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March 2014

IDA Paper P-5123
Log: H 14-000267

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About This Publication
This work was conducted by the Institute for Defense Analyses (IDA) under contract DASW01-04-C-0003, Task AO-6-3631, "Implementing Effective Processes for Ensuring the Affordability of Major Defense Acquisition Programs," for the Office of the Under Secretary of Defense, Acquisition, Technology and Logistics (OUSD (AT&L)). The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

Acknowledgments
The authors would like to thank the reviewers of this publication, Lance Roark and Kathleen Conley.

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Executive Summary

Assuring the future affordability of the Department of Defense's (DOD) portfolio of acquisition programs has been an enduring goal that has rarely been achieved. The consequences of failure are cancelling or curtailing programs that turn out to be unaffordable, with attendant waste. This research is a sequel to previous research by the Institute for Defense Analyses (IDA) on the affordability of defense acquisition programs.[1] The previous research focused on the context and theory of assessing affordability. The conclusions and recommendations of the previous publications are re-enforced by the current research, which focuses on two areas: (1) what can be learned from historical efforts to control the affordability of DOD programs, and (2) how affordability constraints for sustainment costs can best be implemented.

The Better Buying Power (BBP) initiatives[2] mandate "affordability as a requirement" by setting affordability targets for both investment and sustainment, or operating and support (O&S), costs to be considered equivalent to key performance parameters.[3]

Historical Efforts to Control Affordability

Two previous acquisition initiatives bear sufficient similarities to the current affordability initiatives to provide meaningful insights. They are the *Design to Cost* (*DTC*) efforts of the early 1970 to early 1992 period and the *Cost as an Independent Variable* (*CAIV*) initiatives in 1996–2002.

The research team reviewed the major DOD issuances that were in force for both the DTC and CAIV eras to identify provisions that were similar to current affordability policy. This review revealed a great deal of similarity, as well as some key differences, between both DTC and CAIV and current policy. The most significant difference is that in some of their manifestations both DTC and CAIV stressed aggressive efforts to reduce costs (focused on investment), and thus were more similar to the *should-cost* initiative of BBP. Those provisos

1 Gene H. Porter et al., *Affordability of Defense Acquisition Programs*, IDA Paper P-4961 (Alexandria, VA, Institute for Defense Analyses (IDA), April 2013). Both this and the previous paper were produced for the Director, Acquisition Resources and Analysis, in the Office of the Under Secretary of Defense, Acquisition, Technology and Logistics (OUSD(AT&L).

2 Ashton B. Carter, Memorandum for Acquisition Professionals, "Subject: "Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending" (Washington, DC: Department of Defense (DOD), September 14, 2010), 2.

3 The BBP was institutionalized with the issuance of Interim DOD Instruction (DODI) 5000.02, "Operation of the Defense Acquisition System," 25 November 2013.

were based on the questionable premise that commercial developments were far more successful in driving unnecessary costs out of products in development than was DOD.

DTC was "on the books" for about twenty years; however, by the late 1980s it had fallen into disuse. Nonetheless, according to IDA research from the late 1980–early 1990 period, some thirty-four DOD acquisition programs recorded DTC goals in their Selected Acquisition Reports (SAR) between 1971 and 1990 while forty-seven programs of the same era did not. The previous IDA research found that programs using DTC had significantly higher cost growth than those that didn't, as shown in the following table.[4]

Comparison of Production Cost for Programs Using DTC

	Programs (34) Using DTC	Programs (47) Not Using DTC
Mean Production Cost Growth	85%	61%
Median Production Cost Growth	66%	22%

The start dates of non-DTC programs were generally earlier than the start dates of DTC programs (median start dates: 1970 vs. 1976). Starting in the late 1970s, numerous changes occurred in acquisition policies and program management practices, so it cannot be concluded that using a DTC strategy was actually the cause of the observed cost growth.

Perhaps of greater significance than the quantitative results are the findings based on interviews. While the research team did not interview a large number of individuals from the DTC era, those interviewed were in key positions to understand the degree to which DTC was actually used in acquisition management. The interviewees reported that they could recall *no instances* when establishing or exceeding DTC goals was a topic of high-level deliberations. Review of several key decision documents of the period also revealed no discussion of DTC. Although by no means conclusive, this limited evidence *suggests* that, despite the strong language regarding DTC in DOD issuances, the concept may not have been consistently stressed by top acquisition and program managers.

CAIV was in use for a much shorter time than DTC; nonetheless, it was well entrenched in DOD regulations from 1996 to 2002[5] and received the attention of high-level management for several years. Unlike, DTC, however, CAIV cost objectives were never systematically recorded in SARs, and for that reason, among others, no database exists to support statistical analysis of CAIV's impact. Since constructing such a database was beyond the scope of this paper, the research team conducted an analysis of twelve programs known to have employed the CAIV approach. The results were that only two of the twelve CAIV programs reviewed could be said to

4 The observed difference was statistically significant at the 7 percent level using a Kolmogorov-Smirnov test.

5 It still exists in a vestigial form in DODD 5000.1 (published in 2007) and is still current.

have been fully successful in controlling cost growth. The Joint Direct Attack Munition (JDAM) program was successful in not only controlling, but also significantly reducing, production costs and was in fact one of the inspirations for CAIV.[6] Compared to all the other programs examined, JDAM was notable for its simplicity—it was an ideal CAIV candidate.

The failure of CAIV to control system cost growth offers lessons for DOD's current efforts. Although each program has a unique story, the common thread is that each program was started based on assumptions (i.e., *framing assumptions*) that subsequently did not hold up. Of the ten CAIV programs that were unsuccessful in controlling costs, two were cancelled (but probably not primarily because of cost growth). The others were deemed of such importance that they were restructured—some repeatedly—and continued under new (usually implicit) framing assumptions.

DTC, CAIV and the current affordability goals and caps all depend ultimately on the concept of controlling costs by trading performance characteristics (and to a much less extent, schedule). This approach will only be implementable if there is enough performance trade space to be exploited. In some of the CAIV programs reviewed, that was not the case. In others, the available trade space was insufficient to compensate for the cost growth. The lesson is that the amount of performance trade space that is available should be considered in setting affordability targets. If little is available, a greater tolerance for cost growth may have to be accepted if the capabilities offered by a new program are truly required.

Affordability of O&S Costs

Assessing the O&S affordability of a proposed new system means considering an appropriate portfolio of future *force* O&S costs that include the new program to make a realistic projection of whether sufficient funds will likely be available for the portfolio. The definition of the portfolio of forces must be made so that the O&S cost change occurring with the deployment of the new system is clear. Current policy states that programs that are seen as not affordable based on life-cycle costs should not be allowed to proceed unless program or programmatic adjustments can be identified to make it affordable. Such assessments are complicated.

A simpler way to assess O&S cost affordability is to compare the estimated O&S cost of a new system to the system or systems that it will replace—known as antecedent systems. Systems with O&S costs significantly greater than the systems they will replace may not be affordable to operate in the future. The U.S. Congress has required that such a comparison be included in SARs when an appropriate antecedent system exists. However, only forty-two out of a total of eighty-three programs having a SAR in December 2012 provided a comparison of O&S costs to an antecedent system. For those forty-two, the average change relative to the antecedent was +13

[6] Also an inspiration for the notion that aggressive action on the part of program managers could achieve substantial cost reductions, in line with the *should-cost* approach. Some of the early CAIV literature spoke of achieving a 25 percent reduction from "expected" costs—i.e., standard program cost estimates.

percent, indicating a *potential* affordability problem in O&S costs when these systems are fielded.[7]

Another issue in managing O&S cost affordability constraints is the uncertainty in O&S cost estimates for new systems. The uncertainty can be expected to decrease as systems mature; however, it will still be high at least until the system completes initial operational tests. The true costs will not be known until well after fielding. Since there is a tendency to underestimate future O&S costs early in the acquisition process, there is the danger that O&S affordability constraints will be set unrealistically low. Comparisons of O&S cost estimates over time show that O&S cost estimates increased from pre-full-scale development to early production for virtually every program examined.[8] Changes ranged from +50 percent to over +100 percent from earliest estimates to current estimates. To be enforceable, O&S affordability goals and caps must be supported by realistic estimates. O&S costs over time should be re-examined at least annually to prevent a big "surprise" increase at the decision to enter production.

Meeting O&S cost goals will most likely require tradeoffs to improve the O&S cost drivers. Early tradeoffs (e.g., before Milestone B) are much easier to implement than later in the process. However, for Major Defense Acquisition Programs, there is no body empowered to oversee such tradeoffs prior to Milestone B.

Implementation of a standard O&S cost model for each program passing Milestone A could greatly facilitate both tracking O&S costs as the system matures and making tradeoffs to ensure that projected O&S costs remain within affordability constraints. Such a model should include the major controllable O&S cost drivers. The model would be refined as the system matures and better estimates of the drivers become available. Furthermore, the model should be applied to both the new system and its antecedents, as well as other systems within the portfolio.

Conclusions

- Experience with the DTC and CAIV initiatives indicates that past efforts to control costs to ensure the affordability of DOD acquisition programs have been largely ineffective despite having strongly worded policies in place. Probable causes are lack of
  - sufficient emphasis on the critical early phases of program concept formulation and systems engineering, and
  - top level, consistent, and persistent management attention and effective processes for periodic re-assessment of program affordability.

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7 *Potential* because per-system increases might be mitigated by deploying fewer systems or perhaps offset by reductions elsewhere that can be taken because of the new system's capabilities.

8 Changes in the ground rules for O&S cost calculation in 2010 required a manual adjustment for each program in order to track O&S cost growth, which limited the number of programs for which the comparisons could be made.

- Affordability goals and caps established early in a program will only be relevant so long as the framing assumptions under which they were established continue to hold. Furthermore, it is inevitable for the assumptions to change, sometimes greatly. Thus a process is needed to periodically re-examine the affordability of the entire investment program and make the necessary adjustments needed to stay on an affordable track.
- O&S costs have been largely ignored in post-Milestone A systems design trades in the past.
  - Controlling longer-term O&S costs is substantially more difficult than nearer-term investment costs because of the uncertainty in O&S cost estimates, particularly early in the acquisition process.
  - It is difficult to motivate acquisition managers and contractors to maintain control over O&S costs.
- Recently introduced processes and procedures to monitor O&S costs and affordability appear to be on the right track, but have yet to be proven effective in establishing meaningful O&S cost constraints and actually controlling cost growth; however,
  - to properly inform acquisition decision makers, future portfolio O&S costs should be defined so that the true incremental cost of deploying a new system is clearly revealed.

Recommendations

- Continuing top-level management dedication is essential for processes to control affordability to be effective. The recommendations of IDA Paper P-4961 for an effective process to address acquisition program affordability apply.
- A standard O&S cost model, implemented for each major acquisition program at Milestone A, would greatly facilitate documenting framing assumptions, tracking O&S cost affordability, and facilitating O&S cost tradeoffs.
- Continued stress on O&S costs and affordability at both Defense Acquisition Board and Defense Acquisition Executive Summary reviews will more strongly motivate Government managers and their industry counterparts to control O&S costs.
  - Future policy issuances should clarify that assessing the affordability of O&S costs should be made using the portfolio of forces that will be altered with deployment of the new system.
  - If future portfolio force O&S costs will increase with the fielding of the proposed system, the decision maker should insist that the sponsoring component provide a realistic plan for how the increase will be paid for under approved assumptions regarding future fiscal resources expected to be available to the component.

Contents

1. Introduction

This research effort was sponsored by the Director, Acquisition Resources and Analysis, in the Office of the Under Secretary of Defense, Acquisition, Technology and Logistics (OUSD(AT&L) and builds upon previous research in IDA Paper P-4961, *Affordability of Defense Acquisition Programs*, by the Institute for Defense Analyses (IDA).[1] The first two chapters of P-4691 are equally applicable to this paper, and will not be repeated here. P-4961 focused on the overall context and theory of assessing affordability. This paper has a more specific focus on two areas: (1) what can be learned from historical efforts to control the affordability of Department of Defense (DOD) programs, and (2) how can affordability constraints for sustainment costs, also called operating and support costs, best be implemented.

The Better Buying Power (BBP) initiatives[2] have as their first provision the need to "target affordability and control cost growth," more specifically, mandating "affordability as a requirement" by setting affordability targets as key performance parameters (KPPs) at Defense Acquisition Milestone A (entry into the Technology Maturation and Risk Reduction (TMRR) phase of a new acquisition program) and requiring engineering trade studies that show how each key design feature affects costs at Defense Acquisition Milestone B (entry into the Engineering and Manufacturing Development (EMD) phase). (The BBP was institutionalized with the promulgation of a new Department of Defense Instruction (DODI) 5000.02[3] in November 2013.)

BBP is not the first attempt by Defense Acquisition Executives (DAE) to promulgate policies to ensure that DOD acquisition programs will be affordable. Two past efforts are particularly noteworthy, the Design to Cost (DTC) initiative that began in the late 1970s, and the Cost as an Independent Variable (CAIV) concept of the late 1990s. Although neither DTC nor CAIV were exactly the same as the BBP affordability initiatives, there is sufficient similarity to expect that useful lessons can be learned from examining the Department's experience with the two programs. This premise motivated the first part of this paper. The similarities and differences will be explored in Chapter 2.

Even though sustainment or operating and support (O&S) costs for an acquisition program typically comprise 60–70 percent of a program's total life-cycle cost, these costs have received

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1 Gene H. Porter et al., *Affordability of Defense Acquisition Programs*, IDA Paper P-4961 (Alexandria, VA: Institute for Defense Analyses (IDA), April 2013).

2 Ashton B. Carter, Memorandum for Acquisition Professionals, "Subject: "Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending" (Washington, DC: Department of Defense (DOD), September 14, 2010), 2.

3 Interim DOD Instruction (DODI) 5000.02, "Operation of the Defense Acquisition System," November 25, 2013.

less attention in the past, though less does not mean none. In fact, both DTC and CAIV in their policy formulations included O&S costs. In practice, however, the IDA research team found little evidence that control of O&S costs achieved much success in either the DTC or CAIV efforts. There are, however, reasons that support the hope that this time is different because there is good evidence that the BBP initiatives regarding O&S affordability have been institutionalized to a considerable extent. That said, this institutionalization is still too recent to make judgments about its effectiveness in controlling O&S costs for new acquisition programs.

This research draws on other past IDA work regarding the DOD acquisition process. In 2009 IDA conducted in-depth research on cost growth in eleven Major Defense Acquisition Programs (MDAP) between 1999 and 2009. Since several of those programs advertised themselves as employing the CAIV concept, the IDA team was able to draw on that prior work to gain insights into the success of CAIV. It is also fortunate that IDA performed analyses of the effectiveness of acquisition reform initiatives of the 1980s era that included DTC.

IDA has also conducted considerable research on the O&S costs of weapon systems that informed this paper's investigation into affordability of sustainment costs; however, that research does not include actual assessments of the success in controlling O&S costs within a cost cap, as was the case with DTC. The research team's investigation of O&S cost affordability did not have an equivalent base of IDA work to build upon. The two primary sources used were O&S cost estimates reported in Selected Acquisition Reports (SAR) and data from the DOD Visibility & Management of Operating & Support Cost (VAMOSC) systems, which report actual O&S costs for certain DOD systems, with varying levels of completeness and fidelity. The SARs provide O&S cost estimates during the acquisition phases of a system while VAMOCS reports costs after the system is fielded. At some point after initial fielding, SAR O&S costs should reflect VAMOSC experience, and the research team found that usually was the case for the limited number of systems for which O&S costs were analyzed. A systematic comparison of SAR O&S cost estimates to VAMOSC data was beyond the scope of this research. Available data did allow the research team to provide some useful insights regarding the costs of a new system relative to the system or systems it will replace ("antecedent systems") and into the changes over time of SAR O&S cost estimates as programs develop.

Lastly the research team investigated how O&S costs might be better tracked and how programs might be adjusted to achieve more affordable fielded systems and increase the motivation of both government and industry managers to give more weight to O&S costs in systems development.

2. History of Constraining Costs in Acquisition Programs

The documentary record of attempts to constrain the costs of large-scale arms development programs to some pre-specified level extends back at least four centuries, and there are even suggestions that the classical civilizations of ancient Greece and ancient China pursued such efforts. There are, however, few records of success in any period.[4] The modern history of cost-constrained programs in DOD begins with Total Package Procurement (TPP) in the 1960s. Under TPP the prime contractor took contractual responsibility for delivering the system at an essentially fixed life cycle cost (LCC). Almost without exception, TPP programs experienced unusually high cost growth and encountered a variety of other ills, giving the entire concept a bad name.

A. Better Buying Power (BBP) versus Design to Cost (DTC) and Cost as an Independent Variable (CAIV)

BBP was institutionalized in the new DOD Instruction 5000.02, published as an interim document while this analysis was under way in November, 2013. As the best representation of the affordability provisions of BBP, DODI 5000.02 will be used to develop comparisons between BBP, DTC, and CAIV. To do so, it is useful to review the more salient sections of the instruction regarding affordability.

1. The Major Provisions of BBP Regarding Affordability

In accordance with BBP 2.0, the new 5000.02 specifies the establishment of "affordability goals and caps" for all acquisition programs.[5] DODI 5000.02 does not require a formal affordability assessment for the Materiel Development Decision (MDD), which is the entry point of a new program into the DOD acquisition process. However, Enclosure 8, "Affordability Analysis and Investment Constraints," suggests

> …some [affordability] analysis even before that point [i.e., the MDD] is beneficial. The best opportunity for ensuring that a program will be affordable is through requirements tailoring that occurs before and during the AoA. Thus, the Components will incorporate estimated funding streams for future programs within their affordability analyses at the earliest conceptual point and specify

4 Carla Rahn Phillips, *Six Galleons for the King of Spain: Imperial Defense in the Early Seventeenth Century* (Baltimore, MD: Johns Hopkins University Press, 1996).

5 Defined by the new 5000.02 as follows: "Affordability constraints are established to inform the Program Manager and the requirements authority of the cost limitations dictated by the Component's affordability analysis. Affordability *goals* are key objectives set to inform requirements and design tradeoffs during early research and development. Affordability *caps* are fixed requirements equivalent to Key Performance Parameters (KPPs)."

> those estimates at MDD and earlier to inform system design concepts and alternative selection.[6]

However, during the Materiel Solutions Phase, between the MDD and Milestone A (entry into TMRR), a more complete and formal affordability assessment is required to support the establishment of an *affordability goal* for the program at Milestone A. Such an assessment is also needed to support the Analysis of Alternatives (AoA), which is the major activity conducted in the Materiel Solutions Phase, to ensure that the alternative systems costs (both investment and O&S) considered in the AoA's cost-effectiveness comparisons are realistic.[7]

Based on analysis provided by the sponsoring DOD Component at Milestone A, the Milestone Decision Authority (MDA) approves affordability goals for both unit procurement and sustainment (but not for research, development, test and evaluation (RDT&E)), to be documented in the Acquisition Decision Memorandum (ADM). Specifically, the Component must

> Present an Affordability Analysis and proposed goals based on the resources that are projected to be available in the portfolio(s) or mission area(s) associated with the program under consideration. The analysis will be supported by a quantitative assessment of all of the programs in the prospective program's portfolio/mission area that demonstrates the ability of the Component's estimated budgets to fund the new program over its planned life cycle. Affordability Analyses do not produce rigid, long-range plans; their purpose is to inform current decisions about the reasonableness of embarking on long-term capital investments at specific capability levels. The Affordability Analysis will support the Component's proposed affordability goals for unit production and sustainment costs for MDA approval and recording in the Milestone A ADM.[8]

During the TMRR phase (between Milestones A and B), the affordability goal is used in requirements and systems engineering trade studies to ensure that the program will ultimately be affordable. Sustainment affordability is included:

> As the product support package design matures, the Program Manager will ensure that life-cycle affordability is a factor in engineering and sustainment trades.[9]

At Milestone B, an updated affordability assessment is required and is used by the MDA to specify the program's *affordability caps* for unit procurement and sustainment costs. These caps are intended to be equal in importance to performance requirements as the program proceeds through EMD, and they are to be recorded in the Acquisition Program Baseline (APB). An

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6 DODI 5000.02, 120.

7 "The analysis of alternatives will inform and be informed by affordability, sustainability, early systems engineering analyses, and industry studies." DODI 5000.02, 16.

8 Ibid., 16. The portfolio aspects of this proviso will be discussed subsequently.

9 Ibid., 20.

additional update is required before Milestone C, entry into the Production and Deployment Phase.

As noted above, Enclosure 8 of the new DODI 5000.02 is entitled “Affordability Analysis and Investment Constraints.” The five-page document explains the requirements for affordability analyses needed at Milestone reviews in considerable detail.

A key point of the document is that affordability must be determined by the DOD Components in the context of a set of portfolios. The enclosure states that

> If they are provided, Components will use office of the Under Secretary of Defense for Acquisition, Technology and Logistics standardized portfolios for their analysis. Portfolios can be based on mission areas or commodity types, and will define a collection of products that can be managed together for investment analysis and oversight purposes. Components will normally make tradeoffs within portfolios, but if necessary, can and should make tradeoffs across portfolios to provide adequate resources for high-priority programs.[10]

Ideally, the Components’ portfolios will add up to its projection of total obligational authority (TOA) expected to be available under realistic fiscal constraints. (The enclosure states: “The aggregation of portfolio cost estimates for each year, when combined with all other fiscal demands on the Component, may not exceed the Component’s reasonably anticipated future budget levels.”(page 119)) Frequently, however, Components tend to consider only investment portfolios when viewing the affordability of program investment costs (consistent with the definition of portfolios by “commodity types” cited in the paragraph above). Sustainment costs require a different portfolio view, which can be problematic, since it is sometimes difficult to draw plausible portfolio boundaries for O&S costs. Enclosure 8 is somewhat vague on the requirement to submit data supporting its affordability assessments, stating that

> Each Component’s affordability analysis is presented within the governance framework to the MDA in preparation for major acquisition decisions in a format that demonstrates the affordability of the program within the Component and portfolio context, to ensure that the resulting affordability constraints are understood and consistent with the future total budget projection.

And:

> …In general, standardized stacked area charts (or “sand charts”) and spreadsheets listing the estimated budget by year for each element of the analysis, are adequate. The data should compare life-cycle estimates to the historical experience within the portfolio and the Component for sustainment and procurement costs.
>
> …At each major acquisition decision meeting, the DOD Component will provide stacked area charts (“sand charts”) and underlying spreadsheet data showing the program’s budget, what portfolio it fits within, and the top-level total of all portfolios and accounts totaling at or below the future total budget projection,

10 Ibid., 118.

> equivalent to Total Obligation Authority. Additional detail and samples of the sand charts are presented in the Defense Acquisition Guidebook.[11]

These provisions do not appear to require the submissions to include the full programmatic contents of the portfolios. The objective is, thus, to specify affordability goals and caps so that all the programs in a portfolio are executable within the postulated fiscal constraints on the *portfolio*, on the *Component*, and on the *Department*.

Since affordability constraints are to be determined based on the fiscal resources available in the appropriate portfolio, the new DODI 5000.02 argues that affordability goals and caps are distinct from programs' approved cost estimates:

> Affordability analysis and affordability constraints are not synonymous with cost estimation and approaches for reducing costs. Constraints are determined in a top-down manner by the resources a Component can allocate for a system, given inventory objectives and all other fiscal demands on the Component. Constraints then provide a threshold for procurement and sustainment costs that cannot be exceeded by the Program Manager. On the other hand, cost estimates are generated in a bottom-up or parametric manner and provide a forecast of what a product will cost for budgeting purposes. The difference between the affordability constraints and the cost estimates indicates whether actions must be taken to further reduce cost in order to remain within affordability constraints. Independent of affordability constraints or cost estimates, program managers should always be looking for ways to control or reduce cost. Proactive cost control is central to maximizing the buying power of the Department and should be an integral part of all phases and aspects of program management. Cost control approaches are discussed in Enclosure 10 of this instruction.[12]

This point is worthy of discussion: Clearly there must be a close relationship between affordability constraints and program cost estimates. Even in the earliest stages of program initiation, there will be some notion of how much proposed system candidates will cost—usually within a fairly broad range. Such cost estimates would be taken into consideration in determining whether the projected funds for the portfolio are sufficient for the proposed new program. If, after making whatever portfolio adjustments might be required (either in program content or available resources), it appears to Component planners that an acquisition new start can be proposed, then the initial affordability goal is implied by the funds allocated to it within the portfolio. As program plans advance, the cost estimates will be refined, the range of uncertainty reduced, and the portfolio projection adjusted for consistency.

DODI 5000.02 also addresses the important issue of enforcement of affordability constraints:

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11 Ibid., 120.

12 Ibid., 117.

> When approved affordability constraints cannot be met—even with aggressive cost control and reduction approaches—then technical requirements, schedule, and required quantities must be revisited; this will be accomplished with support from the Component's Configuration Steering Board, and with any requirements reductions proposed to the validation authority. *If constraints still cannot be met, and the Component cannot afford to raise the program's affordability cap(s) by lowering constraints elsewhere and obtaining MDA approval, then the program will be cancelled.*[13] (emphasis added)

The sentence in italics in the quotation above deserves elaboration. It will be necessary to periodically review the portfolio and its projected funding to ensure that the previously-determined tentative goals are still viable, and if not, appropriate adjustments made—either to program content and/or timing, to other programs in the portfolio, or even to the funds that can be made available for the portfolio. This is an ongoing process as the program advances (or not), eventually passing Milestone B, when the affordability goals become firmer caps. At that point the program's cost estimates will probably link closely to the affordability caps.

If at any point in the acquisition process the projected costs of a program exceed the affordability constraint that has been established, a multi-prong process should be initiated. For example, in case A: The program is healthy but the costs estimates on which the allocation of portfolio funds to the program were based on assumptions now recognized as invalid. A better-informed cost estimate is available. The issue is thus whether the program still promises sufficient capability benefits to justify its new cost and whether sufficient offsetting funds can be made available, either within the portfolio or external to it. If so, then the program should proceed under revised affordability constraints. If not, cancellation is the alternative. Case B: The program is not healthy, and costs have gone out of control. On its current path, it will not be affordable. In this case, it is a question of whether the program can be put back on track with reasonable certainty. Probably requirements will need to be changed, and/or less risky technologies employed. If successful, then the restructured program might proceed. It may also become apparent that the program's initial cost estimates were faulty, which puts the decision back to Case A. Still other complicating conditions can arise, such as a change in the Department's or the Component's fiscal projection (as has recently occurred). In that case, the funds originally projected for the portfolio may no longer be realistic, so the original affordability constraints are no longer applicable. Or there might be a substantial change in the strategic environment (such as after the terrorist attacks of September 11, 2001 (9/11)), which implies major shifts in priorities. Either of those situations might mean that a perfectly healthy program proceeding within its affordability constraints may have to be cancelled or delayed in favor of now higher priority programs. The point of this discussion is that program cancellation is only one possible outcome of a situation in which, for diverse reasons, a program cannot remain within its affordability constraints, which themselves cannot be considered sacrosanct.

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[13] Ibid., 118.

Affordability caps are to be enforced by the MDA; and program managers (PM) that begin to question whether their program can remain within affordability caps are to promptly report the status to the MDA. Enclosure 8 states that affordability should be also a topic for review under the Defense Acquisition Executive Summary (DAES) process.[14]

Another point worth discussion before proceeding with the comparisons between BBP, DTC and CAIV concerns the *should-cost* provisions of BBP. Should-cost is defined in DODI 5000.02 as follows:

> 'Should Cost' is a management tool designed to proactively target cost reduction and drive productivity improvement into programs. Should cost management challenges managers to identify and achieve savings below budgeted most likely costs.[15]

Should-cost goals are thus well below affordability constraints and serve very different operational ends. A program would not be penalized for failing to meet a should-cost goal, whereas that would clearly not be the case of an affordability cap. As will be seen, DTC and CAIV both had a should-cost flavor in addition to their relationships to affordability. In contrast, BBP makes a clear distinction between aggressive should-cost goals, and more conservative and realistic program baselines. Not making that distinction in the DTC and CAIV implementations might, in fact, be a key reason for their failure. However, there are differences between should-cost goals today and DTC and CAIV target costs. Today's should-cost goals are not expected to be achieved without undertaking some exceptional actions to reduce cost below budgeted levels. Furthermore, it is understood that such actions may not achieve the desired results—there are risks involved.[16]

B. Design to Cost

1. History and Background

Although controlling costs has always been an important aspect of any development or acquisition program, the first reference the research team found to the DTC idea *per se* was in a speech by Director, Defense Research and Engineering (DDR&E) John Foster in March 1970. In it, Foster said that "…price has as much priority as performance…we must design-to-a-price…or else we will not be able to afford what we need."[17]

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14 DAES is a quarterly process for periodic and systematic reviews of MDAPs. Roughly one-fourth of the MDAPs will be reviewed each quarter in a meeting with the MDA or his/her designate.

15 DODI 5000.02, 77.

16 See the *Defense Acquisition Guidebook* for the discussion of should-cost in https://acc.dau.mil/CommunityBrowser.aspx?id=518710. "Unlike affordability requirements, we do not expect them [should-cost goals] to always be achieved, but we do expect strong efforts to do so" (section 10.15.2).

17 See Joseph R. Busek, "A Historical Analysis of Total Package Procurement, Life Cycle Costing, and Design to Cost," AD-A030-141, U.S. Department of Commerce, National Technical Information Service, June 1976. This

In 1971 the first DOD Directive on major systems acquisition was issued by Deputy Secretary David Packard.[18] This document, only six pages in length, is an excellent description of the necessary characteristics of the defense acquisition process, and is as applicable today as it was in 1971. It makes explicit mention of design to cost:

> Cost parameters shall be established which consider the cost of acquisition and ownership; discrete cost elements (e.g., unit production cost, operating and support cost) shall be translated into "design-to" requirements. System development shall be continuously evaluated against these requirements with the same rigor as that applied to technical requirements. Practical tradeoffs shall be made between system capability, cost and schedule. Traceability of estimates and costing factors, including those for economic escalation, shall be maintained. (Section III.C.2) [19]

The 1975 reissue of DODD 5000.1 contained the same provision and DODD 5000.28, dedicated to DTC, was promulgated the same year. In it DTC is defined as:

> A management concept wherein rigorous cost goals are established during development and the control of systems costs (acquisition, operating and support) to these goals is achieved by practical tradeoffs between operational capability, performance, cost, and schedule. Cost, as a key design parameter, is addressed on a continuing basis and as an inherent part of the development and production process.[20]

While from a program management standpoint, a DTC goal is much like an affordability constraint, the directive does not clearly state the relationship between establishing the goal and an assessment of funds likely to be available. Regarding establishing the DTC goal, DODD 5000.28 stated that

> An initial estimate of the resources available for allocation to the program shall be made and cost objectives established during concept formulation. Likewise, the minimum essential performance characteristics shall be quantified to avoid tradeoffs below that necessary to satisfy the required operational capability. Each technically feasible alternative will be analyzed and cost/performance tradeoffs

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is a master's thesis at the Air Force Institute of Technology that provides references to a number of other speeches and memoranda from the formative period of DTC.

18 DODD 5000.1, July 13, 1971. This is the first version that appears in the Pentagon Digital Library at http://www.whs.mil/library/mildoc/DODD.html. See also Joe Ferrara, "DOD's 5000 Documents: Evolution and Change in Defense Acquisition Policy," *Acquisition Review Quarterly* (Fall 1996), which states that the July 1971 issuance is the first.

19 Regarding TPP, the document stipulates: "It is not possible to determine the precise production cost of a new complex defense system before it is developed; therefore, such systems will not be procured using the total package procurement concept or production options that are contractually priced in the development contract" (Section III.C.7).

20 DODD 5000.28, May 23, 1975, "Design to Cost." This directive cancels two previous Deputy Secretary memoranda that addressed DTC, one from June 1973 and one from May 1974. These memos have not been located.

> made to ensure selection of the lowest life cycle cost solution. As soon as the system is definitized to the extent that cost associated with minimum performance needed can be estimated with confidence, a firm Design to Cost goal shall be recommended for the program.[21]

However, the directive gives no guidance on how to make that initial resource estimate. A more detailed implementation guide provided somewhat greater specificity regarding the steps needed to establish DTC goals:

> Every system has many parameters which must be considered in design. … Because of this multiplicity of considerations, there are a great number of possible combinations of values for each. At the outset of an acquisition, the optimum combination cannot be identified. However, certain limits must be identified. Given a threat environment, level of technology and mission scenario, there are dictated certain minimum essential performance parameters, the values of which must be attained or the system is not mission capable. There also results a certain cost which must be achieved or bettered or the system is not affordable. The solution can be visualized as follows:
>
> COST CEILING
>
> RANGE OF ACCEPTABLE SOLUTIONS
>
> PERFORMANCE FLOOR
>
> These limits fix the area in which the optimum combination of performance, cost, and schedule values must fall. In this area, it may be found that performance and schedule values above the minimum established requirement are useful and can be obtained within the affordable cost. Performance and schedule values above minimum will also be found for which the added cost, although within the limits of affordability, are unjustifiable given the utility of the added performance.[22]

Again, this falls well short of the specificity contained in the Affordability Enclosure of the current new DODI 5000.02. Nonetheless, these documents are remarkably close in many respects to the affordability provisions of BBP, with the suggestion in some of the descriptions of a similarity with should-cost.

The difference between current affordability constraints and DTC targets is clearly illustrated by the quote below from DODD 5000.28:

> The recommended Design to Cost goal should be a difficult but achievable objective which should challenge designers, engineers, and program managers to their best efforts. Care must be exercised to ensure the goal is properly selected; a

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21 DODD 5000.28, 4.

22 Department of the Army, the Navy and the Air Force, *Joint Design-to-Cost Guide: Life Cycle Cost as a Design Parameter* (Alexandria, VA: Army Materiel Development and Readiness Command, 15 October 1977) (a re-issue of an earlier 1975 document which has not been found). This document was published under the signature of the Army, Navy, and Air Force systems acquisition/ materiel commanders (and in the case of the Air Force, the logistics commander in addition), 3.

goal which is too high in relation to the required performance wastes money and an excessively low goal sets the stage for cost growth, buy-ins, or unacceptable systems.[23]

This aspect of DTC is a conundrum. If the cost goal is set low enough to be "difficult," then it should be expected that many programs will be unable to achieve them. Such programs will require high-level management attention (Secretary-level). The BBP approach avoids that problem by setting two goals—if set correctly the affordability constraint should seldom be violated, whereas the should-cost goal can be set more aggressively with a much higher risk of non-achievement but lower consequences. While programs are expected to routinely make their "best efforts" to reduce costs, programs are expected to identify initiatives that are effective in reducing costs, consistent with the risks. There is no assumption that cost can be reduced if people perform their jobs well as seems to have been the philosophy of DTC.

DODD 5000.28 was cancelled by the issuance of DODD 4245.3 in April 1983, also entitled "Design to Cost." Though conceptually the same, there are some important differences and refinements that both bring the original document up to date in terms of process and specify more detail in implementation. One important difference is that DODD 4245.3 assigns specific responsibilities for formulating and tracking DTC goals. The Director of Program Analysis and Evaluation (PA&E) is required to "review DTC parameters to ensure that they are feasible, are based on the performance and design specifications required to meet mission objectives, and identify high-cost or high-risk elements of the system."[24] The Director of the Cost Analysis Improvement Group (CAIG), is required to "provide to the DAE, at each DSARC review, an independent assessment of the recommended DTC goals and thresholds."[25] The Under Secretary of Defense (Comptroller) (USD(C)) is required to "ensure that the methodology developed by DOD Component heads for determining actual or estimated costs is uniform and consistently applied and that DTC parameters are compatible with resource planning documents such as the Five-Year Defense Plan and the Extended Planning Annex."[26] There is nothing comparable to these provisions in the new DODI 5000.02.[27]

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23 DODD 5000.28, 4.

24 DODD 4245.3, 5.

25 DODD 4245.3, 5–6.

26 Those responsibilities should logically have been given to Director, PA&E, who had overall responsibility for the FYDP and Extended Planning Annexes. And cost methodologies are logically the purview of the CAIG, which was also under Director, PA&E.

27 There is a question as to whether these provisions were routinely implemented. Several Decision Coordination Papers (DCP) of the era were examined and no DTC provisions were found. Also, individuals who were on the DDR&E staff in the mid/late 1970s do not recall DTC goals being subjects of discussion with leadership nor working any actions to modify DTC goals. This is a subject that deserves more investigation. [The DCP is described in the 1971 issuance of DODD 5000.1 in the following terms: "The considerations which support the determination of the need for a system program, together with a plan for that program, will be documented in the DCP. The DCP will define program issues, including special logistics problems, program objectives,

Another important difference between DODD 5000.28 and DODD 4245.3 is an emphasis on carrying DTC goals forward into acquisition contracts, to include provisions for providing "financial reward" to contractors for achieving DTC goals for both acquisition and O&S costs.[28] Again, there is nothing of comparable specificity for affordability constraints (or should-cost) in the new DODI 5000.02.[29]

The January 1977 DODD 5000.1 contains no provision regarding DTC *per se*, but it does list DODD 5000.28 as a reference. Issuances of DODD 5000.1 beyond the January 1977 contain no explicit reference to either DTC or to the separate DTC directives, though DODD 4245.3 remained in effect. The March 1983 DODI 5000.2 does reference DODD 5000.28 (cancelled one month later with the issuance of DODD 4245.3). The March 1985 DODI 5000.2 *still* references the cancelled DODD 5000.28 but not the DODD 4245.3 then in effect; however, the September 1987 issuance correctly lists DODD 4245.3 as a reference. The February 1991 issuance of DODD 5000.01 (page 5-1) explicitly cancelled DODD 4245.3, and with its cancellation DTC appears to have disappeared from DOD directives and instructions regarding acquisition. It can be concluded from this review that DTC, though still "on the books," received no real emphasis in the latter part of the 1980s.[30] [31]

2. Program Outcomes under DTC

DTC was the official policy of DOD for all MDAPs for almost two decades. This analysis has found neither individuals nor documents that offer a clear explanation of the reasons for its demise.[32] Possibly, it was generally seen as not helpful in controlling costs. As will be seen below, such a conclusion is supportable.

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program plans, performance parameters, areas of major risk, system alternatives and acquisition strategy." There is no modern counterpart.]

28 See page 6 of DODD 5000.28. DODD 4245 states: "Consideration shall be given to making payment of DTC incentives contingent upon attaining required levels of reliability and supportability" (Section E.4.a(2), page 4).

29 Page 19 of DODI 5000.02 contains a general provision in the section on Acquisition Strategy: "The business strategy will describe the rationale for the contracting approach and how competition will be maintained throughout the program life cycle, and detail how contract incentives will be employed to support the Department's goals." This, presumably, would be applicable to affordability constraints.

30 This is confirmed by a remark in a 1992 IDA paper from the period that will be drawn upon extensively below: "While there is still a place in the SAR for the design-to-cost goal, it is often filled by an 'N/A.' Of the 64 programs with FSD [full-scale development] start in the 1980s, only 27 are showing a DTC goal." Karen W. Tyson et al., *Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness*, IDA Paper P-2722 (Alexandria, VA: IDA, November 1992), VIII-2.

31 The early 1980s surge in defense may have translated into reduced urgency in controlling costs. Such an hypothesis is plausible but unproven.

32 John Betti was Under Secretary for Acquisition until December 13, 1990. Donald Yockey was acting on the date of signature. Since DOD directives are drafted long before they are signed, it is most likely that the decision to drop DTC was made under Betti.

In most cases it is impossible to adequately evaluate the efficacy of any cost control technique for a number of years after the program starts, at least until returned costs of production begin to become available. Nonetheless, in March 1978, the General Accounting Office (GAO)[33] expressed concerns about the implementation of DTC based on a review of five MDAPs employing DTC.[34] Based on previous IDA research, it appears that GAO's concerns were warranted.

It is fortunate for this analysis that two IDA papers between 1989 and1992 examined the effectiveness of several acquisition reform concepts instituted in the 1980s, including DTC. [35,] The current research has drawn on these papers extensively for both insights and supporting data. Overall, the first IDA paper, *The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs*, concluded that DTC principles had been applied inconsistently and had produced no clear benefit in controlling cost growth. Production cost growth for the programs using DTC was on average[36] 29 percentage points higher than that of the non-DTC programs (76 percent for thirty-four programs using DTC and 47 percent for forty-six programs that did not). The population of programs examined spanned from the late 1960s to the early 1980s.

The second IDA paper, P-2272, *Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness*, suggested that DTC had a positive effect on production cost growth on programs starting in the late 1970s:

> However, the analysis of cost and schedule outcomes of programs with and without DTC by time period (Figure VIII-2) indicates that DTC programs starting in the late 1970s have slightly less cost growth than non-DTC programs. In this time period the cost growth of the DTC programs is only 51 percent and that of the non-DTC programs is 55 percent This may indicate that, by the late 1970s, the DTC concept had enough time to become established and to be applied early enough in a program to be effective.

The present analysis attempted to confirm that hypothesis through statistical analysis of some of the data in Appendix A of IDA Paper P-2722.[37] The production cost growths for

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33 Since renamed the Government Accountability Office.

34 GAO, "The Department of Defense's Application of the Design-to-Cost Concept," PSAD-78-79; B-163058 (Washington, DC: GAO March 20, 1978). GAO concluded that DOD had not followed DTC principles closely by not establishing cost targets at the concept formulation stage, by controlling near-term acquisition costs rather than life-cycle costs, and by failing to develop adequate databases to establish cost-performance estimating relationships. Only one of the five programs examined (FFG-7) appeared to have successfully employed DTC.

35 Karen Tyson et al., *The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs*, IDA Paper P-2201 (Alexandria, VA: IDA, March 1989); and Karen W. Tyson et al., *Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness*, IDA Paper P-2722 (Alexandria, VA: IDA, November 1992).

36 The analyses computed these averages weighted by the programs' total cost.

37 P-2272 presents no statistical analysis of the data on DTC programs.

programs using DTC was compared to that of programs not using DTC. Kolmogorov-Smirnov tests were used to compare the two distributions, and the results are reported in Table 1.

Table 1. Results of Statistical Analysis of Data from 1989–92 IDA Research

	DTC Programs			*Non-DTC Programs*			Kolmogorov-Smirnov Test Results*	
Case	*Number of Programs*	*Mean Production Cost Growth*	*Median Production Cost Growth*	*Number of Programs*	*Mean Production Cost Growth*	*Median Production Cost Growth*	*D Statistic***	*p-value****
Full Set of programs in studies	34	85%	66%	47	61%	22%	28%	7%
Full Set, outliers excluded	33	71%	63%	45	56%	22%	29%	7%
Programs with FSD start dates later than 1974	25	55%	47%	17	61%	20%	29%	32%
Post-1974 programs, outliers excluded	24	49%	42%	15	13%	10%	38%	11%

* used http://www.physics.csbsju.edu/stats/KS-test.n.plot_form.html
** The maximum difference between the data points in the distributions
***The confidence in rejecting the null hypothesis that the two samples are drawn from the same distribution

For the entire set of eighty-one programs evaluated in the in the two papers, the programs using DTC had higher production cost growth than did the programs not utilizing DTC, and the difference is statistically significant at the 7 percent confidence level. The exclusion of outliers resulted in little change. The programs starting after 1975 had lower, but still significant cost growth, with or without DTC, and the mean growth of the DTC programs was still higher than for non-DTC programs. The p-value of 32 percent indicates, however, low confidence that the observed difference is significant (i.e., that a real effect of DTC is being observed). The exclusion of outliers produced an outcome even worse for DTC, with the increase over non-DTC programs having a higher level of confidence with a p-value of 11 percent. The difference between these results and those presented in P-2722 are probably explained by the latter's use of dollar-weighted averaging (the paper does not provide the cost data needed to confirm that supposition).[38] The bottom line is that the available data do not indicate that the DTC initiative was successful in controlling costs. It may have actually been counter-productive, though that cannot be said conclusively.

The periods of time encompassed by the DTC and non-DTC samples differed significantly, as would be expected since many (but not all) of the non-DTC programs were initiated prior to the implementation of the DTC policy in the early 1970s.[39] The median start year for the DTC sample was 1976, whereas that for the non-DTC sample was 1970. Nonetheless, seventeen of the forty-seven non-DTC programs had start dates of 1975 or later, raising the question of why those programs did not establish a DTC goal.

38 Dollar-weighted average results are less useful for the current analysis because it is focused on the effectiveness of a program management technique, irrespective of program size.

39 The research team has not been able to determine exactly when the formal requirement to establish a DTC goal was put in place. It was clearly in place by 1975.

Over the early 1970s to early 1980s period many changes were occurring in the DOD acquisition process,[40] and it has been observed that cost growth in defense acquisition programs decreased significantly compared to both earlier and later eras, as shown in Figure 1.

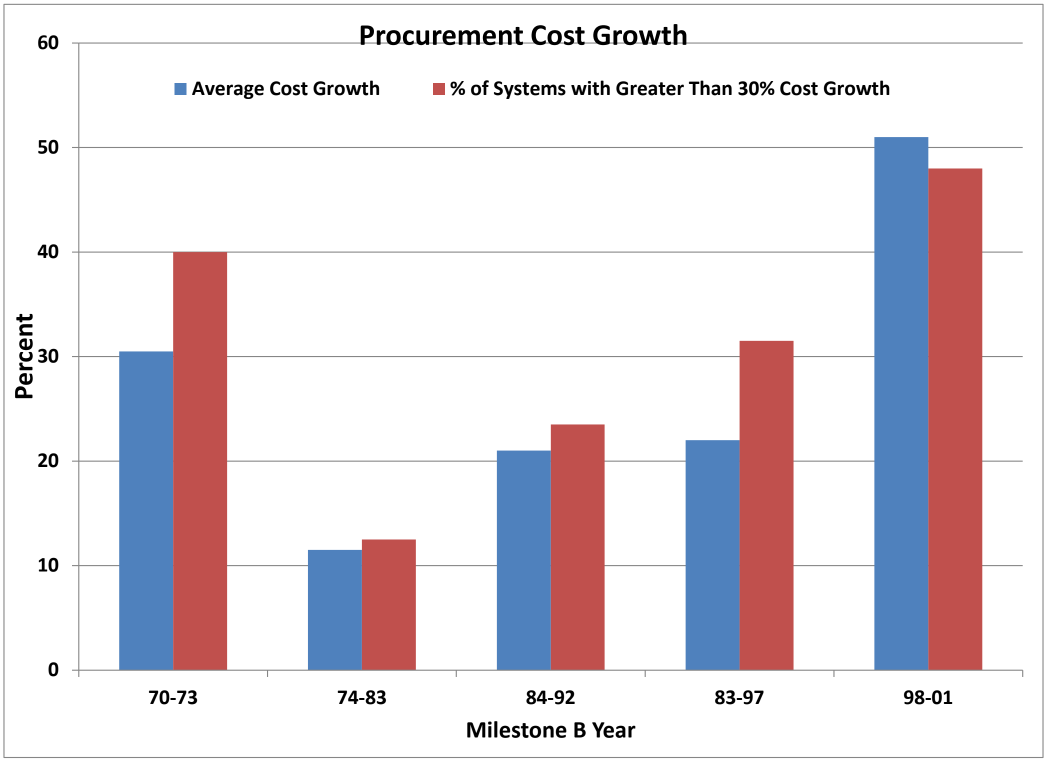

Figure 1. Procurement Cost Growth by Time Period[41]

Unfortunately it has not been possible to establish definitively which changes, if any, produced those encouraging results. It is, of course, difficult to isolate such effects without a much more in-depth review of the programs. Two other factors that were at work in that period may explain the better results—the advent of the CAIG and a far more proactive office of the DDR&E compared to either earlier or later periods. Two separate IDA publications have addressed these topics. The first paper, *Cost Growth in Major Weapon Procurement Programs*, IDA Paper NS P-3832,[42] shows improvements in cost growth in MDAPs starting after the establishment of the CAIG in 1972, attributable at least in part to improved initial cost estimates. The second paper, *What to Buy? The Role of Director of Defense Research and Engineering*

40 See William D. O'Neil, and Gene H. Porter, *What to Buy? The Role of Director of Defense Research and Engineering (DDR&E): Lessons from the 1970s*, IDA Paper P-4675 (Alexandria, VA: IDA, January 2011).

41 This chart, from an unpublished IDA briefing, was developed using an updated version of the database used in David L. McNicol, *Cost Growth in Major Weapon Procurement Programs*, Second Edition, IDA Paper NS P-3832 (Alexandria, VA: IDA, October 2004).

42 Ibid., 9, cites several studies supporting a conclusion that the institution of independent cost estimating resulted in improved initial cost estimates, and thus to reducing cost growth.

(DDR&E): Lessons from the 1970s, IDA Paper P-4675[43] compares Office of the Secretary of Defense (OSD) acquisition management and oversight practices in of the 1970s to those of the 1990s and later and notes that better outcomes, including lower cost growth, were achieved in the mid-late 1970s. The point of this discussion is that other factors are more likely to have contributed to improved acquisition program outcomes in the DTC era—a conclusion supported by the statistical analysis cited above.

C. Cost as an Independent Variable

In the mid-1990s, anticipating new challenges and diminished budgets following the end of the cold war, DOD instituted a comprehensive program of acquisition reform.[44] As that movement developed over the decade it came to encompass some sixty-three initiatives.[45] CAIV is one among the sixty-three, but it was not simply a face in the crowd; statements by top acquisition officials made it clear that they regarded CAIV as among the most important of the five dozen initiatives.

The first codified guidance for CAIV was in DODD 5000.1, *Defense Acquisition*, published in March 1996. That publication was preceded by a memorandum from Under Secretary Paul Kaminski implementing the recommendations of a working group he established under the auspices of the Defense Manufacturing Council and charged to "address approaches and measures to reduce life cycle costs." Among several measures, Kaminski identified the need for

> aggressively managing programs to meet those objectives, thus making cost a major driver while meeting the true needs of the warfighter. This concept is called "cost as an independent variable" (CAIV). CAIV is the DOD equivalent of best commercial business practices. [46]

The memorandum also established eight acquisition programs to serve as "flagships" for CAIV implementation. Using readily available materials, primarily SARs and earlier IDA publications, the current research team conducted a case study analysis of the CAIV flagship programs along with four other contemporary programs that prominently attempted to employ CAIV. These case studies are reported in Appendix A and summarized at the end of this chapter.

Although CAIV figured prominently in issuances of the DOD 5000 documents through April 2002, the May 2003 issuance of DODD 5000.1, *The Defense Acquisition System*, contained only a vestigial reference to CAIV, and the DODI 5000.2, *Operation of the Defense Acquisition System*, issued at the same time contained no reference to CAIV. The May 2003 version of

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43 See O'Neil, and Porter, IDA P-4675.

44 William J. Perry, [Secretary of Defense], "Acquisition Reform: A Mandate for Change," 9 Feb 1994.

45 Christopher H. Hanks et al., *Reexamining Military Acquisition Reform: Are We There Yet?* MG-291 (Santa Monica, CA: RAND Arroyo Center, 2005), 5–13.

46 Paul Kaminski, *Memorandum for Distribution Subject: Reducing Life-Cycle Costs for New and Fielded Systems*, December 4, 1995. No copy of this memo has been found but the text of it is at http://www.navair.navy.mil/nawctsd/Resources/Library/Acqguide/caainvar.htm.

DODD 5000.1 was reissued in 2007[47] with the CAIV language still in place and remains in effect as of this writing.

The original CAIV provision in the 1996 DODD 5000.1 was:

> Cost as an Independent Variable (CAIV). Fiscal constraint is a reality that all participants in the defense acquisition process must recognize. Cost must be viewed as an independent variable. Accordingly, acquisition managers shall establish aggressive but realistic objectives for all programs and follow through by trading off performance and schedule, beginning early in the program (when the majority of costs are determined), to achieve a balanced set of goals, based on guidance from the MDA.[48]

The accompanying DOD 5000.2-R, *Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs*, which was published at the same time,[49] included much more detailed guidance in an entire section (3.3.3) on CAIV. At Milestone I (entry into Program Definition and Risk Reduction (PDRR)—roughly equivalent to Milestone A today) the MDA was to approve "CAIV objectives." The basic philosophy is stated thusly:

> The acquisition strategy shall address methodologies to acquire and operate affordable systems by setting aggressive, achievable cost objectives and managing achievement of these objectives. *Cost objectives shall be set to balance mission needs with projected out-year resources*, taking into account anticipated process improvements in both DOD and defense industries. (emphasis added).[50]

The main conceptual difference between the approach in DOD 5000.2-R and current guidance is the word "aggressive." The guidance in DOD 5000.2-R is further elaborated as follows:

> [At Milestone I the program manager]…shall have established life-cycle cost objectives for the program through consideration of projected out-year resources, recent unit costs, parametric estimates, mission effectiveness analysis and trades, and technology trends. A complete set of life-cycle cost objectives shall include RDT&E, production, operating and support, and disposal costs.[51]

This provision makes it clear that CAIV cost objectives include O&S costs and should be developed based on projected fiscal resources.

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47 And renamed DODD 5000.01. http://www.dtic.mil/whs/directives/corres/pdf/500001p.pdf.

48 DOD, *The Defense Acquisition System*, DODD 5000.1 (Washington, DC: DOD, 15 March 1996), 5, paragraph D.1.f.

49 There was no DODI 5000.2 promulgated at that time. The February 1991 version of DODI 5000.2 was cancelled by the 1996 issuance of DODD 5000.1.

50 DOD, *Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs*, DODR 5000.2-R (Washington, DC: DOD, 15 March 1996), 6, part 3.

51 Ibid., 7, part 3.

The DODD 5000.1 published on October 23, 2000 expanded the CAIV language of the 1996 version:

> 4.5.2. Cost and Affordability. Fiscal constraint is a reality that all participants in the acquisition system must recognize. Cost must be viewed as an independent variable, and the DOD Components shall plan programs based on realistic projections of funding likely to be available in future years. To the greatest extent possible, the DOD Components shall identify the total costs of ownership, and at a minimum, the major drivers of total ownership costs. Consistent with the Chairman of the Joint Chiefs of Staff guidance on requirements generation, the user shall treat cost as a military requirement and state the amount the Department should be willing to invest to obtain, operate, and support the needed capability over its expected life cycle. Acquisition managers shall establish aggressive but realistic objectives for all programs and follow through by working with the user to trade off performance and schedule, beginning early in the program (when the majority of costs are determined).[52]

This issuance cancelled DOD 5000.2-R; however, a memorandum was signed stating that DOD 5000.2-R would remain in effect as interim guidance until a revision was published. When DODI 5000.2 was reissued in April 2002, the only reference to CAIV was

> 4.7.2.1.4. The user or user's representative shall work with the Program Manager or other system developer (e.g., the Demonstration Manager for Advanced Concept and Technology Development projects) to establish and refine cost as an independent variable (CAIV)-based cost and performance objectives and critical schedule dates. The CAIV-based parameters and critical schedule dates shall also be included in the APB.[53]

However, DOD 5000.2-R was also reissued at that time with essentially the same extensive CAIV provisions as the previous issuance. (DODD 5000.1 was not reissued and remained in effect.)

A dramatic turn away from CAIV was evident with the May 2003 reissuance of both DODD 5000.1 and DODI 5000.2. A single reference to CAIV is found in DODD 5000.1 but none whatsoever in DODI 5000.2, and the latter explicitly cancelled DOD 5000.2-R with its extensive CAIV discussion. [54] The DODD 5000.3 of May 2003 was reissued in 2007 including

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[52] DOD, *The Defense Acquisition System*, DODI 5000.1 (Washington, DC: DOD, 23 October 2000), 8.

[53] DOD, *Operation of the Defense Acquisition System*, DODI 5000.2 (Washington, DC: DOD, 5 April 2002), 14. APB—Acquisition Program Baseline. This provision occurs several times in the DODI 5000.2 and DOD 5000.2-R documents of the period; however, the research team's review the APB SARs for the CAIV flagship programs in the DAMIR revealed no instances of recorded CAIV objectives.

[54] Ibid., 1.A January 2002 memorandum signed by USD(AT&L) E.C. Aldridge (in office from May 2001 to May 2003) emphasized CAIV: "I have approved a metric to require, by the end of FY02, 100% of defense programs to incorporate a cost-as-an-independent-variable (CAIV) plan…" Since this memo seems to indicate a buy-in of the CAIV, it is all the more curious that only seventeen months later that commitment vanished entirely.

its single CAIV reference, and remains in effect as of this writing. The language in the 2003/2007 DODD 5000.1 regarding CAIV is as follows:

> E1.4. Cost and Affordability. All participants in the acquisition system shall recognize the reality of fiscal constraints. They shall view *cost as an independent variable*, and the DOD Components shall plan programs based on realistic projections of the dollars and manpower likely to be available in future years. To the greatest extent possible, the MDAs shall identify the total costs of ownership, and at a minimum, the major drivers of total ownership costs. The user shall address affordability in establishing capability needs.[55] (emphasis added)

This provision can only be viewed as opaque by DOD acquisition practitioners unfamiliar with its history.

1. CAIV versus DTC

Inevitably, some have wondered what was really new about CAIV, and several authors attempted to draw a distinction between it and DTC, in some cases displaying ignorance of the actual policies under DTC.[56] Within the context of the several acquisition reform initiatives undertaken in same time period as CAIV, one early review concluded that

> the basic concept of CAIV is not dramatically different from the "Design to Cost" concept applied with mixed results in the early 1970s. The difference, according to advocates, is that CAIV is being implemented in an environment of much more profound change to the traditional acquisition system and culture. They believe that this gives it a much greater chance of success.[57]

However, one could legitimately question whether the 1990s was a period of "much more profound change to the traditional acquisition system and culture" than the early 1970s, which was regarded by contemporaries as a period of radical transformation and the focus of top DOD management on acquisition issues arguably reached its zenith.[58]

The reliance on integrated product teams (IPT), and in particular on a Cost/Performance IPT (CPIPT), is sometimes cited as a distinctive feature of CAIV, as contrasted to DTC. However, IPTs had been widely advocated and employed since the 1980s, including in programs subject to DTC, in the experience of one of the authors of this paper. Moreover, developer-user

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55 DOD, *The Defense Acquisition System*, DODD 5000.1 (Washington, DC: DOD, 12 May 2003), 5, Enclosure 1.

56 Stacy S. Azama, "Cost as an Independent Variable (CAIV): Teaching Note," Defense Systems Management College, Funds Management Department, June 2000. Higgins, Guy, "CAIV—An Important Principle of Acquisition Reform," *Program Manager* 26, No. 1 (Jan–Feb 1997): 44–47. Kausal, B. A. "Tony", IV, "Controlling Cost—A Historical Perspective," *Program Manager* 25, No. 5 (Nov–Dec 1996): 22–28.

57 Mark A. Lorell, et al., *Cheaper, Faster, Better? Commercial Approaches to Weapons Acquisition*, MR-1147-AF (Santa Monica, CA: RAND Corp., 2000), 22, fn. 18.

58 O'Neil, and Porter, IDA P-4675, 49–54.

teams that were functionally equivalent to CPIPTs were employed during World War II, with excellent results.[59]

2. CAIV and *Should-Cost*

Perhaps even more than for DTC, CAIV bore similarities to the current should-cost initiative. The Defense Manufacturing Council working group report that resulted in implementation of CAIV states:

> Aggressive cost objectives means costs objectives that are the DOD-equivalent of sound commercial business practices. These objectives will be set as early as possible (e.g., Milestone I or before for most systems). It is expected that these objectives will be much lower than would be projected for a system using past ways of doing business.[60]

This statement encapsulates the idea that initial cost estimates derived from cost estimating relationships in prior defense acquisition programs (and virtually all of them are so derived) are based intrinsically on the “old ways of doing business” and that those costs can be reduced by sound, aggressive management actions. Even though the report does state that PMs should not be penalized for “failures that might occur despite best management efforts,” it also states that “promotion policies, awards and other formal recognition are important in providing feedback that jobs have indeed been done well.”[61] The clear implication is that success in implementing CAIV should lead to such rewards. The danger of this approach is that managers will be motivated to attempt “heroic” measures to dramatically reduce costs. There is some evidence that such outcomes occurred in some of the CAIV flagship programs, such as JASSM and SBIRS, and possibly in the non-flagship CAIV programs such as EFV and LCS. See Section 2.D for a detailed discussion of this point.

3. CAIV and Commercial Practices

One of the principal arguments for CAIV was that it mirrored the practice in commercial industry, which was presumed to be especially efficient and economical in its operations. This is an oversimplification and analyzing it reveals the limitations of CAIV.

In industries such as consumer electronics, consumer durables, and industrial catalog goods, many firms sell in markets whose structure approximates price-based competition. In such markets development and manufacturing costs generally are a substantial fraction of selling price, and firms need to be able to develop new models to meet a price point, using CAIV-like

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59 Ibid., 13–14.

60 IDA has not been able to locate an image copy of either the Kaminski memo or the attached Defense Manufacturing Council Working Group Report. However, an HTML version is available at http://www.navair.navy.mil/nawctsd/Resources/Library/Acqguide/caivwgp.htm.

61 Ibid., page number unknown since original document has not been located.

techniques. Developing a new model for an established line of automobiles, home entertainment systems, or refrigerators, however, is a task that is very little like that of the typical MDAP.

Occasionally firms in these lines of business seek to develop an entirely new class of good to meet an emergent need or newly available technology, a task more like that involved in an MDAP, although typically on a smaller scale. Although these cases vary, frequently the development objectives place substantially greater emphasis on new kinds of performance, with cost less rigidly constrained.

Moreover, industrial firms often find CAIV-like strategies much more challenging than CAIV advocates recognized, particularly in industries producing goods most comparable in scale and complexity to MDAPs, such as commercial aircraft. The Boeing 787 "Dreamliner" is a well-known example of a project whose costs outstripped its maker's intentions. Sources in the commercial transport industry confirm that throughout the jet age few airliner projects have met cost goals. The industry as a whole has survived because demand growth has exceeded expectations, a critical factor in an industry where learning curves remain relatively steep. But where there were once more than a dozen manufacturers of large airliners in the West, today there are only two. In almost every case, exits from the market or mergers were forced by unexpected cost growth.

In many cases firms are able to suppress news of serious cost growth, out of fear for the effect on stock prices or on customer response. In one industry, however, special circumstances have permitted a knowledgeable analysis of project cost growth, with very interesting results. Edward R. Merrow heads a consultancy that serves clients in the petroleum and petrochemical industry. His firm has been able to amass a very detailed and consistent data set covering a great many projects, and he has published an analysis of "megaprojects," meaning projects costing in excess of one billion dollars.[62] Many of these have a larger share of what in DOD would be classified as MILCON expense than the typical MDAP, and on the whole they involve less of technology advancement than the average MDAP. In terms of size and complexity, however, they are broadly comparable to MDAPs.

Merrow doesn't share the details of his data set, but he's a competent and experienced econometrician with an academic background whose analysis appears entirely consistent internally. The results reported in the book build on and are consistent with a substantial body of earlier work which was reported in greater detail.[63] He provides a clearer, fine-grain picture of the roots of cost growth than has ever been reported for any MDAP.

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[62] Edward W. Merrow, *Industrial Megaprojects: Concepts, Strategies, and Practices for Success* (Hoboken, NJ: John Wiley & Sons, 2011). Also relevant is Edward W. Merrow, "Why Large Projects Fail More Often: Megaproject Failures: Understanding the Effects of Size," annotated briefing (Ashburn, VA: Independent Project Analysts, Inc., 2011).

[63] Edward W. Merrow, *Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects*, R-3560-PSSP (Santa Monica, CA: RAND Corp., 1988); Edward W. Merrow, Kenneth E. Phillips, and Christopher W. Myers, *Understanding Cost Growth and Performance Shortfalls in Pioneer*

All of the projects Merrow reports on had cost objectives, and cost was of crucial importance in every case, as it was the denominator in return on investment (ROI). Since each project was so large, a poor ROI could threaten the profitability of the firm undertaking it, or even the firm's viability. He says that, in general, cost growth of 25 percent will wipe out a project's ROI and that greater growth will result in negative ROI; for this reason he takes 25 percent growth as a critical threshold.

Figure 2 compares the proportion of projects with acquisition costs exceeding 25 percent cost growth as reported by Merrow for industry megaprojects with that for 105 MDAPs initiated between 1971 and 2000, calculated from the Cost Assessment and Program Evaluation (CAPE) refined SAR data set. Questions regarding data comparability counsel some caution in evaluating this comparison, but clearly there's nothing here to support a hypothesis of superior cost control in commercial industry, given comparable challenges.

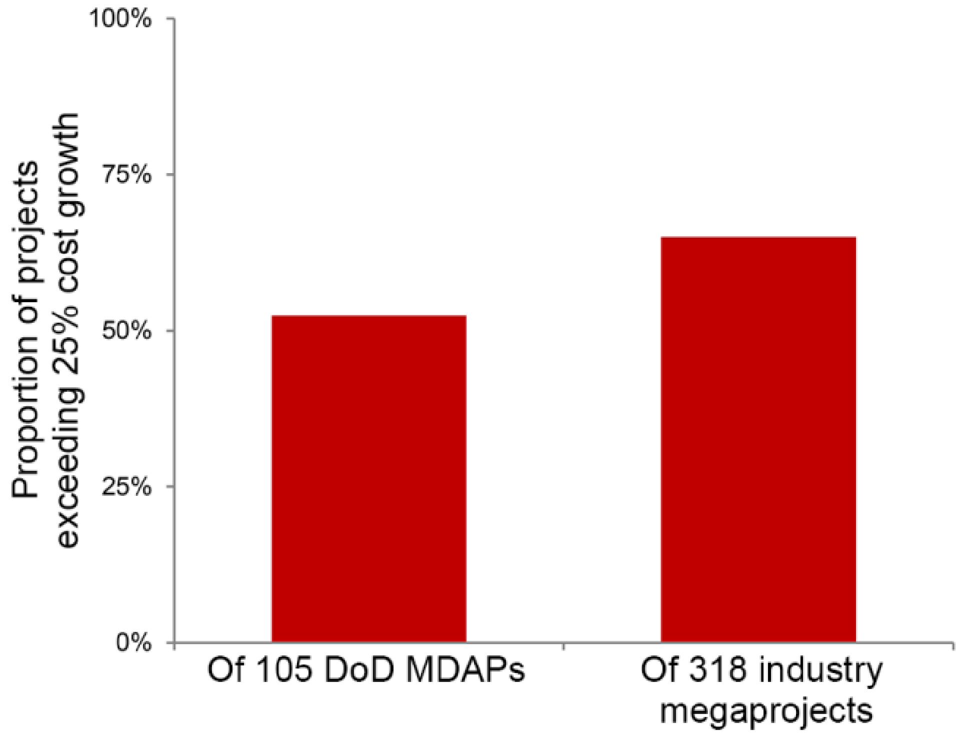

Figure 2. Comparative Large-project Acquisition Cost Growth

Process Plants, R-2569-DOE R-2569-DOE (Santa Monica, CA: RAND Corp., 1981); Edward W. Merrow, Stephen W. Chapel, and Christopher Worthing, *Review of Cost Estimation in New Technologies: Implications for Energy Process Plants*, R-2481-DOE R-2481-DOE (Santa Monica, CA: RAND Corp., July 1979).

4. Obstacles to Evaluating the Efficacy of CAIV

In order to draw lessons for the future from the CAIV experience, it would be helpful to understand CAIV's efficacy in constraining costs. The resources of this research restrict the ability to do so, but beyond that there are inherent uncertainties and situational limits that must be recognized. These obstacles include

- *Overdetermination*. To evaluate the effectiveness of CAIV, one must separate the effects of CAIV from those of other essentially coterminous acquisition policy initiatives, many of which also have controlling costs as at least one objective.
- *Persistent practices*. Essentially, CAIV codified existing "best practice" rather than instituting wholly new and untried doctrines. This substantially reduced the risks associated with its introduction but at the same time meant that its introduction did not represent a sharp change in practices at a defined moment.
- *Long lags*. It can well take twenty years, or even longer, for the actual acquisition costs associated with an MDAP to become accurately known.
- *Small sample*. The actual number of MDAPs that are known to have implemented CAIV remains comparatively small.

Econometrics offers statistical techniques aimed at overcoming such limitations in order to estimate the effect of a single factor such as CAIV; however, the sample size available for programs using CAIV is too small to support such an analysis.[64] Thus, a case study approach was used to produce useful information within the resources available for this project. If sufficient resources do become available, it may be possible to build a database to support an econometric analysis to test and validate the conclusions drawn from the case studies.

D. Analysis of Selected CAIV Programs

CAIV was in use for a much shorter time than DTC; nonetheless, it was deeply entrenched in DOD regulations from 1996 to 2002.[65] Eight CAIV "flagship" programs were named and a number of other acquisition programs purported to use the methodology. Unlike, DTC, however, there was never a systematic recording of CAIV cost objectives in SARs, and for that reason among others, no database exists like the one compiled by IDA in the 1989–92 period for DTC. Thus this research, lacking the resources to construct such a database, depended instead on case study analyses of the eight flagship programs plus four other programs known to have attempted

64 Unlike with DTC, the research team did not have a way of determining the extent to which CAIV principles were actually applied for programs under development during the CAIV era. In any case, the sample size would obviously be much smaller than for DTC because the time period over which the policy was active was considerably shorter.

65 And as noted earlier, CAIV exists in a vestigial form in DODD 5000.1 published in 2007, still current.

to employ the CAIV approach.[66] The CAIV case studies (Appendix A) include reviews of the systems identified in Table 2.

66 These programs include the San Antonio class LPD-17, Expeditionary Fighting Vehicle, and Joint Direct Attack Munition.

Table 2. CAIV Acquisition Programs Analyzed

	Program Short Name	CAIV Flagship?	Program Long Name
Army	Crusader	Yes	Crusader Advanced Field Artillery System
	ATACMS/BAT	Yes	Army Tactical Missile System/ Brilliant Anti-Tank
Navy	MIDS	Yes	Multifunctional Information Distribution System
	AIM-9X	Yes	Sidewinder Air Intercept Missile
	LCS	No	Littoral Combat Ship
	LPD-17	No	San Antonio Class Amphibious Transport Dock Ship
Marine Corps	EFV	No	Expeditionary Fighting Vehicle
Air Force	JDAM	No	Joint Direct Attack Munition
	SBIRS	Yes	Space-based Infrared System
	JASSM	Yes	Joint Air-to-Surface Standoff Missile
	JSF/F-35	Yes	Joint Strike Fight (Lightening II)
	EELV	Yes	Evolved Expendable Launch Vehicle

Table 3 displays cost growth in the programs analyzed, derived using Average Unit Procurement Costs (APUC) from SARs. It can be seen that that only one (MIDS) of the eight CAIV flagship programs was fully successful in controlling procurement cost growth.

Table 3. Average Unit Procurement Cost Growth of Selected CAIV Programs

	Original Estimate	Current Estimate	Percent Change
JDAM ($K)	31	19.8	-36%
JASSM* ($K)	399	703	76%
MIDS* ($K)	309	243	-21%
AIM-9X* ($K)	193	221	15%
SBIRS* ($M)	694	2,775	300%
JSF* ($M)	50.9	85.8	69%
EELV* ($M)	65	298	358%
Crusader* ($M)	10.8	11.5	6%
ATACMS/BAT* ($K)	72	118	64%
LCS ($M)	225	485	116%
LPD-17 ($M)	743	1,304	76%
EFV ($M)	5.3	13.1	147%

Note: *CAIV Flagships; $K = thousands, $M = millions

Four of the case studies were facilitated by previous IDA research that conducted detailed analyses of the causes of cost growth for nine important acquisition programs.[67] The following paragraphs summarize the findings of the case studies presented in Appendix A.

JDAM. JDAM is an all-weather glide-bomb kit that can be fitted to commodity bomb bodies to provide a moderate-precision, relatively inexpensive, guidance system. Although not a CAIV flagship program, JDAM began as a "Defense Acquisition Pilot Project" with a strong cost control focus and was influential in the emergence of the CAIV concept. The principal Military Service (hereafter Service) using JDAM saw it as a mass-use weapon and was willing to be flexible regarding performance to achieve low cost. Limited performance requirements made extensive use of high-volume, commercial-grade parts possible, and acquisition rules were tailored to ease their use. The contract structure provided strong incentives for cost control, with a realistic risk/reward calculus, aided by large production volumes and steep learning curves. The program has been highly successful in both cost and performance. By any measure, JDAM was a signal success for the CAIV concept.

Crusader (Flagship). This system to replace the M-109 self-propelled howitzer suffered to an unusual degree from requirements changes, which greatly increased development costs. It was ultimately cancelled by Secretary Donald H. Rumsfeld in May 2002, prior to Milestone II, because of its lower priority in the post-9/11 environment. While the 1998 SAR claimed a 35 percent production cost reduction, in fact that reduction took place before Milestone I in 1994

[67] Gene H. Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, IDA Paper P-4531 (Alexandria, VA: IDA, December 2009).

and before its designation as a CAIV flagship. Since no independent cost estimate based on a production design was ever completed, the program should be considered a "no test" from CAIV success standpoint.

ATACMS/BAT (Flagship). This "brilliant" munition program faced unprecedented and highly challenging technical performance goals, and the struggle to meet them appears to have crowded out any serious cost-control efforts. The program was cancelled (by the Army) in late 2003 because of technical difficulties evidenced by repeated test failures. No recognition of the program being a CAIV flagship was found in its SARs. APUC grew by 20 percent or more every year except one. While quantities were greatly reduced in the last SAR before program cancellation, there is no evidence that any others adjustments were made to control production costs (or indeed that any such adjustments were even feasible).

MIDS (Flagship). MIDS is a multinational cooperative development program to design, develop and deliver lightweight tactical information system terminals for aircraft, ships, and ground sites. Milestone II was in 1993 and Milestone III was July 2003, so the program was in the middle of full-scale development when designated as a CAIV flagship. The SARs make no mention of CAIV, and neither the SARs nor other reports on the program give any hint of CAIV-type cost-performance tradeoffs. While there were some significant schedule slippages, costs remained under control. The terminals have proven attractive to many users, resulting in high production volumes and attendant unit cost decreases.[68] However, there is no evidence that the outcome was a result of the application of CAIV.

AIM-9x (Flagship). The AIM-9X is the latest variant in a long line of Sidewinder short-range infrared-guided air-to-air missiles. AIM-9X achieved incremental improvements over previous AIM-9 generations by incorporating advanced subsystems. Most of the new subsystems had already been demonstrated in prototype form, so major risk-reduction had already taken place. Thus, it offered good prospects for a successful, if not particularly challenging, CAIV program. In fact, long before the advent of CAIV, cost had been a focus of the program since the initial requirement was approved in 1990. CAIV was mentioned in the December 1997 SAR but not thereafter. APUC remained under control, and in fact decreased somewhat, through 2004. However in 2005 and again in 2009 the APUC increased about 9 percent each time. Overall the program was a success, and its cost growth was lower than average. However, the research team found no evidence that CAIV tradeoffs of cost and performance had occurred.

SBIRS (Flagship). SBIRS replaces the Defense Support Program (DSP) satellites to provide early warning of ballistic missile launches. The program sought to combine major performance advances with substantial cost savings. Early-phase systems engineering was avoided to save costs, contributing to initial cost estimates that were extremely unrealistic. While

68 The figures in Table 3 are not adjusted for quantities. The Dec-12 SAR quantities associated with the APUC is twice that of the Dec-97 SAR. Adjusted for the quantity difference, the unit cost decrease was about 10 percent (assuming an 85 percent production learning curve slope).

there appears to have been a genuine effort to utilize the CAIV approach, the emergence of serious technical issues soon after Milestone II quickly rendered the CAIV cost objectives irrelevant. Government oversight was slashed to save its costs, while performance requirements were informally increased. Contractor incentives had little effect because they were far out of reach. Requirements were eventually trimmed, partly to save costs and partly as a reflection of technological reality, but not until massive cost growth had already taken place. A great deal of growth came from bad engineering. SBIRS represents a dramatic failure of CAIV, teaching a strong lesson that CAIV cannot work for complex systems without sound early systems engineering as a basis for credible initial cost estimates.

JASSM (Flagship). JASSM was initiated after the cancellation of the predecessor Tri-Service Standoff Attack Missile (TSSAM) program, largely because of a substantial cost overrun. With the same PM initially as JDAM and given its success, there was great optimism that taking the same approach on JASSM would lead to similar results. However, soon after Milestone II, costs began to grow. Inadequate systems engineering contributed to late recognition of reliability issues, resulting in costly reworks. Thus the CAIV strategy for JASSM was remarkably unsuccessful, not only in failing to control costs but also in producing a missile with significant effectiveness issues as well. In fact, some of the steps taken to reduce production costs contributed to reliability failures. JASSM demonstrates yet again the importance of an initial cost estimate backed by sound systems engineering as a valid basis for a CAIV cost goal. Ironically, the current APUC for the baseline JASSM is remarkably close to early cost estimates of about $700,000 for a missile with JASSM's characteristics, before the ambitious claims that acquisition reform initiatives (CIAV, among others) could achieve a 40 percent lower cost objective. If both DOD PMs and contractors are strongly incentivized to undertake "heroic" efforts to reduce costs, their risk-reward calculus may translate into excessive risks. There is evidence that JASSM is an example.

JSF/F-35 (Flagship). F-35 is a strike fighter designed for the Air Force, Navy, and Marine Corps, as well as the air forces in at least eight allied nations. Meeting the needs of various users resulted in three distinct versions. A variety of techniques were employed for cost reduction, ranging from early competitive prototyping to a compressed schedule with steep production ramp-up, but most failed and some transformed into major liabilities. Deficiencies in systems engineering and inadequate government oversight led to late recognition of serious problems. By 2003 there was a realization that the designs were substantially overweight and that conventional methods of weight control would not alleviate the problem. The only solution was to redesign the aircraft almost from scratch, even though assembly of production prototypes had already begun. In the process it was necessary to give up many of the features included to save money. Moreover, it was necessary to extract more power from the engine, which further increased its cost. The redesigns seriously disrupted the tight schedules designed to reduce costs. These difficulties probably prevented the CAIV approach from having any real impact on the JSF/F-35 program. Because of the large numbers of aircraft that the F-35 will replace, affordability has always been a major focus of the program. The big tradeoff that the Department was, obviously, not willing to make was on the short takeoff/vertical landing (STOVL) capability needed to replace the AV-8B Harriers of both the Marine Corps and the United Kingdom.

EELV (Flagship). The EELV program began in the early 1990s with the objective of assuring adequate launch services for both military and intelligence payloads. To reduce costs, the original plan was for a hybrid system of launchers that could meet both Government and commercial needs. Savings projections depended heavily on extremely unrealistic market projections that were only slowly acknowledged, resulting in the continued pursuit of policies that were counterproductive in the actual environment. The emergence of low-cost foreign competitors essentially eliminated hopes for commercial sales. Thus, costs could not be controlled through competition and cost-sharing as planned. Significant cost-performance tradeoffs were never really feasible. The size mix of boosters needed was determined by the weight of the payloads to be placed in orbit, which was completely outside of the control of the program. The KPP is launch reliability, and it makes no sense to compromise on reliability and risk destruction of expensive payloads that might be critical to national security. It seems evident that a true CAIV strategy was not realistic for EELV.

LCS. The LCS was not a CAIV flagship program but CAIV was touted as central to its acquisition strategy. The initial cost target was directed by the Chief of Naval Operations (CNO) and was not based on analysis. Lack of early program definition and highly concurrent scheduling led to chaotic development. Late imposition of a requirement for construction to comply with newly-issued Naval Vessel Rules forced extensive redesign while construction of the first ship was in progress. The Navy relied heavily on acquisition reforms, cutting back oversight and support. The requirements tradeoffs that were made reflected a significant misunderstanding of actual cost impacts of failing to recognize the full implications of ship speed. By insisting on a very high ship speed the Navy ensured high costs despite serious sacrifices in areas including seakeeping, endurance, survivability, supportability, maintainability, and durability. The lesson is that effective CAIV application demands a thorough understanding of both engineering as well as operational factors. When it was gradually recognized that a light commercial vessel could not be expected to serve satisfactorily as a warship, the ship designs grew in size and weight and so did the cost per ton. In summary, the Navy’s early efforts to trade performance and cost proved to be highly unrealistic and subsequently required major reversals.

LPD 17. This ship class was designed to replace several amphibious ship types. The design incorporated a sophisticated command and control suite, as well as a variety of features intended to increase efficiency and throughput, putting it on a plane of complexity close to that of surface combatants. The Navy made optimistic assumptions about factors driving costs, due apparently to budget-constrained costing. Then, both Navy and CAIG underestimated the complexity of the ship in initial cost estimates. Though not a CAIV program, there was a heavy emphasis on limiting cost growth. The ship incorporated novel systems and processes to reduce costs. However, the contractor selected had no experience building ships of this complexity, so these efforts actually resulted in added costs even though there was no significant requirements growth in the program. In fact, while early designs traded away defensive features to reduce costs, constraints regarding the fundamental mission and interfaces with other systems left no room for further major trades. It appears that a CAIV approach was seriously taken, at least early on. The problems were primarily in execution, with poor contractor performance being the biggest factor.

EFV. The Marine Corps' EFV was conceived to be an amphibious infantry fighting vehicle capable of operating at high speeds, both in the water and ashore. Performance requirements were entirely unprecedented and demanded major technological advances. Because the engineering issues were not well understood, initial cost estimates were faulty. In 2009, late in full-scale development, the vehicle was unable to complete OT&E because of severe reliability deficiencies. EFV was deleted from the FY2012 President's Budget request, with the announcement of a substitute Amphibious Combat Vehicle (ACV) to be more affordable and far less capable. While EFV was not a CAIV flagship program, in 1998 it won the Packard Award for acquisition excellence in, among other factors, CAIV execution. Early performance trades to meet technical feasibility left little to trade off later, once cost growth materialized. If the ACV program does go ahead with markedly reduced performance goals, it will be, in effect, a CAIV-like trade off of requirements to cut costs. Substantial money and time were wasted because realistic cost-constrained trade studies were not made prior to full-scale development. In other words, a CAIV approach was not really taken.

E. Lessons from CAIV History

CAIV was fundamentally a sound policy. Its potential was clearly demonstrated by its progenitor program, JDAM. Unfortunately, JDAM was the only success that can be reasonably attributed to CAIV. It was successful not only controlling but significantly reducing production costs and was one of the inspirations for the CAIV approach.[69] Compared to all the other programs examined, JDAM was notable for its simplicity—it was the ideal CAIV candidate. The other three non-flagship programs selected were known in advance to have had high cost growth—the objective of the analysis was to determine whether CAIV was, in fact, used and if so, why it failed, if possible.

JASSM, EELV, SBIRS, ATACMS-BAT, LCS, LPD 17, EFV, and F-35 (JSF) have all failed the test of CAIV in varying ways and degrees. As with DTC, it could be argued that, were it not for the use of CAIV, cost growth in these programs might have been even greater. The only program for which that case seems plausible is JASSM. Unlike its predecessor TSSAM, JASSM at least resulted in successful fielding of an important military capability at an affordable cost, if far above its CAIV target.

69 It was also an inspiration for the belief that aggressive action on the part of program managers could achieve substantial cost reductions, in line with the *should-cost* approach. Some of the early CAIV literature spoke of achieving a 25 percent reduction from "expected" costs—i.e., standard program cost estimates.

In one way or another, the poor results can all be traced in large measure not to any inherent defect in the CAIV concept but to the limitations in how it was applied. But to simply say that the deficiencies were all a matter of execution is misleading. While it is easy to read that as implying that better and more diligent execution by PMs would have brought the desired results, the above discussions largely belie that argument.

Indeed, one of the distinctive features of JDAM was not only that the initiating PM was especially experienced and capable but that he was in a position to exercise an unusual degree of control. JDAM's very simple and limited interface with other systems, straightforward requirements, and the customer's strong commitment to cost reduction gave him significant freedom for tradeoffs between cost and requirements, which he made full and resourceful use of. Moreover, the relatively uncomplicated and small-scale nature of the product and its production processes, combined with the absence of high urgency for delivery, allowed the program to largely avoid concurrency and the "marching army" problem that accompanies it.[70]

The authorities given the JDAM program manager could not to be counted on in very many programs. Indeed, in JASSM the same initiating PM, with much the same program team and applying many of the same techniques, encountered different situations involving lesser authority at the program level and, not only had no success in controlling costs, but produced a missile with unacceptable reliability.

One of the major problems of CAIV or other policies in acquisition is that they can encourage the illusion that the processes they foster and promote—such as competition, commercial practices, prototyping, IPTs, financial incentives, etc.—have potency in and of themselves. In fact, acquisition is like war or entrepreneurial business; too complex, varied, and mutable to yield to stereotyped or routinized processes. The processes associated with CAIV are tools that can help achieve powerful results if used appropriately and imaginatively. But they have no intrinsic merit and their incorporation in the program plans provides no inherent guarantee of any results, as the case studies reviewed clearly demonstrate.

The case studies emphasize the wisdom of the CAIV guidance: "The best time to reduce life-cycle costs is early in the acquisition process. Cost reductions shall be accomplished through cost/performance tradeoff analyses, which shall be conducted before an acquisition approach is finalized."[71]

The great majority of the problems seen can be traced largely or wholly to the failure to adequately heed this guidance. The problem was not simply unwillingness to give up

[70] "Once a program enters full-scale development, the commitment to design for production unleashes a marching army of interdependent engineers that needs to keep moving in a tight formation through the development process. Any serious design problems that surface late in the development process can stop this marching army in its tracks at great expense while the problem is addressed and resolved."—Kendall, Frank, "Perspectives on Developmental Test and Evaluation," *ITEA Journal 2013*; 34: 6–10, 7. The term is often used in this sense in referring to acquisition.

[71] DOD, DOD 5000.2-R (15 March 1996), 6, part 3.

performance and other requirements but lack of understanding and/or recognition of what the cost and other implications of the requirements truly were. It is not realistic to characterize that problem entirely as defects in cost estimation. The tools of cost estimators can work well for cost-requirements tradeoffs; but if the input to the cost calculation about weight, power, lines of code, or other crucial system sizing parameters, is seriously flawed then the resulting cost estimate is bound to be inaccurate and cost overruns virtually built-in.

The task of determining the actual system sizing needed to meet a given set of proposed requirements is one of early-phase systems engineering.[72] Studies of SBIRS, LCS, EFV, and JSF/F-35 have specifically noted the lack of early-phase systems engineering, and no references to it have been found with respect to any of the other systems researched here. Thus, it is reasonable to conclude that the lack of early-phase systems engineering was a major factor in inadequate initial cost-requirements tradeoffs which, in turn, were the principal contributor to cost "surprises" in these programs. To attempt to control costs without thorough, independent, and competent early-phase systems engineering is to make bricks without straw.

Why did these programs that employed CAIV fail to control costs? The simple answer is that in most cases the programs were started based on assumptions (i.e., "framing assumptions"), either explicit or implicit, that subsequently did not hold up. Except for two programs cancelled, the programs reviewed were deemed of such importance that they were restructured—some repeatedly—and continued under new (frequently implicit) framing assumptions.[73] Clearly affordability goals and caps established early in a program are only going to be relevant so long as the framing assumptions under which they were established continue to hold. Furthermore, it is inevitable for the assumptions to change, sometimes significantly. What is needed is a process that periodically re-examines the affordability of the entire investment program and makes the necessary adjustments needed so that all major acquisition programs stay on affordable tracks. Such a process was proposed in IDA Paper P-4961.

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72 According to Alexander Kossiakoff, a pioneer in the development of systems engineering techniques, "The function of systems engineering is to guide the engineering of complex systems." He goes on to say that systems engineering differs from other disciplines in that it is focused on the system as a whole, is concerned with customer needs and operational environment, leads system conceptual design, and bridges traditional engineering disciplines and gaps between specialties. See Alexander Kossiakoff and William N. Sweet, *Systems Engineering: Principles and Practice* (Hoboken, NJ: Wiley-Interscience, 2003). The same term is used to denote somewhat different functions in software engineering, and emphasis in other texts is often focused on planning- and management-oriented *later-phase* systems engineering.

73 Implementation of early systems engineering practices would also help clarify initial framing assumptions.

3. Affordability Constraints for Operating and Support (O&S) (Sustainment) Costs

Effectively applying affordability constraints for O&S costs to acquisition programs is complicated by difficulties in estimating and projecting O&S costs in a consistent and meaningful way. This chapter discusses some of those difficulties and examines O&S costs reported in SARs to gain additional insights into these issues. After surveying the background on DOD's experience with attempting to control O&S costs for acquisition programs, the chapter will give a brief overview of problems in estimating O&S costs. Then a sampling of O&S cost estimates from SARs will be examined along two dimensions: comparisons of new systems' O&S costs to antecedent systems and the trends over time in reported O&S costs. The latter data give some insights into the range of uncertainty in early O&S cost estimation.

As already noted, both DTC and CAIV included O&S costs within their scope under the rubric of life-cycle costs, with CAIV seeming to have given them more emphasis than DTC. However, the research team found little evidence that either initiative made serious attempts to actually control O&S costs. In fact, early DTC literature indicates that there was a prevailing view that controlling O&S costs was "too hard" because valid O&S cost models did not exist. The Defense Manufacturing Council working group report that launched CAIV was prescient regarding the difficulty of controlling of O&S costs in the development phase:

> Since O&S costs are not easily measurable in the early stages of the acquisition process, incentives to reduce O&S costs may require a (validated) model that relates specific design parameters to measurable and predictable O&S costs. Reliability and maintainability characteristics, which are more readily measured and projected, might serve as early indicators of progress towards meeting O&S cost objectives. In any event, DOD needs better cost models for the O&S phase of our programs. We face the challenge that CAIV may involve incentivizing savings and cost avoidances that will only be realized in the more distant future.[74]

Since those historical initiatives, the state of the art in O&S cost modeling has improved, though there is wide agreement that the level of fidelity that can be expected of O&S cost models for most defense systems is considerably below that for modeling production costs. This is important because the use of cost models is usually the only plausible way to estimate the future costs of a new defense weapon system. They are used to set initial cost estimates and inform the

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[74] See Defense Manufacturing Council Working Group Report at http://www.navair.navy.mil/nawctsd/Resources/Library/Acqguide/caivwgp.htm.

establishment and tracking of affordability goals and caps. (See discussion in Introduction and in Chapter 2, Section 2.A.1).

A. O&S Cost Estimation

Initial O&S cost estimates for an acquisition system are normally developed by the sponsoring Component's cost analysis center, working closely with the system's program office. For MDAPs, according to law, *independent cost estimates (ICE)* must be developed by CAPE at Milestone A and Milestone B. These estimates will either corroborate or supplant the Component cost estimate. Components are required to update their O&S cost estimates annually and report the results in SARs.

Operating and support costs for many already-fielded systems can be obtained from the DOD VAMOSC systems, which are required by Congress to be maintained by each Military Service.[75] For Air Force and Navy systems, VAMOSC is an extremely valuable source of actual O&S costs; Army and Marine Corps VAMOSC systems are less capable.

The *Operating and Support Cost Estimating Guide*,[76] published by the Office of the Director of CAPE (ODCAPE), is provided to DOD Components for use in preparing O&S cost estimates developed for acquisition planning. This guide breaks down the O&S costs according to a hierarchical structure (see Figure 3). The guide provides definitions of the cost elements, and breaks them down into even lower-levels where appropriate, and discusses techniques that can be used to develop the estimates. Making such detailed estimates for systems not yet fully developed, much less, fielded, can be problematic, and the earlier the system is in the process, the more problematic. Analogy to existing systems is one technique that might be employed for systems that exist only as concepts. VAMOSC data for the most similar existing system might be used as a starting point, with adjustments made for known and quantifiable differences such as crew size, or assumptions of reliability and/or maintainability improvements based on experience with other similar platforms. More subjective adjustments for complexity might also be made based on engineering expertise.

As the design matures, equipment parameters might be well enough defined to employ *cost estimating relationships* (CER)—in effect, a more systematic and rigorous application of the analogy approach. CERs are developed based on historical data that relate system parameters such as weight, payload, range, etc. to operating cost parameters, such as maintenance costs. Complexity factors such as number of moving piece parts or software lines of code might be related to reliability. Time could be a parameter to reflect improvements in manufacturing

75 Background on Navy VAMOSC is at https://www.vamosc.navy.mil/webpages/general/about.cfm?color=003366.

76 Office of the Secretary of Defense (OSD), *Operating and Support Cost-Estimating Guide* (Washington, DC: OSD, Cost Assessment and Program Evaluation, March 2014). Note that this guide is advisory; its use is not mandated by DOD regulations.

tolerances that translate into reliability and maintainability improvements. As the system matures, more parameters become available to use in the CERs, and greater fidelity can be obtained by applying CERs at the subsystem level. Ultimately, developmental and especially operational testing will provide actual O&S cost data to improve or supplant model estimates—a process that will continue through fielding.

Second-Level/Third-Level
O&S Cost Estimating Structure

1. **Unit-Level Manpower**
    - 1.1 Operations
    - 1.2 Unit-Level Maintenance
    - 1. 3 Other Unit-Level
2. **Unit Operations**
    - 2.1 Operating Material
    - 2.2 Support Services
    - 2.3 Temporary Duty
    - 2.4 Transportation
3. **Maintenance**
    - 3.1 Consumable Materials and Repair Parts
    - 3.2 Depot Level Reparables
    - 3.3 Intermediate Maintenance (External to Unit-Level)
    - 3.4 Depot Maintenance
    - 3.5 Other Maintenance
4. **Sustaining Support**
    - 4.1 System Specific Training
    - 4.2 Support Equipment Replacement and Repair
    - 4.3 Sustaining/Systems Engineering
    - 4.4 Program Management
    - 4.5 Information Systems
    - 4.6 Data and Technical Publications
    - 4.7 Simulator Operations and Repair
    - 4.8 Other Sustaining Support
5. **Continuing System Improvements**
    - 5.1 Hardware Modifications
    - 5.2 Software Maintenance
6. **Indirect Support**
    - 6.1 Installation Support
    - 6.2 Personnel Support
        - 6.2.1 Personnel Administration
        - 6.2.2 Personnel Benefits
        - 6.2.3 Medical Support
    - 6.3 General Training and Education
        - 6.3.1 Recruit & Initial Officer Training
        - 6.3.2 General Skill Training
        - 6.3.3 Professional Military Education

Figure 3. Cost Elements Used for O&S Cost Estimation

The key data source for the system technical and programmatic information in an independent cost estimate is the Cost Analysis Requirements Description (CARD),[77] which provides a description of the system detailed enough to develop cost estimates (acquisition and O&S). A CARD is required at Milestone A and Milestone B[78] and it is the basis of the ICE. The

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[77] See DOD, DOD 5000.4-M, *Department of Defense Cost Analysis Guidance and Procedures* (Washington, DC: DOD. December 1992).

[78] DODI 5000.02 specifies: "Recognizing that program details are refined over time, with fewer details available for MDAPs and MAIS programs approaching Milestone A than Milestone B, DCAPE will provide CARD development guidance tailored to the specific review being conducted and the type of system being developed" (page 127).

CARDs are updated as the system matures. Prior to 1992, when the CARD format and reporting time frames became mandatory, the CAPE[79] received information in a piecemeal fashion. In addition, the information itself was subject to frequent changes. This created the potential for giving less credence to the O&S ICE if it was based on data and assumptions that were no longer valid. Without a credible ICE, it was too difficult to manage O&S cost affordability, so little attention was paid to it.

The MDD is the formal entry point of an acquisition program into the DOD acquisition process. There is no formal requirement for an O&S cost estimate for the MDD itself. One is required immediately thereafter, however, to support the Analysis of Alternatives (AoA). The AoA is conducted during the Material Solution Analysis (MSA) phase between the MDD and Milestone A to compare the effectiveness and life-cycle costs of the alternatives being evaluated. Rough cost estimates, usually based on analogy with existing systems for which O&S costs are known, are developed for that purpose.

Early cost estimates are normally made by the sponsoring component cost analysis organization and are typically based on rough analogies or, if sufficient data are available, cost estimating relationships. When separate program offices are formed and have preliminary designs, they may develop their own cost estimates based on engineering, bottom-up, approaches. Those estimates will probably be more detailed and more current. At Milestone B or other decision points the program office's estimates should be consistent with the updated ICE. However, over time, as better data become available, there may be a divergence.[80] The program office estimates, however, may not reflect the official Service cost position.

B. O&S Cost Affordability

Uncertainty in O&S cost estimates means that assessing affordability for O&S costs is more challenging than for investment costs. In addition, there may not be as clearly defined a portfolio for O&S costs of a particular system as for investment costs. (This is particularly true of systems for ground forces.[81]) O&S costs depend on numerous operational and other exogenous parameters that are difficult, even impossible, to estimate with much certainty. These include the future operating tempo (OPTEMPO) for forces, training activities, manning levels, repair rates, overhaul rates, maintenance man-hours required, spares and fuel costs, to name a few. It is also difficult to apportion indirect O&S costs to specific systems when they reside in units with many other types of systems.

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79 Formerly the Cost Analysis Improvement Group (CAIG).

80 For example, late in 2013, the F-35 Program Manager stated that the program office O&S cost estimate for the total force F-35 cost ("C" model) was 20 percent less than the ICE developed at the latest Nunn-McCurdy breach.

81 Since ground units contain a mix of many kinds of equipment, it is more difficult to isolate the costs to man and support a particular piece of equipment than for systems such as aircraft and ships.

One approach to O&S affordability that bypasses some of those issues is to compare the estimated O&S costs of a new system to the system or systems that it will replace (if the actual costs are reliably known). This approach works if there are clearly defined legacy or antecedent systems. For such comparisons to be valid it is necessary, in so far as possible, to define consistent parameters for the systems being compared. The comparisons can be made either on a system-vs-system basis or "force" basis. (The latter approach is relevant, for example, if the number of new systems in a unit is different (usually lower) than for the antecedent systems. If the new system has higher O&S costs (especially for the unit-cost comparison), then it should be incumbent on the sponsoring Component to demonstrate at milestone reviews how the higher costs will be afforded. For example, affordability may be achieved by having fewer (but more capable) units in the force, deactivation of other units or activities no longer needed when the new system enters the force, or possibly lower operating rates.[82]

The best comparison for assessing O&S affordability is to compare the future cost to operate a *portfolio of forces*. The portfolio should be defined to include most, if not all,[83] the forces into which the new system at issue will be fielded. This may seem self-evident, but practical difficulties arise that tend to discourage development of such comparisons. It may be necessary to make assumptions about the future force structure and its peacetime deployment and employment that may not yet be fully determined. Manning levels and future training and operating rates cannot be known with any certainty, but must be estimated. Cost factors such as the cost of fuel, other commodities, and manpower are also uncertain. It also must be decided what proportion of indirect manpower and logistics costs to include. Sensitivity to assumptions and unknown parameters should be analyzed. Despite the difficulties, a forces-based cost comparison is the most rigorous way to assess O&S cost affordability.

C. Selected Acquisition Report (SAR) O&S Costs

Since 1985, the SARs have been required to have a section on O&S costs, and the required level of detail and fidelity has increased. In the past, little attention has been paid to the O&S costs in SARs compared to investment costs. That has changed with the increased emphasis on O&S cost affordability. The data presented in this section illustrate some of the problems and issues discussed in the previous sections. In particular, the difficulties in making consistent and reliable O&S cost estimates is amply illustrated. Furthermore the changes in estimates over time illustrate both the uncertainty and the maturation of estimates as programs transition from early to late development to fielding.

82 For example, if a personnel training for the new system will make greater use of simulators.

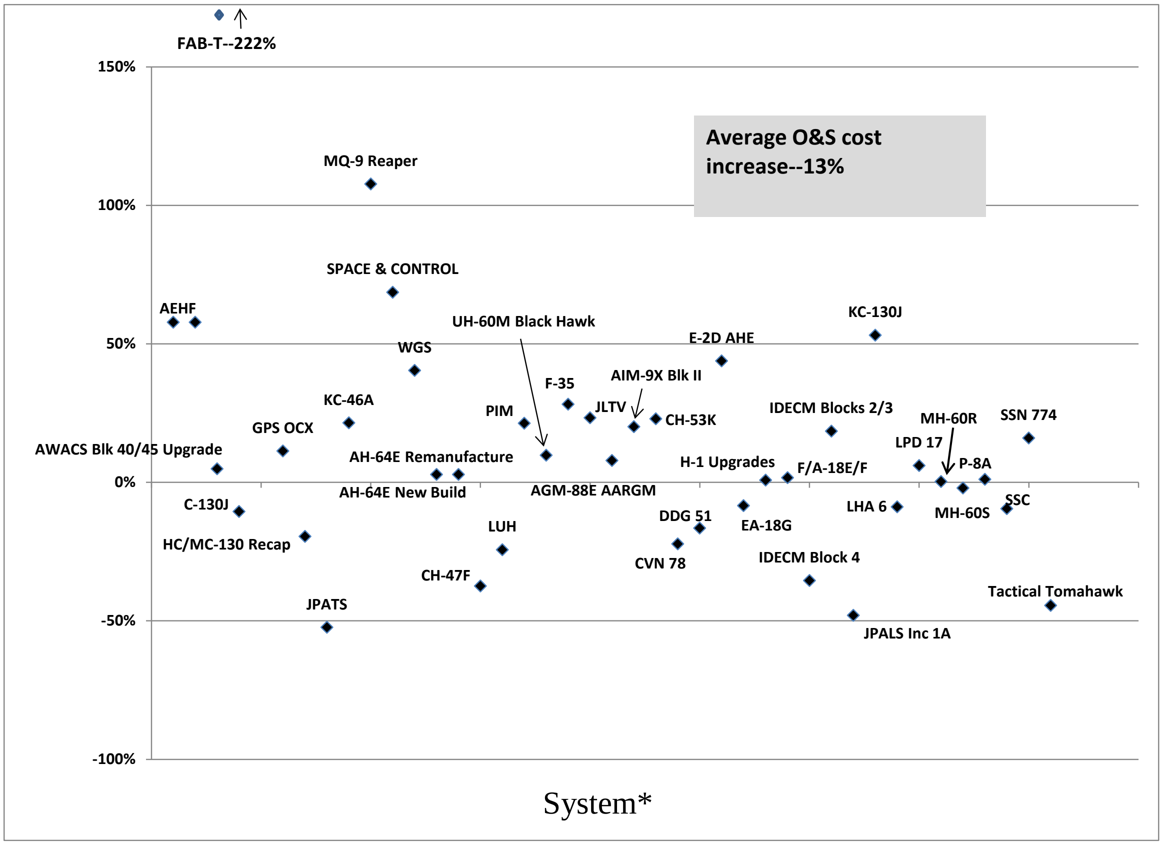
83 If the portfolio is defined too broadly, the change differences will appear less significant compared to the cost to operate the entire portfolio. In addition to the total cost, it will frequently be useful to display the cost comparison for a unit, such as a squadron or a brigade.

1. Comparisons to Antecedent Systems

A provision of the SAR that should be of particular interest for O&S cost affordability is the requirement (imposed by law) to compare the O&S costs of the new system to its antecedent, if one can be clearly identified. Both per-unit ("unitized") cost and total life-cycle O&S costs estimates are required. The research team obtained the results of a query of the SAR database that provided all O&S cost information including antecedent system costs, when available. It is apparent from that data that the Components have wide leeway in deciding whether to include a comparison to an antecedent system—only forty-two out of some eighty-three MDAPs provided data on an antecedent.[84]

Figure 4 is a comparison of unitized O&S costs for new systems versus antecedent systems for those forty-two systems. On average there is a 13 percent increase in O&S costs for new compared to legacy systems. It is interesting, however, that fourteen systems indicate lower O&S costs than their antecedents. These comparisons, if accurate, provide a valuable way to view O&S costs affordability. Increases in O&S costs over antecedent systems are a strong indicator of a potential O&S cost affordability problem in the future.

84 It appears to be strictly up to the Components to determine whether an appropriate antecedent exists. For example, the V-22 Osprey SAR states that there is no antecedent; however, these aircraft are replacing existing rotary wing aircraft, mostly CH-46 Sea Knights. There appears to be no reason why the aircraft being replaced are not suitable as an antecedent for comparison.



Note: The abscissa in this graph is a non-numeric axis used to spread out the ratio for each system to improve visibility.

Figure 4. Comparison of O&S Costs for New versus Antecedent Systems (Dec 2012 SARs)

The research team examined several of these comparisons in more detail to better understand why some new systems are projected to cost less than antecedents while many others cost more, some substantially more. One example examined was the Army's Lakota Light Utility Helicopter (LUH), which is a commercial helicopter adapted for Army use in supporting (non-combat) roles. It was found that the Army had used as the antecedent the UH-60L Black Hawk. While a few Lakotas (less than thirty)[85] will replace UH-60Ls serving in roles where their capabilities are not needed, the vast majority of the planned purchase of 315 Lakotas will replace OH-58s and UH-1s. Because the weight and engine horsepower of the Black Hawk is almost three times that of the Lakota, the OH-58A/C or the UH-1 would be a more appropriate antecedent for Lakotas.[86]

Figure 5 compares the O&S costs from the Dec-12 SARs for several systems—four with lower costs than the antecedent and four with higher. The unitized costs are provided by the categories of cost seen in the SARs. The last entry for each system is the "total force" O&S costs

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85 U.S. Army Homepage, April 2011, "Stateside Lakota deliveries let Black Hawks go to theater," http://www.army.mil/article/55394/.

86 The SAR does not provide a total (force) O&S cost for the antecedent. If it did, it would be appropriate to include the thirty UH-60L's being replaced in the antecedent force cost.

(it is not further decomposed in the SARs). While the SARs usually provide some explanatory information, it varies greatly over systems, and in most cases, it is not possible to fully understand the reasons for the differences from just the information in the SARs, i.e., the data invite in-depth analysis beyond the scope of this paper.

The following bullets discuss issues that emerge from the unitized cost comparisons in Figure 5.[87]

- Higher O&S costs examples:
  - KC-130J. The increases in maintenance costs and sustaining support of over 100 percent may be attributable to the following comment in the SAR: "both the KC-130F and KC-130R were Acquisition Category II programs that relied heavily on United States Air Force (USAF) program sustainment."[88] This comment suggests that not all sustainment costs for the antecedent systems are included. Also the 174 percent increase in continuing systems improvement begs explanation.
  - CH-53K. Since the new K model is significantly more capable than the antecedent—increased lift capacity, operational range, and more powerful engines—it is not surprising that support costs would increase. However, the amount of the increase could be questioned, including the increase in "sustaining support" of over 100 percent. Regarding affordability, there should be concern that the SAR's force cost estimate for the CH-53K is 23 percent higher than for the CH-53E, since it does not appear, based on that comparison, that the USMC plans to reduce the force size for an equivalent force capability.
  - JLTV. Substantial increases in maintenance and continuing systems improvements but none in either sustaining support or indirect support seems inconsistent. The SAR only notes that the antecedent estimates are "rough Order Magnitude …developed used *(sic)* JLTV cost model adjusted with system technical & cost data for High-Mobility Multipurpose Wheeled Vehicle (HMMWV) (M1151, M1152 & M1165). HMMWV data normalized for JLTV quantity, operating schedule, OPTEMPO & other Ground Rules and Assumptions."[89] It is not known how the Army and Marine Corps plan to pay for this significant increase in O&S costs for some 55,000 vehicles.
  - KC-46. The SAR notes a number of reasons to explain the differences in O&S costs vs. the antecedent KC-135 aircraft. The KC-135 costs are based on VAMOSC data

87 All quotes in the bullets below are from the notes to O&S Cost sections of the latest available SARs.

88 DOD, Selected Acquisition Report (SAR), RCS: DD-A&T(Q&A)823-433, "KC-130J Transport Aircraft (KC-130J)" (Washington, DC: DOD, December 2012), 35.

89 DOD, SAR RCS: DD-A&T(Q&A)823-279, "Joint Light Tactical Vehicle (JLTV)" (Washington, DC: DOD, December 2012), 49.

reflecting past costs—the USAF expects future costs to be higher as the fleet age increases. Nonetheless, unless a significant number of KC-135s will not be replaced, the issue of how to pay for a 21 percent increase in O&S costs for the tanker fleet must be addressed. (The SAR does not provide a total force O&S cost for the antecedent fleet—saying simply: "A comparable total O&S cost for the antecedent system, KC-135R&T, is not available"[90] with no explanation of why that is the case.)

- Lower O&S costs examples:
  – JPATS. The SAR provides no explanation for how the decreases in unit manpower and operations will be achieved. Maintenance costs for the new system are projected to be substantially higher, while sustaining support and indirect support are much lower. This is indicative of a difference in support concepts. More research would be required to understand whether this projected decrease in O&S costs is realistic. (Past experience suggests that projections of manpower reductions often are not fully achieved.[91])
  – C-130J. The 11 percent decrease in O&S costs compared to the antecedent is due entirely to lower unit manpower costs. The SAR offers no explanation.
  – CH-47F. The big decreases are in unit manpower, sustaining support, and indirect support. The latter two decrease much more than maintenance costs. The SAR notes that "The CH-47D and CH-47F costs are based on CH-47D actuals extracted from the Operating and Support Management Information System (OSMIS [the Army's VAMOSC]). To calculate the CH-47F costs, these CH-47D actuals were augmented by an improvement factor to account for the increased reliability of recapitalized parts, new airframe, and vibration engineering."[92] No explanation is offered for the decrease in unit manpower, nor why sustaining support and indirect costs decrease so much more than maintenance.[93]
  – EA-18G. The significant increase in unit operations costs is more than offset by decreases in maintenance, sustaining support, and continuing system improvements. While the SAR offers 1½ pages of notes, how these savings in support costs will be

[90] DOD, SAR RCS: DD-A&T(Q&A)823-387, "KC-46A Tanker Modernization (KC-46A)" (Washington, DC: DOD, December 2012), 46.

[91] As an illustration, the Dec-01 F-22 SARs indicate a 41 percent reduction in manpower costs compared to the F-15C but the Dec-10 SAR indicates 27 percent higher manpower costs for the F-22.

[92] DOD, SAR RCS: DD-A&T(Q&A)823-278 "CH-47F Improved Cargo Helicopter (CH-47F)" (Washington, DC: DOD, December 2012), 34.

[93] A research team member discussed reliability improvements in the CH-47F model over the –D model with members of the CH-47 program office, and was informed that the improved reliability was attributable to the fact that the –F models are newer and not to any explicit efforts to improve reliability.

achieved is not explained. The Navy does not intend to replace all its EA-6Bs with EA-18Gs.

Higher O&S Costs

Budget Year 2010	***KC-130J***	KC-130 F/R/T (Antecedent)	*Percent Change*
Average Annual Cost per Aircraft			
Unit-Level Manpower	2283.314	2283.314	0%
Unit Operations	1678.787	1360.657	23%
Maintenance	4227.593	1878.000	125%
Sustaining Support	341.235	131.000	160%
Continuing System Improvements	868.347	317.000	174%
Indirect Support	488.769	488.769	0%
Other	0.000	0.000	
Total	9888.045	6458.740	53%
Force Total	39987.3	26119.1	53%

Budget Year 2006	***CH-53K***	CH-53E (Antecedent)	*Percent Change*
Average Annual Cost per Helicopter			
Unit-Level Manpower	1165.200	1239.700	-6%
Unit Operations	360.300	308.800	17%
Maintenance	4789.800	3247.400	47%
Sustaining Support	221.700	106.400	108%
Continuing System Improvements	552.000	703.600	-22%
Indirect Support	498.200	564.400	-12%
Other	0.000	0.000	
Total	7587.200	6170.300	23%
Force Total	37496.2	30494.1	23%

Budget Year 2012	***JLTV***	HMMWV (Antecedent)	*Percent Change*
Average Annual Cost per Vehicle			
Unit-Level Manpower	8.700	8.700	0%
Unit Operations	5.300	5.800	-9%
Maintenance	12.200	7.100	72%
Sustaining Support	1.200	1.200	0%
Continuing System Improvements	1.700	0.800	113%
Indirect Support	0.000	0.000	
Other	0.000	0.000	
Total	29.100	23.600	23%
Force Total	31708.4	25800.9	23%

Budget Year 2011	***KC-46A***	KC-135R&T (Antecedent)	*Percent Change*
Average Annual Cost per Aircraft			
Unit-Level Manpower	4.400	3.200	38%
Unit Operations	4.000	4.100	-2%
Maintenance	3.200	3.100	3%
Sustaining Support	0.500	0.200	150%
Continuing System Improvements	0.900	0.100	800%
Indirect Support	0.000	0.000	
Other	0.000	0.000	
Total	13.000	10.700	21%
Force Total	103090.5	"NA"	

Lower O&S Costs

Budget Year 2002	***JPATS***	T-37 (AF Only) (Antecedent)	*Percent Change*
Average Annual Per Aircraft			
Unit Level Manpower	0.180	0.260	-31%
Unit Operations	0.052	0.310	-83%
Maintenance	0.095	0.020	375%
Sustaining Support	0.062	0.110	-44%
Cointuing System Improvements	0.000	0.000	
Indirect Support	0.040	0.200	-80%
Other	0.000	0.000	
Total	0.429	0.900	-52%
Force Total	11697.8	"NA"	

Budget Year 1996 $1000	***C-130J***	*C-130H1 & H2 (Antecedent)*	*Percent Change*
Avg Annual Cost per Aircraft			
Unit-Level Manpower	1754.200	2314.900	-24%
Unit Operations	613.700	490.900	25%
Maintenance	1280.400	1309.700	-2%
Sustaining Support	39.300	39.300	0%
Continuing System Improvements	44.300	44.300	0%
Indirect Support	234.300	234.300	0%
Other	0.000	0.000	
Total	3966.200	4433.400	-11%
Force Total	19989.6	22344.5	-11%

Budget Year 2005	***CH-47F***	CH-47D (Antecedent)	*Percent Change*
Average Annual per Aircraft			
Unit Level Manpower	409.484	658.828	-38%
Unit Operations	70.107	76.408	-8%
Maintenance	1200.573	1208.797	-1%
Sustaining Support	16.944	470.291	-96%
Continuing System Improvements	127.061	11.359	1019%
Indirect Support	101.131	652.265	-84%
Other	0.000	0.000	
Total	1925.300	3077.948	-37%
Force Total	16942.6	18837	-10%

Budget Year 2004	***EA-18G***	"Antecedent" EA-6B (Antecedent)	*Percent Change*
Average Annual Cost per Aircraft			
Unit Level Manpower	2.435	2.228	9%
Unit Operations	0.780	0.550	42%
Maintenance	2.935	3.313	-11%
Sustaining Support	0.183	0.363	-50%
Continuing System Improvements	0.941	1.603	-41%
Indirect Support	0.518	0.448	16%
Other	0.000	0.000	
Total	7.792	8.505	-8%
Force Total	16284.0	17797	-9%

Figure 5. Comparisons of Unitized and Force O&S Cost Estimates for Selected Systems ($1,000)

For assessing O&S affordability, the most desirable comparison is between the force with the new system and the force without the new system. Unfortunately, that comparison is more difficult since more assumptions are required. For a number of SARs reviewed (not just those in the table), it does not appear that the "Total O&S Cost" table provides a comparison valid for that purpose. For example, for the CVN 78 nuclear carrier, the Navy seems to compare a single CVN 78 to the entire force of the antecedent (identified as the CVN 68). In the MQ-9 Reaper SAR, the total cost for the 404 MQ-9s being procured is compared to the much smaller force of MQ-1 Predators, thus showing an increase in O&S costs of $32 billion ($37.9 billion versus $5.7 billion) over the antecedent (whereas the cost per flying hour of the Reaper is only about 6 percent higher than the Predator). That comparison raises the issue of how the larger force will be afforded, but that is more of a force size issue than an acquisition issue.

Another example is the DDG 51: The antecedent identified in the SAR is the CG 47 cruiser, and the DDG 51 is shown to have 16 percent *lower* unitized costs. However, the total force cost comparison shows a $58 billion *higher* cost (or 158 percent) for the DDG 51 force! The notes state that this is for a force of seventy-seven DDG 51s, but the number of the ships for the antecedent system is not provided. A valid assessment of force O&S cost affordability would require a resolution of the types of problems discussed in this paragraph. This and similar problems illustrate issues discussed at the end of the previous section.

2. Trends in O&S Costs Reflected in SARs

SAR data viewed over time provide insights into the changes in O&S cost estimates as programs mature—generally, like investment costs, they show increases, sometimes dramatic. Figure 6 shows O&S cost estimate trends for several high-interest programs, displaying both the new system and the antecedent system.

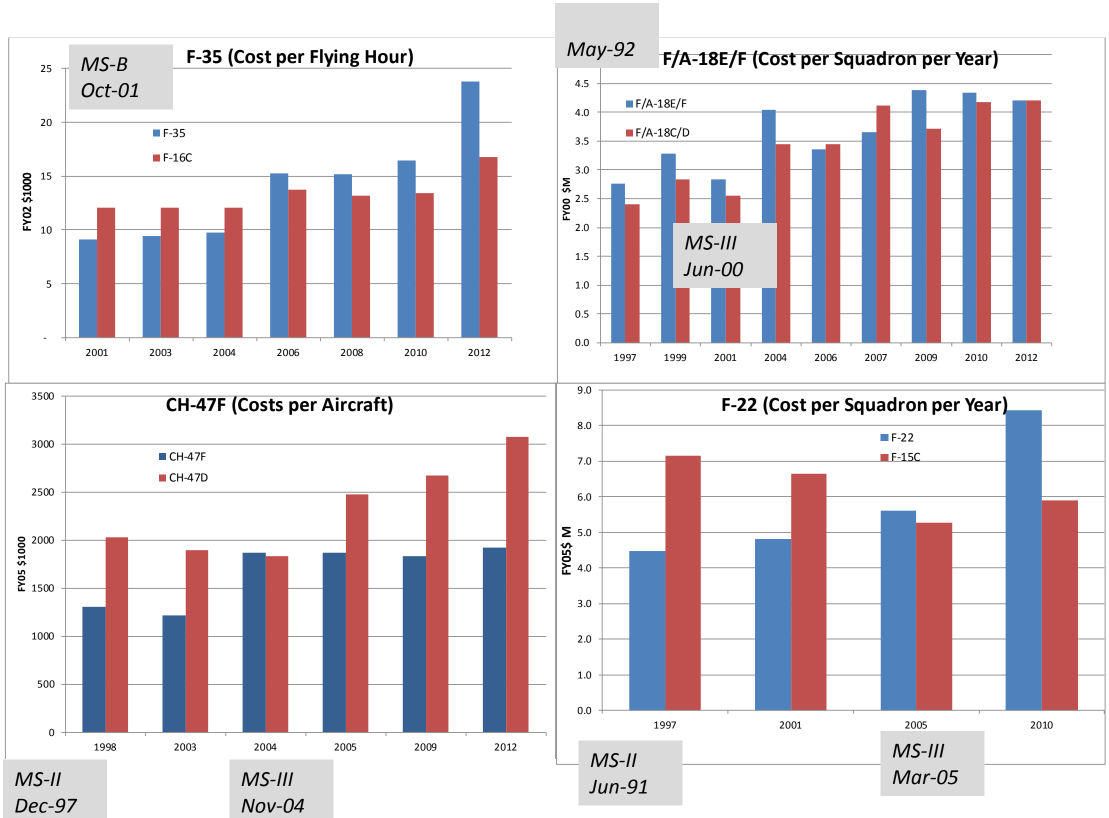

Figure 6. Trends in SAR Unitized O&S Costs for Selected Systems (Dec. SARs)

While explanatory information in the SARs is generally too sparse to understand fully what drove these changes, the research team extracted available insights to produce the notes below. The increases in O&S costs of the antecedent systems presumably reflect increases in actual costs for deployed systems.

- **F-35 (CTOL)**.[94] There was a 57 percent increase for F-35 and 14 percent for the antecedent F-16C in unitized O&S costs from the Dec-05[95] to Dec-06 SARs. The largest increase for the F-35 was in "sustaining support," whereas for the F-16C the largest increase was in depot maintenance. No explanation for these changes is offered in the Dec-06 SAR. The large increases in F-35C costs in 2012[96] reflect a new independent cost estimate by CAPE associated with a Nunn-McCurdy breach. There is also a 67 percent increase in the F-16C figure in the Dec-11 SAR and another 11 percent increase in the Dec-12 SAR; neither was explained.

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94 Estimates are for the CTOL variant; the SAR provides no estimates for other variants.

95 The Dec-05 SAR O&S costs are identical to the Dec-04 SAR costs shown in the graph.

96 The increase was actually first seen in the Dec-11 SAR; the Dec-12 SAR figures were the same as the Dec-11 for the F-35, but the F-16C figure increased by 11 percent.

- **CH-47F**. The research team was unable to understand the SAR CH-47F and CH-47D O&S costs based on information in the SARs. The CH-47Ds have been in service since the 1980s (the last procurement was in 2002), and the F models have been in service since 2002, so presumably a lot of data on operating costs should be available from OSMIS. Instead of using OSMIS data for the CH-47F, the Army bases the O&S costs in the SARs on scaling from the CH-47D values (said to be from OSMIS):

> To calculate the CH-47F costs, these CH-47D actuals were augmented by an improvement factor to account for the increased reliability of recapitalized parts, a new airframe, and vibration engineering.[97]

OSMIS data on the two systems was obtained by the research team and, while they could not be tracked to the data in the SAR, they do indicate lower operating costs for the F-model for the few items with comparable data, but not the 37 percent lower figure seen in the SAR.[98] Why the Army does not use actual data from CH-47F operations for the SAR estimate is not known.

- **F-22**. The Dec-97 (earliest available in Defense Acquisition Management Information Retrieval System (DAMIR) through the Dec-01 SARs, state that the antecedent F-15C O&S costs are based on VAMOSC, whereas the F-22 costs are based on "… a combination of AFI 65-503 Cost and Planning Factors and information provided in the contractor's Affordability Analysis."[99] There is no statement regarding comparability of the two systems.[100] The Dec-02 SAR, however, stated:

> In December 2000, the Air Force Cost Analysis Improvement Group (AFCAIG) worked with the F/A-22 System Program Office and the F-15 System Program Office to develop updated estimates of both the F/A-22 and F-15C to provide an equitable comparison of ownership costs.[101]

Despite this apparent change there was *absolutely no change* in the unitized O&S costs between the Dec-01 and Dec-02 SARs. In Dec-05 however, the O&S costs for the F-22 increased by 41 percent over the previous year, whereas the F-15C costs decreased by 4 percent. There is no explanation other than changing the date of the referenced AFCIAG study from 2000 to 2004. By then ninety F-22s had been delivered so perhaps the increase reflects actual costs (though this was not stated in the SAR).

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[97] Dec-12 SAR, 33.

[98] The data are not displayed because all VAMOSC data is labeled For Official Use Only.

[99] DOD, SAR RCS: DD-A&T(Q&A)823-265, "F-22 Raptor Advanced Tactical Fighter Aircraft (F-22)" (Washington, DC, DOD: December 2001), 42.

[100] Certainly one would think that the dramatically lower O&S costs for the much more advanced, stealthy F-22 compared to the F-15C would have raised questions.

[101] DOD, SAR RCS: DD-A&T(Q&A)823-265F-22, "Raptor Advanced Tactical Fighter Aircraft (F-22)" (Washington, DC: DOD, December 2002), 48.

- **F/A-18E/F**. In the Dec-04 SAR, the F/A-18E/F O&S costs increased 43 percent over the previous year while the antecedent F/A-18C/D increased 35 percent, partially explained by a change in the assumed price of fuel. In the Dec-06 SAR, F/A-18E/F costs decreased by 17 percent over the previous year, with no change for the antecedent. Neither are there any explanations for the changes from the Dec-07 to Dec-09 SAR,[102] or to the Dec-10 SAR.

The research team obtained an extract of O&S cost data for all SAR programs from the DAMIR database with the intention of computing statistics on O&S cost growth for the entire set of MDAPs. Unfortunately extensive inconsistencies in the data made that objective unachievable within the available resources. However, four additional programs examined provide some points of interest (Figure 7). In these cases, no comparison was made with antecedent programs (for three of the four no antecedents were named in the SARs), but the trends in the O&S cost estimates were developed (and compared to the trends in unit procurement costs). Two characteristics are observed: (1) O&S costs tend to increase, sometimes significantly, from the Milestone II/Milestone B to the Milestone III/Milestone C estimates; (2) trends in SAR O&S cost estimates do not appear to correlate strongly to procurement unit cost trends, as might be expected. (Obviously the sample size is far too small for statistical analysis.) Another tentative finding is that, in many if not most cases, SAR O&S costs in the past do not appear to have been updated on an annual basis, between the decision to enter full-scale development and the decision for full-scale production. These indications have implications for O&S affordability goals and caps. To be enforceable these controls must be based on realistic estimates (else the decision to proceed with the program based on its affordability will be faulty) and O&S costs over time must be re-examined at least annually to prevent a big “surprise” increase in O&S costs at the decision point to enter production and eventually field the system.

[102] There were no Dec-08 SARs.

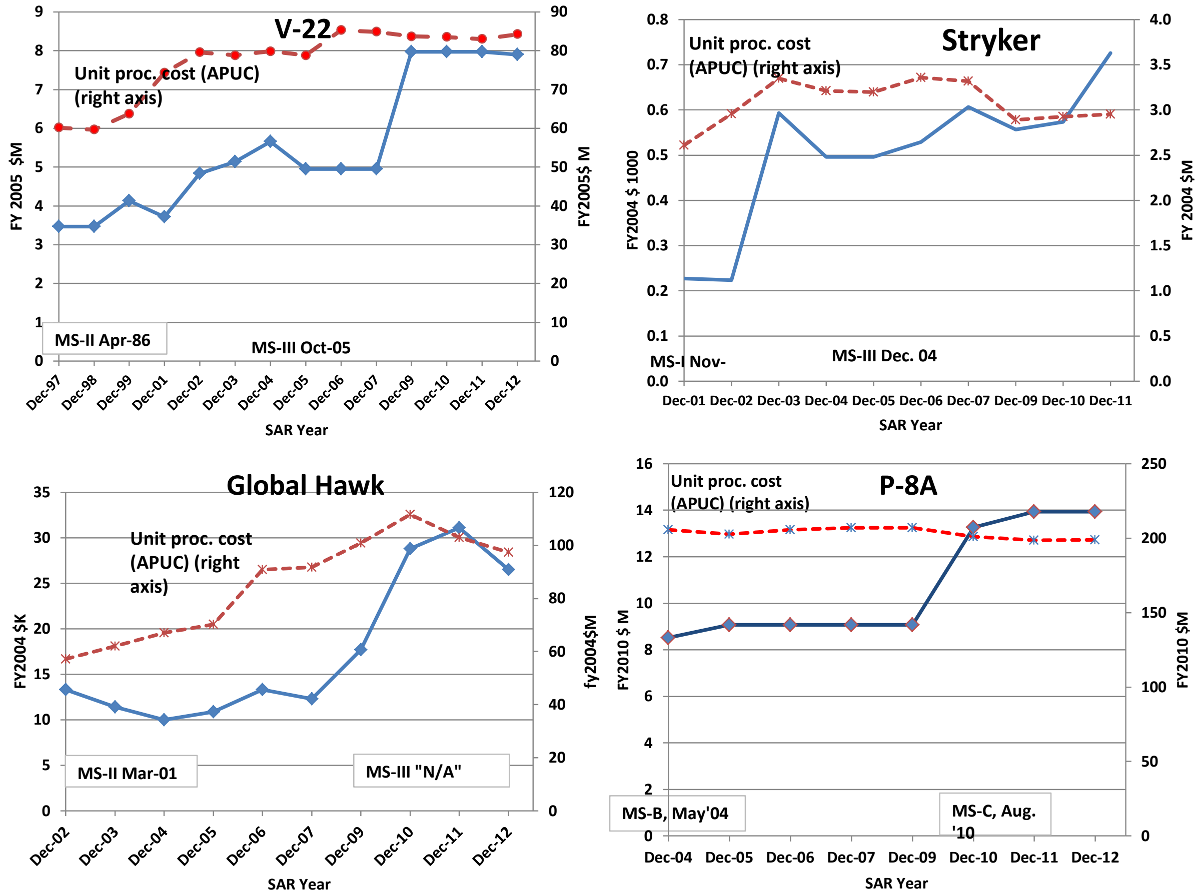

Figure 7. Trends in SAR O&S Costs (Blue Line) Compared with Procurement Costs (Red Line) for Selected MDAPs

4. Controlling O&S Costs within Affordability Constraints

This chapter will discuss approaches to managing programs so that O&S affordability constraints are not exceeded. Topics include the need to make systematic (and possibly periodic) tradeoffs between cost (investment and O&S) and other program characteristics such as technical and operational performance, timing, procurement quantities, and schedule; and controlling O&S costs through the simpler approach of controlling O&S cost drivers. The potential benefits of a standard O&S cost model implemented early and updated often are outlined. Lastly it also discusses ways to better motivate both DOD and industry to manage programs that remain within O&S cost goals and how processes to achieve that end can be better institutionalized.

A. Monitoring Goals and Caps

Effectively monitoring affordability goals and caps is necessary if program affordability is going to be achieved. The intent of BBP 2.0 and the newly published DODI 5000.02 is to use goals and caps to ensure that programs continue to be affordable as they progress through the acquisition process. Expectations are, therefore, that at Milestone A and Milestone B, DOD Components will either (1) have cost estimates that are within the associated goal or cap or (2) be able to provide convincing rationale why the program will be able to lower the costs to meet the goal or cap. This latter situation is more likely to occur at Milestone A than Milestone B for O&S costs since many important decisions driving future cost will be made during the TMRR phase.

In most cases, cost-schedule-performance trade studies only address investment costs. While designers may consider how a design decision will affect investment cost, they may not have effective tools for making such tradeoffs because many O&S cost implications of design decisions may not always be well understood. Since reliability and/or maintainability are normally addressed in either KPPs or Key System Attributes (KSA), reliability and maintainability engineers would normally work closely with designers to facilitate design trades. However, serious tradeoffs are not likely to happen unless meeting an O&S cost target has been defined as a firm constraint. Based on the research team's discussions with several industry subject matter experts,[103] staffing priority may not be given to including reliability and maintainability engineers early enough to inform trade studies unless the contract specifically

[103] These discussions were agreed to strictly on a non-attribution basis.

requires them. In practice it is much more common to make trades to solve technical problems and/or reduce acquisition cost that, in fact, increase O&S cost.

In addition, despite the improvement in O&S cost estimation methodologies since the time of DTC and CAIV, there is wide agreement that the level of fidelity that can be expected for O&S cost models for most defense systems is still below that for modeling production costs. When cost estimates are based on analogy,[104] weaknesses in VAMOSC data and known differences between the new and antecedent systems may lead to biases that are difficult to mitigate. The fidelity of early O&S cost estimates is not sufficient to produce high confidence that the actual O&S costs of the system when fielded will be below the cap. Force structure and operating rates different from those assumed for the estimates would not be unusual. Furthermore, post-Milestone B O&S cost estimates have not always been updated regularly in the SARs.[105]

Experience has shown that O&S costs for fielded systems (even when adjusted for external factors such as OPTEMPO rates and cost of fuel) often turn out to be higher than estimated during development.[106] Reliability and maintainability will be better understood after operational testing and initial fielding. Manning and product support strategies will be finalized. OPTEMPO will be better defined. Unfortunately, most of these data only become available after it is too late (or too costly) to make design changes in the basic system.

O&S cost models are in general use in both DOD and industry; however, there is no requirement in DODI 5000.02 to establish and use such a model to help manage O&S costs for a system under development. To do so within a standard modeling framework could greatly facilitate tracking and managing O&S costs. Initially, such a model could be developed from CAPE's independent cost estimate for the Milestone A decision. The model framework could be agreed upon by all stakeholders and its use required of the TMRR contractors. The model would be continuously refined and updated, as designs mature approaching Milestone B, characteristics become better defined, and engineering-based O&S cost estimates developed. The process would continue post-Milestone B, and eventually when preliminary test results become available to validate the model.

Between Milestones A and B, monitoring evolving O&S costs vis-à-vis the affordability goal may be more problematic. Up to the point of the pre-Milestone B Preliminary Design Review, information on O&S costs will most likely reside with the contractor, and there is currently no requirement to report such data. The existence of a standard agreed-to O&S cost

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[104] For example, early in the conceptual stage before more detailed cost estimating relationships are developed.

[105] See GAO, *DOD Needs Better Information and Guidance to More Effectively Manage and Reduce Operating and Support Costs of Major Weapon Systems*, GAO-10-717 (Washington, DC: GAO, July 2010).

[106] Evidence is provided by the SAR data displayed in Chapter 3, which shows increases in O&S costs estimates after system fielding.

modeling framework, however, should facilitate tracking and support tradeoff analyses that address O&S costs.

Post-Milestone B, the current plan is to monitor affordability caps after Milestone B within the DAES process. The following bullets points describe the value of such improved monitoring activities.

- The modeling framework described above would be particularly valuable because the assumptions behind all O&S cost estimates beginning with Milestone A would, of necessity, be fully documented and agreed to.
- Annual updates of O&S costs in SARs should be the norm, and would flow readily from the O&S cost model, if it exists.

An ancillary point is that, in order to assess O&S cost affordability within a portfolio framework as required by DODI 5000.02, O&S costs for all systems in the portfolio would have to be estimated consistently.

B. O&S Cost Tradeoffs

After approval at MDD, a new acquisition program (and presumed future MDAP, or "pre-MDAP") enters the Material Solutions Analysis phase of the acquisition process. During this phase, the AoA will be conducted, including initial trade studies between cost, schedule, and performance—in fact, virtually all aspects of the program should be subject to tradeoffs. DODI 5000.02 has the following guidance:

> The analysis will … focus on identification and analysis of alternatives; measures of effectiveness; key trades between cost and capability; total life cycle cost, including sustainment; schedule; concepts of operations; and overall risk. The AoA will inform and be informed by affordability analysis, cost analysis, sustainment considerations, early systems engineering analyses, threat projections, and market research.[107]

This guidance is quite clear and specific that O&S costs should be included in the studies. However, the Instruction does not specify that a Department level oversight body be established to oversee the AoA and related trade studies. There is only a requirement that DCAPE assess the AoA after its completion in a memorandum to the DAE, including whether it adequately "Considers tradeoffs among cost, schedule, sustainment, and required capabilities."[108] Assuming that DCAPE scores the AoA as adequate in that regard, it can be assumed that at Milestone A the systems, if developed successfully as planned, will be affordable from both an investment and O&S costs perspectives.

[107] DODI 5000.02,16.

[108] Ibid., 123.

In the next phase (TMRR), the design concept will be translated into actual hardware—usually in a competitive development program. At this point, the major responsibility for ensuring that the materiel solutions remain within affordability goals will lie with the contractors. There is no responsibility for the contractors to work with or report to the government on whatever tradeoffs they find it necessary to make, though it might be hoped that PMs will be informed of such decisions informally. (The considerations that will likely guide such contractor studies will be addressed in the next section of this paper.)

At the completion of the TMRR contracts, a request for proposals (RFP) for the EMD phase will be issued. A critical decision point for the DAB is the approval of that RFP. The DODI 5000.02 identifies this decision as the "Development RFP Release Decision Point:"

> This review is the critical decision point in an acquisition program. The program will either successfully lead to a fielded capability or fail, based on the soundness of the capability requirements, the affordability of the program, and the executability of the acquisition strategy. The acquisition strategy is put into execution at this decision point by asking industry for bids that comply with the strategy. Release of the RFP for EMD sets in motion all that will follow. This is the last point at which significant changes can be made without a major disruption.[109]

Thus the designs selected for full-scale development must have the credible potential to provide the necessary capabilities within affordable life-cycle costs. Since the most likely responders to the RFP are the TMRR contractors, their responses will be based largely on the designs already developed in that phase. If the TMRR contractors have adequately considered life-cycle affordability constraints in their trade studies, they will be able to offer designs for EMD that will be affordable. In turn that will have happened if the TMRR RFP and contract under which that development proceeded appropriately stressed life-cycle affordability.

Prior to Milestone B, the Joint Staff will validate the Component's Capability Development Document (CDD), which refines the specification of the requirements for the system for the EMD phase. At that point, a Configuration Steering Board (CSB) is constituted by the sponsoring Component's Acquisition Executive with members from all the key stakeholders, including OSD and Joint Staff.[110] This body, which is required by law,[111] is charged to "review potential capability requirements changes and propose to the requirements validation authority those changes that may be necessary to achieve affordability constraints on production and

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109 Ibid., 21–22.

110 DODI 5000.02 states that "the Acquisition Executive of each DoD Component will form and chair a CSB with broad executive membership including senior representatives from the Office of the USD(AT&L) (including the Assistant Secretary of Defense for Acquisition), the Joint Staff (DJ8), and the DoD CIO; empowered representatives from the Service Chief of Staff and comptroller offices of the Military Department concerned; representatives from other Military Departments where appropriate; the Military Deputy to the CAE; the PEO; and other senior representatives from OSD and the DoD Component." DODI 5000.02, 21.

111 This requirement is found in Section 814 of Public Law (P.L.) 110–417.

sustainment costs or that will result in a more cost-effective product."[112] According to a diagram in DODI 5000.02, CDD validation will occur just prior to the decision point approving the EMD RFP.[113] Thus key cost-performance trades made before EMD RFP release could be made under the auspices of the CSB; however, it is not clear that there will be adequate time for such a complex activity, including coordination with the relevant stakeholders, to take place in time to affect the RFP. An alternative would be to constitute the CSB earlier than currently required by law and regulation—at least by Milestone A and possibly sooner.

If the process is operating as designed, at the start of EMD the design or designs will be compatible with the affordability cap. However, it is not at all unusual for difficulties to occur soon after Milestone B that will require additional cost-schedule-performance tradeoffs. The CSB is the body responsible for overseeing trade studies.

O&S costs should figure prominently in these trade studies; however, as a practical matter O&S costs will usually be uncertain prior to Milestone B and even well thereafter. That likelihood argues for a management focus on the *drivers* of O&S costs, which are subject to control throughout the development process. The next section focuses on that approach.

C. Managing O&S Cost Drivers

IDA has performed analyses of actual annual O&S costs for Air Force and Navy fighters from 1997 to 2013 for other research efforts. It was found that unit-level manpower, unit operations (primarily fuel consumption), and maintenance (which depend on system reliability and maintainability) account for ~88 percent of the system's O&S costs. These figures break out as follows:

Table 4. Fraction of O&S Costs Determined by Unit Manning, Unit Operating, and Maintenance Costs

	Air Force	Navy
Unit-level manpower	29%	22%
Unit operations	27%	28%
Maintenance	32%	38%
Total Above	88%	88%

From that analysis it appears that, for aircraft, the drivers for O&S cost are manpower, fuel, and maintenance costs. While in many cases these costs are direct consequences of system requirements, the acquisition system does have some ability to control them. Working with both the industry team and the requirements community, the program office can control reliability, maintainability, and fuel consumption rates to some extent. Similarly, the program office can

112 DODI 5000.02, 21.

113 DODI 5000.02. 9, Figure 3.

ensure that the product support strategy is enabled by industry design teams. However, key external factors including operational manning, fuel cost, inflation rate assumptions, and operating tempo are not determined by the supportability of the system and are outside the control of the acquisition process.

A starting point for managing cost drivers is managing the framing assumptions behind the program. For O&S cost estimation, framing assumptions will normally relate strongly to the O&S cost drivers. For example, if a framing assumption that there will only be two levels of maintenance (organizational and depot) for a system were to change to also include intermediate-level maintenance, then there might be significant changes to the cost estimate.

Reliability and maintainability (R&M) have long been recognized as important drivers of O&S costs. Despite that recognition, in the zeal for acquisition reform in the past, specific R&M objectives were sometimes not included in system KPP or KSAs for MDAPs. Serious reliability issues in programs such as JASSM and SBIRS (discussed in Appendix A) resulted in a re-evaluation of that policy and the subsequent inclusion of more stringent "sustainment KPPs" for acquisition programs. Even though the interim DODI 5000.02 provides significant guidance on how R&M is to be managed in the acquisition process, a requirement to include R&M in one or more KPPs or KSAs, though implied, is not stated explicitly.[114] The Instruction requires a "Reliability, Availability, Maintainability, and Cost Rationale (RAM-C) Report in support of the Milestone A decision to provide "a quantitative basis for reliability requirements, and improves cost estimates and program planning."[115] The report is updated prior to the pre-Milestone B development RFP release decision point and is an attachment to the program's Systems Engineering Plan.

Thus, managing the O&S cost drivers themselves may be the most feasible approach to controlling O&S costs. Even though it may not be possible to precisely estimate the O&S cost associated with particular cost drivers, efforts to attack those drivers will likely have a high payoff in reducing O&S costs. As an example, previous IDA research considered the C-17 airlift aircraft, and determined that seven cost drivers collectively determined roughly 75 percent of the system O&S costs.[116] In general, insights can be derived from experiences with legacy systems. Reliability can be increased, improved built-in tests can be implemented, and improved access to components for maintenance can be enhanced.

Based on all of these observations, it can be concluded that

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114 DODI 5000.02 references the "Manual for the Operation of the Joint Capabilities Integration and Development System;" however, that document is advisory and is not published under the signature of an authority. The Joint Staff Instruction CJCS 3170.01H, "JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM," is signed by the Director of the Joint Staff but it does not discuss R&M requirements (but does reference the Manual).

115 DODI 5000.02, 83–84.

116 Harold S. Balaban, Waynard C. Devers, and Lance M. Roark, *Feasibility and Advisability of Baselines for O&S Costs: C-17 Case Study*, IDA Document NS D-4088 (Alexandria, VA: IDA, August 2010).

- Although quantitative impacts of managing controllable O&S cost drivers will be uncertain, activities to manage them will likely have a high payoff.
- Identification and monitoring of O&S-specific framing assumptions will facilitate managing O&S cost drivers.
- A standard O&S cost model established at or before Milestone A, as discussed above, should greatly facilitate tracking progress in controlling O&S costs.

These steps would decrease the risk that O&S costs will exceed goals or caps.

D. Incentives to Reduce O&S Costs

Despite the potential benefits of managing O&S cost drivers, the research team has found no evidence that PMs have been incentivized in this area in the past, The acquisition process tends toward optimism. Requirements are frequently established without a full understanding of the technical and cost implications. Contractors are confident about their technical capabilities and tend to be optimistic about what they can accomplish. Acquisition PMs are success oriented, reinforced by the contractor's optimism. These tendencies translate into programs faced with areas of high risk because integrating advanced technology into operational capabilities is often harder than anticipated.

When such risks materialize, the PM is motivated to solve the problem. Requesting that a requirement be relaxed is likely going to be the last resort, since it may be considered a failure. Most likely, the problem must be addressed by the contractor design teams and engineers. In fact, the contractor will normally learn about a technical problem before the program office. The contractor makes a profit by selling products, and the best way to do so is to deliver what the customer wants. Therefore, if design trades are needed to solve the problem, the contractor will make the trades based on its perception of customer priorities. The relatively short tenure of acquisition PMs means they will probably not be involved when high O&S costs are incurred. Unless the government makes O&S costs an explicit priority, it is relatively easy for industry to largely ignore O&S costs when making tradeoffs associated with inevitable near-term technical issues. In most cases, performance, acquisition cost, and schedule are the highest PM priorities, and the case for "fixing O&S later" is easily rationalized. The government processes, as described above, if implemented effectively, should serve to counter these tendencies.

Reducing O&S costs early in design will likely involve extra cost and time. For example, improving system reliability may require improving the reliability of multiple components in the system. Lowering O&S costs early may also decrease performance, for example, if it is necessary to add weight. During sub-component selection, the contractor will normally make decisions based on its perception of the program's priorities. Consider a situation where the contractor has a choice between two parts where one part likely will just meet reliability requirements and another is much better but more expensive. Industry can be expected to choose the cheaper part unless there is an incentive to do otherwise. Because of enormous pressure to reduce acquisition cost, few programs would entertain a trade that increases investment costs to achieve future O&S cost savings. Such tradeoffs are likely to involve performance requirements or operational parameters, so involvement of the operational community is essential. An effective working relationship among the operational community, the PM, and the contractor is necessary.

Successful implementation of affordability goals and caps involves changing this behavior by assigning a high priority to managing controllable O&S cost drivers. There are two major elements in changing such systemic behavior. Changing the government's behavior will change industry behavior. Industry behavior will be most affected by RFPs, source selection criteria, contract requirements, and contract incentives along with reinforcing behavior by the government.

In weapon system acquisition, there is often competition through TMRR and a down-select made for Milestone B. As discussed above, the period between Milestone A and Milestone B has an enormous impact on both investment and O&S costs. In formulating a proposal in response to a pre-Milestone B RFP, industry will consider various conceptual design alternatives. The alternative believed to have the best chance of winning the EMD contract will be the one selected for further development. The government can reduce O&S costs by incentivizing industry to reduce O&S cost during conceptual design. Once the design is in place, resources should be allocated to making sure that estimated values of the O&S cost drivers are in fact achieved and to seeking ways to reduce them further where feasible.

The following are suggestions for providing such motivations:

- Explicitly state in RFPs that the program is driven by life-cycle costs.
- Heavily weight O&S cost affordability in source selection criterion.
- Perform early systems engineering (by the government) to inform evaluation of proposals.
- Provide a wide enough range between threshold and preferred values for performance criteria to enable real trades with O&S cost during conceptual design.
- Include the O&S cost affordability goal as the upper limit for an O&S cost threshold.
- Require the contractor to show conceptual design tradeoffs to provide the government with the opportunity to widen the trade space if it finds that O&S cost reduction opportunities are not being developed.
- Identify, based on experience with legacy systems, the controllable O&S cost drivers, thereby defining the areas where conceptual design O&S cost reduction efforts should concentrate.
- Require TMRR and EMD contractors to construct, maintain, and report estimates from an accredited life-cycle cost model. (If the standard O&S cost model suggested above is

implemented, the contractor's model should be consistent with it, though probably in greater detail.)

- Require contractors to identify the O&S cost drivers in conceptual designs and to demonstrate how the effects of those cost drivers have been mitigated at the preliminary design review. (The TMRR contractors should also identify the controllable O&S cost drivers for which cost reduction efforts could be implemented during detailed design.)
- Use the life-cycle cost model to effect continuous reductions in O&S costs throughout the development process.

It could be made standard practice to use contract incentives to reduce O&S cost. Incentive fees and award fees are two examples of increasing a contractor's fee as a function of specified criteria. An incentive fee is determined via a quantitative metric. For example, an incentive fee could be based on achieving a certain level of reliability to be demonstrated in particular tests. Award fees, on the other hand, are made based on a qualitative determination by the contracting officer derived from opinions of subject matter experts based on evidence submitted by the contractor. Award fees can be developed for improving reliability and maintainability in general or associated with some particular elements of the system. For example, the contractor can demonstrate maintainability by designing for and demonstrating improvement in component removal times. In addition, award fees could be associated with the contractor trade studies discussed earlier to ensure that O&S costs are considered. While such techniques have been employed in some DOD acquisition programs,[117] these tools have not been widely used.

A Value Engineering Change Proposal (VECP) is a proposal submitted by a contractor under the Value Engineering provisions of the Federal Acquisition Regulation that, through a change in the contract, would lower the program's life-cycle cost to DOD. Contractors are incentivized to do this because they can share in the savings (up to 75 percent). VECPs should be encouraged, and consideration of O&S cost savings should be given equal weight to investment costs. Currently VECPs have been for relatively modest monetary amounts; however, wider usage could potentially generate much greater savings.

Such incentives could lead to the selection of higher reliability parts and/or designs that improve maintainability. The incentives should apply throughout the entire EMD period even though most design decisions are made prior to the Critical Design Review. Between Critical Design Review and Low-rate Initial Production (LRIP), there is intense pressure on schedule, often to the detriment of pursuing additional O&S cost reduction activities. The proper incentive structure will encourage the contractor to focus on both.

[117] One example is the F-16 program.

E. Institutionalization

An ongoing commitment from senior leadership is necessary for any new initiative to have a long-term impact. This is especially important for initiatives involving O&S costs for new acquisition programs because, as discussed earlier, it is likely that acquisition managers will give lower priority to O&S concerns when making tradeoffs associated with inevitable near-term technical issues. A commitment from senior leaders is more than words, policy, and guidance. Effective processes on paper will not change deeply ingrained behaviors. Senior leaders must be willing to force the tough decisions and make the hard choices associated with achieving the desired ends.

While strong commitment of senior leadership to affordability goals and caps appears to exist today, the lesson of history is that it is difficult to achieve long-term institutionalization. Changes in leadership almost always lead to new areas of emphasis. For example, CAIV originated in the 1994–1997 time frame. For the next four years, there was very little public mention of CAIV by senior leadership although former DOD personnel have told the research team that programs were privately encouraged to continue pursuit of the initiative in not-for-attribution reviews of CAIV plans. Similarly, DTC, though deeply entrenched in acquisition policy, apparently failed to receive continued emphasis by acquisition managers.

The commitment of senior leadership must be in place long enough for the permanent workforce implementing the initiative to realize the benefits. That will minimize the likelihood that the next leadership team will undo the changes. Instantiation of policy, guidance, and oversight is a necessary starting point. The evidence that this is occurring for the BBP initiatives is as follows:

- The requirement to establish and enforce affordability goals and caps was included in the recently-published revision of DODI 5000.02.
- An affordability goals and caps section has been included in the *Defense Acquisition Guidebook.*
- A revised *Operating and Support Cost-Estimating Guide* has been published.
- An *Operating and Support Cost Management Guide* is under review.
- The OUSD(AT&L) office of Logistics & and Materiel Readiness (L&MR) has established systematic interfaces with:
  - CAPE on the independent cost estimates required at Milestone A and Milestone B;
  - Systems Engineering as part of the Program Support reviews; and
  - The DAES process to highlight O&S cost issues.

While it is relatively easy to establish policy and guidance, this initiative is still far from the degree of institutionalization required to change behavior. As evidence, RFPs are still being issued without adequate emphasis on O&S affordability. The research team has reviewed RFPs for the Army's Ground Combat Vehicle (GCV) and Armored Multipurpose Vehicle (AMPV) for focus on control of O&S costs.

The GCV TMRR RFP affordability sections stated: "Any proposal received in response to this RFP that proposes a price in excess of $450,000,000 [for the technology development contract] will be considered unaffordable."[118] There is nothing about O&S affordability. The program intent section does refer to both acquisition and O&S cost affordability but as a secondary consideration. The RFP stated:

> Offerors must balance Affordability with the achievement of the "Big Four" imperatives. The Government's average Unit Manufacturing Cost target for the GCV IFV Program is $9,000,000 to $10,500,000 per unit expressed in Government fiscal year 2010 constant dollars (as defined by the 2010 Office of the Secretary of Defense Inflation Guidance FY2011 President's Budget). In addition, the GCV IFV target Operation & Sustainment cost is $200 per mile expressed in Government fiscal year 2010 constant dollars (as defined by the 2010 Office of the Secretary of Defense Inflation Guidance FY2011 President's Budget).[119]

The research team reviewed several charts provided by the Army for DAB reviews that displayed the O&S costs of future ground combat systems. The charts indicate that the Army's program for the systems being displayed (including GVC and AMPV) is not affordable for both investment and O&S costs. GCV is the principal driver of those O&S cost projections.

There is language in the EMD AMPV RFP about O&S affordability: "The Government has determined the Cost Per Mile (consumables, reparables, and fuel cost per mile) threshold target for the AMPV Family of Vehicles (FoV) is $90 per operating mile (Fiscal Year 13 constant dollars)."[120] This is not a very comprehensive treatment of the subject. However, the AMPV's O&S costs are not especially high compared to the GCV. Since there is no evidence that the O&S costs of the rest of the portfolio is under control, a decision to proceed gives the appearance of having ignored O&S affordability.

F. Summary

The following points summarize the insights of this chapter:

- Monitoring affordability goals and caps is necessary but not sufficient to guarantee success.
- Improving O&S cost tradeoff processes would be beneficial.

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118 U.S. Army, Solicitation Number W56HZV-11-R-0001 "GCV TMRR RFP" (Warren, MI: U.S. Army Contracting Command, 30 November 2010), 3.

119 Ibid., 4.

120 U.S. Army, Solicitation Number W56HZV-13-R-0022 "EMD AMPV RFP" (Warren, MI: U.S. Army Contracting Command, n.d.), 37.

- There must be parallel efforts to manage O&S cost drivers from both industry and Government perspectives.
- There should be contract incentives to encourage such activities.
- Irrespective of the virtues of the framework put in place, history has amply demonstrated that OSD management must assiduously and relentless enforce compliance with directives for real, long-term change to occur. Programs of dubious affordability, either investment or O&S, should not be approved until such issues are resolved.

Appendix A
Case Studies of the Application of the Cost as an Independent Variable (CAIV) Concept

This appendix is supplementary to the discussion of Cost as an Independent Variable (CAIV) programs in Chapter 2, Section C. For the twelve programs using CAIV that were examined in this research, the appendix will present

- the cost history of each program;
- the reasons, as best understood, why that history occurred; and
- an assessment of whether CAIV principles were actually applied in the program, and if so, with what success.

To speed understanding and application of acquisition reform, the December 4, 1995 Kaminski memorandum[1] designated eight Major Defense Acquisition Programs (MDAP) as Flagship Pilot Programs (FPP) for CAIV and certain other initiatives.[2] The eight FPPs are

- U.S. Army—Army Tactical Missile/Brilliant Anti-Tank (ATACMS/BAT), Crusader self-propelled artillery systems;
- U.S. Navy (USN)—Multifunctional Information Distribution System (MIDS), Sidewinder air-to-air missile (AIM-9X); and
- U.S. Air Force (USAF)—Space-Based Infrared System (SBIRS), Joint Air-to-Surface Standoff Missile (JASSM), Joint Strike Fighter (JSF/F-35), and an Evolved Expendable Launch Vehicle (EELV).

Each of these FPPs, as well as four other prominent programs that advertised use of CAIV, will be reviewed in this appendix to help to fill out the picture of the application of CAIV principles. The four additional programs are

- USAF—Joint Direct Attack Munition (JDAM)
- USN—Littoral Combat Ship (LCS), Amphibious Transport Dock (LPD-17)
- U.S. Marine Corps (USMC)—Expeditionary Fighting Vehicle (EFV)

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1 Paul Kaminski, *Memorandum for Distribution Subject: Reducing Life-Cycle Costs for New and Fielded Systems*, December 4, 1995. No copy of this memo has been found but the text of it is at http://www.navair.navy.mil/nawctsd/Resources/Library/Acqguide/caainvar.htm.

2 How those programs were chosen was not specified, but it is likely that they were nominated by the Services.

The Selected Acquisition Reports (SAR) have been used for the principal cost measures that CAIV addresses, program acquisition unit cost (PAUC) and average procurement unit cost (APUC), and for information on cost thresholds in the acquisition program baseline (APB) for each program.[3] The SAR analyses of cost variances might be considered a valuable source for this analysis, but unfortunately that information has been shown to be of very limited value.[4]

Fortunately several of the programs of interest have been addressed in considerable depth in a previous IDA analysis: Gene H. Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, IDA Paper P-4531, December 2009, which will be referred to subsequently as "P-4531." The current research will draw from that analysis extensively. To get the full story, the reader is encouraged to review relevant material in Volume III of P-4531. For programs not treated in P-4531, this examination relies on readily available documentary sources, primarily SARs.

JDAM and JASSM are addressed first because of the pivotal roles they played in CAIV and because the two programs were closely linked.[5]

A. JDAM

JDAM was not a CAIV FPP, but it began as a Defense Acquisition Pilot Project (DAPP) with a very strong cost control focus and was influential in thinking about CAIV. It became a CAIV program as CAIV took shape, with strong backing from high level officials encouraging requirements tradeoffs to meet stringent cost goals.[6]

The program designed and produced an all-weather glide-bomb kit that could be fitted to commodity bomb bodies to make them into moderate-precision, relatively inexpensive, free-fall weapons. At the time it was initiated in the early 1990s, the United States had five decades of experience in developing and employing guided bombs, from the AZON [azimuth only] and RAZON [range and azimuth] kits of World War II through the laser-guided bomb kits that began in the 1960s. It was a class of weapons well understood by users and weapons engineers, leading to implicit expectations about engineering approaches and costs. It seemed likely that pursuing the program along established lines would lead to a unit procurement cost in excess of $40,000.

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3 For definitions of precisely what is and is not included in PAUC and APUC, see https://dap.dau.mil/aap/pages/qdetails.aspx?cgiSubjectAreaID=15&cgiQuestionID=16702.

4 Paul G. Hough, *Pitfalls in Calculating Cost Growth from Selected Acquisition Reports*, N-3136-AF (Santa Monica, CA: RAND Corp., 1992). More recent informal analyses conducted by OUSD(AT&L) reveal that this situation has not measurably improved.

5 Col. Terry R. Little, the program manager for JDAM in the mid-1990s, subsequently became the program manager for JASSM in the late-1990s.

6 For an extended history of the initial years of JDAM, see Chynthia Ingols and Lisa Brem, *Implementing Acquisition Reform: A Case Study on Joint Direct Attack Munitions* (Fort Belvoir, VA: Defense Systems Management College, July 1998), http://acquisition.gov/sevensteps/library/JDAMsuccess.pdf. Additional information and perspectives are provided in Mark A. Lorell and John C. Graser, *An Overview of Acquisition Reform Cost Savings Estimates*, MR-1329 (Santa Monica, CA: RAND Corp., 2001).

However, analogs to key guidance system components were available in commercial markets where prices were declining rapidly. For nearly a decade, the USN had exploited similar situations to achieve substantial economies in sonobuoy prices, and there was optimism in some quarters about gaining comparable results in JDAM, despite its greater complexities.

In mid-1995 the JDAM Joint Operational Requirements Document (JORD) was revised to incorporate a unit production price of no more than $40,000 base year 1995 dollars (BY1995 $) as a requirement, with an objective of $30,000 or less. $40,000 was moderately lower than contemporary independent cost estimates, and $30,000 was substantially lower.[7]

As a DAPP, JDAM won permission to use not only commercial technologies but to enter into commercial kinds of relationships with contractors, involving greatly reduced government oversight and control and relying on performance-oriented specifications and strong financial incentives. At that time there were still a number of defense firms that were able to compete, and the program office made effective use of competitive pressures. It is unclear how well that approach would work in today's environment of greatly narrowed competition.

Ultimately both of the two final competitors offered JDAM designs that used commercial and commercial-grade parts, and priced them on a commercial basis (i.e., well down the learning curve and taking a loss on initial lots while turning profits on later lots).

For the competing contractors, JDAM offered an attractive risk/reward calculus. A contractor that underestimated production costs faced a risk of significant loss on the early production lots, but was under little obligation to continue to produce at a loss in the long run, and if the contractor declined to re-bid at a low price for subsequent lots, the government might find itself in a difficult situation.[8] On the other hand, if the contractor's winning bid price proved to be realistic, he stood to make super-normal profits by selling large numbers of JDAM kits on commercial terms over many years—as proved to be the case. Thus there was downside risk, but the upside potential was much greater.

The program has been highly successful in both cost and performance. The original (development) APB APUC was $31,000 in fiscal year 1995 dollars (FY1995 $) based on procurement of 87,496 units. The December 2012 SAR reports a total production of 208,613 units to date with an APUC of $19,800, again in FY1995 dollars. Thus the APUC has decreased by 28 percent, or 21 percent when adjusted for the change in quantity. By any measure, JDAM has been a signal success for the CAIV concept.

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7 Lorell and Graser, *An Overview of Acquisition Reform Cost Savings Estimates,* MR-1329, 66–67.

8 Ibid., 62–63.

B. JASSM (Baseline variant only)

The JASSM program was initiated in 1995 after the highly classified Tri-Service Standoff Attack Missile (TSSAM) program was cancelled, largely because of a substantial cost overrun.[9] Given that history and the contemporary success in cost control of the JDAM program, there was great optimism that taking the same approach on JASSM would lead to similar results. In 2009, the program was divided into two subprograms—the baseline missile and an extended range (ER) variant. This paper will only discuss the baseline missile in any detail. The baseline missile is a subsonic cruise missile with 200nmi range, GPS/inertial guidance plus infrared (IR) terminal homing, a 1,000 lb. warhead, and low observables. It is thus substantially more complex than JDAM, but was intended to utilize much the same acquisition strategy, with the same initial program manager who had set JDAM on its successful course. It was a CAIV flagship program and CAIV was an essential part of its acquisition strategy.

Unlike JDAM, competition was not maintained in the program. An early design competition between McDonald Douglas and Lockheed Martin was won by the latter, which was selected as the prime contractor for the Program Definition and Risk Reduction (PDRR) phase and in a subsequent competition for the full-scale development contract. The original plan was to continue competition at least through PDRR; however, funding constraints curtailed those plans. Prior to its entry into engineering development at acquisition Milestone II in mid-1998, the program initially seemed to enjoy substantial success in controlling cost by allowing and incentivizing the contractor to make broad requirements tradeoffs. It was a period characterized by very high enthusiasm for acquisition reform, and the program was structured to employ many, if not virtually all, of those initiatives including

- streamlining the acquisition process—lower frequency of management reviews, reduced documentation, and less submission of data that facilitated oversight;
- using more commercial practices;
- giving the contractor more flexibility in product design, development and production; and
- implementing CAIV.

The promise of a missile with substantially lower costs though was short-lived, and soon after the Milestone II decision, costs began to grow, as seen in Figure A-1 extracted from P-4531.[10]

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9 JASSM is one of the programs examined in considerable detail in Vol. III, Appendix F, of Gene H. Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, IDA Paper P-4531 (Alexandria, VA: Institute for Defense Analyses (IDA), December 2009). This section is largely drawn from that paper, which the reader is encouraged to consult for a much more detailed discussion.

10 Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, F-15.

	APUC (FY98$K)	Year-to-Year Change	Aggregate Change	Quantity
Dec 99	399			2400
Dec 01	448	12.3%	12.3%	3700
Dec 02*	523	16.7%	31.1%	4340
Dec 03	525	0.4%	31.6%	4366
Dec 04	541	3.0%	35.6%	4900
Dec 05	563	4.1%	41.1%	4900
Dec 06	649	15.3%	62.7%	4900
Dec 07	703	8.3%	76.2%	4900
** The Dec-02 (and subsequent SARs) reflect ER requirement (quantity not specified)*				

Figure A-1. JASSM APUC Cost Growth

As explained in P-4531, Figure A-1 reflects both growth in the cost of the baseline missile and the addition of the ER variant in 2002. In 2009 the program declared a Nunn-McCurdy breach. The subsequent analysis by the Cost Analysis Improvement Group (CAIG) showed that by that time the APUC for just the baseline version had grown to $688 thousand (the estimate in the Dec 2012 SAR is $935 thousand in FY2010, corresponding to about $722 thousand in FY1995 $). This is remarkably close to the original cost objective for TSSAM, whose unit cost had grown to over two million when it was cancelled.

Except for maintaining competition, the JASSM program was structured much like JDAM. However, the other acquisition reform steps that had worked so well for JDAM were unsuccessful when applied to the JASSM program, in fact dramatically so. CAIV-directed efforts, in particular, resulted in significant problems. For example the use of commercial components to drive down costs, some from small companies with little or no experience in producing weapon systems, contributed to reliability issues.

Thus the CAIV strategy for JASSM was remarkably unsuccessful, not only in failing to control costs but in producing a missile with significant effectiveness issues as well, reliability in particular. The quote below is taken from P-4531 (page F-11):

> Factors contributing to JASSM's poor reliability can be traced back to the way the program was formulated and executed, as detailed above. The aggressive use of CAIV led to significant cost cutting, consequently resulting in an insufficiently robust missile design; poor systems engineering; weak manufacturing controls, badly managed supply chains; inadequate live fire testing, and over reliance on modeling and simulation. As already noted, TSPR [Total Systems Performance Responsibility] gave the LM [Lockheed Martin] virtually total control over decisions in making trades between costs and missile performance, as well as exclusive authority over the development and execution of developmental testing.

> That resulted in the heavy reliance on modeling and simulation to predict missile mission effectiveness and reliability, while cutting back on costly but much more meaningful live fire missile testing.

Fortunately it appears that the reliability problems are at last under control, and the APUC estimate has actually decreased modestly in more recent SARs. While one might say "all's well that ends well," there was a great deal of costly program turbulence which might have been avoided and, more importantly, delays in fielding the weapon that could have had serious operational implications had U.S. forces become involved in a contingency that required JASSM's capabilities.

A synthesis of the major causes of acquisition cost growth in the JASSM program described in IDA Paper P-4531 is summarized in Figure A-2.[11]

- **Over-ambitious acquisition reform objectives —"50% savings" (cost/schedule)**
  - Placed undue pressure to achieve unrealistic objectives (cost, schedule and management reforms)
  - Vested too much control with contractor with potential conflict of interests (TSPR)
  - FFP ill-suited for ambitious development with unproven acquisition strategy
  - Insufficient PM visibility and too little OSD oversight)
  - Inadequate development flight testing and misapplication of modeling & simulation
- **CAIV's early cost goals contributed to poor contractor performance (poor supplier management, manufacturing quality, systems and reliability engineering)**
- **Lack of consistent missile reliability forced change in requirements specifications**
  - Original requirement based on simulation-based assessments of mission effectiveness (55 missiles to kill 17 targets)*(which was achieved!)*—no explicit reliability objective specified
  - When lot testing revealed reliability issues, government imposed a reliability criterion that the contractor has not yet been able to meet consistently
  - Resulted in lower funding and production rate and thus increased unit costs
- **Unrealistic unit cost estimates at MS -II (62% APUC cost growth at breach)**
  - At MS-II CAIG APUC estimate of baseline missile14% above Service estimate
  - At Nunn-McCurdy breach, CAIG APUC estimate was 50% higher than at MS- II
- **Post MS-II introduction of requirement for a more costly extended range missile**
  - Could have been mitigated by separate tracking of ER missile cost

Note: PM = Program Manager; OSD = Office of the Secretary of Defense; MS = milestone.

Figure A-2. Reasons for JASSM Cost Growth from IDA Paper P-4531

While JDAM demonstrated that when properly and appropriately employed, the CAIV approach could be a powerful cost-control tool, JASSM by contrast illustrates the many hard-to-foresee pitfalls that the overly-zealous application of CAIV could encounter, even with

[11] Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, F-16.

experienced and expert direction. Another lesson to be learned from JASSM is the importance of a sound initial cost estimate that can serve as a valid basis for setting a CAIV cost goal. It is ironic that the current APUC for the baseline JASSM is remarkably close to early cost estimates of about $700,000 for a missile with JASSM's characteristics, before the ambitious claims of much lower costs based on acquisition reform initiatives (CAIV, among others) led to embedding a figure over 40 percent lower in the APB.[12] It is also an excellent illustration of the dangers of setting overly aggressive cost targets. If both DOD program managers and contractors are strongly incentivized to undertake "heroic" efforts to reduce costs, their risk-reward calculus may translate into excessive risks to DOD and the warfighter. There is good evidence that JASSM is a case in point.

C. SBIRS

SBIRS employs a constellation of satellites in geosynchronous earth orbit (GEO) and high-elliptical orbit (HEO) to maintain continuous multiband IR surveillance of the great majority of Earth's surface, including the entire Northern Hemisphere, with the primary objective of providing very fast alerting of ballistic missile launches and initial trajectory predictions. Other capabilities include observation of space launches and shorter-ranged ballistic missiles, as well as tactical weapons. It supplements and eventually is to replace the Defense Support Program (DSP) constellation.

The SBIRS case was analyzed at length in IDA Paper P-4531.[13] Another IDA paper, *What to Buy? The Role of Director of Defense Research and Engineering (DDR&E): Lessons from the 1970s*, which reviewed some of the history of DSP, SBIRS' predecessor program,[14] will also be used.

DSP (which had earlier been called by a variety of code names) began as a highly risky and extremely urgent effort at the height of the late-1950s concerns about the "missile gap" with the Soviet Union. As the concerns faded (with the acquisition of better intelligence), development grew more deliberate and became part of the development of the systems engineering approach, leading to design simplification and substantially lower costs.

The key factor in limiting the cost was use of a one-dimensional linear sensor array that was swept across the field of regard by means of a purely passive mechanism. This entailed some performance tradeoffs, and elements in the USAF sought from an early date to move to a more sophisticated and costly design employing two-dimensional arrays. Means were found to extend

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12 The earliest ("concept") APB reflected an APUC of $710,000 in FY1995 dollars. The "development" APB reduced it to $400,000.

13 Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, Appendix. J.

14 William D. O'Neil and Gene H. Porter, *What to Buy? The Role of Director of Defense Research and Engineering (DDR&E): Lessons from the 1970s*, IDA Paper P-4675 (Alexandria, VA: IDA, January 2011), 39–44.

the performance of the basic DSP system while further improving its economy, so proposals for a follow-on made little headway until the 1990s.

Expectations of substantial cost reduction through employment of commercial approaches and hardware elements played a key role in getting SBIRS started in the 1990s. But as detailed in P-4531 (Appendix J), these expectations faded dramatically after 2000.

It's quite difficult to present a clear, simple picture of SBIRS costs, as the structure of the acquisition is complex and varying, and the mix of outputs has changed frequently. Figure A-3 shows total acquisition program costs in constant dollars, adjusted for quantity changes. As of the end of 2012 the total acquisition cost had increased by more than 280 percent since program initiation in October 1996, on a quantity-adjusted basis.

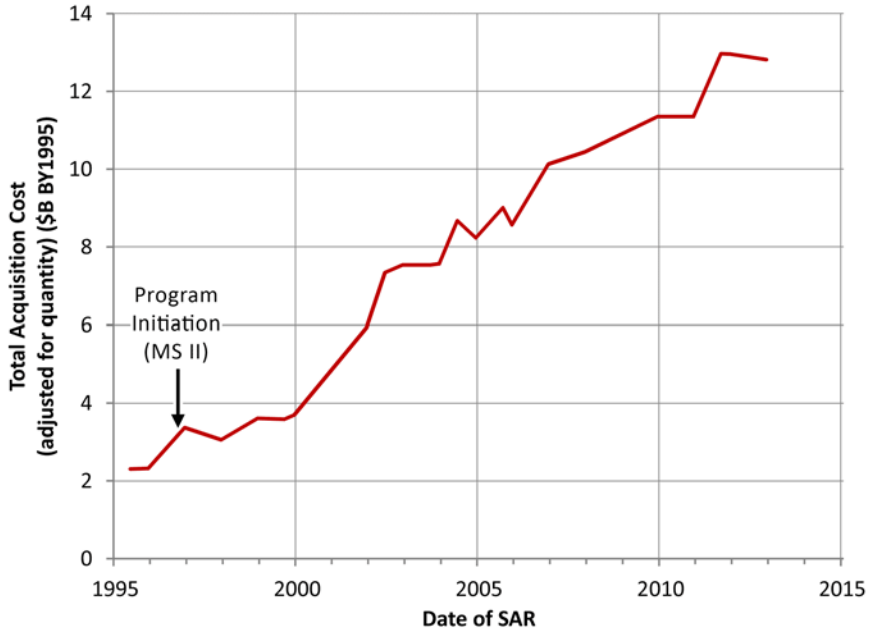

Figure A-3. Estimates of Total SBIRS Acquisition Cost for Five GEO Satellites, Two HEO Packages, and Ground Segment (adjusted as necessary for quantity changes)

The descriptions of the early thinking about SBIRS seem bizarre in retrospect. Although the environment soon gave way to bitter enmity and recriminations, it seems evident that initially there was a good deal of real harmony and unity of purpose within the contractor team and between the contractor and government, possibly reflecting that competing and dissenting voices were being shut out. The systems engineering efforts normally relied upon heavily in space programs to provide clarity and realism were deliberately cut back very severely to save front-end costs. There's little evidence that the contractor believed the initial estimates to be seriously unrealistic. Nor did the CAIG challenge the cost estimates.

The findings in IDA Paper P-4531 regarding cost growth are summarized in Figure A-4.[15]

15 Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, J-22.

- Competitive pressures motivated both government and industry personnel to promise substantial added capability at a cost well below precedent
- Efforts to validate and refine technical plans and identify risk areas through early systems engineering were inadequate considering the complexity of the concept
- Low cost estimates based on projected savings from "acquisition reform" innovations failed to materialize
- It proved technically impossible to deliver the system as designed within the estimated cost, and the inadequate funding resulting from such underestimates prompted shortcuts that were unsuccessful
- The program was restructured to attack the problems that emerged, but the costs of remediation were themselves underestimated

Figure A-4. Findings on SBIRS Cost Growth

While there appears to have been a genuine effort to utilize the CAIV approach, the emergence of serious technical issues soon after Milestone II quickly rendered the CAIV cost objectives irrelevant. The lack of sound front-end systems engineering had a heavy impact on the reliability of the initial cost estimates. To a certain extent SBIRS was a victim of the same inflated expectations for the commercial space market that afflicted EELV cost estimates. It also suffered from a kind of stealth requirements creep, as officers who vastly overestimated the potential for cost reduction also informally pressed for capabilities expansion in integrated product teams (IPT). A great deal of growth came from bad engineering, coupled with abandonment of the parallel risk reduction development policies that had helped keep previous space programs on track.

In any event, SBIRS represents another dramatic failure of CAIV. As with JASSM, there is a strong lesson that CAIV cannot work unless the cost estimate on which the CAIV cost objective is set is sound. Good early systems engineering is essential to establish such a cost objective, and its absence seriously hampered SBIRS—much more so that JASSM, a far simpler system. SBIRS is thus another case in point wherein attempting to achieve very aggressive cost reduction goals appears to have contributed to diametrically opposite outcomes.

D. AIM-9X Air-to-Air Missile BLOCK I AND BLOCK II

The AIM-9X is the latest variant in a long line of air-to-air AIM-9 Sidewinder short-range missiles (SRM). As compared with the preceding AIM-9M, AIM-9X Block I provides

- an expanded kinematic envelope due to lower airframe drag and thrust-aided steering;
- improved sensor performance with an advanced imaging focal plane array and an advanced processing system;
- visual cueing via a helmet-mounted sight or other line-of-sight source;

- improved countermeasures resistance; and
- increased economy of operation through an integral onboard cooling system, and various detailed improvements.

It also provides a limited lock-on-after-launch (LOAL) capability.

AIM-9X Block II goes beyond Block I in incorporating an aircraft-to-missile data link to provide full LOAL capability and was split off as a separate MDAP in June 2011. AIM-9X was not a classic acquisition program in that it involved incorporating a collection of improved subsystems in an existing system, most of which had already been demonstrated in prototype form. As such it offered good prospects for a successful, if not particularly challenging, CAIV program, since major risk-reduction had already taken place. In fact, long before the advent of CAIV, cost had been a focus of the program since the initial requirement was approved in 1990. CAIV was mentioned in the initial SAR (December 1997) but not thereafter.

In 1996 Hughes Electronics won the Engineering and Manufacturing Development (EMD) contract in competition with Raytheon. However, as part of the ongoing DOD defense contractor consolidation, Raytheon bought Hughes Electronics (from General Motors) in 1997. Table A-1 presents the unit cost history of the AIM-9X. Development generally went well, with fairly minor problems but some schedule slippage. External factors caused further schedule slippage. Re-phasing of production affected estimated costs. There were two Nunn-McCurdy breaches as a result of these factors, but neither qualified as critical. Performance generally met goals. Reliability substantially exceeded original estimates, benefitting life cycle costs (LCC).

The large increase in PAUC in 2011 reflected the decision to split the Block II AIM-9X off as a separate MDAP. This meant that future procurement would be carried under the Block II rather than the Block I program, thus decreasing Block I quantity and increasing its program unit cost. APUC increased much more modestly, reflecting the quantity reduction. (In fact, if adjusted for the quantity reduction, APUC actually decreased.) It does not reflect any problem with Block I. Further production will be of the Block II, which is more expensive due to the incorporation of the data link.

Table A-1. PAUC and APUC for AIM-9X Block I

SAR Date	PAUC	APB PAUC	APUC	APB APUC	Prodn. Qty.
	Costs in Budget Year 1997 Dollars				
Dec 1997	258,000	245,000	207,000	193,000	10,000
Dec 1998	250,000	245,000	198,000	193,000	10,080
Jun 1999	250,000	245,000	198,000	193,000	10,080
Dec 1999	230,000	245,000	178,000	193,000	10,097
Dec 2001	239,000	245,000	186,000	193,000	10,097
Dec 2002	248,000	245,000	192,000	193,000	10,097
Dec 2003	249,000	245,000	193,000	193,000	10,097
Jun 2004	249,000	245,000	193,000	193,000	10,097
Dec 2004	242,000	245,000	184,000	193,000	10,097
Dec 2005	258,000	252,000	200,000	193,000	10,097
Dec 2006	261,000	252,000	201,000	193,000	10,097
Dec 2007	263,000	252,000	203,000	193,000	10,097
Dec 2009	282,000	252,000	221,000	193,000	10,097
Dec 2010	290,000	282,000	227,000	221,000	10,097
Dec 2011	421,000	282,000	250,000	221,000	3,097

The AIM-9X can be counted as a cost-control semi-success, a program whose costs rose somewhat (about 10 percent overall), but by less than the average for MDAPs of this class. How much that outcome can actually be attributed to CAIV policies and procedures is not known; there is no indication of the extent (if any) to which requirements were traded off to hold down costs.[16]

E. MIDS

MIDS is a multinational (United States, France, Germany, Italy, Spain) cooperative development program with U.S. Joint Service participation. The program was established to design, develop, and deliver low volume, lightweight tactical information system terminals for U.S. and Allied fighter aircraft, bombers, helicopters, ships, and ground sites. The MIDS program consists of the MIDS Low Volume Terminal (MIDS-LVT) and the MIDS Joint Tactical Radio System (MIDS JTRS) terminal. This analysis only addresses the MIDS-LVT, which was a CAIV flagship program. MIDS passed Milestone II on in December 1993 but was not designated a CAIV flagship program until 1997; this review starts at that point. The unit cost history of MIDS derived from the SARs is displayed in Table A-2.

16 Despite the common perception, not all DOD acquisition programs experience cost growth. In fact, between their initial SARs and the December 2009 SAR, ten out of ninety-one MDAPs showed no increase in APUC.

Table A-2. MIDS-LVT Cost and Quantity History, as Reported in SARs

SAR Date	Base Year	Costs in Base Year Dollars								Prodn. Qty.
		PAUC	PAUC in BY1992 $	APB PAUC	Orig. Baseline PAUC	APUC	APUC in BY1992 $	APB APUC	Orig. Baseline APUC	
Dec 1997	1992	500,000		1,376,000		261,000		704,000		2,358
Dec 1998	1992	472,000		500,000		232,000		261,000		2,374
Jun 1999	1992	472,000		500,000		232,000		261,000		2,374
Dec 1999	1992	491,000		500,000		261,000		261,000		2,499
Sep 2001	1992	474,000		500,000		257,000		261,000		2,638
Dec 2001	1992	515,000		500,000		271,000		261,000		2,573
Dec 2002	1992	503,000		500,000		267,000		261,000		2,803
Dec 2003	1992	522,000		515,000		292,000		271,000		2,842
Jun 2004	2003	616,000	522,000	616,000		345,000	292,000	339,000		2,842
Dec 2004	2003	670,000	568,000	616,000		347,000	294,000	339,000		2,761
Dec 2005	2003	642,000	544,000	656,000	1,624,000	314,000	266,000	339,000	831,000	2,970
Dec 2006	2003	631,000	535,000	656,000	1,624,000	314,000	266,000	339,000	831,000	3,067
Dec 2007	2003	601,000	509,000	656,000	1,624,000	303,000	257,000	339,000	831,000	3,448
Dec 2009	2003	539,000	457,000	544,000	1,624,000	277,000	235,000	277,000	831,000	4,227
Dec 2010	2003	503,000	426,000	544,000	1,624,000	257,000	218,000	277,000	831,000	4,606
Dec 2011	2003	533,000	452,000	544,000	1,624,000	255,000	216,000	277,000	831,000	4,817
Dec 2012	2003	486,000	412,000	533,000	1,624,000	243,000	206,000	255,000	831,000	5,745

A RAND Corporation study of the MIDS-LVT program [1] provides useful insights. MIDS experienced significant schedule slippage along the way to production and installation. A large portion of the slippage was due to extrinsic factors. By the same token, because MIDS terminals play a central role in many aircraft and other platforms, the program's delays adversely affected them. Nevertheless, there was little net effect on MIDS terminal prices.

As the utility and performance of MIDS-LVT became apparent and as the costs remained under control, the market for the terminals expanded steadily, more than doubling in the past decade, bringing further unit cost decreases.

Although there was a cost-control success one cannot unequivocally associate it with CAIV. The SARs make no mention of CAIV and give no hint of any of the cost-performance tradeoffs that are the key point of CAIV. Thus it appears that the program's favorable cost performance is more the product of realistic early planning, good management, and the absence of any particular misfortune.

F. LCS

The LCS was not a CAIV flagship program but CAIV was highly central to its acquisition strategy, at least declaratively. Its acquisition is detailed in P-4531 and the resulting insights will be brought into the present discussion.

Evaluating the effectiveness of CAIV in the case of the LCS presents some challenges. Data on PAUC and APUC are shown in Table A-3. The trends appear to be favorable, with PAUC and APUC below the targets set in the APB approved in April 2011, and falling.

Table A-3. PAUC and APUC for LCS

	PAUC (BY2010 $M)				APUC (BY2010 $M)			
SAR Date	B/L 4-11 APB	Qty.	Curr. Est.	Qty.	B/L 4-11 APB	Qty.	Curr. Est.	Qty.
31 Dec 2010	582.0	55	557.8	55	535.3	53	511.0	53
31 Dec 2011	582.0	55	557.8	55	535.3	53	535.2	53
31 Dec 2012	582.0	55	534.5	55	535.3	53	485.3	50

Yet the Milestone B decision that preceded the APB took place seven years after the first ship contracts were awarded under research, development, test, and evaluation (RDT&E) funding. At the time of the initial contract award the USN and the contractors were estimating unit costs of less than $230 million (M) in FY2005 dollars ($255M in the BY2010 dollars of

[1] Daniel Gonzales, Daniel Norton, and Myron Hura, *Multifunctional Information Distribution System (MIDS): Program Case Study*, DB-292-AF (Santa Monica, CA: RAND Project AIR FORCE, 2000).

Table A-3). Clearly the current estimate of $485.3M APUC for fifty ships represents substantial growth over the 2004 estimates.

RDT&E and total procurement cost estimates are shown in Table A-4.

Table A-4. LCS RDT&E and Procurement Totals

RDT&E (2 prototype ships):

	BY2004 $M				
		Current APB Concept			
SAR date	SAR B/L plan est.	Objective	Threshold	Current Est.	Qty.
30 Jun 2004	1,172.7	1,172.7	1,290.0	1,172.7	2
31 Dec 2004	1,172.7	1,172.7	1,290.0	1,172.7	2
31 Dec 2005	1,172.7	1,172.7	1,290.0	1,595.9	2
31 Dec 2006	1,172.7	1,172.7	1,290.0	1,791.8	2
31 Dec 2007	1,172.7	1,172.7	1,290.0	2,595.2	2
31 Dec 2009	1,172.7	1,172.7	1,290.0	3,349.4	2
	BY2010 $M				
31 Dec 2010	1,339.9	3,433.3	3,776.6	3,426.8	2
31 Dec 2011	3,433.3	3,433.3	3,776.6	3,391.4	2
31 Dec 2012	3,433.3	3,433.3	3,776.6	3,329.1	2

Procurement (53 ships in APB):

	BY2010 $M				
		Curr APB Concept			
SAR date	SAR B/L plan est.	Objective	Threshold	Current Est.	Qty., Current Est.
31 Dec 2010		28,369.2	31,206.1	28,364.0	53
31 Dec 2011	28,369.2	28,369.2	31,206.1	27,083.4	53
31 Dec 2012	28,369.2	28,369.2	31,206.1	24,266.9	50

These data show that the RDT&E (the great majority of which went for the two prototype ships) grew by more than 150 percent in constant dollars between 2004 and 2012. All of the growth took place in the first five years of this period and have leveled off since then.

Clearly, this does not reflect favorably on the application of CAIV in LCS. The program history shows that in fact there was a good deal of effort to trade off requirements for cost savings up to the point at which the basic ship designs were frozen late in 2004. However, much of this effort reflected a significant misunderstanding of actual cost impacts. In particular, it appears that those who were chiefly responsible for the trades failed to recognize the full cost implications (for operating and support (O&S) as well as acquisition) of ship speed. By insisting on a very high ship speed[2] they ensured high costs despite serious sacrifices in areas including seakeeping, endurance, survivability, supportability, maintainability, and durability—many of which will bring penalties in the overall cost of ownership. The lesson is that effective CAIV

2 Believed required for effectiveness and survivability in littoral areas.

application demands a thorough understanding of the engineering as well as operational factors, and informed calculation of the effects of specific trades rather than gross judgment.

Once the ship designs were largely frozen there was little scope for any further savings through performance tradeoffs. Indeed, once it became clear that light ship weight would substantially exceed 2,000 tons, as it did by the spring of 2004, it was obvious that unless something quite radical was done in terms of design and construction, the cost would considerably exceed the $220 million target.[3] At the time, the Navy was thinking in terms of designing and building the LCS like a commercial ferry and simply setting up mission equipment in the space used for vehicles—which might have been possible for not too much more than $220 million, leaving aside the cost of the mission systems. However the mission and operating environment expected for the LCS in no way resembled that of a ferry operating on short routes and only in favorable weather, with no threats beyond the ordinary hazards of the sea. As it gradually was recognized that a light commercial vessel could not be expected to serve satisfactorily as a warship, or certainly not for very long, the ships grew and so did the cost per ton. In summary, that Navy's CAIV-like early efforts to trade performance and cost proved to be highly unrealistic and subsequently required major reversals.

The Navy also counted on savings through a very compressed schedule and buying on essentially commercial terms, with little government management or supervision. This actually increased costs since the lack of planning led to much work being redone or done out of the most efficient sequence.

A summary of the findings of IDA Paper P-4531 regarding cost growth in the LCS program is in Figure A-5.[4]

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3 As a general rule, ships in the LCS's size range built to light warship standards cost $175,000 to $225,000 per light ton, while fast commercial ships generally cost $100,000 to $150,000 per light ton, depending on the quality and extent of the accommodations.

4 Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, I-23–I-24.

- Most of the LCS cost growth can ultimately be attributed to lack of strong acquisition leadership and communication. The CNO and many others saw LCS as a brand new concept for warships. The concept envisioned adapting a commercial design to suit naval missions and in doing so producing it at lower cost and much more quickly than typical warships.
- But other groups within the Navy successfully imposed operational and technical requirements more consistent with warships than commercial vessels.
- The ultimate result was an RFP and acquisition strategy that were only feasible under radically changed acquisition practices and wholesale waivers of traditional ship engineering and design practices.
- For one of the two competing prototype contractors, cost growth resulted from poor performance largely due to an inability to train and maintain a skilled workforce, exacerbated by Hurricane Katrina. In addition, the Austal shipyard did not have rigorous work processes, especially related to systems engineering.

Note: CNO = Chief of Naval Operations; RFP = request for proposal.

Figure A-5. Reasons for Cost Growth in the LCS Program Identified in IDA Paper P-4531

On the whole the cost-reduction efforts made by the Navy on the LCS appear to have been sincere and determined—and seriously misguided. A much more conventional approach would probably have resulted in a product that better fit operational needs at lower overall LCC.

G. San Antonio Class Amphibious Transport Dock (LPD 17)

The LPD 17 class was designed as a replacement for several earlier types of amphibious ships. Although amphibious ships had once been comparatively simple, the LPD 17 incorporates a sophisticated command and control suite, as well as a variety of features intended to increase efficiency and throughput, putting it on a plane of complexity close to that of surface combatants.

The LPD 17 class was not a CAIV flagship program but was a CAIV program and was planned to place strong emphasis on limiting cost growth. As laid out in P-4531, Hurricanes Katrina (2005), Ike, and Gustav (both 2008) had an effect on program costs due to shipyard damage and impacts on shipyard operations, but poor planning and execution had a greater impact.[5] The ship incorporated novel systems and components and was designed with novel techniques for construction with novel processes in efforts to reduce costs. In many cases these novelties were unproven and/or unfamiliar to the builder, and many backfired and resulted in added costs.

Table A-5 reviews the history of PAUC and APUC for the LPD 17 class. It is evident that the greater portion of cost growth preceded the damage from Hurricane Katrina in 2005.

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5 Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, Appendix A.

Table A-5. PAUC and APUC for LPD 17 Class

SAR Date	PAUC (BY96 $M) Curr. Est.	PAUC (BY96 $M) Curr. B/L	APUC (BY96 $M) Curr. Est	APUC (BY96 $M) Curr. B/L	Quantity Curr.	Quantity B/L
Dec 1997	729.2	751.6	720.8	743.8	12	12
Dec 1998	727.7	751.6	719.5	743.8	12	12
Sep 1999	727.7	751.6	719.5	743.8	12	12
Dec 1999	807.8	751.6	799.7	743.8	12	12
Sep 2001	974.6	751.6	962.4	743.8	12	12
Dec 2001	1,078.3	751.6	1,070.2	743.8	12	12
Dec 2002	1,116.6	1,078.3	1,108.3	1,070.2	12	12
Dec 2003	1,098.7	1,078.3	1,090.2	1,070.2	12	12
Dec 2004	1,145.0	1,078.3	1,132.5	1,070.2	9	12
Jun 2005	1,145.0	1,079.6	1,132.5	1,070.2	9	12
Dec 2005	1,156.8	1,079.6	1,144.4	1,070.2	9	12
Dec 2006	1,233.7	1,079.6	1,221.3	1,070.2	9	12
Dec 2007	1,278.7	1,233.7	1,265.8	1,221.3	9	9
Dec 2009	1,304.5	1,233.7	1,294.0	1,221.3	11	9
Dec 2010	1,307.2	1,314.4	1,296.6	1,304.3	11	11
Dec 2011	1,297.2	1,314.4	1,286.7	1,304.3	11	11
Dec 2012	1,292.8	1,314.4	1,282.2	1,304.3	11	11

A summary of the findings in P-4531 regarding cost growth in the LPD-17 program is in Figure A-6.[6]

[6] Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, A-17–A-18.

- The Navy made optimistic assumptions about factors driving costs. It is likely that this was due to budget-constrained costing. Among other matters, the Navy estimated that teaming arrangements would cut costs, contrary to the usual experience of cost increases associated with teaming.
- The Navy and CAIG both underestimated the complexity of the ship.
- The DAE accepted the optimistic Service Cost Position, evidence of its inadequacy notwithstanding.
- The Navy failed to scale up program management and oversight to mitigate risks associated with its selection of a shipyard with no experience in building comparably complex ships.
- The contractor, wrestling with a program of unfamiliar complexity, performed poorly. It depended on a new and untested system of design tools, which resulted in slow release of engineering drawings. But it moved ahead with construction to meet schedules, resulting in out-of-sequence work. And it failed to build and maintain a workforce of the quality needed, resulting in serious quality issues.
- The program was stretched out, due mostly to poor contractor performance, but Congressional and DoD program actions also played some part.
- Hurricane Katrina disrupted work for a considerable period.

Figure A-6. Reasons for LPD-17 Cost Growth from IDA Paper P-4531

There has been no substantial requirements growth over the course of the program. Prior to finalization of the ship design, the USN traded away defensive features for the sake of reduced costs (provoking sharp Congressional criticism), but there is not a great deal left to trade without cutting into fundamental safety and operability, or impacting USMC missions.

There was no clear reason to regard the LPD 17 as ill-suited to CAIV at the outset, but overall it has been quite unsatisfactory from a CAIV standpoint.

H. EFV

The U. S. Marine Corps' EFV was conceived to be an infantry fighting vehicle capable of high speed ashore and also very high-speed afloat in its amphibious mode. Its story is told in an earlier IDA paper and will not be repeated here.[7] At the time that publication was completed in 2009, the program had been restarted and returned to the System Development and Demonstration (SDD) phase,[8] after operational test vehicles proved to be unable to complete operational test and evaluation (OT&E) due to very severe reliability deficiencies. However, EFV was deleted from the FY2012 President's Budget request and on 16 February 2011 the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) signed an acquisition decision memorandum (ADM) directing orderly cancellation.

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7 Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, Appendix C.

8 Now referred to as Engineering and Manufacturing Development (EMD).

In announcing the cancellation, the Commandant of the Marine Corps (CMC) said, "Despite the critical amphibious and warfighting capability the EFV represents, the program is simply not affordable given likely USMC procurement budgets," going on to say that he had decided to pursue a more affordable vehicle, named the Amphibious Combat Vehicle (ACV).[9] The decision to cancel has been sharply criticized in Congress and elsewhere and Congress has directed that the EFV be considered among the options for ACV. The status of the ACV is uncertain, but in any event it is not organized or managed as a continuation of the EFV program.

Leaving aside the anomalous figures for December 2010 resulting from the decision to defund production, Table A-6 shows that the unit procurement cost more than tripled in the six years following program initiation.[10] Since the cost was high for combat vehicles to begin with, it is easy to see how it led to a judgment that the program was not affordable; what seems remarkable is that it took another three years to act on it and cancel the program.

Table A-6. PAUC and APUC for EFV

	BY1993 $M		BY2007 $M		
SAR Date	**PAUC**	**APUC**	**PAUC**	**APUC**	**Prodn Qty**
Sep 2001	6.5	5.3			1013
Dec 2001	7.1	5.7			1013
Dec 2002	7.9	6.3			1013
Dec 2003	7.9	6.2			1013
Dec 2004	8.8	6.9			1013
Dec 2005	8.7	6.8			1013
Dec 2006	13.8	9.9			573
Jun 2007	17.4	13.1	22.2	16.8	574
Dec 2007	17.4	13.1	22.2	16.7	574
Dec 2009	17.5	13.1	22.3	16.8	574
Dec 2010	134.6	158.5	172.1	202.8	1

A summary of the findings from IDA paper P-4531 regarding cost growth in the EFV program is in Figure A-7.[11]

9 Andrew Feickert, "Marine Corps Amphibious Combat Vehicle (ACV) and Marine Personnel Carrier (MPC): Background and Issues for Congress."

10 The reduction in quantity in 2006 was not a major cause of cost increases; see Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, C-6–C-7.

11 Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, C-14–C-15.

The most fundamental cause of the EFV's cost growth was persistent failure to recognize and address the real nature and challenges of the technical problem presented by the requirements. This led to a series of serious deficiencies:

- **Inadequate funding**

  The EMD, in particular, was funded at levels which made effective execution impossible.
- **Unrealistic schedules**

  Even though the schedule was repeatedly extended, the plan never caught up with the reality of what had to be done.
- **Excessive concurrency and compression**

  To meet the unrealistic schedule, too much concurrency and compression was attempted. The critical design review was held within a month of EMD contract award and before analyzing the results of development testing--one example of many resulting in the need for extensive re-work.
- **Skipping critical tasks**

  Another impact of attempting too much with too little was the lack of focus on some critical tasks, most notably systems and reliability engineering. The result was that the program encountered extremely damaging and costly problems.
- **Major underestimation of procurement unit costs**

  Because the nature of the system and its challenges were not clearly understood or recognized, production costs were estimated on the basis of supposed similarity to much simpler and less powerful armored vehicles.

Figure A-7. Reasons for EFV Cost Growth from IDA Paper P-4531

While EFV was not a CAIV flagship program, in 1998 it won the Packard Award for acquisition excellence in, among other factors, CAIV execution. The award reflected cost-requirements tradeoffs made during the PDRR phase, when, of course, there was more scope to make them than at later dates. Despite those tradeoffs, the program entered full-scale development with little to trade off if the basic requirement was to be met using the platform developed in PDRR.

In effect, the sharp cost increase signaled that the engineering risks had been inadequately recognized and hedged against prior to SDD. Because the engineering issues were not well understood, the cost estimates founded on them were faulty. Thus the cost-requirements tradeoffs in PDRR were ultimately unsuccessful in containing costs.

If the ACV program does go ahead with markedly reduced performance goals, it will be, in effect, a CAIV-like trade off of requirements to cut costs. Much money and time could have been saved had realistic cost-constrained trade studies been made prior to EFV's entry into full-scale development. In other words, in spite of the claims, a CAIV approach was not really taken.

I. F-35 Joint Strike Fighter (F-35)

The F-35 program (previously called the JSF) is producing a strike fighter to serve the USAF, USN, and USMC, as well as air forces in at least eight allied nations. In order to meet the needs of various users it is produced in three distinct versions. (See IDA Paper P-4531, Appendix G, for a more complete discussion current through early 2009.)

The F-35 is a CAIV flagship program and affordability was stressed heavily when the program was initially being considered in 1993–95. A variety of quite advanced technologies were incorporated to enhance mission capabilities and, it was hoped, to reduce O&S costs. As of the end of 2013, eighty-five aircraft had been delivered and more than 4,000 hours of flight test completed, but the program continues to have significant development problems with some critical technologies, especially software and the Helmet-Mounted Display System (HMDS).

Table A-7 briefly reviews the history of F-35 unit costs. Although cost growth has leveled out and even declined slightly since 2010, costs remain substantially greater than originally planned. Because of the size and scope of the program, cost growth has received especially wide public and Congressional attention. It has been the subject of several studies, including two root-cause analyses for the OUSD(AT&L) Office of Performance Assessments and Root Cause Analyses (PARCA).

Table A-7. PAUC, APUC, and Unit Recurring Flyaway (URF) Costs for F-35

Source Date	BY2002 $M			U.S. Proc. Qty.
	PAUC	APUC	URF	
Sep 1995			34.1	2,978
Dec 1997			34.9	2,852
Dec 1998			34.9	2,852
Dec 1999			34.9	2,852
Dec 2001	61.9	50.9	40.9	2,852
Dec 2002	65.7	51.6	41.0	2,443
Dec 2003	78.0	61.2	47.4	2,443
Dec 2004	78.3	61.5	47.9	2,443
Dec 2005	82.1	66.0	50.3	2,443
Dec 2006	85.2	69.2	53.0	2,443
Dec 2007	85.5	69.3	54.5	2,443
Dec 2009	97.1	79.0	60.7	2,443
Dec 2010	110.1	90.8	68.2	2,443
Dec 2011	110.2	89.4	68.4	2,443
Dec 2012	106.5	85.9	65.7	2,443

A variety of devices were relied upon for cost control in the F-35 program, including early competitive prototyping, commonality across the three major variants, commercial-type acquisition approach, cost-oriented technology innovations, cost-oriented innovations in development and testing, a compressed schedule with steep production ramp-up, and stable program funding.

The initial program thrust and structure was shaped by a desire to gain support from many quarters by promising something for everyone, prompting the combination of three quite different variants in one, a very broad mission set and demanding performance requirements in multiple dimensions, and commitments to parcel the work out among a great many firms and organizations. There was scarcely any systems engineering to understand the implication of all these requirements and commitments before competitive concept definition (CD) began in the fall of 1996; the government aircraft systems engineering capabilities had been slashed in the 1980s and 1990s but the aircraft industry was not well prepared to step into the breach. The focus of the contractors competing in the CD phase was on winning the all-important SDD contract. As a result, at the end of CD serious engineering issues and risks remained open, and not even identified, like unexploded ordnance.

The program office and contractor mechanisms for warning of these bombs were inadequate. This situation culminated in 2003 in realization that the designs were very substantially overweight and that conventional methods of weight control were not able to deal with the problem. This would have been serious at best but the inclusion of the short takeoff/vertical landing (STOVL) variant in the mix meant that weight was absolutely critical; if the landing weight of that variant exceeded the available lift thrust the aircraft simply could not operate. The engine had already been stretched considerably, which meant that major weight reduction was essential. The only solution was to redesign the aircraft almost from scratch, even though assembly of production prototypes had already begun. Not only was redesign expensive in itself but in the process it was necessary to give up many of the features that had been counted upon to save money. Moreover, even with all possible weight wrung out of the aircraft it was necessary to extract still more power from the engine, which further increased its cost. And to top it off, the redesign and restart seriously disrupted the tight schedules that had been carefully optimized for cost.

The findings on the causes of cost growth in the JSF/F-35 program (through early 2009) are shown in Figure A-8.[12]

[12] Porter et al., *The Major Causes of Cost Growth in Defense Acquisition*, Vol. III, G-15–G-16.

STOVL variant

The unappreciated complexities of the STOVL variant led to the 2003-2004 design crisis. The inclusion of the STOVL added greatly to the complexity of the whole program. Lack of relevant experience with STOVL aircraft hindered estimation of weights and costs, and slowed recognition of problems. The stringent demands of vertical landing demanded more radical solutions to the weight problem than might have otherwise been necessary. Including the STOVL requirement without a sound understanding of STOVL's true costs tilted the early assessments of cost-effectiveness in favor of its inclusion.

Inefficient concurrency in development

Concurrency was deliberately adopted as a strategy for meeting demanding requirements for service dates and for limiting development cost, but the sequencing of activities within the concurrent schedule sharply increased risk relative to an optimum plan, and led directly to substantial cost growth, and ultimately and ironically, schedule delays. Early development efforts should have concentrated on identifying and reducing the highest risk areas, but they were, in fact, spread over many areas of lower risk, which delayed recognition of the critical weight problem and led to a great deal of re-work.

Failure to use very low observable (VLO) aircraft weight data

The government's decision not to allow use of weight data from other VLO aircraft in the statistical weight estimation process for JSF reduced both the accuracy of the weight estimates and the confidence engineers and managers could place in them, and contributed to setting the stage for the weight crisis.

Unforeseeable price increases

Materials price increases were a significant source of cost increases by the end of 2007. They reflect economic trends and thus lay beyond the ability to forecast or influence.

Figure A-8. Reasons for F-35 Cost Growth from IDA Paper P-4531

Although the discovery of the mistakes on weights and its sequelae was not the only factor in cost growth, it was the major one. The software and helmet problems (and earlier problems with critical operational support systems) have increased development and test costs and led to further delays.

The question remains as to whether the CAIV approach had any real impact on the JSF/F-35 program. Because of the large numbers of aircraft that the F-35 will replace, affordability, and by inference procurement costs, have always had a strong focus in the program.[13] Without a much more in-depth review, the research team has been unable to determine what types of performance-versus-cost tradeoffs might have been made along the way. The big tradeoff that the Department was, obviously, not willing to make was on the STOVL capability needed to replace the AV-8B Harriers of both the USMC and the United Kingdom.

J. EELV

The EELV program began in the early 1990s with the objective of assuring adequate launch services for military and intelligence payloads at affordable prices. It has been reasonably successful in technical, schedule, and operational terms, but much less so economically. Costs

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13 See "Joint Strike Fighter Total Cost Still up in the Air," *National Defense*, November 2013. The program manager was quoted as saying: "by 2019, I'm looking for a fifth-generation airplane for a fourth-generation price."

were to have been controlled through multilevel competition and cost-sharing, but the underlying planning assumptions have proven to be erroneous and costs have grown by more than 300 percent.

A complete analysis of EELV cost growth lies beyond the scope of this paper, but it is possible to give a broad sketch of major factors.

The USAF has responsibility for launching all DOD and National Reconnaissance Office (NRO) space payloads. Its performance of this mission has been affected not only by its own policies and DOD acquisition policy in general but by overall national policies regarding space. The interaction of these policies in the 1970s and 1980s was complex and destabilizing for the USAF, which in the meantime continued to use 1960s-era expendable (i.e., one-time) launch vehicles (LV).[14]

After a decade of abortive programs beginning in the mid-1980s, the USAF and DOD decided to pursue what became the EELV.[15] As the title suggests, the plan involved adapting improved, i.e., "evolved," versions of some existing launchers—based on the conclusion that the payoff in reduced operational costs from developing any altogether new launcher system would not be sufficient to justify the higher initial cost and risk.[16]

Early in the 1980s the U.S. government had abandoned the policy requirement that government organizations provide all launch services—the USAF for all military and intelligence payloads and the National Aeronautics and Space Administration (NASA) for commercial payloads in addition to NASA's own and other government payloads. Instead, licensed commercial launch providers were allowed and encouraged to develop or acquire their own vehicles and capabilities.

In the early 1990s, many experts were confident that the market for space launches was on track for quite substantial growth, and EELV was planned to use this trend to reduce costs to the government. (The EELV Program Office relied on the forecasts issued annually by the Federal Aviation Administration's Office of Commercial Space Transportation and the Commercial Space Transportation Advisory Committee.[17]) DOD would select one of the existing families of launchers as the most promising and upgrade it to DOD standards. Then, in addition to

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14 The history is reviewed in Carl E. Behrens, *Space Launch Vehicles: Government Activities, Commercial Competition, and Satellite Exports* (Washington, DC: Congressional Research Service, 20 March 2006) and in U.S. Government Accounting Office (GAO), *Access to Space: Issues Associated with DOD's Evolved Expendable Launch Vehicle Program*, GAO/NSIAD-97-130 (Washington, DC: GAO, June 1997).

15 U.S. Air Force, "DOD Space Launch Modernization Plan," briefing (Washington, DC: USAF, 17 May 1994).

16 For an unofficial but informed account of EELV's origins and early history see Wayne Eleazer, "EELV or Never?" *The Space Review* (4 Dec 2006) http://www.thespacereview.com/article/758/1.

17 Federal Aviation Administration, "Reports & Studies: Commercial Space Transportation Forecasts," http://www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/forecasts/.

producing launchers for DOD, the contractor would also market them to commercial customers, and DOD would benefit from the reduced prices as production volume grew.

By the mid-1990s, doubts about future demand were growing. Russian/Ukrainian and Chinese firms were marketing launchers based on Cold War missiles at low prices.[18] Nevertheless, the EELV program continued to press ahead and to plan on growing commercial sales.

Originally prompted by urging from DOD leaders and then sustained by financial market enthusiasm, the 1990s saw a great consolidation of the defense/aerospace industry. With the defense industry consolidations of the 1990s, all existing launcher production fell under just two firms, Boeing and Lockheed Martin (LM).

Although the plan had been to down-select to just one line of launch vehicles for EELV, in 1997 it was decided to select two, one for each contractor. As explained in the initial SAR

> A new acquisition strategy for EELV was approved by USD(A&T) on November 3, 1997. The previous strategy was to award a development contract and a launch services contract to only one EELV contractor. The new approach allows two contractors to enter the Engineering and Manufacturing Development (EMD)/Initial Launch Services (ILS) phase. The strategy also maintains competition throughout the life of the program, leverages the growing commercial launch market, caps the Government's EMD costs, allows partnering with industry, while still reducing the Government's overall cost to launch the National Mission Model (NMM) by at least 25% over existing systems.[19]

Note that this decision plans to achieve cost avoidance, in accordance with the principles of CAIV, almost entirely via competition between the two contractors, and with other providers. As the then-program manager explained in 2002,

> DOD benefited from the opportunity to retain two proven launch service providers for less than the price of one, captured over $500 million in immediate development cost savings, and leveraged the commercial satellite market to reduce overall program risk. Industry would now fund the additional $3 billion required to bring both systems to market; and if market conditions turned and one EELV provider exited, DOD would be no worse off than if it had stayed with the original down-select strategy. DOD also benefited significantly from the commercial satellite industry's mounting demand for launch services. Viewed as EELV's silent "third partner," the satellite industry's demand for reliable space lift and willingness to "jump" from one launch service provider to another in the event of a launch failure have made reliability a program touchstone.[20]

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18 John Burgess, "American Industry Is Falling Behind in the Space Race," *New York Times*, 22 Feb 1994.

19 SAR as of 31 Dec 1997, 5.

20 R. K. Saxer et al., "Evolved Expendable Launch Vehicle System: The Next Step in Affordable Space Transportation," *Program Manager* 31, no. 2 (March-April 2002): 2–15, 6.

The government paid a total of $1 billion toward development of the new LVs, with Lockheed Martin investing $1.6 billion and Boeing $2.3 billion.[21] Of course the contractors have recovered a substantial portion of this investment through overhead charges on government business, but it, nevertheless, is a strong indication of the confidence they then felt in the commercial market prospects.

Development of the evolved Atlas (LM) and Delta (Boeing) proceeded without unusual problems and the LVs met their performance goals. There were no test flights—all launches have carried actual payloads—and this has prevented formal demonstration of performance, but the in-service reliability record of the LVs has been very favorable. Thus the program has succeeded in providing reliable operational launch capabilities, although no more reliable than those provided by some commercial services such as Europe's Arianespace.

In explaining the program strategy in a 2002 article, the program manager for EELV stressed CAIV and its benefits:

> The single most important tool within the EELV "system of systems" design trade-space is Cost As an Independent Variable (CAIV). Both EELV contractors have made CAIV an integral part of all EELV system design, development, production, and operations activities since program inception. CAIV is a powerful tool, providing for the establishment of aggressive, realistic cost objectives and the equally aggressive management of all associated risks. The emphasis on CAIV is the major reason why EELV has been able to achieve its substantial life cycle cost-reduction goals and better position the U.S. commercial launch industry to be more competitive in the international marketplace.[22]

Despite this impressive endorsement of CAIV, at that time the program was collecting and evaluating little data on contractor performance. In particular, it did not require the contractors to maintain a government certified earned value management (EVM) system, relying instead on their own internal management systems. The program office had access to the relevant contractor internal data, but lacked the personnel to adequately keep track of it or to analyze its implications.[23] Thus it is clear that the program was relying primarily on competitive pressures for cost control. This was consistent with the general thrust of the acquisition reform policies that were instituted in the 1990s, and particularly as they were applied to National Security Space (NSS) programs.

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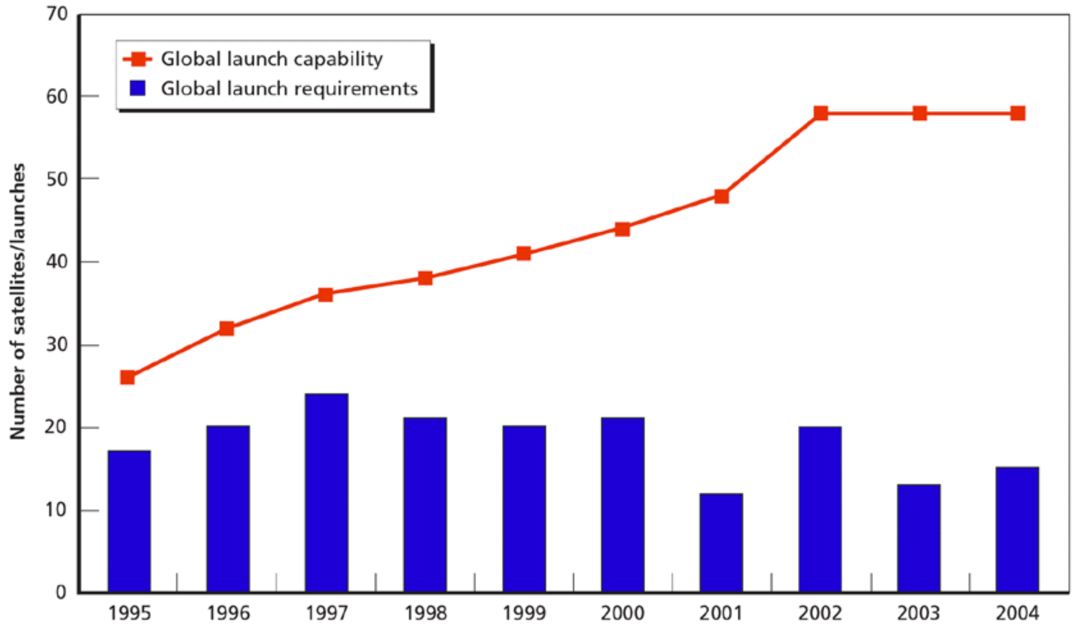
21 Congressionally Mandated National Security Space Launch Requirements Panel, *National Security Space Launch Report*, MG-503-OSD (Santa Monica, CA: RAND National Defense Research Institute, 16 Aug 2006), 28–29.

22 Saxer et al., "Evolved Expendable Launch Vehicle System," 4.

23 U.S. Government Accountability Office (GAO), *Space Acquisitions: Uncertainties in the Evolved Expendable Launch Vehicle Program Pose Management and Oversight Challenges*, GAO-08-1039 (Washington, DC: GAO, Sep 2008), 23.

Figure A-9 shows how hopes of major cost sharing through commercial launch business were doomed by market forces. This chart refers specifically to the economically dominant GEO market segment but trends in the low-earth orbit (LEO) segment were broadly similar. The boom that had been so confidently forecast in the latter half of the 1990s had prompted a great expansion of worldwide launch capacity, with many providers benefitting from subsidies from governments eager to enter or remain in this prestigious and strategically critical business. But the boom itself failed to materialize, leaving a large and widening gap between demand and supply, leading naturally to falling prices. Although it could not be fully commoditized, space launch became much more competitive, and both LM and Boeing were at a disadvantage relative to foreign, state-subsidized competitors, and their DOD partner with them.



SOURCE: David Cavossa, Satellite Industries Association, "'State of the Satellite Industry' Report," briefing to the Panel, September 14, 2005.
RAND *MG503-4.1*

Figure A-9. A Growing Gap between Demand and Supply for Space Launches

Of course if improved versions of the Atlas and Delta LVs had not been developed under EELV, the legacy designs would have been that much less competitive than the new versions. In May 2004 the EELV Program Office estimated that the program, with all its problems, had, nevertheless, saved over 50 percent relative to retaining the heritage LVs in service. In its review of the program, the Government Accountability Office (GAO) noted that it was unable to verify these savings, but did not directly challenge them.[24]

[24] GAO, *Defense Space Activities: Continuation of Evolved Expendable Launch Vehicle Program's Progress to Date Subject to Some Uncertainty*, GAO-04-778R (Washington, DC: GAO, 24 Jun 2004), 5.

In any event, in 2004 the program recognized large increases in PAUC and APUC compared with the APB, as can be seen in Figure A-10. The lack of detailed cost reporting made it more difficult to be certain of the origins of this growth, but the program office attributed well over half of it to lack of commercial sales. Other significant factors (mostly outside the control of the program office) included satellite weight growth requiring the use of larger LV variants as well as steps that had been taken to improve assurance of successful launch in light of a series of costly failures of earlier LVs in the late 1990s. The cost growth occasioned a Nunn-McCurdy breach report, with recertification completed on 26 April 2004.[25]

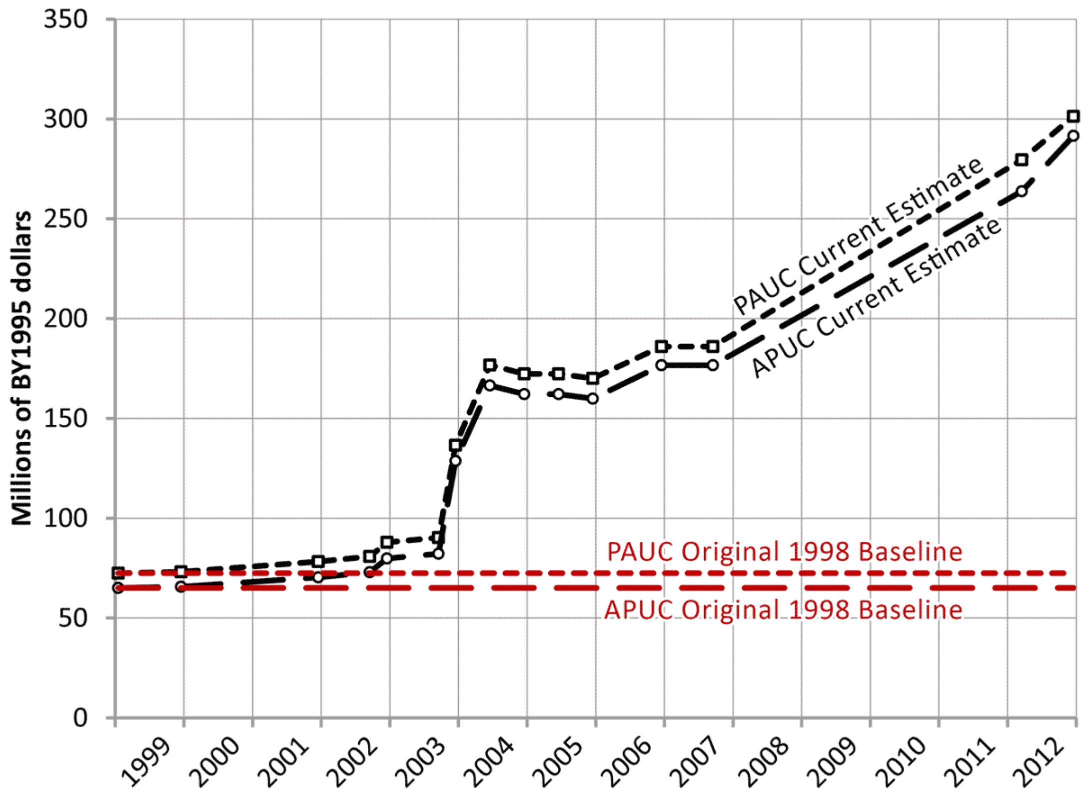


Figure A-10. EELV Unit Cost History

Another factor that increased costs and was a great complication in the program was the 2003 discovery that Boeing had 42,000 pages of Lockheed Martin documents on the Atlas V, obtained through industrial espionage, allegedly with the collusion of USAF officials.[26] The government suspended Boeing from bidding on launcher contracts—but then made exceptions. LM sued and it was claimed that the legal battles could severely disrupt LV procurement.

In 2005, while the legal struggle was in progress, Boeing and Lockheed Martin agreed to form a joint venture, to be known as United Launch Alliance (ULA) that would pool all the

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[25] Ibid., 7–9.

[26] Peter Pae, "Boeing's Misconduct is Detailed in Memo," *Los Angeles Times*, April 23, 2004, C.1.

operations to support the EELV program. (Commercial business, of which there continues to be very little, remained the responsibility of the parent companies.) The firms and DOD said they envisioned substantial savings from consolidation, but the Federal Trade Commission (FTC) opposed the arrangement, seeing it as a monopoly that would have the usual defects of monopolies. DOD said it was justified by military necessity and the FTC gave way. As part of the deal, LM dropped its legal action against Boeing. The new venture became operational in late 2006.[27]

As with JASSM and SBIRS, the USAF pursued acquisition reform with particular vigor in NSS programs, and the results have all been disappointing. Late in 2004 a revision to the *Guidance for DOD Space System Acquisition Process*[28] substantially tightened the process. However, in negotiating the 2005 contracts requirements for certified cost or pricing data were waived.[29] (This appears to have been based on confidence that the program office understood the contractors' cost structure adequately without such data.) In any event, the program office lacked the resources to adequately review and analyze any additional cost information. Efforts to strengthen this capability were stymied by the effects of Service-wide personnel cuts intended to reduce overall USAF costs.[30]

In August 2007 the EELV program was removed from the MDAP category I and transitioned to "sustainment status."[31] Office of the Secretary of Defense (OSD) officials told GAO auditors that the move was impelled by further cost growth that would soon have required a Nunn-McCurdy breach report. By moving to sustainment status the need to report the breach and go through the recertification process was avoided. Moreover, it appears that EELV received a waiver from the requirement to submit EVM and other cost and performance reporting, thus reducing contract costs by eliminating the effort required to gather and report the data.[32]

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27 Renae Merle, "Rocket Monopoly Approved; Boeing-Lockheed Alliance Likely to Increase Costs," *Washington Post*, 4 Oct 2006, D.1.

28 DOD, *Guidance for DOD Space System Acquisition Process*. National Security Space Acquisition Policy No. 03-01 (Washington, DC: DOD, 27 Dec 2004).

29 GAO, *Evolved Expendable Launch Vehicle: DOD Is Addressing Knowledge Gaps in Its New Acquisition Strategy*, GAO-12-822 (Washington, DC: GAO, 13 Aug 2012), 4.

30 GAO report *Space Acquisitions: Uncertainties in the Evolved Expendable Launch Vehicle Program Pose Management and Oversight Challenges* states, "In addition, the EELV program office believes a shortage of staff with the right skills and experience is limiting its ability to effectively manage the program. Air Force staffing initiatives have done little to alleviate this shortage." GAO, *Space Acquisitions*, GAO-08-1039, 23–32.

31 The executive summary of the March 2007 exception SAR states: "The approved APB places the EELV program into sustainment and therefore EELV is no longer an active Major Defense Acquisition Program (MDAP).This will be the final SAR submission for this program." The requirement for SAR reporting is in section 2432 of Title 10 of the U.S. Code. According to that section, SAR reporting only terminates when 90 percent of the deliveries have been made or 90 percent of the planned funds spent. The March 2007 SAR reports that only 6 percent of deliveries had occurred and 16 percent of planned funds spent.

32 GAO report *Space Acquisitions: Uncertainties in the Evolved Expendable Launch Vehicle Program Pose Management and Oversight Challenges* states, "However, according to OSD officials, the sustainment decision may have been influenced by other factors such as avoiding imminent Nunn-McCurdy unit cost breaches and

At this point the competitive strategies that DOD had relied upon to control EELV costs were in ruins. In principle Boeing and LM were still offering launch services to commercial customers, but neither firm was actively marketing them and few customers were seeking them. Indeed, Boeing was the largest single partner in a firm offering launch services using Russian/Ukrainian LVs launched from a sea-based platform that competed with its own Delta LVs.

With little prospect of commercial business, Boeing and LM had no incentive to compete with one another for EELV business unless somehow forced to do so. But DOD had acquiesced in the formation of their joint venture, ULA, making inter-firm competition essentially a dead issue.

In effect, the EELV program was back in the traditional (for DOD) acquisition relationship of a single buyer and sole supplier. In search of lower cost it now turned to what in effect was a strategy of multi-year procurement, envisioning a five-year contract with ULA for production of eight LV booster cores per year, notionally split evenly between Atlas and Deltas.[33] Congress has traditionally cast a skeptical eye on such arrangements, and the proposal led to unwelcome attention from Capitol Hill.

The Defense Contract Audit Agency (DCAA) complained that there was nothing to audit because the EELV program generated so little cost and performance data, leading to GAO concerns that the USAF was preparing to give ULA a blank check. There was also concern that there was no guarantee that the number of satellites to be launched might not increase enough to absorb eight booster cores per year.[34] Over the following year, however, the Program Office implemented the multi-year recommendations well enough to mollify the GAO.[35]

In March 2012, EELV was reinstated as an MDAP with SAR reporting requirements.[36] Since cost growth had exceeded thresholds, a critical Nunn-McCurdy breach was reported. Cost and performance reporting was strengthened and EVM required.

In an ADM dated 27 November 2012 the DAE authorized procurement of up to fifty booster cores over five years, with up to thirty-six to be procured as a block from ULA. The

possible subsequent certification efforts that invariably would have led to decisions to continue DOD's investment in the EELV program. According to these officials, in 2006 the program was facing one or more possible Nunn-McCurdy unit cost breaches, as a result of unplanned cost increases resulting from the change in the acquisition strategy and a decrease in the demand for EELV launches (factors include satellite program development delays and cancellations, and operational satellites lasting longer than anticipated)." GAO, *Space Acquisitions,* GAO-08-1039, 20–21.

33 A light or medium launch requires one booster core, a heavy launch requires three.

34 GAO, *Evolved Expendable Launch Vehicle: DOD Needs to Ensure New Acquisition Strategy Is Based on Sufficient Information*, GAO-11-641 (Washington, DC: GAO, 15 September 2011).

35 GAO, *Evolved Expendable Launch Vehicle,* GAO-12-822.

36 Research conducted for this paper has been unable to determine, without more extensive investigation, the events or decisions that led to this action.

other fourteen are to be open to competition. The competition is the Falcon 9 developed and produced by Space Exploration Technologies Corp. (SpaceX), and Orbital Sciences Corp.'s Antares. Both SpaceX and Orbital Sciences are commercial launch providers that have developed their LVs on their own. They claim to be able to offer prices substantially below those of ULA. News reports indicate that the USAF has begun the process of certifying both companies to compete for LV core contracts.

What can be said of a CAIV program that has so far had more than 300 percent growth in PAUC? It appears that the EELV program's commitment to treating cost as an independent variable was never more than boiler-plate. The size mix of boosters needed was and is determined by the payloads to be placed in orbit, which is completely outside the control of the program. The key performance parameter is launch reliability, and it makes no sense to compromise on reliability and risk destruction of expensive payloads that might be critical to national security. Thus, there was virtually no room for significant cost-performance tradeoffs.

In light of these facts, the decision to designate EELV as a flagship program seems questionable. By claiming a commitment to hold the line on costs in a program wherein making meaningful performance trades was not a realistic possibility, DOD undercut the credibility of CAIV as an instrument for cost control in general, with no compensating advantages.

CAIV aside, it can be concluded that DOD proceeded unwisely in its cost-control strategies for EELV. In the context of expert predictions in the late 1990s of a greatly expanded market for launch services, it was reasonable to attempt to leverage the commercial market to increase LV volume and thus cut costs. What was unreasonable was to count on it without analyzing the risks and without putting a credible fallback strategy in place. By 2000 it was clear that the expanding commercial market was a chimera, yet EELV was locked into commercial competition as its sole hope. It is not known what viable fallback strategies might have existed, but to have failed to recognize that one might be needed and to search for them, diligently and imaginatively, was imprudent.

K. Crusader

Crusader was an Army program to develop a new, highly automated 155mm self-propelled howitzer. The program entered the PDRR acquisition phase (now known as the Technology Maturation and Risk Reduction phase) in 1994. Crusader consists of an armored, self-propelled howitzer and an armored resupply vehicle. The objective was an artillery system with increased range and survivability with autonomous operations. Compared to existing howitzers, Crusader was to provide increased rate-of-fire, hold more ammunition, be more responsive and survivable on the battlefield, with reduced manpower requirements; provide increased lethality; be deployable worldwide; and provide forward maintenance and employ future maintenance concepts. The ADM directed the Army to plan for a Milestone II Defense Acquisition Board (DAB) or equivalent review, incorporating as many acquisition reform measures as practical.

The PDRR program underwent two major restructurings. The first, in March 1996, changed the armament system from a liquid propellant-based system to a solid propellant-based system to reduce development risk. The second, in 1999, was to align the program with the Army's then-current vision for more deployable forces, consistent with initiation of the Future Combat System program. This required Crusader to increase deployability while retaining all key performance parameters, by reducing weight and volume so that two Crusader vehicles could be deployed on a single C-5B aircraft. This required a drastic redesign, requiring almost $1 billion additional funds for the development program.

After the September 11, 2001 attack and subsequent military engagement in Afghanistan, a new howitzer seemed less of a priority. Furthermore, other alternatives to achieve higher lethality in indirect fire (namely high rate-of-fire rocket systems and guided munitions) could be obtained far cheaper than Crusader, and Crusader's survivability improvement seemed less important in the type of conflicts envisioned, at least in the near term. Such considerations led Secretary Rumsfeld to cancel Crusader in May 2002.[37]

In 1996, the Army named Crusader (along with ATAMCS/BAT) a CAIV flagship program. The December 1998 SAR reflected the program's status as a CAIV flagship, including the following paragraph in the Executive Summary section:

> Crusader continued to apply the concepts of Cost as an Independent Variable (CAIV), which have had a significant impact on program cost estimates. To date, the CAIV efforts on Crusader resulted in attaining 35% of the Design-To-Unit-Rollaway-Costs (DTURC) reduction goal. Additional cost reduction initiatives continue to be identified. There are currently over 100 initiatives in various stages of evaluation. The initiatives have the potential to further reduce cost resulting in a high level of confidence in meeting Crusader's DTURC goal. Intensive management efforts this year have resulted in (a) defining the peacetime OPTEMPO levels that represent significant reductions from the current system, (b) building a Crusader battalion that reflects significant reductions in personnel, and (c) utilizing an Auxiliary Power Unit in lieu of the main engine resulting in reduced fuel usage and maintenance. These results are all indicative of a proactive process whereby cost is a key criterion in all design and programmatic decisions.

This, on its face, appears to reflect a serious effort to control and reduce costs, both procurement and sustainment. (No statement of this nature appears in the subsequent SARs.) However, the statement is somewhat misleading because the 35 percent cost reduction cited occurred well before designation of the program as a CAIV flagship.[38] Unfortunately the

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[37] Prepared Statement of the Honorable Donald H. Rumsfeld, Secretary of Defense, on the Crusader Recommendation before the Senate Committee on Armed Services, May 16, 2002.

[38] The IDA research team knows this because the 1998 IDA publication on the CAIV flagships states that the 35 percent reduction occurred "prior to Milestone I," which was in November 1994, well before the CAIV initiative. Danny L. Reed, *Report on the 1996–1997 Workshops on Cost As an Independent Variable (CAIV) Flagship Programs*, IDA Document D-2251 (Alexandria, VA: February 1998).

program's termination eliminated the possibility of determining the ultimate level of success in reducing production costs.[39]

Comparing the costs from the earliest available SAR to the last one indicates modest growth in the production estimate costs (see Table A-8).

Table A-8. Procurement Cost Estimates for Crusader from the SAR Acquisition Program Baselines (FY1995 $ million)

				Unit Cost		Qty.-Adjusted Unit Cost	
Date	**Objective**	**Threshold**	**Qty.**	**Objective**	**Threshold**	**Objective**	**Threshold**
1/4/1995	8868.2	9311.6	824	10.8	11.3	10.8	11.3
10/23/1997	8754.2	9191.9	815	10.7	11.3	10.8	11.3
12/18/2000	5430.5	5702.0	471	11.5	12.1	11.3	11.9
Change from 1995 to 2000						5.3%	5.3%

These costs are reasonably consistent with those in a briefing by the OSD Office of Program Analysis and Evaluation dated April, 2002. The unit cost from that briefing is $14.7 million, given in then-year dollars. An approximate conversion to FY 1995 dollars yields an estimate of $11.2 million. Thus, it appears that there was little or no growth in estimated procurement costs for Crusader between 1995 and 2002. If these estimates are correct, they would presumably indicate some success in controlling procurement costs (if not achieving a stated CAIV goal of a 25–50 percent reduction). That presumption, however, should be tempered by the fact that the program never reached Milestone II. Therefore, an independent cost estimate based on the design that would actually enter the EMD phase was never made.[40] It is more than conceivable that the cost of such a design would have been substantially higher than the PDRR estimate.

L. ATACMS/BAT

The second Army program nominated as a CAIV flagship was ATACMS/BAT. This program met much the same fate a Crusader, having been cancelled, this time by the Army, in late 2003. Unlike Crusader, the program was well into full-scale development, in fact in low-rate initial production (LRIP), prior to its designation as a CAIV flagship. Also unlike Crusader, no recognition of the program as a CAIV flagship is found in any of the SARs.

The "Brilliant Anti-Tank" or BAT is a submunition originally designed to be delivered by the TSSAM. The Army withdrew from that program in 1993, and in 1994 the entire TSSAM

39 Production cost estimates prior to the beginning of full-scale development are subject to a large margin of error, since there is yet no producible design on which to base a constructive estimate.

40 The last SAR in December 2000 indicated a Milestone II (equivalent to today's Milestone B) in April 2003.

program was cancelled, due primarily to cost overruns. After the Army's withdrawal from TSSAM, the BAT was modified to be delivered by the Army Tactical Missile System (ATACMS). The program passed Milestone II in May 1991.

BAT suffered a long and turbulent development program, plagued by test failures of the highly ambitious seeker, which was designed to automatically acquire and guide the missile to home on vehicular targets moving on the battlefield. Soon after entry into LRIP, the program was cancelled. Thus, unlike Crusader, there is some data on production costs. Since the available SAR database from the Defense Acquisition Management Information Retrieval System (DAMIR) only goes back to 1997, the IDA research team could not obtain cost data from Milestone II. However, since its designation as a CAIV flagship occurred in 1996, cost experience since 1997 is applicable to the evaluation of the program as a CAIV initiative.

Table A-9 provides the record of ATACMS/BAT PAUC and APUC from the SARs. In the December 2004 SAR, the quantity was essentially reduced to those that had been procured at the time of program cancellation. Even discounting the last entry, it can be seen that by 1999 APUC had grown by 64 percent (119,000/19,700) over the December 1997 SAR figure.

Table A-9. ATACMS/BAT Unit Cost History from SARs (FY 1991$)

SAR Date	PAUC	APUC	Quantity	Percent Change in APUC	Percent Change in Quantity	Quantity-Adjusted APUC	Quantity-Adjusted % Change in APUC
Dec 1997	$135,000	$72,000	19,700			$72,000	
Dec 1998	$154,000	$87,000	19,554	21%	-1%	$86,935	21%
Dec 1999	$203,000	$119,000	15,707	37%	-19%	$116,421	34%
Dec 2001	$221,000	$118,000	16,089	-1%	10%	$118,284	2%
Dec 2002	$1,232,000	$247,000	1,262	109%	-92%	$191,492	62%
Percent Change in APUC from Original Estimate							166%

The available evidence suggests that, if any CAIV-related activities took place in the ATACMS/BAT program, they were not successful. That said, it can further be observed that, while the SARs document cost growth, they are widely recognized as inadequate in providing explanations of the causes of cost growth. Although categorizations of and reasons for cost changes are nominally included in the "Cost Variance" section of the SAR, it is widely recognized that the SAR categorizations suffer from inconsistencies and ambiguities.[41] The explanations of procurement cost growth in the ATACMS/BAT SARs are no exception. For

41 Joseph G. Bolten, Robert S. Leonard, Mark V. Arena, Obaid Younossi, and Jerry M. Sollinger. *Sources of Weapon System Cost Growth: Analysis of 35 Major Defense Acquisition Programs* (Santa Monica, CA: RAND Corporation, 2008). Available on RAND's website at http://www.rand.org/pubs/monographs/2008/RAND_MG670.pdf.

example, for the two largest procurement cost increases, occurring in the December 1998 and December 1999 SARs, the following explanations are offered in the Cost Variance sections:

> Dec-98:
>
> Change in learning curve assumptions due to re-phasing of annual buy. (Estimating) +$21.1 million
>
> Refinement of estimate to reflect BAT hardware updates. (Estimating) +$83.7 million
>
> Refinement of estimate to reflect P3I BAT hardware updates. (Estimating) +$118.5 million
>
> Refinement of estimate due to BAT/P3I BAT program restructure. (Estimating) +$63.3 million
>
> Dec-99:
>
> Revised estimate for inclusion of submunition budget for Block IIA. (Estimating) +$218.5 million
>
> Revised estimate to reflect negotiated cost of production contract. (Estimating) +$157.7 million

Sources: DOD, SAR RCS: DD-A&T(Q&A)823-545 "ATACMS-BAT" (Washington, DC: DOD, December 1998), 44 and (December 1999), 42.

Figure A-11. SAR Explanations for Two Largest ATACMS/BAT Cost Increases

With the exception of the first, these *explanation*s are opaque as to the underlying causes.

This cursory analysis indicates that either there was no real effort to implement CAIV (suspected) or that if there was, it was unsuccessful. In the latter case, the reasons cannot be determined without access to and analysis of more detailed historical records of the program. Obviously, the program presented serious technological challenges (as evidenced by the repeated test failures), and for that reason alone, was probably not a good choice for a CAIV flagship.

Appendix B
Illustrations

Figures

Tables

Appendix C
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Appendix D
Abbreviations

AAAV	Advanced Amphibious Assault Vehicle
ACV	Amphibious Combat Vehicle
ADM	Acquisition Decision Memorandum
AFCAIG	Air Force Cost Analysis Improvement Group
AMPV	Armored Multi-Purpose Vehicle
AoA	Analysis of Alternatives
APB	Acquisition Program Baseline
APUC	Average Unit Procurement Cost
ASD	Assistant Secretary of Defense
AT&L	Acquisition, Technology and Logistics
ATACMS/BAT	Army Tactical Missile System/ Brilliant Anti-Tank
BAT	Brilliant Anti-Tank
BBP	Better Buying Power
BY	Base Year
CAIG	Cost Analysis Improvement Group
CAIV	Cost as an Independent Variable
CAPE	Cost Assessment and Program Evaluation
CARD	Cost Analysis Requirements Description
CCDR	Combatant Commander
CD	Concept Definition
CDD	Capability Development Document
CER	Cost Estimating Relationship
CMC	Commandant of the Marine Corps
CNO	Chief of Naval Operations
CPIPT	Cost/Performance Integrated Product Team
CSB	Configuration Steering Board
CTOL	Conventional Takeoff and Landing
DAB	Defense Acquisition Board
DAE	Defense Acquisition Executive
DAES	Defense Acquisition Executive Summary

DAMIR	Defense Acquisition Management Information Retrieval System
DAPP	Defense Acquisition Pilot Project
DCAA	Defense Contract Audit Agency
DCAPE	Director, Cost Assessment and Program Evaluation
DCP	Decision Coordinating Paper
DDR&E	Director, Defense Research and Engineering
DOD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DSP	Defense Support Program
DTC	Design to Cost
DTURC	Designed-to-Unit-Rollaway Cost
EELV	Evolved Expendable Launch Vehicle
EFV	Expeditionary Fighting Vehicle
EMD	Engineering and Manufacturing Development
ER	Extended Range
EVM	Earned Value Management
FCS	Future Combat System
FoV	Family of Vehicles
FPP	Flagship Pilot Program
FSD	Full-scale Development
FTC	Federal Trade Commission
FY	Fiscal Year
GAO	U.S. Government Accountability Office
GCV	Ground Combat Vehicle
GEO	Geosynchronous Earth Orbit
HEO	Highly Elliptical Orbit
HMDS	Helmet-Mounted Display System
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
ICE	Independent Cost Estimate
IDA	Institute for Defense Analyses
ILS	Initial Launch Services
IPT	Integrated Product Team
IR	Infrared
JASSM	Joint Air-to-Surface Standoff Missile

JCIDS	Joint Capabilities Integration and Development System
JDAM	Joint Direct Attack Munition
JORD	Joint Operational Requirements Document
JSF	Joint Strike Fighter
JTRS	Joint Tactical Radio System
KPP	Key Performance Parameter
KSA	Key System Attribute
L&MR	Logistics & and Materiel Readiness
LCC	Life-Cycle Cost
LCS	Littoral Combat Ship
LEO	Low-earth Orbit
LM	Lockheed Martin
LOAL	Lock-on-After-Launch
LRIP	Low-rate Initial Production
LUH	Light Utility Helicopter
LV	Launch Vehicle
LVT	Low Volume Terminal
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MDD	Material Development Decision
MIDS	Multifunctional Information Distribution System
MILCON	Military Construction
MS	Milestone
MSA	Material Solution Analysis
NASA	National Aeronautics and Space Administration
NMM	National Mission Model
NRO	National Reconnaissance Office
NSS	National Security Space
O&M	Operations and Maintenance
O&S	Operating and Support
OCO	Overseas Contingency Operation
ODCAPE	Office of the Director of Cost Assessment and Program Evaluation
OMB	Office of Management and Budget
OPTEMPO	Operating Tempo
OSD	Office of the Secretary of Defense

OSMIS	Operating and Support Management Information System
OT&E	Operational Test and Evaluation
OUSD(AT&L)	Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics
PA&E	Program Analysis and Evaluation
PARCA	Office of Performance Assessments and Root Cause Analyses
PAUC	Program Acquisition Unit Cost
PDRR	Program Definition and Risk Reduction
PM	Program Manager
POM	Program Objective Memorandum
PPBS	Planning, Programming and Budgeting System
R&D	Research and Development
R&M	Reliability and Maintainability
RAM-C	Reliability, Availability, Maintainability, and Cost Rationale
RDT&E	Research, Development, Test and Evaluation
RFP	Request for Proposal
ROI	Return on Investment
ROM	Rough Order of Magnitude
SAF/AQ	Office of the Secretary of the Air Force for Acquisition
SAR	Selected Acquisition Report
SBIRS	Space-Based Infrared System
SDD	System Development and Demonstration
SECDEF	Secretary of Defense
SLEP	Service-Life Extension Program
SRM	Short Range Missile
STOVL	Short Takeoff Vertical Landing
TMRR	Technology Maturation and Risk Reduction
TOA	Total Obligation Authority
TPP	Total Package Procurement
TSPR	Total Systems Performance Responsibility
TSSAM	Tri-Service Standoff Attack Missile
ULA	United Launch Alliance
URF	Unit Recurring Flyaway
USAF	United States Air Force
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics

USD (C)	Under Secretary of Defense (Comptroller)
USMC	United States Marine Corps
USN	United States Navy
VAMOSC	Visibility and Management of Operating and Support Cost
VECP	Value Engineering Change Proposal
VLO	Very Low Observable
WIN-T	Warfighter Information Network—Tactical

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. REPORT DATE (DD-MM-YY) March 2014	2. REPORT TYPE Final	3. DATES COVERED (From – To)

4. TITLE AND SUBTITLE Implementing Effective Affordability Constraints for Defense Acquisition Programs	5a. CONTRACT NO. DASW01-04-C-0003 5b. GRANT NO. 5c. PROGRAM ELEMENT NO(S).
6. AUTHOR(S) R. Royce Kneece, Jr., John E. MacCarthy, Jay Mandelbaum, William D. O'Neil, Gene H. Porter	5d. PROJECT NO. 5e. TASK NO. AO-6-3631 5f. WORK UNIT NO.
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institute for Defense Analyses 4850 Mark Center Drive Alexandria, VA 22311-1882	8. PERFORMING ORGANIZATION REPORT NO. IDA Paper P-5123
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of the Under Secretary of Defense Acquisition, Technology and Logistics Pentagon Washington, DC 20301	10. SPONSOR'S / MONITOR'S ACRONYM(S) OUSD(AT&L) 11. SPONSOR'S / MONITOR'S REPORT NO(S).

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Assuring affordability for Department of Defense (DOD) acquisition programs has been an enduring goal that has seldom been reached. The consequences are cancellation or down-scaling of unaffordable programs with much attendant waste. Building on previous IDA work, this research focuses on implementing the "Better Buying Power" initiatives of the Under Secretary Defense for Acquisition, Technology, and Logistics regarding affordability. Efforts to control acquisition program affordability in DOD are not new. Two initiatives of the past, Design to Cost (DTC) and Cost as an Independent Variable (CAIV), were both similar in many ways to current efforts to implement affordability constraints; however, there are also key differences. Using historical data and previous IDA analyses, this research drew on the lessons learned from these past experiences that are applicable today. The second topic addressed is implementing affordability constraints for operating and support (O&S) costs. O&S costs are more difficult to control because they are more difficult to estimate accurately during system development and their impacts begin later. The key finding of the research is that past failures to control costs, both in investment and in O&S, resulted primarily from lack of persistent and rigorous enforcement of policies by DOD acquisition management.

15. SUBJECT TERMS

Affordability, long-term investment planning, operating and support costs

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NO. OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE	UU	124	19b. TELEPHONE NUMBER (Include Area Code)
U	U	U			