 Patriot Advanced Capability 3 (PAC-3)
- AH-64 Apache Helicopter
- Army Tactical Missile System (ATACMS) Preplanned Product Improvement (P3I) Brilliant Anti-armor Technology (BAT)

It appeared in each of these cases that the change or changes introduced went well beyond those commonly introduced in the course of an Engineering and Manufacturing Development (EMD) program. The changes were not the only cause of growth in the procurement costs of these programs, but there is a solid presumption that they were a major cause.

These cases present three distinct puzzles:

1. Were the changes made unforced decisions to develop and procure a more capable system than that approved at Milestone II, or were they required to meet the requirements established for the system at Milestone II?
2. If the changes were unforced, why were the cost increases they drove not classified as due to *decisions* in the PA&E database?
3. Were the costs of the changes registered in the DoD budget more or less when the decisions to change the programs were made, or did commitment of resources catch up with the lag of a few years?

The second of these probably is much less a puzzle than it appears to be at first glance. The seven systems listed above were identified based on comments in the SAR narrative sections, while the PA&E classifications seem to have been based more on the descriptions of individual variances, which tend to be opaque and do not necessarily appear in the same year's SAR as the change (identified in the narrative) that produced them. It is also relevant to recall that PA&E guidelines called for classifying as *decisions* only cost variances due to changes that were clearly exogenous.

Resolving the other two puzzles requires information that goes beyond what is available in the SARs. Such information proved to be readily available for two of the seven systems, the Bradley, discussed in the preceding chapter, and the SOTAS.

The SOTAS was intended to provide an Army commander with "real-time radar imagery of virtually all moving targets on the enemy side of the battlefield."[40] As originally proposed by the Army, the SOTAS was a mechanically steered radar, mounted on a UH-60 helicopter, with an anti-jam data link to a ground station, which had communications links to various elements of a

division (the tactical operations center and the artillery, for example). Pre-Milestone II, the SOTAS was an extremely successful program:[41]

> In 1976, one demonstration model, using mostly commercially available material, was produced....The model was shipped to Germany for participation in the annual Return of Forces to Germany (REFORGER) exercise. The system's performance exceeded all expectations....[Its] accomplishments were so extraordinary that...the 7th Army Commander refused to allow the system to be returned to the U.S.

The SOTAS came to a Milestone II Defense Systems Acquisition Review Council (DSARC) review in November 1978. During the Milestone II meeting, a DoD official requested that the Army incorporate in the SOTAS a new requirement for an electronic scanning capability, and the Army agreed to this request. The procurement cost estimate, however, apparently was not revised to reflect the increase in requirements, or it was revised to only a limited extent, because the DoD budget submission was then in its final stages of preparation. An update of the cost estimate was not initiated until August 1980, in preparation for Army and OSD reviews of the program held in the spring of 1981. It is likely that this revised estimate was reflected in the final SAR for the program filed in January 1982.

The Defense Department terminated the program on December 2, 1981; the ground segment remained an Army program, but the airborne segment was replaced by the Joint Surveillance Target Attack Radar System (JSTARS). By that point, the estimated procurement cost (adjusted for quantity changes) had approximately doubled.

The SAR data do not tell us how much of the increase in SOTAS procurement cost was due to the incorporation of an electronic scanning capability. We do know that this was a major cause of development cost growth,[42] and it was also likely a major cause of procurement cost growth. Under the accounting conventions employed in the data used in this study, the costs driven by these changes should have been classified as due to *decisions*. They seem largely not to have been.[43] Finally, it seems clear that the inclusion of electronic scanning in the SOTAS was not matched by resource commitments at Milestone II.

On the evidence readily available, we cannot reach these same conclusions for the other five systems listed previously. The changes introduced to each of these systems during EMD drove a significant element of the cost growth they experienced. It is possible on the evidence in the SARs that these changes had to be made to meet Milestone II requirements, in which case they were properly classified as due to *mistakes* (in particular, an unrealistic program assumption). It is also possible on this evidence that the funds required by the change

were committed when the change was made, in which case the original problem was not compounded by further delays in funding. This study was not able to provide further resolution of these uncertainties.

Modification Programs During 1989–1997

The data in Table 5 point to another set of seven programs whose scopes seem to have changed since Milestone II.[44] This table compares procurement cost growth experience on modification programs during the period 1970–1988 with the period 1989–1997. The DoD procurement budget was tight during the latter period, and modification programs (rather than entirely new systems) were encouraged.

Table 5. *Mistakes* Component of Procurement Cost Growth on Modification Programs in Two Periods

	1970–1988			1989–1997		
	≤30%	≥30%	Total	≥30%	≥30%	Total
Army	2	0	2	3	4	7
Navy	17	0	17	7	0	7
Air Force	8	2	10	1	3	4
Total	27	2	29	11	7	18

Source: OSD PA&E Cost Growth Database.

There is a reasonable expectation that major programs to modify an existing system and then procure the modified system will experience less procurement cost growth than programs that start from scratch. The services all meet this expectation for the earlier period. Of the 29 systems classed as modifications of existing systems, only two—both Air Force systems—had a *mistakes* component of procurement cost growth of more than 30 percent. None of the Navy modification programs of the period 1989–1997 fell into the top tier of cost growth. The experiences of the Army and, to a lesser extent, the Air Force are strikingly different between the two periods, however. During 1989–1997, four of the Army's seven modification programs had a *mistakes* component of procurement cost growth of at least 30 percent, as did three of the Air Force's six modification programs.

It would not be plausible to suggest that the Army and the Air Force (but not the Navy) suddenly became bad at estimating the procurement costs of modification programs. A suggestion that is more plausible on its face is that substantial changes were made in these modification programs and that the cost increases they drove were incorrectly posted as *mistakes*.

In these cases, and in the seven Army programs listed earlier, we do not have direct evidence of how much of the procurement cost growth is explained by the program changes. Indirect evidence presented in Table 6 suggests that most of the explanation is provided by *decisions* misclassified as *mistakes*.

Table 6. *Mistakes* Component of Cost Growth in Development (EMD) and Procurement

	EMD	Procurement
Army	26%	40%
Navy	10%	6%
Air Force	27%	16%

Source: OSD PA&E Cost Growth Database.

Table 6 compares the *mistakes* component of both EMD and procurement cost growth for each of the services. It is usually assumed that EMD costs are harder to estimate than procurement costs because the costing techniques available are less satisfactory for EMD and because (even at Milestone II) cost estimators typically have better information on procurement than they do on the EMD phase of the program. The data for both Navy and Air Force programs are consistent with this expectation. For each of these, the *mistakes* component of EMD cost growth is a bit more than half again as large as that of the procurement estimate. The figures for the Army are dramatically different—the *mistakes* component of procurement cost growth is about 40 percent and that of EMD about 26 percent.

It would, again, not be plausible to suggest that the Army and the independent cost estimators in OSD are good at estimating the EMD costs of Army systems but not good at estimating their procurement costs. Consequently, looking for poor cost estimating in the Army systems experiencing high procurement cost growth doesn't look promising. It is more promising to look to cost growth due to misclassifications of large variances that the SARs do not clearly label as due to decisions to change the program.

Conclusions

Changes introduced during EMD appear to have been a significant factor for 14 of the 35 systems that experienced extreme cost growth classified as *mistakes* in the PA&E database as due to *mistakes*. We can be fairly confident that the main problem in these cases was not poor costing. In fact, they appear to be good examples of the cost estimator's lament: "My cost estimate was OK but the system built was not the one [approved at Milestone II] that I estimated." It is also fairly likely that, in most of these cases, the adjustments in procurement funding were made at least years after the changes in the programs were adopted.

Approved for public release; distribution unlimited.

In two of these cases, the Bradley and the SOTAS, the changes appear to have been unforced; that is, they were not adopted when it became clear that the system under development would not meet the Milestone II requirements. In the other twelve cases, we are not certain on either of these counts; adjustments in procurement may have been made at about the time that the changes were introduced, and those changes may have been prompted by an emerging failure to meet Milestone II requirements.

For two reasons, this study has leaned towards the assumption that these changes were unforced. First, these systems do not fit the mold of programs making extensive use of advanced technologies on which "technological surprises" might be expected. Second, the evidence on cost growth on modification programs pre- and post-1988 is much easier to understand on the assumption that the changes were unforced than it is on the assumption that the changes were required to meet Milestone II requirements. That is true because on the latter assumptions it seems necessary to explain why the Army and the Air Force were much less capable after 1988 than they had been before of matching design of a modification program to the requirements the modified system was to meet. This evidence, however, is only circumstantial, and the conclusion is therefore open to modification on the basis of more detailed examination of the experience of the systems in question.

For example, the information presented on the seven Army systems could be read directly as indicating that the Army has some tendency to bring systems to Milestone II at an earlier stage of evolution than do the other services. If so, the likelihood is that decisions during EMD to change the capabilities of the system to be procured probably would be matched by a modification of the requirements the system is to meet. In these circumstances, the question of whether the decision was unforced or the result of changes in requirements may be meaningless and of secondary importance. The key fact would be that bringing relatively immature systems into EMD tends to be associated with the introduction during EMD of major changes in what is developed and procured.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

5. *Mistakes* Related to Unrealistic Milestone II Estimates

This chapter examines the extent to which growth in the *mistakes* component of procurement cost can be attributed to the adoption of an unrealistic cost estimate at Milestone II.

The DoD's policy since the early 1970s has been that budgets for major weapon acquisition programs be based on a realistic cost estimate. The attitude prevalent in the DoD acquisition communities toward the policy that all major defense acquisition programs (MDAPs) should be "realistically costed"[45] seems to be much like those of most American drivers to speed limits. If, for example, the posted speed limit is 55 miles per hour on some stretch of highway, it could easily be that the average speed is 65, that driving 75 risks a speeding ticket, and that driving 90 is dangerous and most drivers would not drive that fast regardless of the speed limit. Moreover, the bureaucratic mechanisms involved in deciding on the cost estimates of MDAPs at Milestone II contain the main elements suggested by the speeding metaphor:

- Propensity to speed—the services generally prefer at least somewhat optimistic costing of weapon system acquisition programs;
- Speed limit—DoD policy is that MDAP budgets be based on realistic estimates of cost;
- Police—the independent weapon system cost-estimating groups—detect and ticket speeders;
- Court—the Defense Acquisition Board—tries alleged violations of the speed limit (among many other matters); and
- Judge—the Under Secretary of Defense (Acquisition, Technology, and Logistics)—resolves disputed cases.

The highway patrol, of course, ordinarily does not observe the speed of every vehicle on most stretches of highway. In contrast, within the speeding model as applied to weapon system acquisition, each vehicle presents to the court a proposed speed before setting out. The proposed speed is either accepted, presumably because it is judged to be consistent with the speed limit, or the "judge" directs a reduction to the speed limit—that is, directs that the MDAP's budget be based on what is presumed to be a realistic, or at least more nearly realistic, cost estimate.

The speeding model of how Milestone II cost estimates become the basis for budgeting leaves out a great deal. It includes the central elements of the process, however, and hence provides a useful framework for the discussion presented here.

Approved for public release; distribution unlimited.

It is a safe bet that those outside the Defense Department assume that the dominant influence on weapon system costing is a desire on the part of the service sponsoring the program to ensure that it will be started. This chapter accordingly continues by looking at the extent to which the services' presumed preference for optimistic costing explains observed patterns of cost growth. It then goes on to look at the other elements of the speeding model, again asking to what extent they are related to observed cost growth.

Changes in the Propensity to Speed

It is hard to pin down in a satisfactory way how optimistic the services prefer Milestone II cost estimates to be and how intensely held those preferences are. To make any progress, it is necessary to step back and ask why there might be a systematic preference for optimistic pricing.

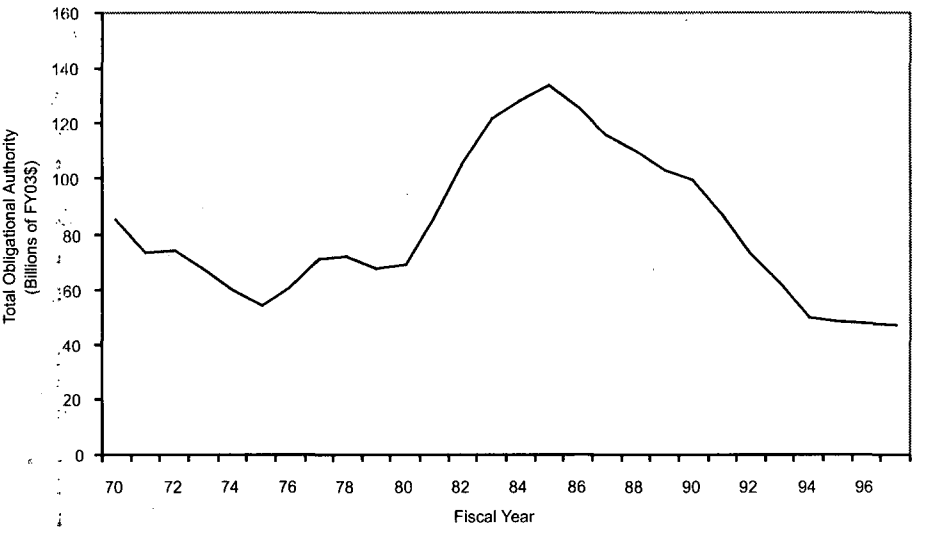
One reason is that lean funding helps ensure that the program manager will pay attention to cost control and that senior acquisition officials will approve any significant expansions of the program's scope.[46] Second, advocates of a program may adopt a "camel's nose" strategy—that is, adopt an optimistic cost estimate in the hope that doing so will increase the chances that the program will be approved by senior officials in the Defense Department and by the Congress. A third, and probably more powerful, reason is that optimistic costing permits any given budget level to accommodate a larger number of programs. Both national security concerns—ideas for systems that would contribute to national defense—and bureaucratic considerations—the problems of saying "no"—create strong pressures for optimism in costing so as to fit as many acquisition programs as possible into the budget.

Is this propensity to speed greater in some periods rather than others, or greater for some identifiable classes of systems? The answer presumably is "no" for the first motive for optimistic costing, but possibly "yes" for the other two.

The "pinch" of a tighter budget constraint is linked to the propensity to adopt optimistic cost estimates for MDAPs in two opposite ways. First, in periods when the budget is particularly tight, competition for funding is even more intense, and for that reason, the incentives for optimism are stronger. On this basis, MDAPs that go through Milestone II in periods of tighter budgets would be expected to show more cost growth than those that pass Milestone II when funding is less tightly constrained. Second, when the budget is tight and expected to stay tight, overruns that predictably follow from optimistic costing will be even more painful and difficult to deal with, which would argue for more conservative costing and, hence, less cost growth. Which of these forces is the stronger is an empirical issue.

The deterrent effect of prospective stretches provides a further implication that is unambiguous. A given percentage underestimate for a large system will have a far more pervasive effect on a service's acquisition program than the same percentage error on a smaller system. Furthermore, large systems tend to be the flagships of their services, and so are programs that the service would make particular efforts to avoid stretching. If so, the tendency on large systems will be to "budget to cost," that is, to set planned funding at Milestone II on the basis of a realistic cost estimate. Smaller and usually lower priority systems will, on this hypothesis, more often be "costed to budget." The implication is that larger systems would tend to experience less cost growth in percentage terms than smaller systems.

Figure 8 presents the DoD procurement budget in constant dollars over the period considered by this study. Judged by these data, the period 1970–1997 includes one "boom-bust" cycle. Procurement spending was relatively low during 1970–1980, which included the years when a "peace dividend" was expected following the end of the Vietnam War. During the last two years of the Carter administration (1979–1980), the expectation that defense spending would increase developed, and defense spending during the 8 years of the Reagan administration (1981–1988) was in fact much higher than it had been during the 1970s. Procurement spending dropped sharply after the fall of the Berlin Wall (1989) and the collapse of the Soviet Union (1991), and it remained comparatively low through the 1990s.



Source: Office of the Under Secretary of Defense (Comptroller), "National Defense Budget Estimates for FY 2003," March 2002, Table 6-1, p. 62+.

Figure 8. Department of Defense Procurement Budget, FY 1970–FY 1997

Appendix D presents a regression equation that includes markers for all of the variables of the speeding model and some factors discussed in the following chapter not related to the speeding model. Table 7 reports the estimates for the parameters related to the propensity to speed. Only the estimates obtained are discussed here; Appendix D explains further how the variables were measured and the statistical properties of the equation were estimated.[47]

Table 7. Estimated Coefficients Interpreted in Terms of Preferences for Optimistic Costing of MDAPs

Variable	Definition	Coefficient (t-statistic)
Intercept		1.346** (10.105)
A	Army programs: 1 for Army program; 0 otherwise	0.232** (2.861)
AF	Air Force programs: 1 for Air Force program; 0 otherwise	0.063 (0.871)
BUDGET	Marker of periods of "tight" procurement budget: 1 for 1970–1980 or 1989–2001; 0 otherwise	–0.017 (–0.176)
P$	Constant dollar size of procurement program planned at Milestone II (FY 2002 dollars)	–2.5E-06 (–0.783)

** Significant at the 1% level.

The dependent variable in the regression equation from which the estimates in Table 7 are drawn is the *mistakes* component of procurement cost growth, measured from the Milestone II baseline. For technical reasons, one of the services must be used as the baseline in estimating the propensity towards optimistic costing. The estimates in Table 7 use the Navy. Laying aside a problem discussed in the following paragraph, we see the estimated constant term (1.346) implies that the Navy Milestone II procurement cost estimates for MDAPs would show growth of about 35 percent before taking account of other influences. The estimates imply that the built-in cost growth would be slightly higher for Air Force programs, about 41 percent (35 percent plus 6 percent), and for Army programs, about 58 percent. The Air Force coefficient is not statistically significant, but the estimated Army coefficient is.

The crucial difficulty with this argument lies with its point of departure—the assumption that the estimated constant term measures the Navy's propensity towards optimism in its Milestone II cost estimates. It does include that, but it also includes the average effect of all of the influences omitted from the

Approved for public release; distribution unlimited.

estimated equation. Consequently, we do not know from these results what the baseline propensity to speed is; in fact, we do not know for sure that it is smaller than the 35 percent implied by the estimated constant term. The strongest statement on the propensity to speed that can be made is that the estimates are consistent with the assumption that each of the services does have a propensity towards optimistic costing of MDAPs. It is possible to say also, and with much greater confidence, that the Army has a much stronger propensity towards optimistic procurement cost estimates than the Navy or the Air Force.

The estimated negative coefficient of the budget variable, taken at face value, implies that MDAPs that pass Milestone II when the DoD budget constraint is relatively tight show less cost growth than those that do so when funding is less constrained. Thus, the estimate suggests that the imperatives of competition for a place in the budget are outweighed by concerns about coping with the consequences in subsequent years of optimistic pricing at Milestone II. Other studies have found this as well.[48] Other studies have also observed the negative correlation between the dollar size of a program and the amount of cost growth it exhibits.[49] Thus, the results lend a little support to the suggestion that there is a tendency to "cost to budget" for smaller MDAPs. Both coefficients are small and not statistically significantly different from zero, so the appropriate conclusion on this evidence is that budget strategy seems to have little or no effect on procurement cost growth.

A camel's nose strategy may nonetheless explain cost growth in particular cases. For example, it may explain the large cost growth observed on some modification programs that passed Milestone II in the early 1990s. The evidence presented here does not run strongly against such a suggestion; it indicates only that budgetary strategy does not seem to be an important systematic influence on cost growth.

Pressed to their limits, the propensity to speed on the one hand and the ability of the traffic police to detect speeding on the other provide mutually exclusive explanations of cost growth. To the extent that the traffic police have a good ability to detect speeding, an increase in the propensity to speed will have little effect on the amount of speeding actually observed. Conversely, to the extent that the propensity to speed is the dominant effect, we would expect to find that changes in the speed limit and capabilities of the traffic police have little to do with the amount of speeding observed. Consequently, having found that measures of budget strategy aren't closely associated with cost growth, we'd expect to find that changes in the ability of the traffic police to detect speeding and changes in the speed limit are associated with observed cost growth.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Ability to Detect Speeding—Authority of the Traffic Force

As noted in Chapter 1, Secretary Laird directed in January 1972 that independent parametric costing be made a part of the DoD acquisition process. The Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) began operating in the spring of 1972. Because several months are required to complete a cost estimate, the new process would not have been felt much until well into FY 1973 (which began July 1, 1972) but independent estimating should have been fully involved in the cost estimates of all of the systems brought forward for Milestone II reviews in FY 1974.[50] Accordingly, to the extent that the new process was effective, it would be expected to find less cost growth in FY 1974 and later years than before.

Two major changes after FY 1974 raised the status of independent costing and also might be expected to show up in the record on cost growth. The first of these was the enactment in 1983 of a statute requiring an independent cost estimate for each MDAP at Milestone II and again at the production decision:[51]

> The Secretary of Defense may not approve the full-scale engineering development or production of a major defense acquisition program unless an independent estimate of the cost of the program has first been submitted to (and considered by) the Secretary of Defense.

While this provision simply required the Defense Department to do what it was already doing, a statement of congressional interest expressed in statute served to establish independent costing as a permanent feature of OSD oversight of major weapon system acquisition programs and, if only by that, increased the influence independent costing had.[52]

The second major change, which occurred in 1992, stemmed from a feature of the 1983 statute. The statute defined an "independent estimate" as one not made by an office:[53]

> ... under the supervision, direction, or control of the military department that is directly responsible for carrying out the development or acquisition of the program.

This provision was problematical because, at the time it was adopted, DoD practice assigned to the services the task of preparing an "independent" cost estimate, which the CAIG reviewed[54] and modified as its own analysis dictated.

From the standpoint of the DoD process at the time, the question was whether CAIG review of the service independent cost estimate was enough to satisfy

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

statutory direction. This question lay dormant until a DoD Inspector General (IG) review of the DoD independent cost estimation process began in 1990. The IG review itself did not squarely address under what conditions a CAIG review of a service cost estimate could satisfy the requirements of the statute.[55] It did, however, result in a number of "corrective actions," one of which was that the CAIG make its own life-cycle-cost estimates. (CAIG staffing was increased significantly at this time to accommodate the additional workload.) This change was codified in the next revision of the acquisition regulations, which included a clear statement assigning the CAIG the statutory responsibility of providing independent life-cycle-cost estimates of major weapon acquisition programs.[56]

Table 8 presents the *mistakes* component of procurement cost growth during each of these periods identified above: 1970–1973, pre-independent costing; 1974–1983, pre-statute; 1984–1992, pre-IG report; and 1993–1997, post-IG report. The rows report the number of systems and average cost growth for categories suggested in the preceding chapter; reading from the bottom: all systems that passed Milestone II during the period, the small number of systems for which costs were overestimated by more than 20 percent, the large middle tier for which cost growth fell in the range –20 percent to +30 percent, and the top group for which the *mistakes* component of procurement cost growth exceeded 30 percent.

Table 8. *Mistakes* Component of Growth in Procurement Cost from the Milestone II Baseline

Cost Growth	FY 1970–73	FY 1974–83	FY 1984–92	FY 1993–97	Total
≤30%					
Number of Systems	6	8	11	10	35
Average Cost Growth (%)	80	69	86	46	70
–20% to 30%					
Number of Systems	8	30	43	15	96
Average Cost Growth (%)	3	5	1	5	3
≤–20%					
Number of Systems	1	2	3	1	7
Average Cost Growth (%)	–41	–33	–27	–54	–35
Total Sample					
Number of Systems	15	40	57	26	138
Average Cost Growth (%)	30	16	16	18	18

Approved for public release; distribution unlimited.

The average cost growth for the middle tier was only 3 percent pre-independent costing (1970–1973), and the introduction of independent costing does not seem to have any pronounced, continuing effect on cost growth. The introduction of independent parametric costing also had no effect visible in these data on the small number of systems in the bottom cost growth tier. It did apparently have a pronounced effect at the other end of the scale—systems that exhibited procurement cost growth due to *mistakes* of more than 30 percent.

About 40 percent of the major systems that passed Milestone II during 1970–1973 experienced *mistakes* procurement cost growth of more than 30 percent. During the two decades that followed, the proportion of systems in this top cost-growth group declined by half, to about 20 percent. (Compare the number of systems with cost growth of more than 30 percent with the total number of systems that passed Milestone II during the period.) It was for that reason that the average cost growth for all of the systems that passed Milestone II fell from 30 percent during 1970–1973 to about 16 percent in 1974–1983. During 1994–1997, the portion of the sample exhibiting cost growth of more than 30 percent increased to about its 1970–1973 level, but the average cost growth on those systems was much less than the average of the systems in the top cost-growth tier in the earlier periods. As a result, the average *mistakes* component of procurement cost growth during 1993–1997 was, at about 18-percent, only slightly above the average for the preceding 20-years, although there is a considerable prospect that some of these systems will show further cost growth.

While the evidence in Table 8 is striking, there is a problem resting conclusions on it. Doing so assumes that the advent and subsequent strengthening of independent costing were the dominant influence on cost growth. They certainly were not the only influences; two others have already been mentioned—the tightness of the budget constraint and policy on budgeting on the basis of realistic cost estimates—and only a little reflection is sufficient to suggest others.

The estimated regression equation mentioned previously, presented in its entirety in Appendix D, responds to this criticism. Table 9 reports the estimated coefficients for the three variables that mark the introduction of the independent costing process and its subsequent strengthening. The coefficients all have the expected negative signs—that is, less speeding when the traffic police have more capability—and each is statistically significant at a reasonable level. Moreover, the estimated magnitudes are consistent with expectations. In particular, the estimated effect of independent costing is greater after the passage in 1983 of the statute requiring independent cost estimates at certain milestones. It is greater still during the post-IG period (1993–1997). The latter point needs to be qualified, however. As discussed in the following chapter, some acquisition reform measures that may have had an effect on cost growth were adopted in the early to mid-1990s. (The estimated equation includes a variable marking

the earlier Packard Commission reforms.) Consequently, the stronger effect attributed to the post-IG report independent costing regime probably is due in part to acquisition reform measures.

Table 9. Estimated Coefficients of Variables Marking Major Changes in the Independent Costing Process

Variable	Definition	Coefficient (t-statistic)
COSTI	Early CAIG: 1 for 1974–1983; 0 otherwise	–0.267* (–2.465)
COSTII	Post-statute CAIG: 1 for 1984–1992; 0 otherwise	–0.397** (–2.700)
COSTIII	Post-IG report CAIG: 1 for 1993 on; 0 otherwise	–0.500** (–2.535)

* Significant at the 5% level.

** Significant at the 1% level.

These estimates, along with the data in Table 8, make two points. The first is that the introduction of independent parametric costing in the early 1970s had a major, continuing effect on reducing procurement cost growth.[57] Second, this reduction has come about through the proportion of systems showing extreme cost growth or, during the 1990s, in the magnitude of that growth. The latter conclusion has not appeared in previous studies, but is not surprising. The services knew how to do parametric costing before Secretary Laird directed its use. Consequently, the presumption has to be that the advent of independent parametric costing in the OSD was associated with less cost growth because it put a tool for requiring more realistic costing in the context of acquisition decisions in the hands of senior DoD leaders who were ready to use it.

Ability to Detect Speeding—Technology of Detection

The ability to detect speeding depends not only on how well the roads are policed—that is, the size and bureaucratic standing of the independent cost groups—but also on the quality of their radar guns—that is, the completeness of the program descriptions provided to cost estimators and the capabilities of their costing techniques and data.

Weapon system costing methods have improved over the years and historical data useful in costing have accumulated. Accordingly, within the logic of the speeding model, all else equal, we would expect to see a gradual reduction over time in cost growth. Apart from this, a substantial effort was undertaken in 1994 to improve the cost data available to DoD cost analysts,[58] and two innovations significantly improved cost estimators' access to information about the content of the programs whose cost they are to estimate. First, DoD acquisition

regulations were revised to require that all programs coming to the Defense Acquisition Board (DAB) for a Milestone II or Milestone IIIa/Milestone IIIb review provide a preliminary description of the program content to be estimated 6 months before the DAB review. This is contained in the Cost Analysis Requirements Description (CARD).[59] Second, the staff work leading up to a DAB review began to be done through Integrated Product Teams (IPTs), including an IPT for cost. The IPT process provided OSD cost estimators better access to relevant data and greatly improved communications between OSD cost analysts and program office personnel at a time at which it tends to be comparatively easy to resolve cost and funding issues.

The introduction of IPTs and CARDs arguably is the most important change in the DoD weapon system costing process since the advent of independent parametric costing. Unfortunately, the sample available for this study ends in 1997 and, hence, does not permit the effects of those changes to be untangled from the changes made to the independent costing process after the IG report and the acquisition reform measures, mentioned above, were adopted in the early to mid-1990s. Similarly, the presumed gradual improvements in costing methods and data cannot be distinguished statistically from the variables that mark strengthening of the independent costing process.

In addition to these time-linked changes, there is reason to suspect that the ability to detect speeding varies systematically across systems. In particular, the hardest MDAPs to cost are those for which there are the fewest relevant precedents.[60] This will be emphatically the case for entirely new categories of systems (nuclear submarines in the 1950s, for example) and tends to be true also for systems that incorporate large advances over their immediate predecessors.

The potential importance of this point is suggested by Figure 9, which presents the average *mistakes* component of growth in procurement cost against the Milestone II baseline for the MDAPs used in this study, grouped into eight commodity classes.[61] The number of systems in the commodity class appears (on the horizontal axis) just after the label of the class. The key feature of this figure is that the commodity classes with the smallest number of MDAPs in them—helicopters, vehicles, and munitions—show by far the largest cost growth. (Space, with six systems and an average forecast error of about 17 percent, does not entirely fit the pattern, but there is some reason to question how representative of the commodity class as a whole the six systems included are). All of the commodity classes (except ships) include systems from at least two services. There is a substantial variation within each commodity class in terms of program size (measured in constant dollars) and program vintage. All systems of a given vintage faced much the same budget climate, and there is no reason to think that budget strategy would involve radically different considerations for one commodity class over another. If these points are granted, it is

plausible to attribute the effect that shows up in Figure 9 to richer cost data producing more accurate or more persuasive cost estimates.

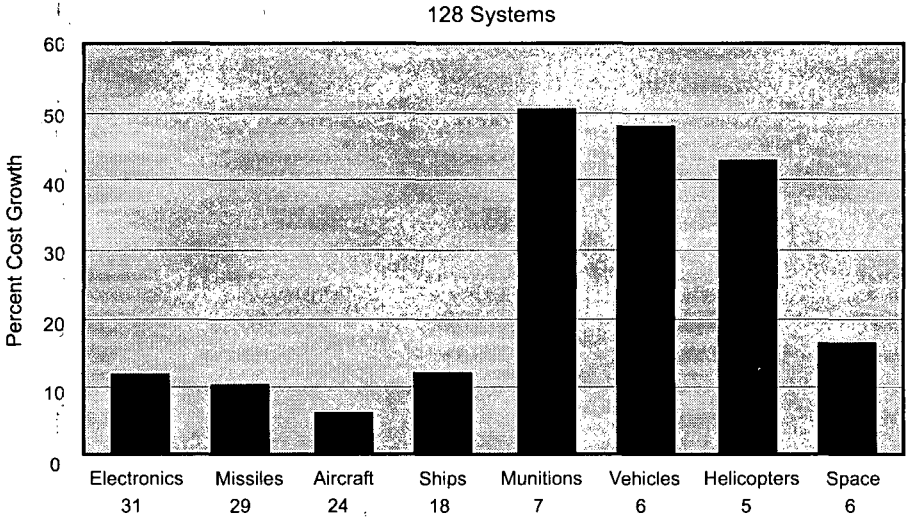


Figure 9. Average Error in Forecasts of Procurement Cost Relative to the Milestone II Baseline for Eight Commodity Classes

The opposite case is that of major systems for which the data are particularly good and which are, therefore, comparatively easy to estimate. This is, for example, reasonably assumed to be the case for major systems that are modifications of a system in the active inventory. It would also be expected to be the case, although perhaps less strongly, for systems for which a prototype was built as part of the development work done prior to the start of EMD.

The coefficients estimated for variables marking the factors identified in this section are presented in Table 10. Also included is a variable (BAD) that marks the Family of Medium Tactical Vehicles (FMTV) for which, as discussed in Chapter 2, the cost growth from Milestone II is known to reflect, at least in large part, an inadvertent costing error (rather than a decision to adopt a highly optimistic estimate). Modification programs (MOD) and those that had a prototype (PROTO) have the expected negative coefficients, but they are small and not statistically significant. The variable marking systems with comparatively few useful precedents (FEW) has the expected positive sign and is statistically significant.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Table 10. Estimated Coefficients of Variables Marking Presumed Differences in the Quality of the Data Used in Estimating Costs

Variable	Definition	Coefficient (t-statistic)
BAD	Dummy variable marking for FMTV: 1 if system was known to embody major, inadvertent cost-estimating errors; 0 otherwise	0.382 (1.112)
FEW	Dummy variable marking estimates with few useful precedents: 1 if system had few useful precedents; 0 otherwise	0.464** (3.687)
MOD	Modification programs: 1 if program was a modification of an existing system; 0 otherwise	–0.050 (–0.591)
PROTO	Prototypes: 1 if program included a prototype; 0 otherwise	–0.117 (–1.317)

**Significant at the 1% level.

There is no reason to think that enforcement of policy on realistic costing is particularly stern for modification programs and programs with prototypes but lax for programs with few precedents useful for costing. Similarly, there is no reason to think that these systems are particularly susceptible (or immune) to the mechanisms of cost growth described in the following chapter. So the estimates provide clear evidence that cost growth is associated with how solid the Milestone II cost estimate is.

Why the cost estimates for systems with few useful precedents will tend to be *uncertain* is clear. The usual presumption, however, is not that the estimates are uncertain, but that they are almost always too *low*. The evidence presented here tends to agree with this presumption, but it is not obvious why cost estimates for difficult cases should tend to be low. Cost estimators work hard at identifying the uncertainties in the system whose costs are being estimated and, left to their own devices, include reasonable allowances for these uncertainties in their estimates. To the extent that they do so, the estimates for hard cases would be expected to show particularly large variation, but not to be systematically too low.

Nonetheless, it could be that, given the task of estimating the cost of a system with few precedents, cost estimators typically fail to recognize and take account of the novel features of the system, and those novel features usually come at a price. There is also another, more subtle possibility that needs to be considered. This is that the greater the uncertainty in the independent cost estimate, the less likely it is to have any marked influence on the budget adopted at Milestone II (from which cost growth is measured). Acceptance of the

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

independent cost estimate is by no means automatic even in administrations that more strictly enforce the policy on budgeting MDAPs on the basis of realistic cost estimates. The independent estimate is more likely to be influential when the differences between it and the estimate of the service sponsoring the acquisition can be easily explained in concrete terms; it is less likely to be influential when the differences hang on complex, somewhat conjectural factors. This point is reinforced by the widespread perception that OSD and service comptrollers tend to reallocate to other applications substantial reserves in an MDAP's funding. Consequently, adopting a higher, realistic estimate in these cases may not appear to be an alternative actually available.

The question here is not whether there tends to be more cost growth for systems whose costs are hard to estimate than for those for which the task is easier. The evidence indicates that this is the case. What we don't know from the evidence is whether the independent cost estimates were too low or whether the facts are explained by features of the decisionmaking process.

Changes in the Speed Limit

There probably is some degree of selective enforcement within any administration of policy of budgeting on the basis of realistic cost estimates, but this is not something that can be readily modeled.[62] It is possible, however, to capture large changes between administrations in how strictly the policy is interpreted. There have been no explicit changes in the speed limit—the policy of budgeting MDAPs on the basis of realistic cost estimates—since the policy was adopted in late 1972. The observable changes have been in the enforcement of the policy.

The first change came around 1977, when James Schlessinger, Secretary of Defense under President Nixon, was replaced by Harold Brown, Secretary of Defense under President Carter. Senior DoD officials of that period endorsed budgeting for weapon system procurement programs on the basis of realistic cost estimates, and the speed limit imposed by Secretary Laird in 1972 was not rescinded during that period. During Secretary Brown's tenure, however, the Defense Department took a more relaxed view of what constituted a realistic estimate. The most readily accessible evidence of this is found in congressional interest in the subject. There was evident congressional dissatisfaction with the Defense Department's record on weapon system cost growth in the late 1970s and early 1980s. Between 1979 and 1983, two full committees, one subcommittee, and one special panel of a full committee held hearings devoted entirely or in significant part to cost growth on weapon systems,[63] and the Congress commissioned General Accounting Office and Congressional Budget Office studies on cost growth.

Policy on enforcement of the costing speed limit changed again in 1981, when Caspar Weinberger became Secretary of Defense under President Reagan. Late

Approved for public release; distribution unlimited.

in 1981, then-Deputy Secretary of Defense Frank Carlucci adopted a series of initiatives to improve the DoD weapon system acquisition process, one of which was budgeting for MDAPs on the basis of the most likely cost estimate. While the words used were slightly different, the thought was the same as that of the Laird/Packard policy adopted a decade earlier. Moreover, in 1982 a process intended to ensure that the independent cost estimates were appropriately considered in the services' budgets was added to the summer review of the DoD program. Both this process and the emphasis placed on budgeting to most likely cost were retained for the next decade, through the end of the administration of the first President Bush in January 1993.

The policy of budgeting to a realistic cost estimate was not abandoned during the Clinton administration. It was not endorsed by Secretaries Aspin, Perry, or Cohen, however, and the policy was less rigorously enforced during the Clinton administration than it had been during the Reagan and Bush administrations.

Table 11 reports the estimated coefficient of a variable marking changes in the enforcement of policy on realistic costing. The estimated coefficient is positive, as would be expected, but not statistically different from zero. That is, the estimate implies that less strict enforcement of the speed limit is associated with more speeding, although the magnitude of the effect is imprecisely measured by the estimates reported here.

Table 11. Estimated Coefficients of Variables Marking Changes in Enforcement of DoD Policy in Realistic Costing

Variable	Definition	Coefficient (t-statistic)
RELAXED	Less stringent enforcement of realistic costing: 1 for 1977–1980 and 1993–1997; 0 otherwise	0.088 (0.884)

Conclusions

This chapter is concerned with understanding the cost growth that results from the adoption at Milestone II of an unrealistic procurement cost estimate.

Popular comment on this topic tends to start with the presumption that DoD decisions on cost estimates and budgets for major systems are geared primarily towards getting those systems approved. Popular comment also tends to end at that point. This is unfortunate because, while the presumption that the services prefer optimistic cost estimates for major systems is not flatly wrong, it falls short of being right in two crucial respects.

Approved for public release; distribution unlimited.

First, the evidence presented here indicates that, while the preference for optimistic pricing probably does vary among the services, it seems to be more or less uniform across time and types of systems. Thus, the preference for optimistic costing is of no help in explaining the wide variation in cost growth that is observed.

Second, the evidence generally supports the speeding model used here to structure the discussion. The introduction of independent parametric weapon system costing in 1972 has had a continuing, marked effect in reducing growth in procurement costs from the Milestone II baseline. The evidence also less strongly indicates that the subsequent strengthening of the independent costing process has further reduced cost growth, and that observed cost growth is influenced by the stringency with which policy on realistic costing is enforced. Thus, the Milestone II procurement cost estimates from which cost growth is measured are at least to a significant degree constrained by the DoD policy of budgeting for major weapon systems on the basis of realistic cost estimates.

We do not get from these conclusions alone an indication of the number of instances of extreme cost growth due to adoption of an unrealistic cost estimate at Milestone II. The discussion returns to this point in the final chapter.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

6. *Mistakes* Unrelated to Milestone II Estimates

This chapter examines causes of the *mistakes* component of procurement cost growth other than the adoption at Milestone II of an unrealistic cost estimate. In the taxonomy used in this study, these fall under two main families—program instability and effectiveness of program management.

The initial task of this chapter is to identify "experiments" in the historical record and program attributes that presumably have an important connection with program stability and the effectiveness of program management. That done, the chapter takes up the question of how large an effect on cost growth the factors identified seem to have had.

There is no conceptual frame for this chapter like the speeding model of cost growth used in the previous chapter. In its absence, the only available approach is a largely open-ended examination of the historical record and program attributes in terms of the study's central task—explaining cost growth. The relevant experiments are the major changes in statute, DoD regulations, and DoD policy that deal with acquisition. A long list of program attributes might be relevant. Of these, the only ones that can be examined within the confines of this study are those reported in the Selected Acquisition Reports (SARs) or other readily available documents.

The range of search is also narrowed by the purpose of the study. It is, first, concerned with major defense acquisition programs (MDAPs), while some of the important changes in the acquisition process over the past 30 years have been directed to the ways the Defense Department buys commodities and services. Second, the study deals with growth in procurement costs; it does not go into growth in development costs. Finally, the study is concerned with cost growth, not cost. Many elements of acquisition reforms were directed primarily at *what* rather than *how* the Defense Department buys. These elements may have affected the costs of post-reform systems, but they presumably had little effect on cost growth. Changes directed at how the Defense Department buys MDAPS are more likely to have influenced subsequent cost growth, but even these do not necessarily do so. In particular, such changes will have little or no discernable effect on procurement cost growth to the extent that they are taken into account in the baseline cost estimates.[64]

Experiments Relating to Funding Instability and Effectiveness of Program Management

The history of acquisition reform is a natural place to look for experiments in the record that might reveal the role of program instability and effectiveness of program management in procurement cost growth. Discussion of program attributes that may be relevant is postponed until the following section.

Approved for public release; distribution unlimited.

The first round of acquisition reform was initiated by then-Deputy Secretary of Defense David Packard in 1969.[65] As was noted in Chapter 1, one of the main elements of these reforms was the incorporation within the acquisition process of independent cost estimates at major decision points. David Packard also directed that no further use be made of Total Package Procurement (TPP). TPP and TPP-like contractual arrangements are included under management effectiveness on the premise that they could have been made to provide results acceptable in terms of cost, schedule, and performance. (See Chapter 3, Section B.) The TPP contracts used from the mid to late 1960s had not done so, however.

David Packard also played the leading role in a second round of acquisition reform, which began about a decade later. The start of this second round can be placed in 1979 with the first of a series of hearings by various congressional committees (mentioned in the previous chapter) into cost growth in weapon acquisition programs. This congressional interest was given a sharp impetus and a wider focus by spare parts scandals that occurred during 1981–1982, early in the first Reagan administration. Several statutes directed at various aspects of the weapon system acquisition process, including cost estimation, emerged from these hearings. In July 1985, President Reagan established the Blue Ribbon Commission on Defense Management, chaired by David Packard and generally known as the Packard Commission. The report of the Packard Commission was published in 1986.

The Packard Commission probably is most widely remembered for its recommendation that the Congress create the position of Under Secretary of Defense (Acquisition), or USD(A).[66] The Commission also proposed changes in the DoD acquisition management structure below the USD(A) level. Before the Packard Commission report, the program managers (PMs) of major acquisition programs typically reported (ordinarily through one or more intermediate levels) to the commander of a service systems command or commodity command, who in turn reported to the service chief. The Packard Commission recommended taking the PMs out of the commodity commands. Instead, PMs would report to newly created Program Executive Officers (PEOs). The PEO was to have charge of a small number of related programs. From the PEO, the proposed chain on acquisition decisions for major programs ran through the also newly designated Service Acquisition Executive (SAE) (the assistant secretary responsible for weapon system acquisition programs) to the USD(A), who served as the Defense Acquisition Executive (DAE).

The implementation of the PM/PEO/SAE/DAE structure was completed during the administration of the first President Bush. The principal step in this regard was reorganization of the services' systems and commodity commands. With this, program managers of major weapon systems were taken entirely out of the chain of the systems command, and the PEO/SAE/DAE structure was fully installed.

The Packard Commission also made a closely related recommendation to stabilize program funding. Within the organizational structure proposed by the Packard Commission, the program manager (through the PEO and the SAE) and the DAE were to be bound together in a "contract." Viewed narrowly, the contract for a major program was to take the form of an acquisition program baseline (APB) specifying year-by-year cost, key elements of the planned schedule, and the crucial aspects of performance. Baselines that contained this information had been used in the Defense Department since at least the early 1970s. The Commission recognized this in recommending that the "DoD should fully institutionalize "baselining" of major weapon acquisition programs at the initiation of full scale engineering development."[67]

The new element in the Commission's recommendation on stabilizing programs was that the "Congress approve multi-year funding for the development and low-rate production of all major programs approved for full scale development."[68] By this, the Commission meant that the Congress should routinely authorize and appropriate funds for Engineering and Manufacturing Development (EMD) and Low-Rate Initial Production (LRIP) when a major program enters EMD, rather than authorizing and appropriating the funds annually. Doing so would permit the DAE to uphold his end of the contract—to provide stable funding and backing for the PM so long as the program held to the APB.

The Packard Commission recommendations were only partially adopted. The Congress established the position of Under Secretary of Defense for Acquisition, and the first USD(A) took office in September 1986. The Defense Department had several months earlier adopted the PM/PEO/SAE/DAE management structure recommended by the Commission.[69] The Congress also passed legislation requiring the Defense Department to establish an APB for each major weapon acquisition program.[70] Thus, in form, the Defense Department adopted the notion of a contract between the PM and the DAE. The Packard Commission's recommendation that the Congress adopt milestone funding for all major systems as they entered EMD was not adopted.

Increased use of competition had been adopted as a policy early on in the first Reagan administration, and was also recommended by the Packard Commission. Insofar as the procurement phase of MDAPS was concerned, the direction to make greater use of competition led to two quite different steps. First, somewhat greater use was made of dual sourcing. Second, in several other cases TPP-like arrangements were used in an attempt to stretch the beneficial effects of competition at the start of the EMD phase to the early stages of procurement.

A third round of acquisition reform occurred during the two Clinton administrations, especially during the first, when William Perry was successively Deputy Secretary and Secretary of Defense.[71] Large parts of acquisition reform

during this period were entirely within the spirit of the Packard Commission's work. One major thrust of acquisition reform under Secretary Perry, however, went well beyond the Packard Commission Report in concept. The capstone statement on defense acquisition reform during the Clinton administration contained the following statement: "DoD and the Nation can no longer afford the luxury of maintaining a totally unique defense industrial base."[72]

More was involved here than encouraging the Defense Department to learn how to buy commercial products like a commercial firm or to make greater use of commercial items. Both of those were major strains of acquisition reform, but the language pointed to an additional step—the use of commercial methods to procure defense-unique items. That did not mean exclusively material, parts, subassemblies, and subsystems; the language was also understood to include, at least to a significant extent, major weapon systems.

Major systems must, of course, be developed before they can be bought, and it typically is not economical to buy a major system from more than one supplier. To protect the Government in these cases, price ordinarily is effectively, if not always nominally, negotiated on the basis of cost. Consequently, the contractor must provide the Government with extensive information of its past and prospective costs and profits. Moreover, before final payment is made, the system must go through an acceptance testing process to ensure that the Government in fact gets what it pays for.

Viewed from that angle, acquisition reform in the Defense Department during the Clinton administration set itself the extremely challenging problem of buying major systems using commercial methods while still visibly providing reasonable protection for the Government's interests. One tool used to explore ways in which this might be done was demonstration projects, which the Congress initially authorized in connection with the Packard Commission recommendations. Most of these were fairly small programs, and only two are in the sample used in this study. The other, more important strand of this element of acquisition reform during the Clinton administration was a new contracting approach that sought to increase the range of procurements for which a TPP-like arrangement is workable.

The new approach replaced production options obtained with the competitively awarded EMD contract with what is called a Price Commitment Curve (PCC). In this contracting strategy, bidders submit a proposal of the usual sort for the EMD work, which would be under a cost contract with incentive provisions. In addition, firms competing for the contract would submit a PCC. The PCC would specify prices for annual production lots of given sizes (or annual production lots that fall within specified ranges.) The contract would specify how those prices would be adjusted for inflation and changes in lot size (which the contract probably would permit the Defense Department to do only within

Approved for public release; distribution unlimited.

stated limits). The PCC might cover the entire planned procurement or, more likely, some fraction—the first half, for example—with the remainder to be procured under at least one new contractual vehicle with its own negotiated price. Competition would be based on the PCC's bid, in addition to anticipated performance of the system bid, schedule, and other elements of cost.

In contrast to the production options of earlier TPP-like arrangements, the PCC (although in the contract) is not a legally binding commitment to produce at no-more-than-stated prices, and the firm could negotiate different prices without suffering any contractual penalty. Rather, the root idea is to induce the firm to stay within the PCC by a provision that at first glance may seem trifling—that it need not submit data on the production costs that it has incurred on preceding lots (including LRIP lots and the test articles produced during EMD) so long as the negotiated price for successive lots remains on the PCC.

This provision involves economic incentives similar to those of a multi-year production contract. If procurement is carried out through a succession of one-year, firm fixed-price contracts (which is the usual arrangements for major weapon system programs), "this year's" price will be negotiated on the basis of "last year's" cost. In this context, "last year" should not be taken literally—the lags will usually be somewhat longer than a year. From the producer's point of view, however, this still means reductions in costs of production are captured fairly quickly by the Government; in other words, cost reductions go more into reduced prices than into higher profits.[73] In a multi-year contract, however, the contractor gets to keep the profits longer and, hence, has an incentive to achieve cost reductions that are both more rapid and larger. If the multi-year contract price is sensibly negotiated, both the Defense Department and the contractor will gain. This same mechanism can be expected to work in a contractual arrangement in which a PCC is obtained as part of a competitively awarded EMD contract, which must also provide that the contractor need not submit data on production costs actually incurred so long as prices remain on the PCC.

Evidence on the Effects of Acquisition Reform and Acquisition Policies

The acquisition reform initiatives of the early to mid-1990s roughly coincide with major changes in the independent cost-estimating process, and their separate effects on procurement cost growth cannot be disentangled using the data and methods of this study. It is possible, however, to isolate the effects of the shift to the PM/PEO/SAE/DAE structure implemented at the recommendation of the Packard Commission. This shift is interesting both for its connection with acquisition reform and because it is the only large-scale "experiment" in the data that at least potentially has something to say about the effect of program management on cost growth.

Approved for public release; distribution unlimited.

As was discussed previously, the Packard Commission's intent was to bind the PM to the DAE with a "contract" covering performance, cost, and schedule. Had this been done, there is a reasonable expectation that it would have reduced cost growth on major weapon system procurement programs. In fact, it was not; the new management structure was implemented, but provisions (especially, milestone funding) that would have permitted a strong "contract" between the PM and the DAE were not. The effect on cost growth this partial implementation of the Packard Commission recommendations should be expected to produce is not clear. It seems somewhat likely, however, that the effect was to reduce the tightness of the management constraints operating on the PMs of major programs and, hence, to permit more cost growth.

That is, in fact, what we observe. Table 12 shows the estimated coefficient of the variable that marks the implementation of the PM/PEO/SAE/DAE structure is positive and statistically significant. The new management structure, then, seems to have resulted in more growth in procurement cost.

Table 12. Estimated Effects on the *Mistakes* Component of Procurement Cost Growth of Implementing Packard Commission Recommendations on Management Streamlining

Variable	Definition	Coefficient (t-statistic)
PEO	Program Executive Officer management structure: 1 for 1987 on; 0 before 1986	0.240† (1.871)

† Significant at the 10% level.

The effects of the new management structure may, however, be tangled up with another, almost certainly unintended consequence of the Packard Commission reforms. From the introduction of independent parametric costing in 1972 through implementation of the Packard Commission recommendations in 1987, the Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), or USD(AT&L), shared responsibility for basing acquisition program budgets on realistic cost estimates with the DoD Comptroller's office and the Office of the Director, Program Analysis and Evaluation (PA&E). Cost estimates developed in connection with milestone reviews informed the Defense Systems Acquisition Review Council (DSARC) chairman of cost issues, but did not require him to make a decision on the cost estimates or the program's budget. By and large, those decisions were made in the programming and budgeting phases of the Planning, Programming and Budgeting System (PPBS). "Realistic costing" was routinely an issue in the programming phase of the PPBS throughout the period 1982–1993, and, for several years during the mid-1980s, these included reviews by the Cost Analysis Improvement Group (CAIG) of 20 to 25 major acquisition programs' cost estimates.[74]

Approved for public release; distribution unlimited.

Moreover, the DoD Comptroller staff tended to consider the CAIG estimate in the subsequent budget phase of the PPBS.

There is no indication that the introduction of the APB was intended to alter the roles of PA&E and the Comptroller in policing policy on "budget to most likely cost," but it gradually did so, largely because it required USD(AT&L) to make an explicit decision on what cost estimate to use in the APB. Early in President Clinton's first term, it was made explicit that PA&E and the Comptroller were generally to defer to the decision on cost made by USD(AT&L), and realistic weapon system costing was not marked out as a separate topic in the programming process of the Clinton years. Historically, the strongest proponents of realistic costing have been the Comptroller and, especially, PA&E, so it is a reasonable conjecture that, by reducing the role of these organizations, the introduction of the APB tended to permit greater cost growth.

This change in roles happened only gradually, and did not take hold fully until early in FY 1994, while the effect of the new management structure seems to be visible from FY 1987 on. Hence, it seems likely that the estimated coefficient in Table 12 mainly reflects the management changes.

Table 13 reports the estimated coefficients of three variables associated with the following Packard Commission recommendations: prototyping (Use Technology to Reduce Cost), multi-year procurement (Stabilize Programs), and dual sourcing (Increase the Use of Competition.) Also reported is the estimated coefficient of a variable marking EMD contracts that included binding production commitments. Use of such arrangements was not a recommendation of the Packard Commission. Rather, it reflected an application of the policy strongly favoring competition that prevailed during the 1980s when DoD procurement budgets were at historical peacetime highs.

Table 13. Estimated Effects on the *Mistakes* Component of Procurement Cost Growth of Aspects of Acquisition Strategy

Variable	Definition	Coefficient (t-statistic)
PROTO	Prototype: 1 if program included a prototype; 0 otherwise	–0.117 (–1.371)
MY	Multi-year contract: 1 if program employed a multi-year contract in procurement; 0 otherwise	–0.116 (–1.125)
DS	Dual sourcing: 1 if program was dual sourced; 0 otherwise	–0.036 (–0.397)
TPP	Total Package Procurement: 1 if binding price commitments for some procurement lots were obtained in competition for EMD contract; 0 otherwise	0.438** (2.994)

**Significant at the 1% level.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

The estimated effect of prototyping was discussed in the preceding chapter. As noted there, the estimated coefficient of PROTO is negative, small, and not statistically significant. This is not surprising since prototyping prior to EMD can be expected to influence both the procurement cost of a program and the estimate of the procurement cost made at Milestone II. The fact that the estimated coefficient is statistically insignificant does not imply that prototyping is a bad idea or doesn't have a major effect on procurement cost; it implies only that those effects cannot be reliably inferred from cost growth.

The Congress generally has approved the use of a multi-year contract only for systems that have stable requirements and are reasonably anticipated to have stable funding. Consequently, the MY variable marks particularly stable programs. These programs are generally thought to result in substantially less cost growth than other programs. The estimated coefficient of MY does not bear this expectation out. It has a negative sign, as expected, but is small and statistically not significantly different from zero. Again, the most plausible explanation is not that use of multi-year contracts has no effect on cost, but that those effects are anticipated reasonably well in Milestone II estimates.

The estimated coefficient of the variable marking programs that were dual sourced (DS) is small, negative, and statistically insignificant. As in the other cases, we would expect to observe a substantial effect on cost growth only if the Milestone II estimate did not anticipate the use of dual sourcing or if its effect on procurement cost is systematically underestimated. In this case also, the obvious explanation of the estimated coefficient is that the effects of dual sourcing on cost are anticipated reasonably well. (It is certainly the case that during the early to mid-1980s, DoD weapon system cost estimators put a good deal of effort into developing the tools required to do so.) There is also a feature of the sample of dual-sourced systems that needs to be recognized. The sample includes a small number of instances in which dual sourcing was implemented in an effort to halt further large increases in procurement cost. Those efforts generally worked, but did not undo, at least fully, the cost growth that occurred before the start of dual sourcing.[75] Thus, the sample includes some dual-sourced systems with large *mistakes* components of procurement cost growth, which partially masks the effects of dual sourcing.

The last of the variables in Table 13 marks six systems procured using watered-down versions of TPP. This variable is worth detailed discussion because it provides a clear and statistically significant explanation of a mechanism that in several instances has caused extreme growth in procurement cost.

Total package procurement was used to procure a number of major systems during the 1960s. In these cases, the Defense Department obtained a single contract covering both EMD and procurement and, often, parts of the support required by the system once it had been fielded (for example, provision of spares.)

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Characteristically, this was a fixed price incentive fee (FPIF) contract obtained through a competition in which price was an important selection factor.

TPP was intended to solve a problem deeply rooted in the economics of weapon system procurements. Competition during the procurement phase of a weapon system acquisition often is not feasible. When it is not, the Defense Department must rely on the contractual vehicle and contract management to achieve results otherwise provided by competition. The Holy Grail of contracting theory is a contract award process and contractual vehicle that (1) reliably identifies the firm with the lowest costs, (2) provides incentive to the winner to develop a system that meets the stated requirements at minimum cost, and (3) minimizes cost during the procurement phase.

TPP approaches this problem by extending the scope of competition from the EMD phase only to EMD and procurement, and often some of the support phase as well. The essential feature of TPP is that bidders are required to make contractually binding commitments on procurement price in a competition at the start of EMD. TPP is fundamentally a way of extending the reach of competition from a point at which it is feasible—the selection of a firm to do the EMD work—to the procurement phase, for which competition ordinarily is not economical.

In most of these cases, TPP worked poorly for fairly straightforward reasons. Firms' bids for a TPP contract presumably will be their expected costs plus a competitive return if they expect that the contract will be enforced more or less as it is signed. Otherwise, they have a strong incentive to "buy-in"—that is, to make an optimistic bid to gain the contract in the expectation that it will eventually be substantially modified and they will be able to make a more than a competitive return.

The most complete account of experience with TPP is provided by an IDA study published in 1992.[76] IDA judged the Maverick weapon system to be a successful program. All of the other TPP programs encountered severe technical and financial problems. The TPP contracts were then restructured as cost reimbursable contracts, and in three instances, the Defense Department "bailed out" the contractor—that is, paid part of the cost overruns incurred by the contractor to the time of the restructure. Growth in procurement cost for the TPP programs (except possibly Maverick) was far greater than the average for all programs IDA considered.

In 1970, then-Deputy Secretary of Defense Packard directed that TPP no longer be used, and it has not been. After a few years, the Defense Department began experimenting with more flexible forms of TPP that arguably provided most of the theoretical benefits of TPP without the brittleness that usually defeated it. The six systems in the sample marked by TPP, in particular, had two TPP-like

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

features. First, the contracts obtained at the start of EMD covered both EMD and at least the early part of production. Second, this contract was contained through a competition in which price was a significant factor. They were a step back from the TPP contracts of the 1960s in that the EMD contracts typically were not FPIF, but cost reimbursable contracts with incentive features; not all of production was covered; and the procurement part of the contract was more likely to use "not to exceed" prices than firm fixed-price quotes.

These TPP-like contracts also have not worked well, for the same reasons as the TPP contracts of the 1960s. All of the 6 systems marked by TPP are among the 35 systems in the sample with a *mistakes* component of procurement cost growth, and one (the C-17) was one of the most troubled major acquisitions of the past 20 years.

A further refinement of a TPP-like contracting strategy (use of the PCC, described previously) was introduced as an element of acquisition reform during the Clinton administration. Insofar as data are concerned, the jury on whether this approach will work is still out.

Concluding Comment

After more than 20 years of acquisition reform efforts, there is no surprise at all in the general notion that the DoD acquisition process can be implicated in cost growth. There is an element of surprise in this chapter's suggestion that the discernable effects of those changes are statistically insignificant, with one, or perhaps two, exceptions. First, the introduction of the PEO structure—which was part of one of the reforms proposed by the Packard Commission—has a (marginally) statistically significant association with higher cost growth. Second, TPP-like contracts, adopted as a way of extending the benefits of competition up to the start of EMD to the procurement phase, were strongly associated with extreme procurement cost growth.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

7. Conclusions and Recommendations

This study was organized around three tasks. The first was to determine whether growth in the costs of major defense acquisition programs (MDAPs) is enough of a problem to warrant corrective action. Chapter 1 argues that it is. The problem proves to be not the modest growth in procurement cost that is typical of major weapon acquisition programs. Rather, the damage that procurement cost growth does to the DoD program as a whole is largely done by the comparatively small number of systems that show extreme cost growth.

The second task was to get a sense of the relative importance of the various mechanisms through which cost growth in procurement programs occurs. The initial steps in this task were taken in Chapter 2 (Introduction to the Data) and Chapter 3 (Mechanisms of Cost Growth). Chapters 4 through 6 then turned directly to the evidence on the importance of various mechanisms of cost growth.

The third task—taken up in this chapter—was to sort through the bits and pieces of evidence presented in Chapters 4 through 6 for pointers on which steps to reduce cost growth might be useful.

The discussion is built around the mechanisms of cost growth identified in Chapter 1:

1. A decision is made to increase the capabilities of the system beyond what was approved at Milestone II and captured in the Milestone II procurement cost estimate.
2. The decision maker at Milestone II, for whatever reason, adopts an unrealistic estimate of procurement cost.
3. Poor program execution or exceptional budget instability cause cost growth avoidable by better program management or more budget stability.

The discussion is, in particular, directed towards assessing the evidence identifying mechanisms that reliably operate in a significant set of cases to cause extreme cost growth, since it is those that are of principal importance in considering corrective actions.

Post-Milestone II Baseline Changes and Post-1988 Modification Programs

Table 14 provides an overview of the factors identified in this and preceding chapters as possible explanations of extreme cost growth for the systems in our sample. The definitions of the column headings in that table are as follows:

- POST—Indications of changes introduced during Engineering and Manufacturing Development (EMD) beyond what would be required to meet Milestone II requirements

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

- MOD2—Marker of post-1988 modification programs: 1 if modification program passed Milestone II in 1989–2001 or a major post-Milestone II preproduction addition to capability is noted; 0 otherwise
- TPP—Total Package Procurement: 1 if binding price commitments for some procurement lots were obtained in competition for EMD contract; 0 otherwise
- FEW—Dummy variable marking estimates with few useful precedents: 1 if system had few useful precedents; 0 otherwise
- BAD—Dummy variable marking for the Family of Medium Tactical Vehicles (FMTV): 1 if system was known to embody major, inadvertent cost-estimating errors; 0 otherwise

Substantial increases in capability were introduced during EMD (POST) for seven of the systems. Patterns of cost growth also suggest that this was the case for the seven systems that were modification programs adopted after 1988 (MOD2). We can be reasonably sure that, in these fourteen cases, much of the extreme cost growth was due to a change in what was procured rather than to adoption of an unrealistic cost estimate at Milestone II. Although the evidence is circumstantial, substantial delays in funding appear to be typical in these cases.

The pivotal question about the fourteen systems in this category is whether the changes apparently introduced during EMD were unforced decisions to procure a more capable system or were necessary to meet the requirements for the system that was approved at Milestone II. We have direct evidence for two systems—the Bradley and the Stand-off Target Acquisition System (SOTAS)—that the changes were unforced. This study's inclination to assume that at least most of the others were as well, however, rests entirely on circumstantial evidence. The point is important because the remedy is somewhat different for each of the two possibilities.

The first line of defense against the adoption of an unrealistic program assumption is composed of the studies and development work done by the sponsoring service before the Milestone II decision. The second line is the elaborate source-selection process that ordinarily precedes the Milestone II review, and the third is the milestone review process. One important task of the Office of the Under Secretary of Defense (Acquisition, Technology and Logistics) in the milestone review process is to ensure that the program complies with the long-standing DoD policy that the technologies to be used in a system achieve reasonable levels of maturity before the system enters EMD. These safeguards are not foolproof, of course, but to the extent that their failure is a significant source of cost growth, the obvious remedy is more effective use of existing processes, not new processes.

Approved for public release; distribution unlimited.

Table 14. Factors Contributing to Extreme Cost Growth for Systems with *Mistakes* Component of Procurement Cost Growth of at Least 30 Percent

Name	POST	MOD2	TPP	FEW	BAD
Army					
SADARM 155mm Projectile	✓			✓	
FIM-92 Stinger Missile	✓				
USQ-84(V) SOTAS	✓				
M2/M3 Bradley FVS	✓			✓	
MIM-104 Patriot PAC-3	✓				
AH-64D Apache Helicopter Airframe					
FMTV					✓
FGM-148A Javelin AAW Missile					
UH-60A Blackhawk Helicopter				✓	
Hunter Short-Range JTUAV					
AH-64 Apache Helicopter	✓		✓	✓	
M1 Abrams Tank					
ATACMS P3I (BAT)	✓				
M712 CLGP (Copperhead)				✓	
ATCCS ASAS Block II/III		✓			
AIQ-212(V) ATIRCM/CMWS		✓			
ATCCS FAAD C2I					
ATACMS Block II/IIA		✓			
M2/M3 Bradley FVS Upgrade		✓			
Navy					
NATO Pegasus-Class PHM					
T-45 Goshawk Training System			✓		
AGM-84A Harpoon Missile			✓		
AN/SQR-19 TACTAS					
NATBMD					
Air Force					
E-3 Sentry AWACS RSIP		✓			
JSTARS			✓		
DSCS-III					
BGM-109G Tomahawk GLCM					
AIM-9L Sidewinder Missile					
T-6A JPATS			✓		
GPS					
C-17A Globemaster Aircraft			✓		
C-130J Hercules Aircraft		✓			
LGM-30 Minuteman III GRP		✓			
F-15 Eagle Aircraft					

Note: See the list of abbreviations at the end of this paper for the meanings of abbreviations used here.

Approved for public release; distribution unlimited.

As noted previously, this study leans toward the position that the changes in most of the fourteen cases under consideration here were not needed to meet Milestone II requirements. Somewhat different processes bear on the problem of seeing that there is timely recognition of the funding implications of such decisions. A clear view of this problem requires distinguishing among the following: (1) when a post-EMD pre-production change in a system was adopted, (2) when the cost estimate was revised to reflect the change, and (3) when the increased funds required by the change were committed. A decision to change a system's baseline ordinarily requires putting that change on the EMD contract. Such decisions should compete for funding in the regular resource allocation process. If the proposal is adopted in that context, the change can be placed on the EMD contract and the cost estimate for the system can be revised and funding, including out-year funding, committed.

DoD processes do not require that these steps be taken in concert, however. Particularly if the additional EMD funding required is initially fairly small, it is possible to decide on a baseline change and place it on contract through one bureaucratic process, fully revise the cost estimate to reflect the change later, and commit all of the funding required only after a further lag.

At some point, a major change in a program will generate a cost or schedule breach, which will trigger a review by USD(AT&L) and, if the breach is large enough, notification of the Congress.[77] This process includes review of the system's cost estimate by the Cost Analysis Improvement Group (CAIG), and it is likely that this will lead to consideration of the system's funding in the budget process. These steps are reactive, however, and may come several years after the change has been adopted. Although of secondary importance, it is also relevant that the cost reviews are done under great time pressures, and they usually are not as searching as those done at a milestone review.

At a broad level, the following correction for this problem is appropriate and straightforward: alter the acquisition regulations to require prior USD(AT&L) approval of any major change in a major defense acquisition program's baseline; support the approval decision with a careful estimate of the cost of the change and verification that the funding required has been committed; and require that any major change in an MDAP baseline compete for funding in the ordinary resource allocation process. The devil in this case would be very much in the details. Crafting a rule that applied to major changes (and to a series of small changes that cumulate to a major change) but filtered out smaller changes would be challenging.

DoD acquisition regulations were recently changed to establish "spiral development" as the preferred acquisition strategy for major systems. Although not adopted for that reason, spiral development in principle provides a conclu-

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

baseline changes.[78] For the problem at hand here, the key features of the new spiral development process are:

1. The content of the first spiral (and, to the extent that they are known, succeeding spirals) must be fully specified when the program is initiated.
2. The capability of any one spiral must be demonstrated (via testing) before development of the next spiral begins.
3. A separate milestone authorization is required for each spiral.

The second and third of these features are the most important in terms of growth in procurement cost due to major baseline changes. Given these requirements, a service could not introduce a major change in a system in development without consulting with USD(AT&L).

Unrealistic Milestone II Cost Estimates

Six of the 35 instances of extreme cost growth employed TPP-like contracts. Including the 14 cases with baseline changes, 20 of the 35 cases have a plausible proximate cause of extreme cost growth. That leaves 15 cases for which the evidence presented does not rule out the adoption of an unrealistic cost estimate at Milestone II as the main cause of their extreme cost growth.

Two key conclusions from preceding chapters provide a clear view of this problem. First, the problem is not with the average or typical system. For 80 percent of the systems in the sample, the *mistakes* component of procurement cost growth was small enough not to be a serious problem; the problem presented by growth in the *mistakes* component of procurement cost is largely due to the 35 systems with extreme cost growth.

Second, the statistical results tend to reject the popular notion that cost growth, especially cases of extreme cost growth, can be explained by budget strategy, that is, by the deliberate adoption at Milestone II of an unrealistic cost estimate. There is statistical evidence that the services, especially the Army, prefer relatively optimistic Milestone II cost estimates. There is also some weak statistical indication that some administrations have taken a more permissive attitude towards cost growth than have others. There is, however, no statistical evidence that budget strategy has had any marked effect on cost growth. Moreover, there is clear, statistically strong, evidence that the independent costing process that the Defense Department adopted in 1972 has been reasonably effective.

The second conclusion leaves the following two possible explanations for the adoption of (apparently) unrealistic cost estimates at Milestone II: (1) a straightforward, inadvertent costing error; and (2) one of the major program assumptions on which the cost estimate rested proved to be unrealistic. Unfortunately,

Approved for public release; distribution unlimited.

this study provides only a blurry picture of the relative importance of these two ways to arrive at an unrealistic cost estimate at Milestone II. The only general evidence we have on this point is that the *mistakes* component of procurement cost growth tends to be larger for systems with fewer precedents useful in cost estimation.

This correlation points in the direction of inadvertent error and uncertainty in the independent cost estimate developed for the Milestone II review. It also points towards a suggestion for reducing cost growth. Systems that are going to present particularly difficult costing issues ordinarily can be identified at Milestone I, which is typically 3 or 4 years before the Milestone II review. Occasionally, the period when the system is in Program Demonstration/Risk Reduction is used to tackle crucial costing issues, which can then be resolved by the time of the Milestone II review. The DoD acquisition regulations, however, do not require or especially encourage this, and efforts directed at cost-estimating issues don't happen unless some of those involved go out of their way to initiate them and the PM concurs. Ordinarily, costing efforts begin 6 months before the Milestone II review, and this is not enough time in challenging cases.

The Joint Strike Fighter (JSF), now the F-35, provides an excellent example of what can and more often should be done. The JSF is to be developed and produced in three distinct variants, one each for the Navy, Air Force, and Marine Corps. Much of the idea behind the JSF is that these three variants have a great deal of commonality, which should reduce costs of their development, procurement, and operation. The commonality in question is not exclusively a straightforward matter of identical parts; rather, it also involves distinctions among different types and degrees of commonality. Not long after the JSF entered the pre-EMD phase of its development, the cost group at the Naval Air Systems Command (NAVAIR) initiated a study to establish a useful taxonomy of commonality for the JSF and begin the task of establishing "how much" each of the variants would have in common with the others. This study involved the Air Force and Office of the Secretary of Defense (OSD) cost groups as well as the contractors. It took about 8 months to complete, was updated several times before the Milestone II review of the JSF, and provided the foundation for the Milestone II JSF cost estimates.

The recommendation suggested by these comments is as follows: modify the DoD acquisition regulations to provide for explicit consideration during the Milestone I review of what efforts related to cost estimating need to be undertaken during the pre-EMD development phase. This modification might usefully be structured under three headings:

1. *Data.* What direction needs to be given to ensure that the data important to the cost estimates made at Milestone II are captured during the pre-EMD phase? This is an elementary point, but it is common to find that the

cost data collected during the pre-EMD phase is so "dirty" that they can be employed only if the Milestone II review is pushed back by several weeks to permit time to clean them up.

2. *Demonstrations.* Which demonstrations designed to narrow the uncertainty on major determinants of cost should be included in the pre-EMD program? For example, it probably would be sensible to provide for demonstrations of technologies that might cause the costs of the system being developed to be much lower than the costs of its most recent historical precedents.
3. *Studies.* Which studies of major cost issues (like the JSF commonality study) ought to be initiated?

These items should be considered for all systems and then explicitly directed as warranted in individual cases.

Production Commitments Obtained with the EMD Contracts

Procurement cost growth due to abnormally great budget instability and that due to ineffective program management were folded into the discussion in Chapter 6 about the discernable effects on cost growth of acquisition reform. As noted there, many of the more important reforms proposed were either not implemented or implemented only partially. Of the changes that were implemented, only that associated with the introduction of the Program Executive Officer (PEO) management structure in 1986 had a measured effect that was (marginally) statistically significant, and the effect in that case was to cause increased procurement cost growth.

The contribution of that chapter to the explanation of extreme instances of procurement cost growth lies in its results for the six systems in the sample that used a TPP-like contractual arrangement. All of these were in the top cost growth tier, and there is no real doubt that the TPP-like contract was the root problem that led to the growth in procurement cost experienced.

The record of the procurement process over the last 30 years points to three alternative policies that could be adopted in response to the almost uniformly unsatisfactory experience with TPP and TPP-like arrangements. The first of these is to not use TPP or TPP-like contractual arrangements. This was DoD policy during the period covered by this study, although exceptions were made in connection with the strong emphasis placed on the use of competition in procurement of major systems, especially during the mid-1980s, and as an acquisition reform measure in the mid-1990s.

Second, the use of TPP-like arrangements could be limited to cases in which they have a reasonable chance of being successful. The key requirement is that

bidders in the competition that leads to award of a TPP-like contract be induced to make realistic bids. There are at least two conditions that need to be satisfied to achieve this result. First, bidders must be persuaded that it is unlikely that the requirements that the system is to meet will be changed substantially during EMD. Second, it must seem highly likely that the budget for the system will remain stable, because bidders ordinarily will insist on at least lower limits on annual lot sizes.

The first of these conditions requires the agreement of the user community within the acquiring service. That will be difficult to obtain for large, technologically challenging systems that remain in EMD for several years, because the threats that the system is intended to counter can change over the course of a few years, existing components and subsystems will go out of production, and technology will advance. The second condition requires the concurrence of the resource allocation sides of OSD and of the acquiring service, OSD, and, perhaps the Congress. That will be difficult to obtain, particularly for larger programs. On this view of the matter, then, it appears that TPP-like arrangements could be made to work in a satisfactory way only for the few programs that are both comparatively small and not technologically challenging.

The third approach is the use of the Price Commitment Curve (PCC), discussed in the preceding chapter. Such arrangements are far from guaranteed to work. They contain two features that can provide bidders with strong incentives to buy-in. First, the PCC must be adjusted for changes in the system introduced during EMD. These changes may be individually and cumulatively small, but they also may not be. As noted in Chapter 4, some changes introduced post-Milestone II but pre-production seem to have had costs that were a considerable fraction of the baseline program's costs. Accommodating these changes introduces an element of cost-based contracting into the arrangement. Hence, what starts out as a procurement built around a PCC will become a hybrid. Moreover, the bidder on such a contract has an incentive to structure his technical proposal in a way that increases the likelihood of major post-Milestone II changes.

Second, the prices of the portion of the procurement not covered by the PCC presumably will be negotiated on the basis of cost. Again, the total cost of the procurement will be a blend of the prices of the PCC, obtained with the EMD contract through a competition, and cost-based prices. The latter easily could be somewhat more than half the total procurement cost. The importance of this point is brought out by asking where the Defense Department is to get the cost data needed to protect the Government's interests in negotiation of the first of these post-PCC lots. Requiring data for the last of the production lots covered by the PCC might reveal that the contractor has obtained abnormally large profits and, hence, call the arrangement into question. The Government largely

is flying blind in the negotiations if it does not obtain these data, however, and it is not clear what prices could be expected to occur in their absence.

The upshot of these comments is that arrangements that use a PCC in place of binding production commitments obtained with a competitively awarded EMD contract also require stable requirements and budgets to be successful; hence, they are likely to be useful in only a narrow range of cases.

Arrangements employing a PCC generally like what has been outlined here are being used for two major procurement programs, the Joint Direct Attack Munition (JDAM) and the Joint Air-to-Surface Standoff Missile (JASSM).[79] The JDAM is technologically far simpler than the typical major weapon system, has enjoyed stable requirements, and funding stable enough for the contract to have remained in place. By all accounts, it appears to have been a great success. The JASSM is a more ambitious program, although one that, compared to other major weapon systems, is not exceptionally challenging technologically. It is not clear yet whether the JASSM will be successful in terms of cost, so the jury on arrangements employing a PCC is still out.

Concluding Comment

This chapter has paired with each of the main mechanisms of procurement cost growth a direction for reducing the number of programs that exhibit extreme cost growth:

1. Use of spiral development as specified in the new DoD acquisition process ordinarily would preclude baseline changes while a system is in EMD. Thus, rigorous use of spiral development would block one of the main processes that resulted in extreme instances of procurement cost growth during the period considered in this study.[80]
2. Systems that will be particularly difficult to cost should be identified early in the development phase. An appropriate mix of data collection, demonstrations, and studies should be directed to provide adequate foundations for making a sound cost estimate when the system's sponsor seeks approval to proceed to the later stages of development.[81]
3. TPP-like arrangements should be used, if at all, only for technologically undemanding systems with firm requirements and excellent prospects for stable funding.

Adoption of these recommendations would not entirely eliminate the growth in procurement costs due to mistakes—that is, inadvertently poor forecasts of procurement cost, more or less deliberate acceptance of unrealistic Milestone II estimates, cost growth due to budget instability, use of a flawed contract mechanism, or poor program execution—or decisions to increase capability that are

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

not fully funded when they are made. It would not even eliminate all extreme instances of growth in procurement cost from these causes, since the recommendations would not provide any additional means for precluding extreme cost growth from unique constellations of circumstances. However, adoption of these recommendations could be expected to significantly reduce instances of extreme cost growth and, hence, the damage they do to the DoD program as a whole.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Appendix A.
Memoranda on Use of Parametric Cost Estimates and Creation of the OSD Cost Analysis Improvement Group

THE DEPUTY SECRETARY OF DEFENSE
WASHINGTON 25, D.C.

DEC 7 1971

MEMORANDUM FOR SECRETARIES OF MILITARY DEPARTMENTS

SUBJECT: Use of Parametric Cost Estimates

The problem of poor initial estimates for weapon systems continues to be of major concern to me. An indication of the magnitude of this problem is the fact that for the 34 SAR systems for which FY 72 procurement was proposed, current program cost estimates average twice as large as the original planning estimate. In the case of some programs, this ratio is over 4 to 1. A major portion of this growth can only be explained by poor initial estimates. Low cost estimates can lead to (1) the choice of non-cost effective designs, thereby foregoing other attractive opportunities, (2) serious budget impacts resulting in program stretchouts, and reduced force levels, (3) questioning of DOD's capability to manage its own program.

This situation is even more regrettable since in many cases much better initial estimates were available. Parametric cost estimates available in 1964 on the F-111A and in 1965 on the C-5A came within 20 percent of the actual costs currently being experienced. Parametric cost estimates can serve an important function in providing an early test of the reasonableness of our cost estimates during concept formulation and when we make our major commitments of funds for development and initial production.

In the light of the above, I want you to perform an independent parametric cost analysis on each major weapon system at key decision points and to make that analysis available for each DSARC review. I expect you to begin incorporating such cost analysis in your DSARC presentations beginning in January 1972. I would also like to hear from you as soon as possible on the steps you are taking to improve your capability to perform independent parametric cost analyses and to make use of them in acquisition management.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

THE SECRETARY OF DEFENSE
WASHINGTON, D. C. 20301

JAN 25 1972

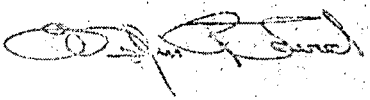
MEMORANDUM FOR The Secretaries of the Military Departments

SUBJECT: Cost Estimating for Major Defense Systems

Deputy Secretary Packard's memorandum of December 7, 1971, "Use of Parametric Cost Estimates," advised that starting with January 1972 an independent parametric cost analysis was to be incorporated in each DSARC presentation. I am keenly aware of the importance of these estimates and have established an OSD Cost Analysis Improvement Group to review the estimates presented and to develop uniform criteria to be used by all DoD units making such cost estimates. This group has representation from DDR&E, ASD (C), ASD (I&L), and ASD (SA). They will be responsive to the DSARC Chairman in assessing the reasonableness of cost estimates and the criteria followed in their development.

Because valid cost estimates are so critical to our successful defense posture, it would appear that each Service Secretary should have a staff component capable of preparing independent parametric cost estimates. This component should be responsible to the Service Secretary and organizationally separate from program proponents. Service groups responsible for independent estimates and the OSD Cost Analysis Improvement Group should work closely in developing uniform criteria for cost estimates. Our goal is to have formalized procedures for DSARC program cost presentations, as well as uniform criteria to which future parametric cost analyses will be expected to conform, developed prior to May 1, 1972.

Your comment with respect to an independent Service capability and how such a group should interface with the OSD Cost Analysis Improvement Group would be most helpful. I would like to have an improved system for top level review of all major cost estimates at the earliest practical date.



Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Appendix B.
Consequences of *Mistakes* Cost Growth

This appendix assumes that basing the initial budget for a system on an unreasonably optimistic cost estimate typically leads to program stretches, which increase the total cost incurred in acquiring the system. The task of the appendix is to estimate the costs of stretches made to accommodate mistakes in forecasting procurement costs at Milestone II.

The items needed to compute an estimate of this cost are:

- Knowledge of the extent to which mistakes in forecasting cost are accommodated by stretches rather than by cancellation of one or more systems or by addition of funds from some source outside the DoD procurement budget and
- A means of estimating the cost of production stretches for each system in the set.

These requirements are very demanding. It is possible, however, to easily get a crude approximation of the cost of stretches made to accommodate unrealistic Milestone II cost estimates and flawed program execution.

Repricing Formula

The conventions of weapon system cost estimation provide a simple way of computing an approximate estimate of the cost of a program stretch. The key assumption is that the total variable cost of a procurement program is (within reason) independent of production rate. (That is, that the total variable cost incurred in producing, say, 50 units at a rate of 10 per year for 5 years is the same as the total variable costs of producing the 50 units at a rate of 5 per year for 10 years.) Although textbook weapon system costing methods usually embody this assumption, it is not one that many cost estimators would care to defend vigorously. The assumption is made here because it provides a simple way of computing a lower bound on the cost of a stretch.

The computation is for a single weapon system program. Only procurement cost is considered. It is assumed that an unrealistically optimistic procurement cost estimate was adopted for the program at Milestone II. Other causes of growth from the Milestone II baseline are assumed not to be present. Milestone II procurement funding is compared to procurement cost for a case with the following characteristics:

- The Milestone II inventory objective is procured;

Approved for public release; distribution unlimited.

- The higher level of funding required is accommodated exclusively by stretching the program—i.e., reducing the number of systems bought annually, but buying the system for additional years; and
- Average annual procurement funding is the same in both the stretched and unstretched programs.

Finally, it is assumed the amount of overhead allocated annually to the program is independent of production rates and that procurement cost is observed at a time (well past Milestone II) when it is known for certain.

Many details that may be important in particular instances do not appear in the simple cost model used here. For example, a stretch is likely to be much more costly than it otherwise would be if it requires renegotiation of a multiyear contract. Another example is presented by requirements for jigs, fixtures, tooling and some items of machinery, which tend to be rate dependent. Timing is then important: The cost of a stretch is less if it is directed before the jigs, fixtures, tooling, and special equipment required for the higher rate have been acquired.[82] Although not in every instance, it seems probable that overall omission of such details might lead to an understatement of the amount of observed cost growth that should be attributed to schedule slips.

The notation and definitions used are provided in Table B-1. In terms of those, the objective is to compute the total mistakes cost growth in procurement z given the initial mistake z_0 computed on the assumption that the procurement is completed on the Milestone II schedule L_0.

Table B-1. Variable Definitions for the Simple Repricing Model

Variables	Definitions
B_0	Milestone II estimate of procurement cost
Q	Milestone II inventory objective
L_0	Years of production planned at Milestone II
B	Actual cost of producing Milestone II inventory objective
$C(Q)$	Actual average variable cost of producing inventory objective Q
F	Actual annual fixed cost allocated to the program
L	Actual years to produce the Milestone II inventory objective
z	*Mistakes* component of procurement cost growth from Milestone II
z_0	*Mistakes* cost growth assuming Milestone II inventory objective produced in L_0 years
z_s	Cost growth due to stretch of the program from L_0 to L years

Approved for public release; distribution unlimited.

ERRATA

A software translation problem resulted in errors in equations B-3a through B-3c on page 81 and equation B-5 on page 82 in Appendix B. The correct forms of the equations are as follows:

$$z_0 \equiv \frac{C(Q)Q + L_0 F}{B_0} - 1, \qquad \text{(B-3a)}$$

$$z_s \equiv \left[\frac{L - L_0}{L_0}\right]\frac{L_0 F}{B_0}, \qquad \text{(B-3b)}$$

$$z \equiv z_0 + z_s, \text{ and} \qquad \text{(B-3c)}$$

$$\left(\frac{L - L_0}{L_0}\right)\frac{L_0 F}{B_0} \equiv z_s = \left[\frac{L_0 F}{B_0 - L_0 F}\right] z_0. \qquad \text{(B-5)}$$

Approved for public release; distribution unlimited.

The definitions employed are as follows:

$$B = C(Q)Q + LF, \tag{B-1}$$

$$z = \frac{C(Q)Q + LF}{B_0} - 1, \tag{B-2}$$

$$z_0 \int \frac{C(Q)Q + L_0F}{B_0} - 1, \tag{B-3a}$$

$$z_s \int \left[\frac{L - L_0}{L_0}\right]\frac{L_0F}{B_0}, \text{ and} \tag{B-3b}$$

$$z \int z_0 + z_s. \tag{B-3c}$$

Rewrite Equation (B-3a) as follows:

$$z_0 = \left[\frac{B - (L - L_0)F}{B_0}\right] - 1. \tag{B-3a'}$$

Rearranging terms yields:

$$B = (1 + z_0)B_0 + (L - L_0)F. \tag{B-3a''}$$

Assume that planned annual funding at Milestone II is a constant $b_0 = B_0/L_0$. Assume further that annual procurement funding in the stretched program remains at b_0. Then $B = b_0L$. Substitute $B = b_0L$ into Equation (B-3a'') and simplify, noting that $B_0/B_0 = L_0$ to obtain:

$$\frac{L - L_0}{L_0} = \left[\frac{B_0}{B_0 - L_0F}\right]z_0. \tag{B-4}$$

Multiplying by L_0F/B_0 yields:

$$\left(\frac{L-L_0}{L_0}\right)\frac{L_0F}{B_0}\int z_s = \left[\frac{L_0F}{B_0-L_0F}\right]_0 \qquad \text{(B-5)}$$

Substitute Equation (5) into Equation (3c) and simplify to obtain:

$$z = \left[\frac{B_0}{B_0-L_0F}\right]z_0, \qquad \text{(B-6)}$$

which is the result sought. Using the rule of thumb that the fixed cost attributed to a weapon system characteristically is about 25 percent of its total cost yields the following:

$$\frac{L-L_0}{L_0} = \frac{4}{3}z_0;$$

$$z_s = \frac{1}{3}z_0;$$

and

$$z = \frac{4}{3}z_0.$$

Note also that these imply $z_0 = 0.75z$ and $z_s = 0.25z$.

Resist for the moment the temptation to apply the formulas given to the estimated 18 to 22 percent *mistakes* component of procurement cost growth and conclude that stretches added about 4.5 percent to the cost of procuring the 138 systems in the sample on the schedules established at Milestone II. Taking this only as a trial solution, the appropriate next step is to look at what additional factors need to be considered in applying the formulas derived.

Effects of the Assumptions behind the Trial Solution

These effects fall into three groups. First, it is necessary to look at the mechanisms other than adoption of an unrealistic estimate at Milestone II that contribute to the *mistakes* component of procurement cost growth, because, as will be discussed, these can induce cost increases beyond just those of any stretches

Approved for public release; distribution unlimited.

they cause. Second, it is necessary to consider the implications for the computation of *decisions* improperly classified as *mistakes*. Third, account must be taken of the considerations involved in applying a formula derived for a single system to a sample of 138 systems for the entire period 1970–1997.

Chapter 1 points to the following two mechanisms other than adoption of an unrealistic cost estimate at Milestone II that generate *mistakes* cost growth:

- Budget instability; and
- Poor program execution.

We have an upper bound of about 4 percent on the procurement cost growth due to program stretches. (See Chapter 2.) It is likely that this figure picks up almost exclusively the effect a stretch has on overhead cost, and it hence falls far short of capturing what is usually understood to be the key link between budget instability and procurement cost. As noted in Chapter 3, the link most often posited is between the steepness of the learning curve and program stability, which means reasonable stability in planned budgets and production profiles as well as in requirements. This conjecture is plausible since program instability tends to discourage the investments that play a predominant role in moving costs down the learning curve. To the extent that this mechanism is important, the formula given above understates the cost of a stretch.

The magnitude of these effects has proven to be illusive.[83] One useful handhold on this problem is provided by the conjecture that—apart from requiring payment of overhead for more years—the important effects of stretches show up in how fast a program comes down the learning curve. It is plausible on that basis that the effects of stretches (via variable cost) in the sample were 2 or 3 percent of procurement cost, but not twice that.

The implications of ineffective program management for procurement cost are not captured entirely by any program stretches that they require. In these cases, more effective program management would have avoided both the higher cost of the program—that is, the higher cost of buying the Milestone II capability—and the need to accommodate the higher cost by stretching the program. In terms of the metaphor employed in Chapter 1, ineffective program management would cause the Defense Department to pay a Rolls Royce price for a Ford, and then increase the price even more by stretching the procurement. So, the "damage" in this case is not just the cost of the stretch, but also the cost growth that could have been avoided by effective program management.

The only visibility this study has into the effect on cost growth of program management is provided by the introduction in 1986 of a new structure for managing major weapon systems acquisition programs. (See Chapter 6.) While the evidence is mixed, on balance it seems to favor the conclusion that ineffective

Approved for public release; distribution unlimited.

program management is not a large factor in explaining the *mistakes* component of procurement cost growth.

This study also classified the cost growth of systems procured using a Total Package Procurement (TPP)-like arrangement under ineffective management execution. That classification rests on the premise that TPP-like contracts could have been successful. If that premise is accepted, it is necessary for the purposes of this appendix to add the procurement cost growth that could have been avoided by successful execution of the TPP-like contracts to the cost of stretches made to accommodate errors in forecasting cost at Milestone II. No attempt was made to do so, however, for two reasons. First, the computation would be at best extremely speculative (even by the relatively permissive standards of this appendix). Second, the underlying premise is very problematic.

The second set of considerations that must be considered stem from the apparently substantial misclassification of *decisions* as *mistakes*. Chapter 4 notes that a major part of the *mistakes* procurement cost growth seems to be provided by changes in the program adopted after Milestone II but before the program goes into production. The increment to procurement cost due to these changes should have been classified with *decisions*, but much of it appears not to have been. The key question about this part of procurement cost growth is: Was it funded when the changes were adopted or were the higher procurement costs recognized in the programs' budgets only with lags of several years.

If the added costs were funded at about the time the changes were adopted through the regular DoD resource allocation process, they did not require stretches, so including them with *mistakes* leads to an overestimate of the tax due to misestimation of cost at Milestone II. If funding caught up with a lag of several years, however, the added costs presumably would be accommodated by stretches. In this case, this misclassification of the *decisions* as *mistakes* obscures the source of the problem but does not cause any error in the computation outline here. While the evidence is far from clear, the SARs for these programs tend to suggest that, in most cases, the changes were not funded when they were adopted.

It is necessary, finally, to look at the problems involved in moving from the formula for an individual system to an estimate for the sample as a whole for the entire period 1970–1997. There are three.

First, the percentage of cost growth in procurement due to *mistakes* tends to be smaller the larger the dollar size of the major defense acquisition program (MDAP).[84] Consequently, the trial solution should have taken as its base the weighted average procurement cost growth due to *mistakes* (weighted by program size). For the 138 MDAPs in the sample, the weighted average *mistakes*

growth in procurement cost is about 11 percent. The trial estimate of the cost of the induced stretches would then be 25 percent of this, or about 3 percent.

Second, use of an average (weighted or unweighted) over the entire sample assumes that funds released by overestimates are available to provide the additional funding required by systems whose costs were underestimated. Procurement funds freed up in this way ordinarily are not fungible across service lines, however, and are fungible over time within a service to only a limited extent. Consequently, only part of the funds released as overfunding becomes apparent can be used to provide additional funding to systems with funding shortfalls; the remainder will be applied to new starts and upgrades or used outside the procurement accounts.

The top of the range of costs of induced stretches is based on the assumption that none of the funds released by MDAPs that underrun their costs are used to fund overruns. On that assumption, the computation should be based on the 96 MDAPs in the sample that overran their Milestone II baselines (adjusting for quantity and decisions). The weighted average procurement cost growth due to *mistakes* for these systems was about 20 percent. If we apply the formula given previously, the induced cost of stretches would be at least 5 percent of the total costs of procuring the systems in the sample. Third, the assumption that all cost increases due to *mistakes* are accommodated by stretches is not accurate for the entire period 1970–1997. This is most clearly the case for the defense buildup that began in 1979, was greatly expanded when the Reagan administration took office in 1981, and continued through the fiscal year 1985 budget. During this period, some stretches certainly were avoided by the addition of funds to the DoD budget. It is also relevant that about a dozen MDAPs were cancelled during the defense drawdown that occurred in the few years after the Berlin Wall fell. The funds thus released were not necessarily retained in the procurement accounts, but to the extent that they were, they reduced the need to stretch other MDAPs.

The latter effect probably is small, since the programs cancelled tended to be small, still in development, or towards the end of their procurement phase. The defense buildup of the late 1970s through the mid-1980s, however, clearly did have an effect. Insofar as cost growth is concerned, the main beneficiaries of the buildup were programs that entered Low-Rate Initial Production (LRIP) in the period 1979–1985 and that had not been realistically funded at Milestone II.[85] A total of 41 MDAPs began production during that period, of which 30 were included in the sample used in this study. Table B-2 shows that 6 of those systems had a *mistakes* component of procurement cost growth of more than $1 billion in FY 2002 dollars. The total *mistakes* cost growth on these 6 programs was about $22 billion, and underruns exceeded overruns for the remaining 24 programs. It is reasonably assumed that all the *mistakes* cost growth in the systems in Table B-2 was accommodated by the additional procurement funding

Approved for public release; distribution unlimited.

available during the Reagan defense buildup, especially since considerable emphasis was placed during that time on full funding and maintenance of efficient production rates. On this assumption, the cost of stretches is reduced by a full percentage point.

Table B-2. *Mistakes* Cost Growth for Systems that Entered Production during 1979–1985 (Billions of FY 2002 Dollars)

System	*Mistakes* Cost Growth
M2/M3 Bradley FVS	6.8
M1 Abrams Tank	5.5
AH-64 Apache Helicopter	4.4
FIM-92 Stinger Missile	2.2
BGM-109G Tomahawk	1.6
M712 CLGP Copperhead	1.5
Total	22.0

Source: Preliminary DoD data.

Net Results

The lower end of the range of the costs of induced stretches that emerges from this discussion is 2 percent. This figure takes off from the weighted average *mistakes* component of procurement cost (11 percent; note that 25 percent of this figure is about 3 percent). (Note that use of this figure makes the extreme assumption that all underruns are used to offset overruns.) One percentage point is deducted to reflect funds added during the Reagan defense buildup that avoided stretches that would have added 1 percent to the total cost of procuring the 138 systems in the sample. The resulting 2 percent estimate also reflects the assumption that stretches did not increase the total variable costs incurred in producing these systems; that all funds released by programs that underrun their Milestone II cost estimates offset cost overruns; and that more effective management of the six programs in the sample procured using TPP-like arrangements would not have reduced the cost growth they experienced. These are all extreme assumptions, and would tend to the conclusion that the 2 percent is a lower bound. The figure may be overstated in one respect, however, in that it also makes the polar assumption that none of the cost growth (for the 14 systems identified in Chapter 4) misclassified with *mistakes* was funded in a timely way. In fact, it is quite likely that some of it was. Considering all of these factors, the 2 percent figure must be regarded as an illustrative benchmark, not a lower bound.

The top end of the computed range is 8 percent. This figure starts with the weighted average *mistakes* cost growth of 20 percent for systems for the 96

Approved for public release; distribution unlimited.

MDAPs in the sample that overran their Milestone II baselines. (Again, note that 25 percent of 20 percent is 5 percent.) The top end also includes a deduction of 1 percent for stretches avoided by funds added during the Reagan build-up, but includes 3 percent for effects of budget instability on variable costs. In addition, it adds 1 percent to account for the fact that the data used in this study classify with *decisions* with about 4 percentage points of procurement cost growth due to stretches that should be classified under *mistakes*. It is not clear that this 8 percent is an upper bound. On the one hand, it is based on the assumption that none of the funds released by underruns is available to offset overruns, while, in fact, some are (although probably not a large proportion). Like the lower bound, it also makes the polar assumption that none of the cost growth (for the 14 systems identified in Chapter 4) misclassified with *mistakes* was funded in a timely way. On the other hand, the actual effect of budget instability on variable costs might exceed the 3 percent assumed, and the 8 percent estimate makes no provision for cost growth that might have been avoided by effective enforcement of the TPP-like contracts used for six of the systems in the sample. Hence, the 8 percent should be taken as a benchmark indicating a possible magnitude of the tax, not an upper bound on it.

Concluding Comment

Stretches required to accommodate adoption of unrealistic cost estimates and, perhaps, ineffective program management seems to have increased the costs of procuring the 138 programs in this study's sample substantially. Representative figures for the top and bottom of this range appear to be 8 percent and 2 percent, respectively. Even the lower end of the range implies a dollar figure large enough to be a problem in efficient management of public resources, which motivates this study's inquiry into the mechanisms of cost growth.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Appendix C.
Deflation and Quantity Normalization

The data used in this study were downloaded from a Web site maintained by the Office of Program Analysis and Evaluation (PA&E) in the Office of the Secretary of Defense (OSD). Some documentation of the data is provided on the opening page of the site. This appendix provides additional information based on notes provided to the author by PA&E staff.[86]

Deflation

The Selected Acquisition Reports (SARs), starting in 1974, report costs (including cost variances) in both the dollars of the program's base year and then-year dollars. The data posted on the PA&E site, and used in computing cost growth, are those in constant dollars. That is, the required reduction of the data to base-year dollars was done by the program offices in preparing the SARs for 1974 and subsequent years. Chapter 6 of Paul G. Hough, *Pitfalls in Calculating Cost Growth from Selected Acquisition Reports* (RAND Corporation, N-3136-AF, Santa Monica, 1992) provides a useful overview of the evolution of SAR procedures for deflation and their shortcomings.

The sample used in this study includes 15 systems with program baselines in 1970–1973. The SARs for these years reported costs only in then-year dollars. PA&E staff computed the cost for these years in program base-year dollars using deflators developed by the OSD Comptroller's office. (The Comptroller publishes different rates for each appropriation account; e.g., for Air Force aircraft Research, Development, Test, and Evaluation, and for Navy ship procurement.) The primary problem in deflating the SAR data for 1970–1973 is that of extracting from the SARs for those years a coherent series of then-year data to deflate.

Quantity Normalization

Chapter 7 of the study by Hough lays out the three methods available for normalizing the SAR cost data for changes in the inventory objective (i.e., in the total quantity of the system procured). The PA&E data are normalized using the third of these, which is the most demanding in terms of data requirements and also the most satisfactory.

The first step is the classification of the posted SAR cost variances (in program base-year dollars) as "quantity related" or "not quantity related." This work is done by NAVSEA Naval Shipbuilding Support Office (NAVSHIPSO) with funding and guidance from PA&E. The dollar magnitude of a posted variance reflects the inventory objective as of the time the SAR is filed. A variance

Approved for public release; distribution unlimited.

is judged to be "quantity related" if it would be larger for a larger inventory objective (and smaller for a smaller inventory objective). Many elements of development cost are not quantity related, but most other cost variances are. The quantity-related variances are cumulated.

The second step is the estimation of a learning curve for each system in the sample. This is done by PA&E staff. In most cases, the learning curve slope is estimated by regressing cumulative output on cumulative cost as reported in successive SARs for the system. (For example, if a system ended after being in production for 15 years, the SARs for the system provide fifteen pairs of cumulative output-cumulative cost observations.) The regression was not used if the estimated learning curve parameter was unreasonable (in particular, greater than one) or the R2 was less than 0.7. In those cases, a leaning curve slope was assumed based on the most pertinent information available (e.g., the slope characteristic of other systems in the commodity class.)

The final step was the mechanical one of adjusting the cumulated quantity related variance for the change in the inventory objective. This step is actually accomplished in the database software PA&E uses.

Approved for public release; distribution unlimited.

Appendix D.
Variable Specifications, Data Sources, and Estimated Regression Equations

This appendix presents in its entirety the estimated regression equation discussed in parts of Chapters 5 and 6. It also provides estimates of two other variants of the model, provides additional discussion of some of the variables, and identifies the sources of the data used for several of the variables.

Specification of the Variables

Appendix B describes the cost growth variables. The data on program size (P$) were drawn from the same source. The specifications of most of the other variables are described in the main text. Comment here is therefore limited to the following variables not fully described in the brief definitions provided with the estimates: BUDGET, FEW, TPP, and DS.

BUDGET is intended to capture expectations as of Milestone II of how tight the budget will be over several upcoming years. At first glance, the Future Years Defense Program (FYDP) provides exactly the data needed. In fact, the FYDP data are not useful for this purpose because, for most of the period considered here, it was widely understood that the out-year assumptions built into the FYDP were unrealistically optimistic. A naive forecasting rule (such as a moving average of past budgets) probably would be little better and is not plausible in the context of DoD procurement decisions. In the end, the simple specification used was adopted because it is arguably better than the practical alternatives. (The BUDGET variable was specified to be 0 in the Reagan years and 1 in the other years of the sample.)

FEW marks nine systems for which it seemed clear that the precedents available for use in cost estimation were particularly sparse. These are:

- UH-60A Blackhawk helicopter (1972)
- CH-53 Super Stallion/MH-53 Sea Dragon helicopters (1975)
- AH-64 Apache helicopter (1976)
- CH-47 Chinook helicopter (1978)
- M1 Abrams tank (1976)
- Bradley Fighting Vehicle System (FVS) (1978)
- M712 CLGP Cannon-Launched Guided Projectile (Copperhead) (1975)
- CBU-97B Sensor Fused Weapon (SFW) (1985)
- Sense and Destroy Armor (SADARM) 155mm projectile (1988)

Approved for public release; distribution unlimited.

It would be preferable to have a measure of the number of precedents available for use in costing for each of the systems in the sample. While such a variable could be easily updated for successive systems within a commodity class, there is no ready way to estimate the initial values. For example, both the F/A-18 and the M1 Abrams tank passed Milestone II in 1976. It is clear that there was a great deal more past history available for use in costing the F/A-18 than there was for the M1, but there does not seem to be any good way of estimating how much more.

TPP marks the following six systems that used Total Package Procurement (TPP) or TPP-like contracts:

- AGM-84A Harpoon missile (1973)
- M1 Abrams tank (1976)
- T-45 Goshawk Training System (1984)
- C-17A Globemaster aircraft (1984)
- Joint Surveillance Target Attack Radar System (JSTARS) (1985)
- T-6A Joint Primary Aircraft Training System (JPATS) (1995)

The Harpoon initially passed Milestone II in 1970; a restructured program passed Milestone II in 1973. It was the initial contract that had TPP-like features. The Abrams program was characterized as a "design to unit production cost" rather than as being similar to earlier TPP contracts, but options for the first three lots were obtained as part of the EMD contract.

Although none of these programs were fully TPP contracts, all had at least two of the following three features:

- The development contract included production options with fixed price features (e.g., not-to-exceed prices for early production lots);
- The development contract itself had fixed price aspects (e.g., fixed price/incentive fee); and
- The development contract (including the production options) was obtained through competition.

It is argued in the text that with respect to cost growth these contracts should be similar to full-blown TPP contracts.

DS is a marker for dual sourcing. For some systems, dual sourcing was a part of the acquisition strategy adopted at Milestone II. In other cases, dual sourcing was adopted well after the start of EMD, often in response to severe cost growth or quality problems. There also seem to be intermediate cases, in which dual sourcing was considered at Milestone II, but not implemented until later,

Approved for public release; distribution unlimited.

after problems had emerged. Unfortunately, the available data do not separate these cases and some dual-sourced systems are among those showing a *mistakes* component of procurement cost growth of 30 percent or more. It is possible that if the definition of the variable were narrowed to systems in which dual sourcing was a part of the Milestone II acquisition strategy, dual sourcing would be more strongly associated with less cost growth.

Sources

The data used for MOD, PROTO, MY, TPP, and DS were drawn from the following sources:

- Karen W. Tyson, Neang I. Om, D. Calvin Gogerty, J. Richard Nelson, and Daniel M. Utech, "The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs. Vol. I: Main Report," Institute for Defense Analyses, Paper P-2722, November 1992.
- J. A. Drezner, J. M. Jarvaise, R. W. Hess, P. G. Hough, and D. Norton, "An Analysis of Weapon System Cost Growth," RAND Corporation, MR-291-AF, 1993, pp. 45–46.

These two sources agreed in most instances. When they did not, other information was used as the tiebreaker. TPP is a partial exception to this rule; in some cases, the specification of TPP draws on SAR data or information in other published studies.

Results

Table D-1 reports the complete estimated equation from which the tables of estimated coefficients in Chapters 5 and 6 were drawn. The dependent variable in this case, and the other two reported, was the *mistakes* component of procurement cost growth from the Milestone II baseline. The seven systems with Milestone II procurement cost estimates that, after excluding *decisions*, had negative cost growth in excess of –20 percent were excluded in estimating this and the two other equations reported here. Inclusion of these systems does not alter the main features of the estimated equation. It was clear from the results that the model estimated did not provide much insight into the cost experience of these systems, and they were excluded for that reason.

Approved for public release; distribution unlimited.

Table D-1. Estimated Equation for *Mistakes* Component of Procurement Cost Growth

Variable	Definition	Coefficient (t-statistic)
Intercept		1.346** (10.105)
A	Army programs: 1 for Army program; 0 otherwise	0.232** (2.861)
AF	Air Force programs: 1 for Air Force program; 0 otherwise	0.063 (0.871)
BUDGET	Marker of periods of "tight" procurement budget: 1 for 1970–1980, 1989–2001; 0 otherwise	–0.017 (–0.176)
P$	Constant dollar size of procurement program planned at Milestone II (FY 2002 dollars)	–2.5E-06 (–0.783)
RELAXED	Less stringent enforcement of realistic costing: 1 for 1977–1980 and 1993 on; 0 otherwise	0.088 (0.884)
COSTI	Early CAIG: 1 for 1974 –1983; 0 otherwise	–0.267* (–2.465)
COSTII	Post-statute CAIG: 1 for 1984–1992; 0 otherwise	–0.398** (–2.700)
COSTIII	Post-IG report CAIG: 1 for 1993 on; 0 for 1992 and earlier	–0.500** (–2.535)
BAD	Dummy variable marking for FMTV: 1 if system was known to embody major, inadvertent cost-estimating errors; 0 otherwise	0.382 (1.112)
FEW	Dummy variable marking estimates with few useful precedents: 1 if system had few useful precedents; 0 otherwise	0.464** (3.687)
MOD	Modification programs: 1 if program was a modification of an existing system; 0 otherwise	–0.050 (–0.591)
PROTO	Prototype: 1 if program included a prototype; 0 otherwise	–0.117 (–1.317)
PEO	Program Executive Officer management structure: 1 for 1987 on; 0 for before 1986	0.240† (1.871)
MY	Multi-year procurement: 1 if program employed a multi-year contract in procurement; 0 otherwise	–0.116 (–1.125)
DS	Dual sourcing: 1 if program was dual sourced; 0 otherwise	–0.036 (–0.397)
TPP	Total Package Procurement: 1 if binding price commitments for some procurement lots were obtained in competition for EMD contract; 0 otherwise	0.438** (2.994)
MOD2	Marker of post-1988 modification programs: 1 if modification program passed Milestone II in 1989–2001 or a major post-Milestone II pre-production addition to capability is noted; 0 otherwise	0.040 (0.311)

† Significant at the 10% level.

* Significant at the 5% level.

** Significant at the 1% level.

$R^2 = 0.26$, F = 3.654, N = 131.

Approved for public release; distribution unlimited.

It was noted in the text that the independent parametric costing process began to function in about March 1972, but the estimates reported (including those in Table D-1 and succeeding tables) assume that the process first influenced the cost estimates of systems that passed Milestone II in FY 1974. That assumption places in the pre-independent costing period the nine systems shown in Table D-2 along with their Milestone II dates.

Table D-2. Systems in the Sample with 1973 Milestone II Baselines

System	DSARC II
AGM-84A Harpoon Missile	March 1970[a, b]
E-3A Sentry AWACS RSIP	June 1971
AIM-9L Sidewinder (Navy)	June 1971
AIM-9L Sidewinder (Air Force)	June 1971[b]
FIM-92 Stinger Missile	May 1972[b]
FFG-7 Perry-Class Frigate	August 1972
NATO Pegasus-Class PHM	September 1972[b]
A-10 Thunderbolt Aircraft	January 1973
E-4A Airborne Command Post	August 1973

[a] The Harpoon initially passed Milestone II in March of 1970. It was subsequently restructured, and the restructured program passed Milestone II in 1973. The data used in this study apparently measure cost growth from the 1970 baseline.

[b] The *mistakes* component of procurement cost growth is at least 30 percent.

The first four of these passed Milestone II before January 1972, when Secretary Laird directed the creation of the independent costing process.[87] The next three (two of which had cost growth of more than 30 percent) passed Milestone II within 6 months of the start of the independent costing process; for each of these it is reasonable to assume that the costing was too far advanced to be influenced to any appreciable extent by the new process. The A-10 and the E-4A could reasonably be included in the post-independent costing period, but the *mistakes* component of procurement cost growth was modest for the A-10 (about 8 percent) and negative for the E-4A (about –2 percent).

Table D-3 reports an estimated equation that includes Army and Air Force slope dummies for BUDGET, SDBA, and SDBAF. (The Navy is used again as the point of reference.) Inclusion of these slope dummies allows for the possibility that the services react differently to changes in how tight the procurement budget constraint was.

The estimated coefficients provide some statistically weak indications that they did. The small negative coefficient on BUDGET implies that the Navy had a slight and statistically insignificant tendency to adopt more conservative costing in periods of particularly tight budgets. Although statistically insignificant,

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

the estimated effect for the Army is positive (–0.124 + 0.178 = 0.054). The estimated effect for the Air Force is also positive (–0.124 + 0.173 = 0.049) and statistically not significantly different from zero.

Table D-4 reports the estimated coefficients obtained if all of the variables in the equation of Table D-1 with t-statistics of less than one are dropped. The estimated coefficients of BAD, PROTO, and MY are not statistically significantly different from zero at a reasonable level, but the other estimated coefficients are. As it must, $\overline{R}^2$ increases, but only slightly.

It is worth noting that experience provides a rough guide to the expected variance of an unbiased Milestone II procurement cost estimate and, therefore, of a rough upper bound on $\overline{R}^2$ that a model of procurement cost growth can achieve. After netting out the *decisions* part of procurement cost growth, it seems reasonable to guess that at least two-thirds of the Milestone II procurement cost estimates would have errors of no more than ±20 percent. It is doubtful that two-thirds would have errors within ±10 percent. Assuming further that the percentage errors are normally distributed, the variance in the percentage error of a Milestone II procurement cost estimate will be 0.01 to 0.04.[18] The variance of the *mistakes* component of cost growth for the sample is 0.15. The maximum $\overline{R}^2$ that could be achieved (without peering into the error terms for the underlying estimates) would be 0.97 (1 – 0.01/0.15) to 0.73 (1 – 0.04/0.15). The estimated equations reported here, then, perhaps explain between roughly one-third and one-half of the potentially explainable variation in procurement cost growth.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Table D-3. Estimated Equation for the Model of Table D-1 Plus Army and Air Force Slope Dummy Variables for the BUDGET

Variable	Definition	Coefficient (t-statistic)
Intercept		1.409** (10.040)
A	Army programs: 1 for Army programs; 0 otherwise	0.109 (1.829)
AF	Air Force programs: 1 for Air Force programs; 0 otherwise	–0.044 (-0.381)
BUDGET	Marker of periods of "tight" procurement budget: 1 for 1970–1980, 1989–2001; 0 otherwise	–0.124 (–1.017)
P$	Constant dollar size of procurement program planned at Milestone II (FY 2002 dollars)	–2.4E-06 (–0.743)
RELAXED	Less stringent enforcement of realistic costing: 1 for 1977 –1980, and 1993 on; 0 otherwise	0.097 (0.967)
SDBA	Army dummy variable for slope of BUDGET: 1 if A = 1 and BUDGET = 1; 0 otherwise	0.178 (1.175)
SDBAF	Air Force dummy variable for slope of BUDGET: 1 if AF = 1 and BUDGET = 1; 0 otherwise	0.173 (1.197)
COSTI	Early CAIG: 1 for 1974–1983; 0 otherwise	–0.264* (–2.411)
COSTII	Post-statute CAIG: 1 for 1984–1992; 0 otherwise	–0.386** (-2.625)
COSTIII	Post-IG report CAIG; 1 for 1993 on; 0 for 1992 and earlier	–0.508** (–2.576)
BAD	Dummy variable marking for FMTV: 1 if system was known to embody major, inadvertent cost-estimating errors; 0 otherwise	0.416 (1.191)
FEW	Dummy variable marking estimates for systems with few useful precedents: 1 if system had few useful precedents; 0 otherwise	0.463** (3.652)
MOD	Modification programs: 1 if program was a modification of an existing system; 0 otherwise	–0.072 (–0.829)
PROTO	Prototype: 1 if program included a prototype; 0 otherwise	–0.104 (–1.165)
PEO	Program Executive Officer management structure: 1 for 1987 on; 0 for before 1986	0.254* (1.970)
MY	Multi-year procurement: 1 if program employed a multi-year contract in procurement; 0 otherwise	-0.131 (–1.260)
DS	Dual sourcing: 1 if program was dual sourced; 0 otherwise	–0.037 (–0.410)
TPP	Total Package Procurement: 1 if binding price commitments for some procurement lots were obtained in competition for EMD contract; 0 otherwise	0.436** (2.905)
MOD2	Marker of post-1988 MOD programs: 1 for modification program passed Milestone II in 1989–2001 or a major post-Milestone II pre-production addition to capability is noted; 0 otherwise	0.055 (0.418)

† Significant at the 10% level.

* Significant at the 5% level.

** Significant at the 1% level.

$R^2 = 0.26$; F = 3.379; and N = 131.

Approved for public release; distribution unlimited.

Table D-4. Estimated Equation for the Model of Table D-1 Excluding

Variable	Definition	Coefficient (t-statistic)
Intercept		1.350** (15.274)
A	Army programs: 1 for Army programs; 0 otherwise	0.230** (3.346)
AF	Air Force programs: 1 for Air Force programs; 0 otherwise	
BUDGET	Marker of periods of "tight" procurement budget: 1 for 1970–1980, 1989–2001; 0 otherwise	
P$	Constant dollar size of procurement program planned at Milestone II (FY 2002 dollars)	
RELAXED	Less stringent enforcement of realistic costing: 1 for 1977–1980, and 1993 on; 0 otherwise	
COSTI	Early CAIG: 1 for 1974–1983; 0 otherwise	-0.273** (-2.868)
COSTII	Post-statute CAIG: 1 for 1984–1992; 0 otherwise	-0.419** (-3.534)
COSTIII	Post-IG report CAIG; 1 for 1993 on; 0 for 1992 and earlier	-0.421** (-2.778)
BAD	Dummy variable marking for FMTV: 1 if system was known to embody major, inadvertent cost-estimating errors; 0 otherwise	0.393 (1.185)
FEW	Dummy variable marking estimates for systems with few useful precedents: 1 if system had few useful precedents; 0 otherwise	0.465** (3.831)
MOD	Modification programs: 1 if program was a modification of an existing system; 0 otherwise	
PROTO	Prototype: 1 if program included a prototype; 0 otherwise	-0.114 (-1.402)
PEO	Program Executive Officer management structure: 1 for 1987 on; 0 for before 1986	0.229* (2.130)
MY	Multi-year procurement: 1 if program employed a multi-year contract in procurement; 0 otherwise	-0.102 (-1.040)
DS	Dual sourcing: 1 if program was dual sourced; 0 otherwise	
TPP	Total Package Procurement: 1 if binding price commitments for some procurement lots were obtained in competition for EMD contract; 0 otherwise	0.449** (3.116)
MOD2	Marker of post-1988 MOD programs: 1 for modification program passed Milestone II in 1989–2001 or a major post-Milestone II pre-production addition to capability is noted; 0 otherwise	

† Significant at the 10% level.

* Significant at the 5% level.

** Significant at the 1% level.

$R^2 = 0.28$; F = 6.043; and N = 131.

Approved for public release; distribution unlimited.

Appendix E.
Mistakes Component of Growth in Development Cost

This appendix presents some data on the *mistakes* component of development cost measured from the Milestone II baseline. The Milestone II baseline includes the costs of the pre-EMD phase, but these are sunk and do not contribute to cost growth.

Table E-1 shows the *mistakes* component of development cost growth for 1970–1997 and four sub-periods. The rationale for distinguishing these four sub-periods is provided in Chapter 5. The rows in this table report the number of systems and cost growth for the following three tiers: top (a *mistakes* component of development cost growth of at least 30 percent); middle (–20 percent to 30 percent); and bottom (less than –20 percent.) Table 8 in the main text is the corresponding display for the *mistakes* component of procurement cost growth; for convenience, the information is repeated here in Table E-2.

As was discussed in Chapter 5, there was sharply less *mistakes* procurement cost growth after 1973 than there was earlier. This occurred because the number of systems in the top cost growth tier declined or, for 1993–1997, because the average *mistakes* component of procurement cost growth was less that it had been before 1973. The *mistakes* component of development cost growth shows the opposite pattern; it is lower before 1973 than after, and the increase is largely driven by an increase in the number of systems in the top tier and an increase in the average cost growth of the systems that fall into that group. The sub-period 1993–1997 also shows the opposite pattern for development; compared to the two preceding sub-periods, the proportion of systems in the top tier and the average cost growth on them are both slightly lower.

This study attributes the decline in the *mistakes* component of procurement cost growth to the introduction of independent costing. (Most other studies have not treated procurement and development separately, but they have also found cost growth to be less after 1973.) The independent costing process considers all parts of cost, not just procurement cost. Why then should the *mistakes* component of development cost show the opposite pattern? It would not be surprising to find that the introduction of independent costing had little or no effect on growth in development cost, because the costing methods used by independent cost estimators are more suited to estimating procurement costs than they are to estimating development cost. It is surprising, however, to find that development cost growth increased after 1973. There does not seem to be any ready and clearly plausible explanation of this feature of the data.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Table E-1. *Mistakes* Component of Cost Growth: Development Cost

Cost Growth	FY 1970–73	FY 1974–83	FY 1984–92	FY 1993–97	FY 1970–97
>=30%					
Number of Systems	3	11	16	6	36
Average	53.9%	80.5%	78.4%	55.6%	73.2%
–20% to 30%					
Number of Systems	10	40	24	18	92
Average	8.9%	7.5%	9.1%	7.1%	8.0%
<=30%					
Number of Systems	2	0	2	1	5
Average	49.7%	N/A	–22.6%	–20.2%	–33.0%
Total					
Number of Systems	15	51	42	25	133
Average	10.1%	23.3%	34.0%	17.7%	24.1%

Table E-2. *Mistakes* Component of Cost Growth: Procurement Cost

Cost Growth	FY 1970–73	FY 1974–83	FY 1984–92	FY 1993–97	FY 1970–97
>=30%					
Number of Systems	12	13	0	10	35
Average	83.9%	74.3%	N/A	46.3%	69.6%
–20% to 30%					
Number of Systems	3	37	41	15	96
Average	–4.1%	6.5%	0.3%	4.7%	3.2%
<=30%					
Number of Systems	0	3	3	1	7
Average	N/A	–35.8%	–27.2%	–54.0%	–34.7%
Total					
Number of Systems	15	53	44	26	138
Average	66.3%	20.7%	–1.6%	18.5%	18.1%

Approved for public release; distribution unlimited.

Table E-3 provides a list of the systems that had a *mistakes* component of development cost growth of at least 30 percent. (This table is parallel to Table 4 in Chapter 2.) Army systems are, again, over represented on this list, and about half of the Army systems showed *mistakes* components of both procurement and development cost growth of more than 30 percent. There was slightly less of a tendency for Navy and Air Force systems to be on both lists. Overall, 15 systems are in the top cost growth tier for both procurement and development.

Table E-3. Systems in the Sample with *Mistakes* Development Cost Growth of at Least 30 Percent

System	Milestone II	*Mistakes* Component of Development Cost Growth (percent)	*Mistakes* Component of Procurement Cost Growth > 30% (percent)
Army			
FAAD LOS-F-H ADATS	1986	219	
M2/M3 Bradley FVS	1978	123	×
USQ-84(V) SOTAS	1978	68	×
JSTARS GSM	1985	65	
ARC-210 SINCGARS	1983	62	
FMTV	1988	59	×
ATCCS FAAD C2I	1990	53	×
SMART-T	1992	45	
ATACMS P3I (BAT)	1991	45	×
FGM-148A Javelin AAW Missile	1989	45	×
AFATDS	1990	39	
MIM-104 Patriot PAC-3	1994	38	×
M1 Abrams Tank	1976	36	×
M712 CLGP (Copperhead)	1975	32	×
ATCCS ASAS Block II/II	1993	31	
SADARM 155mm Projectile	1988	30	
Navy			
DDG-51 Burke-Class Destroyer	1985	159	
MH-60R Strikehawk Helicopter	1994	76	
CH-53 Super Stallion and MH-53 Sea Dragon Helicopters	1975	75	
SH-50F CV Helicopter	1985	72	
AIM-9L Sidewinder Missile	1973	56	
NATBMD	1997	52	×
E-2C Hawkeye AEW	1994	38	
RGM-109 Tomahawk Multi-Mission Missile	1977	36	
T-AO 187 Oiler	1984	34	
T-45 Goshawk Training System	1984	30	×
Air Force			
BGM-109G Tomahawk GLCM	1977	250	×
Titan IV ELV (Expend Launch Vehicle)	1985	197	
SBIRS-High Altitude	1996	99	
DSCS-III	1977	92	×
JSTARS	1985	73	×
ANTRN-45 MMLS Ground Components	1985	69	
E-4A Airborne Command Post	1973	63	
EF-111A Tactical Jamming System	1976	63	
AGM-88 HARM Missile	1978	50	
CBU-97B SFW	1985	50	
F-15 Eagle Aircraft	1970	43	×

Note: See the list of abbreviations at the end of this paper for the meanings of abbreviations used here.

Approved for public release; distribution unlimited.

Figure E-1 is a histogram of the *mistakes* component of development cost growth. This figure has generally the same shape as that for the *mistakes* component of procurement cost growth. (See Figure 5 in Chapter 2.) The pie charts on top of the bars show the split between *mistakes* and *decisions*.

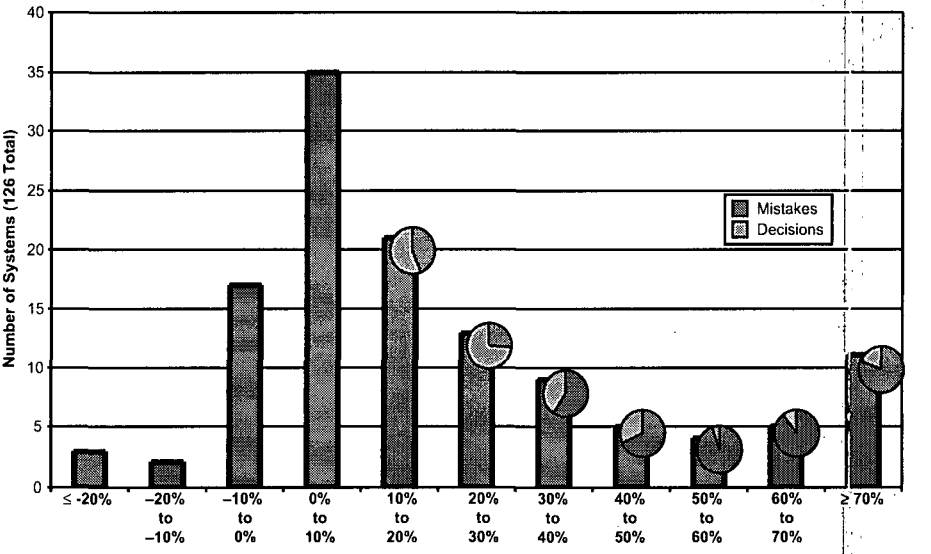


Figure E-1. Distribution of the *Mistakes* Component of Development Cost Growth

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Notes

Chapter 1

[1] In an article published on the occasion of his retirement as Under Secretary of Defense (Acquisition, Technology, and Logistics), E. C. Pete Aldridge stated that the second of the five main items on his agenda when he took office was "the proper pricing of programs which...is critical to program stability." See "Acquisition Credibility: Retiring Aldridge Highlights Stable Production," *Defense News*, May 19, 2003, p. 29.

[2] MDAPs are defined by statute to be acquisition programs with expected costs in excess of certain dollar thresholds or that the Secretary of Defense designates as MDAPs. In FY 2000 dollars, any program with development costs of more than $375 million or procurement costs of more than $2.25 billion is an MDAP.

[3] A major change in the definitions of the phases of the acquisition process was adopted in 1998. As the cutoff for the data used in this study is 1997, the older definitions are relevant.

[4] In 1987, the Congress created the position of Under Secretary of Defense for Acquisition. The title was changed to Under Secretary of Defense for Acquisition and Technology in 1993, and "Logistics" was added in 1999.

[5] An AoA is essentially what was formerly called a Cost and Operational Effectiveness Analysis (COEA).

[6] Operating and support costs are also included in the cost estimates, but, in most cases, they are budgeted by organizational unit rather than by weapon system.

[7] Actual O&S expenditures on most major systems are reported through the Visibility and Management of Operating and Support Costs (VAMOSC) system. Any attempt to assess the accuracy of the O&S cost estimate probably would attempt to compare the actual costs reported in VAMOSC for a system with the earlier estimates. While certainly possible, such comparisons are difficult because a variety of data problems, not the least of which is stating the earlier cost estimate and the VAMOSC data on the same set of definitions.

[8] Overprogramming is not due only to unrealistic procurement cost estimates. As a general matter, the Defense Department has only ineffective mechanisms for matching "today's" decisions on procurement programs with "tomorrow's" resources.

[9] Donald Srull, ed., *The Cost Analysis Improvement Group: A History*, McLean, VA: The Logistics Management Institute, 1998, p. 6.

[10] For an account of this briefing and the events that preceded it and followed from it, see Srull, *The Cost Analysis Improvement Group*, Chapter 1, "Introduction of Independent Parametric Cost Estimating." Donald Srull was the first chairman of the OSD Cost Analysis Improvement Group (CAIG), and he played a major role in developing Gardiner Tucker's briefing. Milton A. Margolis also played an instrumental role. He was at the time director of the cost estimation unit in the Office of Systems Analysis; he succeeded Srull as CAIG chairman in 1973.

[11] The baseline estimates used are referenced in the source as the "Original Planning Estimate." These seem to correspond roughly to the cost estimates made at what was later called Milestone I. Under the revised acquisition process adopted in 2000, the old Milestone I falls between Milestone A and Milestone B.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

[12] Paul G. Hough, "Pitfalls in Calculating Cost Growth from Selected Acquisition Reports," RAND Corporation, N-3136-AF, 1992, p. 7.

[13] Srull, *The Cost Analysis Improvement Group*. The first sentence appears on p. 11, the second on p. 1.

[14] A cost increase necessarily reflects some underlying fact about the program—that more labor than had been anticipated is required, that more or more expensive materials must be used, and so on. Observations that cost increases are produced by such changes, while accurate, beg the question of whether the requirement for more labor or more or more expensive materials might have been reasonably anticipated. Tucker made the point that the answer to that question had often been "yes."

[15] The implications for cost of particular acquisition strategies—dual sourcing, for example—would be recognized at a higher level of aggregation—the airframe, for example, if that is what will be dual sourced.

[16] Bottom-up estimates could build in allowances for missteps and misfortunes, but they generally do not. It is also important to note that "what goes wrong" often involves interaction of elements of a development program. Hence, the more detailed the cost estimate, the more necessary it is to look at risks involved in interactions.

[17] The December 7 memorandum signed by Packard was drafted around his desk on December 2 after Tucker completed his briefing. See Srull, *The Cost Analysis Improvement Group*, p. 11.

[18] The CAIG was established as an intra-OSD group that was responsive to the DSARC. The bulk of the CAIG's work, however, was done by people in the Office of Systems Analysis, and its eventual successor, the Office of the Director, Program Analysis and Evaluation (PA&E). Participation from other OSD offices declined over time, and early in the 1990s, the CAIG was formally established as a function of PA&E. From that point, the designation "CAIG" simply meant work done for the USD(AT&L) by the PA&E's office of the Deputy Director for Resource Analysis. However, USD(AT&L)—in practice usually a DAB committee chairman acting on his behalf—can task the CAIG directly, and the Director, PA&E does not review CAIG products that respond to such tasking.

[19] A brief survey of the early studies is provided by Congressional Budget Office, "Cost Growth in Weapon Systems: Recent Experience and Possible Remedies," report prepared for the Senate Committee on Governmental Affairs, Washington, DC: Government Printing Office, 1983.

[20] Defense Science Board, "Report of the Acquisition Cycle Task Force," Defense Science Board 1977 Summer Study, March 15, 1978.

[21] See Congressional Budget Office, "Cost Grown in Weapons Systems," p. 2. The 200 percent figure cited by the DSB is consistent with the data in Figure 2 on the plausible assumption that the DSB figure is the ratio of the current cost estimate to the planning estimate. The ratios in Figure 2 are the increase in cost (current estimate less planning estimate) divided by the planning estimate, times 100 percent.

[22] The article by E. C. Pete Aldridge mentioned previously ("Acquisition Credibility: Retiring Aldridge Highlights Stable Production," *Defense News*, May 19, 2003, p. 29) indicates that realistic pricing is required to ensure that "the costs they [elected representatives] promise their constituents...will be the costs their constituents eventually do pay."

Approved for public release; distribution unlimited.

[23] The most obvious instance is the F-22. In 1996, the Congress by statute required the CAIG to make an independent estimate of the procurement cost of the F-22 and required the Secretary of Defense to transmit the CAIG's estimate to the Congress.

[24] Appendix B includes a formula for computing the approximate slip required to accommodate a given underfunding of procurement at Milestone II. For the parameter values typical of weapon acquisition programs, the required slip is roughly 4/3 of the fraction by which the procurement program was underfunded. Thus, underfunding of 10 percent, for example, would require a slip of about 13 percent. It appears that the underfunding of the programs in the sample was in the range of 12 percent to 15 percent. The average slip expected because of the initial underfunding, therefore, would be 16 percent to 20 percent. Of course, slips occur for reasons other than initial underfunding, so the average slip for all reasons presumably would be greater than these percentages.

Chapter 2

[25] SARs were inaugurated by the Defense Department in 1967. In 1975, the Congress required that SARs be submitted for all major defense acquisition programs (MDAPs). SARs are submitted quarterly, but "the" SAR for a year is understood to be the so-called "December SAR," which is ordinarily submitted to the Congress by the end of March and which should match the budget submitted to the Congress in late January or early February. A SAR is first filed at about the point that a program is designated an MDAP, and SARs are filed annually thereafter until funding is no longer requested for either development or procurement of the system, ordinarily when the last units have been purchased. Initially only development costs are reported, but after the system enters EMD, both procurement and development costs are ordinarily included. For each year of the Future Years Defense Plan (FYDP), the funding reported in the SAR should agree with that provided to the Congress in budget documents and the FYDP. The post-Milestone II SARs also show projected funding required through the end of the program. A brief history of the SARs and a useful analysis of the problems involved in using them are provided by Hough, "Pitfalls in Calculating Cost Growth from Selected Acquisition Reports."

[26] Such cases are anomalous because SAR reporting is not generally required before a system enters EMD.

[27] Figure 3 shows cumulative average cost; that is, how average cost varies with the total amount procured, not how average cost varies with the size of any particular annual lot.

[28] One frequently heard line of argument is that (1) the Milestone II cost estimates are often too low; (2) as a result, the budgets for many systems are insufficient to buy the quantity planned at Milestone II; and (3) the inevitable cost increases are accommodated by stretches in the programs and reductions from Milestone II plans in the quantities bought. Viewed from this angle, the key issue is how the Milestone II cost estimates influence later decisions on the quantity purchased. This is an excellent question. The purpose of this study, however, is to look in detail at the first step of the argument: How frequently are the Milestone II estimates too low, by how much, and why?

[29] These definitions are based on those provided by Hough, "Pitfalls in Calculating Cost Growth from Selected Acquisition Reports," pp. 5–6.

[30] The classifications were done by the Naval Sea Systems Command (NAVSEA) Naval Shipbuilding Support Office (NAVSHIPSO) under contract with PA&E and according to guidelines specified by PA&E. PA&E cost analysts also reviewed the NAVSHIPSO classifications.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Chapter 3

[31] Not all statements by a DoD official that endorse a low estimate of a program's cost are advocacy. Instead, such a statement may be made to signal something about the budget constraints that the program will face to the service sponsoring the program, likely contractors, and the Congress. This is most likely to be useful in the early stages of a program, when its shape remains open to a considerable extent and major funding decisions are a decade or more in the future. Such signals tends to have sharply diminished utility once requirements for the system are adopted, since the requirements convey a more forceful message on likely cost than any statements that DoD officials might make about what they expect to pay for the system.

[32] Table D-1 of Appendix D implies that the error described above explains about half of the cost growth in the FMTV from its Milestone II baseline. The author, who then directed the CAIG, bears a major share of the responsibility for this error.

[33] There is some ambiguity about the cost estimators' responsibility for checking the realism of the program assumptions on which their cost estimates rest. Cost estimators usually look at the reasonableness of assumptions on schedule, planned utilization of test assets, and the degree of concurrency built into the development program. Ordinarily, however, they do not have the capability to assess the degree of technological risk in the program, and they ordinarily do not attempt to do so.

[34] Anthony G. Bower and James N. Dertouzos, "Essays in the Economics of Procurement," RAND Corporation, 1994, is a useful collection of theoretical analyses bearing on this topic.

[35] The General Accounting Office (GAO) occasionally argued that cost growth should not be adjusted for model changes and major upgrades, an argument that seems to imply that DoD cost estimates should include provisions for such changes. This position has some merit for cost estimates done for Analyses of Alternatives to the extent that such costs have a bearing on the choice among the various alternatives considered. It is harder to see its merit for Milestone II estimates used as the basis for budgets. Doing as the GAO suggests would amount to reserving a funding wedge for as yet unspecified new models or major upgrades. Most analysts would argue to the contrary that these should compete for funds on an equal footing with alternative uses of resources. Two related points need to be noted: (1) Milestone II estimates ordinarily will include the cost of software updates (and any similar updates that are routinely part of the operation of any system) and any pre-planned product improvements included in the program plans, and (2) cost estimators should note and include the costs of any major items required to achieve Milestone II capabilities that are not included in planned program content.

[36] This example is pointed out in Hough, "Pitfalls in Calculating Cost Growth from Selected Acquisition Reports," p. 13.

[37] This comment points to an important feature of the PA&E data. The *mistakes* component of procurement cost growth should not include cost growth due to unforced changes in the program's content. It does, however, include growth in the costs of those changes (apart from the unlikely possibility that that growth is itself offset by later unforced changes in the program.) Thus, in the PA&E database, programs with large post-Milestone II changes can show exceptional cost growth even if the costs recognized when the change is adopted are classed as *decisions*.

Approved for public release; distribution unlimited.

[38] Hough, "Pitfalls in Calculating Cost Growth from Selected Acquisition Reports," p. 13, notes that "[c]ost estimates for the 25-mm gun and the TOW missile were first included in the March 1979 SAR."

[39] This statement assumes that the distribution of the error in the estimate is approximately normal.

Chapter 4

[40] Mark J. Lumer, "Why Programs Die: The Stand-Off Target Acquisition System (SOTAS) Case Study," The Industrial College of the Armed Forces, Washington, D.C., 1993, p.3.

[41] Lumer, "Why Programs Die: The SOTAS Case Study," p. 5.

[42] Lumer, "Why Programs Die: The SOTAS Case Study," pp. 12–14.

[43] The underlying problem here is that the SARs usually provide little insight into why costs have changed. PA&E followed the rule of posting variances as *mistakes* unless it was clear from the SARs that they were due to *decisions*. One consequence of this sensible rule seems to be that some substantial increases in procurement cost that resulted from *decisions* to increase a system's capabilities were posted as *mistakes*.

[44] I am indebted to Karen W. Tyson of IDA for pointing me in this direction. In a 1992 IDA study, she found clear evidence that modification programs experienced less cost growth than other programs. See Karen W. Tyson, Neang I. Om, D. Calvin Gogerty, J. Richard Nelson, and Daniel M. Utech, "The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs, Volume I: Main Report," Paper P-2722, Institute for Defense Analyses, November 1992. For a sample of systems that included those that passed Milestone II up to and including 1997, I found the opposite, which led me to look closely at the experience of modification programs that passed Milestone II during 1989–1997.

Chapter 5

[45] This is generally understood to mean that there is as much chance that the estimate is too low as too high.

[46] The late Don Yockey, who served as Under Secretary of Defense (Acquisition) during 1991–1992, captured this thought by saying that in his view funding for MDAPs should provide him with some "tension on the reins."

[47] There is an objection on statistical grounds to estimating the model using ordinary least squares (OLS) given that program size is included among the independent variables. Program size also enters the computation of the variable on the left-hand side—the *mistakes* component of procurement cost growth. It is, therefore, necessarily correlated with the residual term in the model, and the OLS estimates are both biased and inconsistent. There is no readily available measure of program size that avoids this problem, and no sensible set of instruments that could be used in an instrumental variables approach. Dropping program size alters the estimated coefficients of the other variables little, which suggests that inclusion of program size does not create much of a problem in estimating the other coefficients. It remains possible that the estimated coefficient of program size itself is seriously biased towards zero.

Approved for public release; distribution unlimited.

[48] J. A. Drezner, J. M. Jarvaise, R. W. Hess, P. G. Hough, and D. Norton, "An Analysis of Weapon System Cost Growth," RAND Corporation, MR-291-AF, 1993, pp. 45–46.

[49] See Congressional Budget Office, "Cost Growth in Weapons Systems," pp. 5–6; Drezner et al., "An Analysis of Weapon System Cost Growth," pp. 22–23; and Karen W. Tyson et al., "The Effects of Management Initiatives, Volume I," Appendix B.

[50] This point is important to the estimates obtained, since several of the systems that appear in the database with 1973 Milestone II baselines showed large procurement cost growth. Appendix D identifies these systems and provides the apparent dates of their Milestone II reviews.

[51] See Section 1203 of Public Law 98–94, which amended Chapter 4 of Title 10, United States Code, by adding a new Section 139c. The language cited was subsection (a) of the new Section 139c. The relevant provisions have been modified on several occasions, and are now codified in Title 10, United States Code, Chapter 4, Section 2434.

[52] The Defense Authorization Act for 1984 (adopted in September 1983) also required the Secretary of Defense to provide the Congress with a report on the Defense Department's use of independent cost estimates. Srull, *The Cost Analysis Improvement Group*: A History, p. 28, provides a brief description of this requirement. These reports were required annually through 1986 or 1987.

[53] Subsection (b)2 of Section 139c as specified in Section 1203 of Public Law 98–94.

[54] During much of the 1990s, the Army and the Air Force chose to provide three distinct estimates—the program office estimate, the service independent cost estimate, and the service cost position.

[55] The key question was what limitations the statute put on use by the CAIG of cost estimates prepared by a service's headquarters cost group. Originally, the CAIG was to develop standards and criteria for independent parametric cost estimates and review service estimates in terms of those standards and criteria. Such professional standards might have provided the necessary basis for the CAIG to make use of selected parts of estimates made by a service's headquarters cost group. The CAIG had not developed explicit standards or criteria for estimating procurement cost, however. Moreover, circumstances surrounding the then-recent cancellation of the A-12 made risible the notion that use of good costing methods was sufficient to produce a realistic estimate. Hence, it appeared that the Defense Department probably could not plausibly argue that CAIG review of service cost estimates satisfied the statute. In addition, mid-1991 expressions of congressional interest in the question of whether CAIG review of service estimates satisfied the statute may have contributed to the final outcome.

[56] There was also one less visible change worth noting. From 1972 to 1986, the CAIG was the only regular staff-level forum before a DSARC review. Consequently, the CAIG was fairly widely used by the OSD staff as a way to become informed about a program. Beyond that, it was not uncommon for OSD staff to package their concerns as cost issues in an attempt to get them in front of the DSARC via the CAIG report. Informally, many felt that the role of the CAIG was to serve as the Consumer Advisor of the US weapon system acquisition process. This began to change in 1987, when the DSARC was replaced by the DAB. With the DAB came a small number of subordinate committees whose main role was to prepare issues for DAB decision. Moreover, in the late 1980s and early 1990s, cost and operational effectiveness analyses were revived as an ingredient of DAB milestone reviews, and assessments of whether a proposed system was "affordable" added. With these changes, by the early 1990s the CAIG's informal role had narrowed to its formal charge—cost analysis.

Approved for public release; distribution unlimited.

[57] Several previous studies have noted that cost growth on MDAPs was lower during the 1970s than it had been during the 1960s. See Congressional Budget Office, "Cost Growth in Weapons Systems," p. 2, and Tyson et al., "Effects of Management Initiatives, Volume 1," p. IV-2.

[58] This concerned the Contractor Cost Data Reports (CCDRs), which provide extensive information on the actual costs incurred in the development and production of individual weapon systems. The data required on CCDRs was revamped, a modern system for collecting, storing, and disseminating the data installed, and a small office (now called the Defense Cost and Resource Center) was established to manage the CCDRs as well as a wide array of other information used in cost analysis.

[59] The CARD provides a fairly detailed description of the physical attributes of the system, the acquisition strategy that will be employed to acquire it, the development schedule, the planned profile of annual purchases of the system, and plans for how the system will be supported. The Strategic Defense Initiative Organization (SDIO), now the Missile Defense Agency, introduced the requirement for CARDs on SDIO systems in the mid-1980s. Partly in response to an Inspector General audit, the CAIG in 1989 began requiring a CARD for any system undergoing a DAB review that involved a CAIG cost estimate. The requirement for a CARD was retained in the acquisition reforms adopted during the early part of the first Clinton administration, and by 1994 was accepted as a requirement for the DAB process. The CARD requirements were codified in DoD Directive 5000.4, "OSD Cost Analysis Improvement Group (CAIG)," and DoD 5000.4-M, "Cost Analysis Guidance and Procedures," December 1992. Before the CARD requirement was adopted, it was generally up to cost estimators to document the assumptions they made about program content. These assumptions were often not well documented, and they were not always those of the program actually brought forward for approval.

[60] The relevant precedents are not only at the system level but also at the subsystem level.

[61] Figure 9 omits the data for twelve systems that could not be unambiguously placed in one of the eight commodity classes.

[62] A first guess might be that administrations tend to be lenient on costing favored systems, particularly those judged likely to face strong opposition. In those cases in which there is some real doubt about gaining congressional approval for a program, however, there is reason to adopt a relatively conservative cost estimate in order to guard against arguments that the program actually will cost more than the Defense Department advertises. More conservative costing might, for that reason, be adopted for favored systems.

[63] House Committee on Government Operations, Subcommittee on Legislation and National Security, 1979; Senate Committee on Governmental Affairs, 1981; House Armed Services Committee, Special Panel on Defense Procurement Procedures, 1981; Senate Armed Services Committee, 1983.

Chapter 6

[64] A recent RAND study provides an excellent example of this point. During the 1990s, the Defense Department undertook a number of initiatives intended to reduce defense contractors' indirect costs, which on average account for about half the total procurement costs of a weapon system. Weapon system cost estimates ordinarily use negotiated rates provided by Forward Pricing Rate Agreements in estimating indirect costs. Those negotiated rates reflect not only all cost reductions made to some recent date but also anticipated reductions over a period of several years in the future. To the extent that weapon system cost estimates are made in this

Approved for public release; distribution unlimited.

way, even highly successful efforts to reduce indirect cost will not be reflected systematically in cost growth. See Mark Lorell with Jack C. Graser, "An Overview of Acquisition Reform Cost Savings Estimates," RAND Corporation, 2001, p. 122.

[65] For an analysis of the first round of acquisition reforms, see Edmund Dews, Giles K. Smith, Allen Barbour, Elwyn Harris, and Michael Hesse, "Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s," RAND Corporation, R-2516-DR&E, October 1979.

[66] The Commission's Acquisition Task Force provided an interim report to the President on February 28, 1986. (See The President's Blue Ribbon Commission on Defense Management, "A Formula for Action: A Report to the President on Defense Acquisition," April 1986, p. 1.) National Security Decision Directive 219, issued April 1, 1986, implemented most of the Task Force's recommendations. (See Barbara A. Becksler, David R. Graham, Robert P. Hilton, Marshall H. Hoyler, and Hershel E. Kanter, "Defense Acquisition: Observations Two Years After the Packard Commission, Volume I: Main Report," Institute for Defense Analyses, Report R-347, November 1988, pp. II-1–4.) This report provides a thorough account of the initial implementation of the recommendations of the Packard Commission.

[67] President's Blue Ribbon Commission on Defense Management, "Report to the President on Defense Acquisition," p. 22.

[68] President's Blue Ribbon Commission on Defense Management, "Report to the President on Defense Acquisition," p. 22.

[69] See Becksler et al., "Defense Acquisition," p. II-1 and II-9.

[70] This was done by the Defense Acquisition Improvement Act of 1986, which was included in the FY 1987 Defense Appropriation Act, which was, in turn, included in the FY 1987 omnibus appropriation act (Public Law 99-591).

[71] William Perry was a member of the Packard Commission and directed its Acquisition Task Force. Paul G. Kaminski, who served as Under Secretary of Defense (Acquisition, Technology and Logistics) during most of Perry's tenure as Secretary of Defense, was a Technical Advisor to the Task Force. See President's Blue Ribbon Commission on Defense Management, "Report to the President on Defense Acquisition," pp. 1 and 45.

[72] See Secretary of Defense William Perry, "Acquisition Reform: A Mandate for Change," Department of Defense, February 1994, p. 4.

[73] Firms do nonetheless have incentives to make the investments that bring them down the learning curve, because they retain the profits for some period of time before they are captured by the Government in subsequent production lots. On this, see William P. Rogerson, "Economic Incentives and the Defense Procurement Process," *Journal of Economic Perspectives*, Vol. 8, No. 4 (Fall 1994), pp. 65–90, especially pp. 77–83, and David A. Lee, The *Cost Analyst's Companion*, Logistics Management Institute, 1997, Chapter 2.

[74] The programming part of PPBS during this period also had a paper, usually led by the Office of the USD(AT&L), on major system new starts; a paper on maintaining efficient production rates for MDAPs in rate production; and a paper that considered proposals for multi-year procurement contracts. In the early part of the 1980s, there also usually was a paper on dual sourcing, which was replaced, after the procurement budget started dropping, with a paper that looked at competitive buyouts of systems for which a dual-source acquisition strategy had been adopted.

Approved for public release; distribution unlimited.

[75] There is an offsetting factor. In the case of late dual sourcing, the costs compared to the Milestone II baseline should have removed both the costs of bringing a second source into production and the benefits of doing so. Both should be posted as *decisions*. It is likely that the SARs would specifically identify the costs and, hence, that these would be posted in the PA&E data with *decisions*. It is unlikely, however, that the benefits would be recorded in the SARs in a way that allowed them to be recognized as the results of *decisions*. To the extent that the benefits are not posted as *decisions*, the association of late dual sourcing with large growth prior to the introduction of the second source is offset.

[76] Karen W. Tyson et al., "Effects of Management Initiatives, Volume I," Chapter X.

[77] These are commonly referred to as Nunn-McCurdy breaches. An increase of 15 percent in either of two particular definitions of unit cost triggers a requirement to report the increase to the Congress. For an increase of 25 percent or more, the Secretary of Defense must in addition provide a certification to the Congress of four items, of which one is that the new unit cost estimate for the program is reasonable. These requirements were first established in 1982 in Public Law 97-252, Title XI, Section 1107(a) and are now codified in Title 10, U.S. Code, Section 2433.

[78] More precisely, not adopted primarily because of problems of cost growth; the implications of spiral development for cost growth apparently were recognized. See Aldridge, *Defense News*, May 19, 2003, p. 29.

[79] A price commitment curve was also obtained for the early post-EMD procurements of the F-22. This curve was established long after the EMD phase of the F-22 program began, however, and it seems unlikely at this point that the F-22 will prove to be a case that proponents of PCCs will want to claim.

[80] The new process is specified in DoD Directive 5000.1, "The Defense Acquisition System," and DoD Instruction 5000.2, "Operation of the Defense Acquisition System," both dated May 12, 2003. Two provisions of the latter are crucial in the present context. First, System Design and Development (SDD) on a succeeding increment of capability is not to begin until the technology of the preceding increment has been demonstrated by testing and the Milestone Decision Authority has approved the succeeding increment's entry into SDD. Second, at the start of SDD both the remainder of development and procurement are to be fully funded (for the years of the FYDP) to a realistic cost estimate. SDD in the new process occurs at a somewhat earlier stage of development than EMD, but that fact does not detract from the point made here.

[81] That is, Milestone B. The actions to provide a basis for costing should in most cases be directed in the Milestone A Acquisition Decision Memorandum.

Appendix B

[82] More generally, sometimes an important variable input clearly is "lumpy" at the annual buy rates of interest, and cost models that reflect that fact depart from a strict proportionality of average variable cost and output.

[83] The following comment seems to be representative of what can be found in the literature on the subject: "We suspect that funding-induced schedule instability is indeed an important contributor to cost growth, but we could not rigorously test this hypothesis using the available data." (Edmund Dews, Giles K. Smith, Allen Barbour, Elwyn Harris, and Michael Hesse, "Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s," RAND Corporation, R-2516-DR&E, October 1979, p. 72)

Approved for public release; distribution unlimited.

[84] A Congressional Budget Office study, "Cost Growth in Weapon Systems: Recent Experience and Possible Remedies" (prepared for the Senate Committee on Governmental Affairs, Washington DC: Government Printing Office, 1983), and later studies of cost growth on weapon system programs, note that cost growth is negatively correlated with program size. This is also true of the data for the *mistakes* component of procurement cost growth used in this study.

[85] Weapon system procurement programs ordinarily are fully funded to a realistic cost estimate by the time they get into Full-Rate Production because by then there is little uncertainty left in the cost estimates.

Appendix C

[86] The data used were posted on the site as of about March 10, 2003. The author was one of about two-dozen beta testers for the site, which is password protected. Those who wish access to the data should contact the Director, Economic Analysis and Resource Planning Division.

Appendix D

[87] It is not clear why these systems would be recorded as having a 1973 baseline.

[88] A procurement cost estimate ordinarily is made up of estimates of perhaps a dozen to as many as two or three hundred individual elements. Many, although not all, of these will be statistically independent of each other. Hence, in many cases, the assumption of normality is a reasonable one.

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

Bibliography

Asher, Norman J., and Theodore F. Maggelet, "On Estimating the Cost Growth of Weapon Systems," Institute for Defense Analyses, Paper P-1494, October 1980.

Becksler, Barbara A., David R. Graham, Robert P. Hilton, Marshall H. Hoyler, and Hershel E. Kanter, "Defense Acquisition: Observations Two Years After the Packard Commission, Vol. I: Main Report," Institute for Defense Analyses, Report R-347, November 1988.

Bower, Anthony G., and James N. Dertouzos, "Essays in the Economics of Procurement," RAND National Defense Research Institute, 1994.

Comptroller General of the United States, "Impediments to Reducing the Costs of Weapon Systems," General Accounting Office, November 8, 1979.

Congressional Budget Office, "A Review of the Department of Defense December 31, 1981 Selected Acquisition Report," CBO Special Study, May 1982.

Congressional Budget Office, "Cost Growth in Weapons Systems: Recent Experience and Possible Remedies," prepared for the United States Senate Committee on Governmental Affairs, Washington, DC: Government Printing Office, 1983.

Daly, George G., Howard P. Gates, and James A. Schuttinga, "The Effect of Price Competition on Weapon System Acquisition Costs," Institute for Defense Analyses, Paper P-1435, September 1979.

Defense Science Board, "Report of the Acquisition Cycle Task Force," 1977 Summer Study, March 15, 1978.

Dewes, Edmund, Giles Smith, Allen Barbour, Elwyn Harris, and Michael Hesse, "Acquisition Policy Effectiveness: Department of Defense Experience in the 1970's," RAND Corporation, R-2516-DR&E, October 1979.

Drezner, J., "The Nature and Role of Prototyping in Weapon System Development" RAND Corporation, R-4161-ACQ, 1992.

Drezner, J., and G. K. Smith, "An Analysis of Weapon System Acquisition Schedules," RAND Corporation, R-3937-ACQ, December 1990.

Drezner, J. A., J. M. Jarvaise, R. W. Hess, P. G. Hough, and D. Norton, "An Analysis of Weapon System Cost Growth," RAND Corporation, MR-291-AF, 1993.

Fox, J. Ronald, *Arming America: How the U.S. Buys Weapons*, Cambridge, MA: Harvard University Press, 1974.

Approved for public release; distribution unlimited.

General Accounting Office, "Weapon Cost: Analysis of Major Weapon System Cost and Quantity Changes," NSIAD-89-32FS, Washington, DC: Government Printing Office, November 1988.

Hough, Paul G., "Pitfalls in Calculating Cost Growth from Selected Acquisition Reports," The RAND Corporation, N-3136-AF, 1992.

Jarvaise, J. M, J. A. Drezner, and D. Norton, "The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports," The RAND Corporation, MR-625-OSD, 1996.

LaBerge, Walter B., "Defense Acquisition: A Game of Liar's Dice," *Concepts*, Winter 1982, pp. 56–63.

Margolis, Milton A., "Improving Cost Estimation in the Department of Defense," *Concepts*, Spring 1981.

McNichols, Gerald R., and Bruce J. McKinney, "Analysis of DOD Weapon Cost Growth Using Selected Acquisition Reports," Management Consulting and Research, Inc., February 27, 1981.

McNichols, G. R., J. P. McFarland, B. J. McKinney, and S. J. Balut, "The Problem of Cost Growth (Analysis of Weapon System Costs as of December 1983)," Management Consulting and Research, Inc., April 30, 1984.

Merrow, E. W., "A Review of Cost Estimation in New Technologies: Implications for Energy Process Plants," RAND Corporation, R-2418-DOE, July 1979.

Moses, O. D., "Estimating and Explaining the Production Cost of High Technology Systems: The Case of Military Aircraft," Naval Postgraduate School, Thesis, May 1989.

Perry, Robert, Giles K. Smith, Alvin J. Harman, and Susan Henrichsen, "System Acquisition Strategies," RAND Corporation, R-733-PR/ARPA, June 1971.

Rich, M., and E. Dews, "Improving the Military Acquisition Process: Lessons from Rand Research," RAND Corporation, R-3373-AF/RC, 1986.

Singleton, P. J., "Estimating Potential Cost Growth of the Most Probable Cost Estimate," Air Force Institute of Technology, Thesis, September 1991.

Srull, Donald, ed., *The Cost Analysis Improvement Group: A History*, Logistics Management Institute, 1998.

The Analytical Sciences Corporation, "An Analysis of the Impact of Dual Sourcing of Defense Procurements," August 7, 1981.

Tyson, Karen W., J. Richard Nelson, Neang I. Om, and Paul R. Palmer, "Acquiring Major Systems: Cost and Schedule Trends and Acquisition Effectiveness," Institute for Defense Analyses, Paper P-2201, March 1989.

Tysor, Karen W., Neang I. Om, D. Calvin Gogerty, J. Richard Nelson, and Daniel M. Utech, "The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs, Volume I: Main Report," Institute for Defense Analyses, Paper P-2722, November 1992.

U.S. Congress, House of Representatives, Committee on Government Operations, Subcommittee on Legislation and National Security. "Inaccuracy of Department of Defense Weapons Acquisition Cost Estimates," Report 96–656, 96th Congress, 1979.

U.S. Congress, Senate, Committee on Armed Services, Hearings on the Department of Defense Authorization for Appropriations for Fiscal 1984, February 25, 1983, "Cost Growth in Military Procurement," Washington, DC: Government Printing Office, 1983.

Approved for public release; distribution unlimited.

Abbreviations

AAW	Anti-Air Warfare
ADATS	Air Defense Antitank System
AEW	Airborne Early Warning
AFATDS	Advanced Field Artillery Tactical Data System
AoA	Analysis of Alternatives
APB	Acquisition Program Baseline
ASAS	All Source Analysis System
ASD(SA)	Assistant Secretary of Defense (Systems Analysis)
ATACMS	Army Tactical Missile System
ATCCS	Army Tactical Command and Control System
ATIRCM	Advanced Threat Infrared Countermeasures
AWACS	Airborne Warning and Control System
BAT	Brilliant Anti-armor Technology
C2I	Command, Control, and Intelligence
CAIG	Cost Analysis Improvement Group
CARD	Cost Analysis Requirements Description
CBO	Congressional Budget Office
CCDR	Contractor Cost Data Report
CLGP	Cannon-Launched Guided Projectile
CMWS	Common Missile Warning System
COEA	Cost and Operational Effectiveness Analysis
DAB	Defense Acquisition Board
DAE	Defense Acquisition Executive
DoD	Department of Defense
DSARC	Defense Systems Acquisition Review Council
DSB	Defense Science Board
DSCS	Defense Satellite Communications System
DSMC	Defense Systems Management College
EMD	Engineering and Manufacturing Development
FAAD	Forward Area Air Defense

Approved for public release; distribution unlimited.

Approved for public release; distribution unlimited.

FMTV	Family of Medium Tactical Vehicles
FPIF	Fixed Price Incentive Fee
FY	Fiscal Year
FYDP	Future Years Defense Program
FVS	Fighting Vehicle System
GAO	General Accounting Office
GBS	Global Broadcast Service
GLCM	Ground-Launched Cruise Missile
GRP	Guidance Replacement Program
GSM	Ground Station Module
IDA	Institute for Defense Analyses
IG	Inspector General
IPT	Integrated Product Team
JASSM	Joint Air-to-Surface Standoff Missile
JDAM	Joint Direct Attack Munition
JPATS	Joint Primary Aircraft Training System
JSF	Joint Strike Fighter
JSTARS	Joint Surveillance Target Attack Radar System
JTUAV	Joint Tactical Unmanned Aerial Vehicle
LRAACA	Long Range Air ASW-Capable Aircraft
LOS-F-H	Line-of-Sight, Forward, Heavy
LRIP	Low-Rate Initial Production
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MICV	Mechanized Infantry Combat Vehicle
MMLS	Mobile Microwave Landing System
NATBMD	Navy Area Theater Ballistic Missile Defense
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAVSHIPSO	NAVSEA Shipbuilding Support Office
O&S	Operating and Support

Approved for public release; distribution unlimited.

O&M	Operations and Maintenance
OLS	Ordinary Least Squares
OSD	Office of the Secretary of Defense
P3I	Preplanned Product Improvement
PAC-3	Patriot Advanced Capability 3
PA&E	[Office of the Director] Program Analysis and Evaluation
PCC	Price Commitment Curve
PEO	Program Executive Officer
PHM	Guided Missile Patrol Combatant (Hydrofoil)
PM	Program Manager
PPBS	Planning, Programming and Budgeting System
RSIP	Radar System Improvement Program
SADARM	Sense and Destroy Armor
SAE	Service Acquisition Executive
SAR	Selected Acquisition Report
SADARM	Sense and Destroy Armor
SBIRS	Space-Based Infrared System
SDD	System Design and Development
SDIO	Strategic Defense Initiative Organization
SFW	Sensor Fused Weapon
SINCGARS	Single Channel Ground and Airborne Radio System
SMART-T	Secure Mobile Anti-Jam Reliable Tactical Terminal
SOTAS	Stand-off Target Acquisition System
TACTAS	Tactical Towed Array Sonar
TPP	Total Package Procurement
TOW	Tube-Launched, Optically Tracked, Wire Guided
USAF	United States Air Force
USD(A)	Under Secretary of Defense (Acquisition)
USD(AT&L)	Under Secretary of Defense (Acquisition, Technology and Logistics)
VAMOSC	Visibility and Management of Operating and Support Costs

Approved for public release; distribution unlimited.

Institute for Defense Analyses

Approved for public release; distribution unlimited.