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Post-Milestone B Funding Climate and Cost Growth in Major Defense Acquisition Programs

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Post-Milestone B Funding Climate and Cost Growth in Major Defense Acquisition Programs

David L. McNicol

Executive Summary

Motivation

This paper examines whether Major Defense Acquisition Programs (MDAPs) that entered a boom climate for procurement funding some time after passing Milestone (MS) B on average had higher unit cost growth than programs whose acquisition cycles did not extend into a boom climate. While this conjecture seems plausible, possibly even obviously correct, it has not been recognized in the cost growth literature.

The topic is worth pursuing because it bears on why unit cost growth was significantly higher for MDAPs that passed MS B in bust periods than it was for those that passed in boom periods. This observation was reported by the first paper in this series, hereafter P-5126.[1] The explanation offered there was a version of the "camel's nose" hypothesis—that unrealistic cost, programmatic, and technological assumptions are made in the hope that, by making the program appear to be lower in cost or more capable, they will increase the odds that the program will be successful in competition for funds. P-5126 goes further by suggesting that the incentives for adopting very optimistic assumptions are stronger for programs that pass MS B in bust funding climates than they are for programs that pass in boom periods, and that, consequently, unrealistic MS B baselines are more common in programs that passed MS B in bust climates.

For present purposes, the key point to note is that the explanation offered by P-5126 supposes that most of the growth in unit cost shown by programs that pass MS B in a bust funding climate is "baked into" the baselines established at MS B. There are other possibilities, however, one of which is that a significant part of these programs' cost growth might be due to increases in program content made during a post-MS B boom climate when funding is more readily available. To the extent that is the case, we may be mistaking the costs of decisions to improve the capabilities of an existing system for growth in the costs of acquiring the capabilities specified in the MS B baseline.

Approach

The most analytically satisfactory approach to exploring the existence and character of boom effects would be to look in detail at content changes for programs that did and

[1] David L. McNicol and Linda Wu, "Evidence on the Effect of DoD Acquisition Policy and Process on Cost Growth of Major Defense Acquisition Programs," IDA Paper P-5126 (Alexandria, VA: Institute for Defense Analyses, September 2014), 5.

did not experience a boom funding climate after passing MS B. That would require far more resources than were available for this paper, however. Instead, this paper uses a statistical approach that relies on data that are comparatively easy to acquire and natural experiments present in the historical record.

In the language of medical testing, the plan is to compare unit cost growth for a treatment group—programs that experienced a boom climate post MS B—with that of a control group—programs that did not. The measure of cost used is Program Acquisition Unit Cost (PAUC). PAUC growth is computed by comparing the MS B baseline value for PAUC—which can be thought of as a goal or a prediction—to the actual PAUC reported in the final Selected Acquisition Report (SAR) for the program, normalized to the MS B quantity. Both the MS B value and the actual value of PAUC are stated in constant dollars.[2] In what follows, *PAUC growth* means PAUC growth normalized to the MS B quantity. Note that we do not normalize PAUC growth for any changes in the capabilities that the program acquires.

We first compare the average of PAUC growth for MDAPs that passed MS B in bust climates and did not continue into a subsequent boom with the average for MDAPs that passed MS B in a bust climate and went on into a boom climate. The control group in this scenario is programs that passed MS B in a bust period but were completed before the subsequent boom period. A second natural experiment is provided by programs that passed MS B during the boom of the early to mid-1980s and were still underway in the post-9/11 boom.

The analysis takes account of two other factors that may systematically influence average PAUC growth over a period of years. The first of these is acquisition policy and process. The paper employs three acquisition policy and process bins:

- McNamara-Clifford (Fiscal Year (FY) 1964–FY 1969)
- Defense Systems Acquisition Review Council/Defense Acquisition Board (DSARC/DAB, FY 1970–FY 1993 and FY 2003–FY 2007)
- Acquisition Reform (AR, FY 1994–FY 2002)

McNamara-Clifford and AR are statistically similar to each other but statistically different from DSARC/DAB.[3] The text of the paper considers the DSARC/DAB period, which includes two separate bust periods and two boom periods. Appendix C provides the sparse results obtained for McNamara-Clifford and AR.

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2 See Appendix B; pages B-5 through B-9 explain the PAUC growth estimates used in this paper.

3 See David L. McNicol et al., "Further Evidence on the Effect of Acquisition Policy on Cost Growth of Major Defense Acquisition Programs," IDA Paper P-5330 (Revised) (Alexandria, VA: Institute for Defense Analyses, August 2016).

The second factor considered is program duration. Not surprisingly, programs that fall into the treatment groups—i.e., those that passed into a boom period post MS B—had considerably longer durations on average than did programs in the control groups. Consequently, we need to examine the extent to which the longer average duration of programs, as well as an encounter with a boom funding climate, accounts for their higher PAUC growth. This was done for programs that passed MS B in bust periods by estimating a model that includes two explanatory variables: (1) the number of years that the program spent in boom climates post MS B; and (2) the number of years the program spent in bust climates. A similar model was estimated for programs that passed MS B during one of the boom periods. This paper finds that for MDAPs that passed MS B in bust climates, PAUC increases by about 1.6 percent for each year the program spends in a bust climate and by about 5 percent for each year spent in a boom climate post MS B.

Conclusions and Limitations

This paper, like earlier papers in the series, observes that PAUC growth measured from MS B is significantly higher in programs that passed MS B in bust climates than in boom climates. Moreover, among MDAPs that passed MS B in a bust phase of DSARC/DAB, only those that continued into a boom climate showed PAUC growth significantly higher than that of programs that passed MS B in a boom climate. This conclusion is important because it implies that much of the observed PAUC growth may have causes other than flaws in MS B baselines.

The conclusion tells us less than might be hoped, however. This is so because the PAUC growth associated with the boom may reflect purchase of capability beyond that specified in the MS B baseline or, alternatively, PAUC increases that occur when programs take advantage of a boom climate to "get well."

The average PAUC growth of all programs in DSARC/DAB that passed MS B in bust climates is 38 percent. Without making a specific estimate, P-5126 suggested that most of this PAUC growth stemmed from flawed MS B baselines. If all of the unit cost growth is actually a matter of "getting well," the PAUC growth due to flawed MS B baseline problems remains at 38 percent. It is less than 38 percent to the extent that PAUC growth for MDAPs that passed MS B in bust periods and continued into a boom period acquires capabilities beyond these of the MS B baselines. Similarly cost accretion during years spent in bust climates that does acquire capability beyond that of the MS B baseline should be deducted.

A substantial part of the PAUC growth observed in MDAPs that continued into a boom climate post MS B probably does reflect acquisition of capabilities beyond that of the MS B baseline. Unfortunately, we do not have a marker for PAUC growth due to acquisition of additional capability (as opposed to that due to recognition that the costs of the MS B capability are higher than anticipated at MS B). Further statistical analysis along the lines of that presented here seems unlikely to be useful in untangling these two elements. Instead, further insight into why programs that continued into a boom climate post MS B had higher PAUC growth probably will require detailed examination of changes in the relevant programs post MS B.

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- Data and Computations for In-house Cost Growth Estimates.xlsx
- IDA Paper P-2722-VOL-1.pdf
- IDA Paper P-2722 Vol 1_Main Report Appendix A Tables 1-10.xlsx
- McCrillis Briefing.pdf
- Program Notes.docx

A. Introduction

This paper examines whether Major Defense Acquisition Programs (MDAPs) that entered a boom climate for procurement funding some time after passing Milestone (MS) B on average had higher unit cost growth than programs whose acquisition cycles did not extend into a boom climate. While this conjecture seems plausible, possibly even obviously correct, it has not been recognized in the cost growth literature.

The topic is worth pursuing because it bears on why unit cost growth was significantly higher for MDAPs that passed MS B in bust periods than it was for those that passed in boom periods. This observation was reported by the first paper in this series, hereafter P-5126.[1] The explanation offered there was a version of the "camel's nose" hypothesis—that unrealistic cost, programmatic, and technological assumptions are made in the hope that, by making the program appear to be lower in cost or more capable, they will increase the odds that the program will be successful in competition for funds. P-5126 goes further by suggesting that the incentives for adopting very optimistic assumptions are stronger for programs that pass MS B in bust funding climates than they are for programs that pass in boom periods, and that, consequently, unrealistic MS B baselines are more common in programs that passed MS B in bust climates.

For present purposes, the key point to note is that the explanation offered by P-5126 supposes that most of the growth in unit cost shown by programs that pass MS B in a bust funding climate is "baked into" the baselines established at MS B. There are other possibilities, however, one of which is that a significant part of these programs' cost growth might be due to increases in program content made during a post-MS B boom climate when funding is more readily available. To the extent that is the case, we may be mistaking the costs of decisions to improve the capabilities of an existing system for growth in the costs of acquiring the capabilities specified in the MS B baseline.

B. Framework

The topic of this paper requires distinguishing between bust funding and boom funding climates. The period Fiscal Year (FY) 1965–FY 2009 considered here spans two bust-boom cycles in Department of Defense (DoD) procurement funding: (1) The bust climate for modernization of weapon systems that began in the mid-1960s[2] and lasted until the Carter-Reagan buildup of the early to mid-1980s, and (2) the long post-Cold

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[1] David L. McNicol and Linda Wu, "Evidence on the Effect of DoD Acquisition Policy and Process on Cost Growth of Major Defense Acquisition Programs," IDA Paper P-5126 (Alexandria, VA: Institute for Defense Analyses, September 2014), 5.

[2] The DoD budget was high during the years of the Vietnam War, but much of the acquisition budget went for munitions and to weapon systems lost in combat. Consequently, funding for major system new starts was relatively constrained. See Appendix A, page A-8.

War bust climate followed by the post-9/11 boom. The rationales for the break points between the funding climates are provided in Section C of Appendix A.

A measure of cost growth also is required. One option is based on Program Acquisition Unit Cost (PAUC). PAUC is the sum of Research, Development, Test and Evaluation (RDT&E) cost and procurement cost, divided by the number of units acquired. For this study, PAUC growth is computed by comparing the MS B baseline value of PAUC—which can be thought of as a goal or a prediction—to the actual PAUC reported in the last Selected Acquisition Report (SAR) for the program, normalized to the MS B quantity.[3] (The quantity normalization computations are described in Appendix B, pages B-7 to B-9.) Both the MS B baseline and the actual value of PAUC are stated in constant dollars. The alternative to PAUC growth is growth in Average Procurement Unit Cost (APUC), which does not include RDT&E cost. The effects of changes in the capabilities procured may be more likely to show up clearly in APUC growth, which is an advantage, but it is a less comprehensive measure of unit cost growth. We compute the results for both cost growth measures, and report the results for APUC only in the one instance in which when they differ in an important way from those obtained using PAUC. Note that PAUC growth and APUC growth are adjusted for quantity but not for changes in the capabilities the program is directed to acquire.

In what follows, the term *PAUC growth* means PAUC growth from the MS B Baseline with the final SAR PAUC normalized to the MS B quantity. Similarly, the term *APUC growth* means APUC growth from the MS B Baseline with the final SAR APUC normalized to the MS B quantity. Appendix B provides the conventions used in assembling the database and the sources of the data used. The unit cost growth estimates were updated to the most recent comprehensive information available, that in the December 2015 SARs. Only completed programs (defined as programs with an end date of FY 2016 or earlier) are used in this analysis because some costs associated with a program may not be fully reflected in its SAR until the program is completed.

Average PAUC growth reported in Table 1 for programs that passed MS B in bust climates is significantly higher (43 percent) than it is for programs that passed MS B in boom periods (15 percent).[4] This observation serves only to confirm for the data used in this research the result mentioned above from P-5126.

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[3] PAUC and APUC growth measures used for purposes of Nunn-McCurdy Act reporting are not quantity normalized. The median MDAP that passed MS B in the period FY 1988–FY 2007 acquired 100 percent of MS B baseline quantity, and the average program acquired 111 percent. See David L. McNicol, Sarah K. Burns, and Linda Wu, "Evidence on the Effect of DoD Acquisition Policy and Process and Funding Climate on Cancellation of Major Defense Acquisition Programs" IDA Paper P-5218 (Alexandria, VA: Institute for Defense Analyses, May 2015), 7–8. Compared to the PAUC growth measures used in Nunn-McCurdy reporting, quantity adjusted decreased measured PAUC growth for programs for about half of the programs in the sample and increased it for the other half.

[4] $P < 0.001$ for the Mann-Whitney U (M-W U) test ($U = 1261.5$, $n_1 = 108$, $n_2 = 44$).

Table 1. Average PAUC Growth for Completed MDAPs by MS B Funding Climate

Bust		Boom	
FY 1964–FY 1980	47% (64)	FY 1981–FY 1986	18% (35)
FY 1987–FY 2002	37% (44)	FY 2003–FY 2009	0% (9)
Total	**43% (108)**	**Total**	**15% (44)**

Note: Numbers of MDAPs that passed MS B and were completed by the December 2015 SARs are shown in parentheses.

Finally, it is necessary to recognize changes over time in acquisition policy and process configurations because they are associated with significant difference in average PAUC growth. A previous paper in this series (P-5330 (Revised)[5]) distinguished the following six policy and process configurations:

1. McNamara-Clifford (FY 1964–FY 1969)
2. Defense Systems Acquisition Review Council (DSARC, FY 1970–FY 1982)
3. Post-Carlucci DSARC (P-C DSARC, FY 1983–FY 1989)
4. Defense Acquisition Board (DAB, FY 1990–FY 1993)
5. Acquisition Reform (AR, FY 1994–FY 2000)
6. DAB Post AR (DAB Post AR, FY 2001–FY 2009)

Average PAUC growth does not differ significantly among DSARC, P-C DSARC, DAB, and DAB Post AR within a budget climate.[6] Their statistical similarity permits these periods to be combined into a single acquisition policy and process configuration, which will be referred to as DSARC/DAB. The main text is concerned only with the DSARC/DAB. A previous paper in this series found that average APUC growth was significantly higher in McNamara-Clifford and AR configurations, which for that reason

5 David L. McNicol et al., "Further Evidence on the Effect of Acquisition Policy on Cost Growth of Major Defense Acquisition Programs," IDA Paper P-5330 (Revised) (Alexandria, VA: Institute for Defense Analyses, August 2016).

6 For bust climates, Analysis of Variance (ANOVA) fails to reject the null hypothesis that APUC growth for completed programs in each of these bins has the same normal distribution ($P = 0.996$). Kolmogorov-Smirnov (K-S), Anderson Darling (A-D), and an F-test of the variances indicate that the assumptions of ANOVA are satisfied. For boom climates, K-S and A-D find that the observations for the boom portion of DSARC and the DAB periods are consistent with a normal distribution, but K-S rejects normality for the boom portion of P-C DSARC. The M-W U test does not detect a significant difference between the means of the (1) DSARC-Boom and P-C DSARC-Boom ($P = 0.968$, $U = 88.5$, $n_1 = 29$, $n_2 = 6$); (2) DSARC-Boom and DAB Post AR-Boom ($P = 0.317$, $U = 36$, $n_1 = 9$, $n_2 = 6$); or (3) the P-C DSARC-Boom and the DAB Post AR-Boom ($P = 0.215$, $U = 94$, $n_1 = 29$, $n_2 = 9$).

are treated separately.[7] Appendix C provides results for the McNamara-Clifford and AR configurations.

Section B of Appendix A provides brief descriptions of the acquisitions configurations as defined here. Readers who have read previous papers in this series or who are generally familiar with the Office of the Secretary of Defense (OSD)-level acquisition process and various acquisition reform efforts can use Appendix A selectively. Others may wish to read Appendix A before proceeding with the main text.

C. Evidence of a Boom Effect

The term boom effect is used here to label a feature observed in the unit cost growth data—MDAPs that passed through a boom climate post MS B had a higher average unit cost growth than those that did not.

Many MDAPs that passed MS B in one of the bust climates continued into a boom climate, and some programs that passed MS B during the Carter-Reagan defense buildup continued into the post-9/11 boom. A two-part naming convention is used to label two bins of programs: those that did, and those that did not, pass through a boom climate post MS B. The first part of the label gives the funding climate prevailing when the program passed MS B—bust or boom. The second part—0, 1, or 2—denotes the number of boom climates a program passed through post MS B. For example, programs that were completed entirely within a single bust phase will be referred to as Bust0—Bust because they passed MS B in a bust funding climate and zero because they were completed without entering a boom climate. Programs that passed MS B in a bust period and continued into or through a subsequent boom period are called Bust1.

A detailed evaluation of content changes for programs that did and did not experience a boom funding climate after passing MS B would be the best approach to exploring the importance and character of boom. This type of analysis would require greater resources than were available, however. Instead, this paper uses a statistical approach that relies on data that are comparatively easy to acquire—PAUC growth from the MS B baseline, the year programs passed MS B, and the year the programs were completed. In the language of medical testing, the plan is to compare unit cost growth for a treatment group—programs that experienced a boom climate post MS B—with that of a control group—programs that did not. The question asked in this section is whether the observed boom effects are statistically significant. We look first at the two bust climates and then at the two boom climates.

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[7] McNicol et al., "Further Evidence on the Effect of Acquisition Policy," Appendix C, which provides a Bayesian analysis using APUC growth data. That result also probably holds for the PAUC data.

PAUC growth for Bust0 and Bust1 are presented in Table 2 for each of the two bust periods of DSARC/DAB. In both periods, average PAUC growth for the treatment group (Bust1) is higher than it is for the control group (Bust0)—42 percent compared to 16 percent for the first period and 51 percent compared to 13 percent for the second. These differences are statistically significant.[8] For programs that passed MS B in a bust period, subsequent entry into a boom period is then associated with higher PAUC growth.

Table 2. Average PAUC Growth for Completed MDAPs in DSARC/DAB Bust by the Number of Boom Periods Experienced

Bin	1st Bust Period FY 1970–FY 1980	2nd Bust Period FY 1987–FY 1993
Bust0	16% (6)	13% (8)
Bust1	43% (39)	51% (17)
Bust2	19% (3)	none

Bust2 does not follow this pattern: average PAUC growth for Bust2 is slightly higher than that of Bust0 but less than that of Bust1. The number of programs in this bin (N=3), however, is so small that there is no point in speculating about why it does not fit the pattern.[9] While no attempt is made to explain the observation for Bust2, it is included in an analysis discussed below that includes all of the MDAPs that passed MS B during the two DSARC/DAB bust periods.

APUC growth also does not entirely follow the pattern of PAUC growth for Bust0 and Bust1 of the two DSARC/DAB bust periods. In particular, APUC growth for programs initiated in the first DSARC/DAB bust period does not show a statistically significant boom effect in APUC growth. (The six programs of Bust0 have an average APUC growth of 21 percent, which is not significantly different from the 42 percent average APUC for the 39 programs of Bust1.[10]) APUC growth in the second bust period

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[8] K-S and A-D find the PAUC growth data in each of the two bins of the first bust period to be consistent with a normal distribution. An F-test found the two variances to be significantly different. A two-tailed t-test assuming unequal sample variances found the means of Bust1 and Bust0 for the first period to be significantly different (P = 0.011). K-S and A-D also find the PAUC growth data in each of the two bins of the first bust period to be consistent with a normal distribution. Again, an F-test found the two variances to be significantly different. A two-tailed t-test assuming unequal sample variances found the means of Bust1 and Bust0 for the first period to be significantly different (P = 0.004).

[9] The programs in Bust2 are the CNV 68, with a PAUC growth of 7 percent; the NAVSTAR GPS (85 percent); and ATCCS-MCS (-34 percent).

[10] K-S and A-D find the APUC growth data in each of the two bins of the first bust period to be consistent with a normal distribution. An F-test found no significant difference between the two variances. A two-tailed t-test of the APUC data found the means of Bust1 and Bust0 for the first period not to be significantly different (P = 0.241).

does follow the pattern—43 percent for Bust1, which is significantly higher than the 17 percent average APUC growth for Bust0.[11]

Table 3 presents data on PAUC growth for the two DSARC/DAB boom periods. The nomenclature used for the boom periods parallels that used for bust periods. Boom0 programs passed MS B in a boom climate and were completed in that boom or the succeeding bust climate. Boom1 programs passed MS B during the Carter-Reagan defense buildup and were completed during the post-9/11 boom or during the following three years. There is no treatment group (i.e., Boom1) for the second boom period and hence no experiment to examine.

Table 3. Average PAUC Growth for Completed MDAPs in DSARC/DAB-Boom by the Number of Boom Periods Experienced

Bin	1st Boom Period MS B FY 1981-FY 1986	2nd Boom Period MS B FY 2003-FY 2009
Boom0	12% (28)	0% (9)
Boom1	45% (7)	none

Average PAUC growth for the Boom1 programs of the first boom period (45 percent) is significantly higher than that for the Boom0 programs (12 percent).[12] This finding is somewhat unexpected, since the relevant programs passed MS B in a boom funding climate and presumably had realistic baselines and were robustly funded at least initially. In fact, the finding may be spurious. Average PAUC growth for the Boom1 bin of the first boom period is dominated by three MDAPs, each of which had PAUC growth of more than 40 percent: C-17 (57 percent), T-45 Goshawk (70 percent), and JSTARS (123 percent). These programs had the essential features of Total Package Procurement (TPP).[13] Acquisition reforms adopted in mid-1969 ruled out use of TPP and fixed-price development contracts because they typically resulted in severe cost growth and schedule problems.[14] During the Reagan Administration, however, TPP-like contracts were used

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11 M-W U P = 0.041 (U = 32.5, n_1 = 17, n_2 = 8).

12 K-S found the distribution of APUC growth of the 28 Boom0 programs that passed MS B in the first bust phase to be non-normal. M-W U found the difference between average APUC growth of Boom0 and Boom1 for the first boom phase to be significant. (P = 0.007, U = 164.5, n_1 = 28, n_2 = 7).

13 David L. McNicol, *Cost Growth in Major Weapon Procurement Programs*, 2nd ed. (Alexandria, VA: Institute for Defense Analyses, 2004), 62.

14 See McNicol et al., “Further Evidence on the Effect of Acquisition Policy,” 7, and for further discussion of TPP and FFP development contracts, see Karen Tyson et al., “The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs, Vol. I: Main Report,” IDA Paper P-2722 (Alexandria, VA: Institute for Defense Analyses, November 1992), Chapter X; McNicol, *Cost Growth,* 53 and 57–59; and 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: Institute for Defense Analyses, January 2011), 9–31.

for a few MDAPs, including the three programs noted here. (The other four of the seven programs in Boom1 had conventional cost plus incentive fee contracts for Engineering and Manufacturing Development (EMD).) The PAUC growth of the C-17, T-45, and JSTARS programs was on a par with that of TPP programs that passed MS B during FY 1965–FY 1969 and did not continue into the Carter-Reagan boom. Their contracting strategy, not their continuation into a boom funding climate, could then account for their high PAUC growth. If the three programs are excluded, the average PAUC growth for Boom1 is 17 percent, which is not significantly higher than the average for Boom0.[15]

Table 4 combines data from Table 2 and Table 3. The 73 MDAPs of the DSARC/DAB bust climates had an average PAUC growth of 38 percent, which was significantly higher than the 9 percent average of the 41 MDAPs in DSARC/DAB that passed during boom climates.[16] Average PAUC growth of MDAPs in Bust0 is not significantly different from the average PAUC growth of DSARC/DAB boom, and therefore has little effect on this result.[17] Instead, the higher average of DSARC/DAB bust is mainly due to the programs in Bust1. This adds an important point to the narrative of P-5126: the higher PAUC growth of MDAPs that passed MS B in bust climates largely reflects a subset associated with those programs—those that passed MS B in a bust climate and continued on into a boom climate.

Table 4. PAUC Growth for the Combined Bust and the Combined Boom Phases of DSARC/DAB

Bust0	14% (14)	Boom0	9% (37)
Bust1	45% (56)	Boom1	17% (4)*
Combined Bust**	**38% (73)**	**Combined Boom**	**9% (41)**

* Excludes C-17, T-45, and JSTARS.

** Includes the three programs in Bust2, which have an average PAUC growth of 19 percent.

D. Funding Climate, Program Duration, and the Boom Effect

This section takes an additional step towards explaining why the data show boom effects. Table 5 presents rearranged data from Table 2 and Table 3 and, in addition, shows average program duration for each bin. Average PAUC growth is greater in Bust1 than in Bust0 for each of the two bust periods and greater for Boom1 than for Boom0 for the first boom period. (The second boom period is excluded because there are no programs in Boom1.) The programs in Bust1 and Boom1, however, also had a longer

15 M-W U $P = 0.117$ ($U_A = 83.5$, $U_B = 28.5$, $n_1 = 28$, $n_2 = 4$).

16 M-W U $P < 0.001$ ($U = 633$, $n_1 = 73$, $n_2 = 4$).

17 M-W U $P = 0.121$ ($U = 367.5$, $n_1 = 41$, $n_2 = 14$).

average duration than the programs in the corresponding Bust0 and Boom0 bins. Consequently, we need to examine the extent to which longer average duration in addition to an encounter with a boom period account for their higher PAUC growth. Note that including the three programs of Bust2 (of the first bust period) and the three programs excluded from Boom1 would not change this conclusion.

Table 5. Average PAUC Growth and Average Program Duration by Number of Boom Periods Encountered for Completed Programs in DSARC/DAB

Bin		Average PAUC Growth	Average Duration †
1st Bust Period ‡	**Bust0**	16% (6)	6.7
	Bust1	42% (39)	14.2
2nd Bust Period	**Bust0**	13% (8)	7.5
	Bust1	53% (17)	15.8
1st Boom Period	**Boom0**	12% (28)	9.2
	Boom1§	17% (4)	22.3

† From MS B through the year in which the program's last SAR was filed.

‡ Excludes the three programs of Boom2.

§ Excludes C-17, T-45, and JSTARS.

We approach this problem by dividing the duration of the program into two parts:

1. T_{boom} = number of years post MS B spent in boom climates
2. T_{bust} = number of years post MS B spent in bust climates

These two variables are hypothesized to have distinct linear relationships to PAUC growth (abbreviated as PAUC):

$$PAUC_i = a_0 + a_1 T_{boomi} + a_2 T_{busti} + e_i$$

In this equation, the subscript i denotes the ith MDAP in the sample and e_i is the error term, which is assumed to be a normally distributed random variable. The coefficient a_1 is the change in PAUC for each year the program spends in a boom climate. Similarly, a_2 is the change in PAUC per year in a bust climate. The estimated intercept term a_0 is the average net effect of excluded variables. The coefficients of the model are estimated (using multiple regression) separately for programs that passed MS B in bust periods of DSARC/DAB and those that passed MS B in its first boom climate. (The second boom climate is excluded because it has no programs.) The estimates obtained are presented in Table 6.[18]

[18] An alternative to the model above posits two categories of MDAPs, one that tends to short duration and low unit cost growth and another that tends to long duration and higher unit cost growth. Modifications

Table 6. Years in Bust Climates and Years in Boom Climates and PAUC Growth for MDAPs in the DSARC/DAB Acquisition Policy and Process Configuration

	Passed MS B in Bust Period†		Passed MS B in Boom Period‡	
	Estimate	**P-Value**	**Estimate**	**P-Value**
Intercept	3.4%	0.719	3.7%	0.608
Years in Boom	5.0%/yr***	< 0.001	3.7%/yr**	0.039
Years in Bust	1.6%/yr**	0.042	0.05%/yr	0.937

** Statistically significant at less than the 5 percent level.

***Statistically significant at less than the 1 percent level.

† R-Square = 0.22 F = 9.445 (P < 0.001) N= 70. Estimated by Ordinary Least Squares (OLS). Excludes the three MDAPs in the Bust2 bin of DSARC/DAB.

‡ R-Square = 0.20 F = 5.563 (P = 0.002) N= 32. Estimated by OLS. Excludes C-17, T-45, and JSTARS.

Programs that passed MS B in a bust climate characteristically experienced PAUC growth of 1.6 percent for each year spent in a bust climate. PAUC growth for each year spent in a boom climate post MS B was three times that level—about 5 percent per year. Each of these estimates is statistically significant.

The effect of boom years for programs that passed MS B in boom periods is smaller (about 3.7 percent per year). This is reasonable, as we expect programs that passed MS B in boom climates to have realistic baselines and to be adequately funded (at least initially). The estimated effect per bust year on PAUC growth for programs that passed MS B in boom periods is very small and statistically not significant, which also seems reasonable.

A sense of the importance of the boom periods entered into post MS B is provided by Table 7. The table shows the estimated relationship evaluated at the sample means for T_{Boom} and T_{Bust} for Bust0 and Bust1, respectively. Programs in Bust0 have an average PAUC growth of about 14 percent. Of this, about 11.4 percentage points is associated with years spent in bust climates, and, of course, none for continuation into a boom climate. For Bust1 programs, boom years post MS B account for about 26 percentage points of the Bust1 average PAUC growth of 45 percent; the years spent in bust climates account for 15.2 percentage points.

and upgrades would seem to be examples of the first category and major platforms an example of the second. The "short duration" and "long duration" programs were defined, respectively, as the 20 percent of programs in the bin with the shortest durations, and the 20 percent with the longest durations. The results for all of the forms of this model considered rejecting the hypothesis that shorter vice longer duration is a statistically significant factor in PAUC growth.

Table 7. Amount PAUC Growth in Boom Climates and in Bust Climates for MDAPs in DSARC/DAB that Passed MS B in Bust Climates

Period	Intercept	T_{Boom}	T_{Bust}	Average PAUC Growth
Bust0	3.4%	0	11.4%	14.3% (14)
Bust1	3.4%	26%	15.2%	45% (56)

Note: Evaluated at the sample means for T_{Boom} and T_{Bust}.

E. Conclusions and Limitations

This paper, like earlier papers in the series, finds that PAUC growth measured from MS B is significantly higher in programs that passed MS B in bust climates than in boom climates. Moreover, among MDAPs that passed MS B in a bust phase of DSARC/DAB, only those that continued into a boom climate showed PAUC growth significantly higher than that of programs that passed MS B in a boom climate. This conclusion is important because it implies that much of the observed PAUC growth may have causes other than flaws in MS B baselines. The conclusion tells us less than might be hoped, however. This is so because the PAUC growth associated with the boom may reflect the purchase of capability beyond that specified in the MS B baseline or, alternatively, PAUC increases that occur when programs take advantage of a boom climate to "get well."

The Global Broadcast System (GBS) provides an example of a program whose content was increased early in the post-9/11 boom:

> The current GBS architecture is based on Asynchronous Transfer Mode (ATM) technology…. In December 2002, DoD directed GBS's migration to a more sustainable commercial and standards-based open architecture, based upon the Internet Protocol (IP). Also, the GBS program received FY03 Iraqi Freedom Funds (IFF) supplemental funding for IP Acceleration of production units to replace deployed ATM units. Based upon extensive warfighter inputs, the accelerated IP production effort included design and development of a new, single case version of the Receive Suite (88XR) for the Army, Navy, and Marine Corps.[19]

Space Based Infrared Satellite-High (SBIRS-High) is a convenient and useful contrast to GBS, even though it passed MS B in 1997 and hence is not included in DSARC/DAB. As of the December 2015 SARs, funding for the Baseline SBIRS-High program was expected to end in FY 2018. A large portion of the growth in SBIRS-High unit procurement cost for the baseline program—roughly one-third—occurred before FY 2003, while most of the other two-thirds occurred during FY 2003–FY 2009. This

[19] *Selected Acquisition Report: Global Broadcast System*, Defense Acquisition Management Information Retrieval (DAMIR) System, December 2003, 7.

increase was not driven by increased capability, however, but by the unrealistic cost estimate in the MS B SBIRS-High baseline.[20]

In the GBS example, it seems clear that capabilities beyond those in the MS B baseline were added to the program. While unit cost did increase, that was a matter of paying more for more. For SBIRS-High, in contrast, it appears that the advent of a boom funding climate provided a program experiencing severe problems an opportunity to "get well." In effect, in such cases, what otherwise would have been capability shortfalls were converted into cost growth and, relative to MS B, DoD eventually paid more for the MS B capability than had been anticipated. The boom effect includes both of these cases. So does accretion of PAUC growth during bust years.

The average PAUC growth of all DSARC/DAB bust programs is 38 percent. Without making a specific estimate, P-5126 suggested that most of this PAUC growth stemmed from flawed MS B baselines. In the language of the present paper, if all of the unit cost growth actually is a matter of "getting well," the PAUC growth due to flawed MS B baselines problems remains 38 percent. It is less than 38 percent to the extent that PAUC growth of MDAPs in Bust1, in both the years they spent in bust climates and they spent in boom climates, is due to decisions to acquire capabilities beyond those of the MS B baselines. Parts of PAUC growth in years spent in both boom and bust climates post MS B very probably do reflect acquisition of capabilities beyond that of the MS B baseline. Unfortunately, we do not have a way to differentiate between PAUC growth due to acquisition of additional capability and that due to an increase in the actual costs of the MS B capability. Further statistical analysis along the lines of that presented here seems unlikely to be useful in untangling these two elements. Instead, progress on the question of why some programs but not others in Bust1 experienced a boom effect probably will require detailed examination of changes in the relevant programs post MS B.

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[20] See Gene Porter et al., "The Major Causes of Cost Growth in Defense Acquisition: Volume I-Executive Summary," IDA Paper P-4531 (Alexandria, VA: Institute for Defense Analyses, December 2009), especially ES-29. See also Obaid Younossi et al., "Improving the Cost Estimation of Space Systems," MG-690-AF (Santa Monica, CA: The RAND Corporation, 2008), 26–27; and Yool Kim et al., "Acquisition of Space Systems, Volume 7: Past Problems and Future Challenges," RAND MG-1171/7-OSD (Santa Monica, CA: The RAND Corporation, 2015), 7.

Appendix A.
Background

This appendix provides brief descriptions of (1) the approach taken in this paper to the examination of unit cost growth; (2) each of the acquisition policy and process periods used, and (3) the funding climates. The material is drawn mainly from Institute for Defense Analyses (IDA) papers P-5126, P-5218, and P-5330 (Revised).[1]

A. Approach

Binning cost growth in terms of budget climate and acquisition policy and process is a departure from other statistical studies of cost growth and, for that reason, warrants brief discussion. Statistical studies on cost growth in individual Major Defense Acquisition Programs (MDAPs) typically assume that most cost growth can be explained by characteristics of the program. The objective of these studies is to link program characteristics to cost growth and thereby provide a basis for identifying program characteristics—program "do's and do not's"—that will promote program success in terms of cost, schedule, and performance.

This paper, in contrast, does not attempt to explain *why* cost growth occurs but instead *when* it occurs, in chronological time and in the acquisition cycle, and *where* it occurs in terms of Department of Defense (DoD) processes. The analysis takes it as a point of departure that the proximate causes of Program Acquisition Unit Cost (PAUC) growth are decisions embedded in programs approved at Milestone (MS) B (unrealistic cost estimates or programmatic assumptions, for example) and decisions made during program execution (such as failing to act promptly enough on test results) that eventually caused the PAUC growth. With this assumption in the background, this paper and the others in the series in effect ask whether factors that cause (for example) cost growth tend to cluster in certain circumstances.

[1] David L. McNicol and Linda Wu, "Evidence on the Effect of DoD Acquisition Policy and Process on Cost Growth of Major Defense Acquisition Programs," IDA Paper P-5126 (Alexandria, VA: Institute for Defense Analyses, September 2014); David L. McNicol, Sarah K. Burns, and Linda Wu, "Evidence on the Effect of DoD Acquisition Policy and Process and Funding Climate on Cancellation of Major Defense Acquisition Programs," IDA Paper P-5218 (Alexandria, VA: Institute for Defense Analyses, May 2015); and David L. McNicol et al., "Further Evidence on the Effect of Acquisition Policy on Cost Growth of Major Defense Acquisition Programs," IDA Paper P-5330 (Revised) (Alexandria, VA: Institute for Defense Analyses, August 2016).

The list of factors that can be expected to cause such clustering is short. The first of these is acquisition policy and process. For example, acquisition reforms adopted in mid-1969 strongly discouraged the use of fixed price contracts for development of MDAPs, and put in place a process for oversight of compliance with this and other acquisition policies. The second is funding climate, on the expectation that unrealistic or unduly optimistic assumptions are more likely to be embodied in the baselines of MDAPs that pass MS B in bust funding climates.

B. Acquisition Policy and Process Periods

The President of the United States or the Secretary of Defense, from DoD's early days, occasionally cancelled or initiated major acquisitions. MDAPs were also subject to review during the budget cycle by the Office of the Assistant Secretary of Defense (Comptroller) and the Office of Management and Budget. From the creation of the National Security Establishment in 1947 through 1960, however, the Office of the Secretary of Defense (OSD) had no institutionalized process for the oversight of major weapon system acquisitions.

The first steps towards installing an OSD-level acquisition oversight process were taken by then Secretary of Defense Robert McNamara in 1964. There have since been many dozens of changes in acquisition policy or process made by senior OSD officials and on the order of a dozen major changes directed by the Congress.

We organize the large number of policy and process changes by identifying time periods during which the main features of acquisition policy and process remained approximately the same. These are as follows: [2]

1. The McNamara-Clifford years, FY 1964–FY 1969
2. The Defense Systems Acquisition Review Council (DSARC), FY 1970–FY 1982
3. The Post-Carlucci Initiatives DSARC, FY 1983–FY 1989
4. The Defense Acquisition Board (DAB), FY 1990–FY 1993
5. Acquisition Reform (AR), FY 1994–FY 2000
6. The DAB Post-AR, FY 2001 to date

[2] These categories are abstracted from J. Ronald Fox, *Defense Acquisition Reform, 1969 to 2009*: *An Elusive Goal* (Washington, DC: U.S. Army Center of Military History, 2011).

1. McNamara-Clifford, 1964-1969

The best known of McNamara's changes in OSD decision-making processes was the creation of the Office of Systems Analysis (OSA) and the Planning, Programming, and Budgeting System (PPBS), which moved decisions on what major systems to procure to the Secretary of Defense level. OSA and PPBS so overshadowed development of an OSD-level acquisition oversight process that the latter is no longer part of the collective memory of the DoD acquisition community. Nonetheless, the evolution of the OSD-level acquisition process began with initiatives taken by McNamara in the mid-1960s.

Provisions for milestone reviews appeared in 1964 with the issuance of DoD Directive (DoDD) 3200.9, *Initiation of Engineering and Operational Systems Development*.[3] This original version of the directive set one point at which OSD—in principle, the Secretary of Defense—approval was required for an acquisition program to proceed. In 1965, a second decision point was added.

The two milestones of the revised DoDD 3200.9 defined an acquisition cycle with three phases. The first of these "was called *concept formulation*. During concept formulation OSD and the Service(s) involved assured themselves that they were buying the right system to meet real needs and that the technology was fully ready."[4] Concept formulation typically was initiated by a Service, but involved the Director, Defense Research and Engineering (DDR&E) and the Office of the Assistant Secretary of Defense for Systems Analysis (OASD(SA)), and included what would now be called an Analysis of Alternatives, led by OASD(SA). It also apparently included what would later be called a Mission Element Need Statement and also the main parts of an Acquisition Strategy and plans for oversight of the program as it proceeded.

Approval to proceed from the Concept Formulation phase authorized the Service sponsoring the program to fund at least one company to prepare a definitized contract proposal. Preparation of a definitized contract was the second phase of the acquisition process. The third phase was the award of a contract for development and procurement of the system. That is to say, the second of DoDD 3200.9's milestones combined what now would be called MS B and MS C authority.

The 1965 revision of DoDD 3200.9 stated that one of the purposes of the Concept Formulation phase was to "[p]rovide a basis for a firm fixed price or fully structured

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[3] The first version of DoDD 3200.9 was issued in 1964. A revision that made provision for the Contract Definition Phase was issued July 1, 1965. See Thomas K. Glennan, Jr., "Policies for Military Research and Development," RAND Paper P-3253 (Santa Monica CA: The RAND Corporation, 1966), 12.

[4] 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: Institute for Defense Analyses, January 2011), 30.

incentive contract for Engineering Development."[5] In addition, McNamara directed the use of Total Package Procurement (TPP) when it was judged to be practicable and, when not, a Fixed Price Incentive Fee (FPIF) or Cost Plus Incentive Fee (CPIF) contract. By 1966, McNamara had concluded that TPP contracts were in fact not a practicable way to acquire most major weapon systems,[6] although acquisition policy apparently still had a tilt towards fixed price contracts, even for development.

The OSD-level milestone reviews were structured around what was then called the Development Concept Paper (DCP). The requirement for a DCP was instituted in 1965 by the DDR&E,[7] and in 1968, it was required in order to initiate any major development project. DDR&E coordinated initial DCPs with concerned OSD offices (and probably the Joint Staff and other Services) and with what now would be called the Milestone Decision Authority (MDA) for the initial DCP.[8] Once approved by DDR&E, the proposed new start went to the Secretary of Defense, although the sources consulted do not indicate whether it went as a separate action or as part of the Service's budget submission. It is also not clear which OSD official was the MDA for the second milestone.

2. The 1969 Packard Reforms

The start of the second acquisition period is marked by reforms initiated by then Deputy Secretary of Defense David Packard in mid-1969. The elements of the Packard reforms fall into three main categories. First, Packard clarified and formalized the OSD-level acquisition oversight process that had emerged under McNamara and Clifford. This was achieved through a combination of steps:

- The Defense Systems Acquisition Review Council (DSARC) was established to advise the MDA at each milestone.
- DDR&E was designated as the MDA at MS I and MS II; the Assistant Secretary of Defense for Installations and Logistics was the MDA for MS III.

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5 DoDD 3200.9, *Initiation of Engineering and Operational Systems Development*, July 1, 1965, V.B(1).

6 Gordon Adams, Paul Murphy, and William Grey Rosenau, *Controlling Weapons Costs: Can Pentagon Reforms Work?* (New York: Council on Economic Priorities, 1983), 19–20. A TPP contract is one that covers EMD, at least a significant portion of procurement, and at least part of the support of the system (for example, depot maintenance). Fox also notes that McNamara moved to consolidate acquisition functions in defense agencies—e.g., the agency that became the Defense Logistics Agency—and promoted the use by program managers of particular management tools such as PERT and earned value.

7 Fox, *Defense Acquisition Reform*, *1969 to 2009*, 24–47, provides a sketch of how the process evolved and worked during the 1960s.

8 See C. W. Borklund, *The Department of Defense* (New York: Frederick A. Praeger, 1969), 83.

- The Development Concept Paper was renamed the Decision Coordinating Paper (retaining the acronym).
- Acquisition policy and the process of OSD-level milestone and program reviews were laid out in a new directive (DoDD 5000.1) and a new top-level process instruction (DoDI 5000.2).[9]

As each of these steps had antecedents in the McNamara-Clifford process, it seems reasonable to say that they were evolutionary rather than revolutionary.[10]

Second, Packard made changes to policy on contract types. Picking up on this topic where McNamara had left off, he ruled out the use of TPP and discouraged the use of FPIF for development contracts in favor of CPIF. (Cost Plus Award Fee may not have been included in the contracting play book yet). As a general matter, Packard's policy was to match contract terms to the riskiness of the acquisition.

Third, and finally, Packard redefined the milestones so as to separate the decision to allow the program to enter Engineering and Manufacturing Development (EMD) (now MS B) from the decision to enter the Production phase (now MS C) and required OSD-level approval of each decision. He also collapsed DoDD 3200.9's Contract Definition phase into the new and broader Validation phase, which has at various times since been called Demonstration and Validation, Program Development and Risk Reduction and, currently, Technology Maturation and Risk Reduction. MS I (now MS A) authorized entry into this phase. These changes were more revolutionary than evolutionary.[11]

Packard's reforms were at the time explained as a return to the Components of the authority to manage major acquisition programs. Compared to cases such as the F-111, in which McNamara played a very active role making decisions about the program, it was. Under the new acquisition directives, the Secretary of Defense, while retaining full legal authority over acquisition programs, would act through the established acquisition process except in extraordinary circumstances. Decisions at the DSARC level were advisory to the Secretary and Deputy Secretary of Defense but, apart from exceptional cases, they probably reached that level by way of the Service's proposed budgets (and the Comptroller was the backstop enforcer of the requirement for milestone approval before a program could advance to the next stage). In comparison to cases such as the F-111, this

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9 DoDD 5000.1, *The Defense Acquisition System*, May 12, 2003; and DoDI 5000.2, *Operation of the Defense Acquisition System*, May 12, 2003.

10 Fox, *Defense Acquisition Reform, 1969 to 2009*, 57, provides a useful schematic comparison of the DoDD 3200.9 milestones and those of Packard's DoDD 5000.1/DoDI 5000.2.

11 DoDI 5000.2, issued October 23, 2000, formally established MSs A, B, and C (in place of MSs I, II, and III) as the main decision points for an MDAP. The definitions are such that MS B is placed several months earlier in the process than MS II.

implied less OSD-level control over major acquisitions. The DSARC, however, had a greater substantive scope than the 1960s process for the more typical program and was more tightly organized. For the large majority of major acquisition programs, then, the new DSARC process probably was more effective.[12]

The process instituted by Packard in mid-1969 had all of the basic features that are still central to OSD-level oversight of MDAPs—three milestones, with definitions similar to those used now; formal milestone reviews; a body to advise the MDA; and a document(s) that described the basic features of the program, provided a vehicle for staff inputs, and set down the cost, schedule, and performance goals that the program was to meet.[13] This is an important point because it implies that the effects of Packard's reforms would endure, so long as the process was not altered in a fundamental way.

3. The More Recent Periods

The vehicle for the transition from the first phase of the DSARC (FY 1970–FY 1982) to the second (FY 1983–FY 1989) was the Carlucci Initiatives, named after then Deputy Secretary of Defense Frank Carlucci. These were developed during calendar year (CY) 1981 and implemented during FY 1982–FY 1983. The Carlucci Initiatives did not involve any major changes in the DSARC process or in the policies Packard had established; in these terms, the Carlucci Initiatives were more reaffirmation than change. The Initiatives, however, included measures designed to coordinate decisions on MDAPs made in the PPBS and those made in the DSARC process. Important statutory changes were also made during 1982 and 1983.

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[12] Clark A. Murdock, *Defense Policy Formation* (Albany, NY: State University of New York Press, 1974), 155–179, disagrees with this judgment. Murdock is primarily concerned with Systems Analysis and resource allocation, but also comments specifically on the acquisition process. In particular, he notes that the new Decision Coordinating Paper did not provide "any mechanism for ongoing managerial control." This is accurate in that the Packard reforms placed management of the programs in the hands of the Services. It is incomplete in that the Services were responsible for staying within what would later be called the Acquisition Program Baseline, and the MDA was enjoined to act in cases in which they did not.

[13] In January 1972, the DSARC process was expanded to include an independent cost estimate at MS II and MS III provided by the Cost Analysis Improvement Group (CAIG), newly established by a memorandum signed by Melvin Laird on January 25, 1972. A December 7, 1971 memorandum signed by David Packard directed the Military Departments to begin using "independent parametric cost analysis." See Donald Srull, ed., *The Cost Analysis Improvement Group: A History* (McLean, VA: Logistics Management Institute (now LMI), 1998), 47–48. Since the implementation of the Weapon Systems Acquisition Reform Act of 2009 (WSARA), the independent cost estimates have been provided by the Cost Assessment Deputate of the Office of Cost Assessment and Program Evaluation (CAPE).

The DSARC was followed by the DAB.[14] While the DAB itself bears a strong family resemblance to the DSARC, the statute that created it also created the position that is now called Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) and Service Acquisition Executives who reported to the USD(AT&L); designated USD(AT&L) as the MDA for most MDAPs; and removed the Service chiefs from the acquisition chain of command. In addition, the statute created the position of Vice Chairman of the Joint Chiefs of Staff (VCJCS) and prompted a new requirements process centered on the VCJCS.

AR (FY 1994–FY 2000) was to a large extent intended to put acquisition of major weapon systems on a more commercial basis and make it easier for firms outside the defense sector to sell to DoD. Contracts were structured so that defense contractors assumed more responsibility for system performance; correspondingly, DoD's role in contract management decreased. OSD oversight of MDAPs also was relaxed somewhat. Substantial cuts in acquisition staffs at both the OSD level and Service Headquarters level were made, and senior decision makers took a more permissive attitude towards cost growth.

The post-AR DAB period was marked by the arrival of a new administration in January 2001. This period saw no overt rejection of AR, but most of its initiatives were no longer pursued. The new administration seemed implicitly to favor a return to the *status quo ante* in OSD-level oversight of acquisition programs.

In 2006, the Congress strengthened the Nunn-McCurdy Act, which had been passed in 1982.[15] In 2009, the Congress passed the Weapon Systems Acquisition Reform Act (WSARA), which made several changes that may prove to be consequential.

C. Funding Climates

It is important to realize that funds appropriated for procurement are a lagging indicator of a change in budget climate. Funding and programmatic decisions embedded in the MS B baselines of MDAPs are made at least one or two years before the President's Budgets in question are submitted to the Congress. Consequently, those decisions necessarily reflect expectations held by decision makers about the future DoD budget climate, and the breakpoints between different budget climates should mark the points at which there were major shifts in expectations.

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[14] There is some uncertainty about when the Post-Carlucci Reforms DSARC should end and the DAB period should begin. The relevant statutes were passed in December 1985 (first quarter FY 1986), and the DAB began functioning under that name in late FY 1987 or early FY 1988; however, DoD did not implement the full set of reforms required by statute until 1990. We have for that reason set the line at 1990.

[15] The Nunn-McCurdy Act imposes reporting and other requirements that senior DoD officials must meet if an MDAP breaches certain unit cost thresholds.

It is also important to recognize the distinction between the development of the DoD budget request for acquisition and the amount the Congress eventually appropriates. The Components' acquisition programs are built subject to funding constraints specified by senior Component officials (in particular, the Service Secretaries) based on fiscal guidance they are given by the Secretary of Defense. It is reasonable to assume that expectations about future funding levels are formed as much by "this year's" fiscal guidance as by "last year's" congressional appropriation.

We used four events to identify the breakpoints between funding climates: (1) the invasion of Afghanistan by the USSR in late December 1979; (2) passage of the Gramm-Rudman-Hollings Act in December 1985; (3) the terrorist attack on the United States on September 11, 2001; and (4) the start of the withdrawal of US forces from Iraq in late FY 2009. Senior decision makers could reasonably expect each of the events identified to signal major and sustained changes in the defense funding climate, which in fact they did.

1. The First Bust Climate

DoD procurement funding increased markedly during the first three years of the Kennedy administration (CY 1961–CY 1963) and remained relatively high through the 1960s. A large part of the increase in procurement funding during FY 1964–FY 1969, however, was for munitions and procurement to replace systems lost in combat, particularly aircraft. Insofar as modernization of weapon systems was concerned, there was little or no boom associated with the Vietnam War.[16]

Gerald Ford was sworn in as president on August 9, 1974, about six weeks into FY 1975. The FY 1976 budget, preparation of which was far advanced when Ford became president, increased procurement by 13.5 percent. The amount appropriated for procurement in FY 1977 increased by an additional 30 percent, and the amounts appropriated for procurement during the next two years were only modestly lower.

There are three main reasons for concluding that the FY 1976 and FY 1977 increases did not cause a major shift in expectations about defense spending. First, they basically reversed sharp declines in procurement funding during the years 1970–1975, roughly the period of the "Peace Dividend" that had accompanied the end of the War in Vietnam.

Second, there was no political consensus in favor of a sustained substantial increase in funding for DoD procurement. As evidence of this point, during the 1976 campaign,

[16] These comments are based on an unpublished IDA working database drawn from various US government sources. We are indebted to Dr. Daniel Cuda for providing these data.

President Carter "pledge[d] to reduce the defense budget by $7 billion and submit a balanced budget in fiscal year 1981."[17]

Third, while Ford opposed cuts to defense spending, the material consulted for this paper (Ford's three State of the Union addresses and campaign material) did not indicate that he attempted to establish a consensus favoring large increases in DoD spending. It also is far from clear that he was in a position to do so during most of his presidency. The Democrats controlled both houses of the Congress. In his inaugural address to the Congress, Ford said: "I am your man, for it was your carefully weighted confirmation that changed my occupation." That is, his legitimacy as president was derived from the Congress rather than from election by the people.

The Carter administration followed through on this campaign commitment by reducing the FY 1978 DoD budget request left by the Ford administration by about $3 billion. Moreover, on August 17, 1978, President Carter vetoed the 1979 Defense Authorization Act. The veto message implies that the Congress had put a $2 billion nuclear powered carrier into the budget Carter had submitted from the Ford administration and cut some other procurement programs, some readiness funding, and some RDT&E funding. Carter wanted the carrier removed from the budget and the other funding he had requested restored. The veto was sustained. As these facts suggest would be the case, DoD Budget Authority (BA) was lower for FY 1978 and FY 1979 than it was for FY 1977, and FY 1980 was only slightly larger.

2. Start of the First Boom Climate

The Soviet invasion of Afghanistan in late December 1979 (three months into FY 1980) prompted a change in the Carter administration's policy on defense spending. One source states that "only a month after the Soviet invasion of Afghanistan, Carter called for increases in defense spending of 4.6 percent per year, every year over five years."[18] Carter's State of the Union address delivered on January 21, 1980, listed as one of his few new proposals "Initiatives implementing my response to the Soviet invasion of Afghanistan." The "Defense Spending" portion of the State of the Union address stated that requested FY 1981 funding authority was a more than 5 percent real increase over the funding requested for FY 1980. It goes on to characterize this as "a growth rate for defense that we can sustain over the long haul." In fact, the real increase in enacted DoD

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17 Frank L. Jones, *A "Hollow Army" Reappraised: President Carter, Defense Budgets, and the Politics of Military Readiness* (Carlisle, PA: Strategic Studies Institute, U.S. Army War College, 2012), 16.

18 Andrew Krepinevich, "What Would Jimmy Carter Do?," Defense One, March 11, 2014, http://www.defenseone.com/ideas/2014/03/what-would-jimmy-carter-do/80335/?oref=search_what%20would%20jimmy%20carter%20do.

BA for FY 1981 was 12 percent for DoD as a whole and about 25 percent for procurement.

President Reagan, who took office in January 1981, requested increases in DoD funding that went well beyond what the Carter administration had planned. By FY 1985, DoD funding for procurement was more than 70 percent above what it had been in FY 1981.

3. The Second Bust Period

Congressional appropriations for defense procurement peaked in FY 1985. The Congress did not enact the increase in DoD funding for FY 1986 requested by the administration, and in December 1985 passed the Gramm-Rudman-Hollings (GRH) Act, which provided for sequestration to satisfy budget targets.

None of this was known, however, when the FY 1986 DoD budget request was sent to the Congress in late January or early February 1985, and the defense buildup was in full swing during FY 1983 through FY 1985 when the FY 1986 request was being developed. For that reason, this paper takes FY 1986 as the last year of the Carter-Reagan boom climate.

The Congress cut DoD funding for FY 1987 about 3 percent below the FY 1986 level. Cuts in defense spending continued through the end of the Reagan administration. Procurement funding for FY 1987 was down about 16 percent from its FY 1986 level and dropped modestly further over the next three fiscal years. Additional large drops came after the fall of the Berlin Wall on November 9, 1989 (first quarter FY 1990) and the collapse of the Soviet Union on December 25, 1991 (first quarter FY 1992). By the mid-1990s, DoD procurement funding had returned to about the post-Vietnam War levels of the mid-1970s and was little more than one-third of its peak (FY 1985) level. Altogether, the second bust phase continued—for a total of 16 years—through FY 2002.

4. The Second Boom Period

The defense spending boom that followed was prompted by the Al Qaeda attacks of September 11, 2001 (late FY 2001) and the subsequent wars in Afghanistan and Iraq. The question is where the start of the boom climate should be placed—at FY 2001, FY 2002, or FY 2003?

George W. Bush was inaugurated on January 20, 2001. It is not clear that the outgoing Clinton administration submitted its final (FY 2002) budget to the Congress. The Bush administration apparently submitted a pro forma budget (*A Blueprint for New Beginnings*) on February 29, 2001, and a complete FY 2002 request proposal on April 9. The Bush administration also requested a $5.2 billion increase in the FY 2001 appropriation. According to the budget news release, this was primarily for Military

Personnel (MILPERS) and Operations and Maintenance (O&M). As a candidate, Bush had not committed to increasing procurement, and his proposed budget for FY 2002 did not do so. In fact, procurement was actually $1.4 billion *lower* than the FY 2002 column of the FY 2001 Clinton Future Years Defense Plan.

Post 9/11, the budget climate was radically different. On December 28, 2001 (end of the first quarter of FY 2002), the Congress adopted an emergency supplemental for FY 2001, even though it had ended three months earlier, and on January 10, 2002 adopted an emergency supplemental for FY 2002. The spending plans that went into the proposed FY 2002 budget could not have been influenced by these events.

Planning for the FY 2004 DoD budget certainly took place in a boom climate. That is less clearly true of the FY 2003 budget. The FY 2003 DoD budget submitted February 4, 2002 was about 10 percent above the FY 2002 budget request and, more important for present purposes, provided for about a 10 percent increase in procurement funding. Barely four months elapsed between 9/11 and the submission of the FY 2003 DoD budget. On the supposition that major changes in acquisition programs could have been made within that amount of time, this paper places the start of the post-9/11 boom climate at FY 2003.

DoD funding for procurement increased in FY 2003 by about 20 percent over the preceding year and continued to increase through FY 2008. FY 2009 probably should be counted as the last year of this second boom period because the Great Recession began in its first quarter and the withdrawal of US troops from Iraq began in July of 2009. Expectations of a decline in defense spending developed at that time, and were solidified by passage of the Budget Control Act of 2011, which was signed into law in August 2011.

Appendix B.
The Data

A compact disc (CD) in a pocket on the inside back cover of this paper contains the database used in this research. The CD also contains several other files that help to document or explain the data. This appendix provides background information that facilitates access to and use of the files on the CD.

A. Cost Growth Metric and Ground Rules

The cost growth metric used in this paper is quantity normalized growth in Program Acquisition Unit Cost (PAUC) in program base year dollars. In most instances the PAUC growth figure used is measured from the MS B baseline. PAUC includes Research, Development, Test, and Evaluation (RDT&E) funding as well as procurement funding. Appendix D provides a brief discussion of the association of post-MS B funding climate and RDT&E cost growth.

Each of the programs for which the database includes a PAUC growth estimate completed Engineering and Manufacturing Development (EMD), went into production, and fielded at least some units to operating forces. Programs that were cancelled (or programs that never proceeded beyond EMD or which were not a Major Defense Acquisition Program (MDAP)) were not used in the statistical analyses. One reason to not include cancelled programs is that it is generally very difficult, and sometimes impossible, to get a reasonable estimate of the unit cost growth they experienced. A better reason is that the relevant outcome metric for these programs is “cancellation.” Another paper in this series (P-8280, forthcoming) will examine the extent to which changes in acquisition policy and process are associated with differences in cancellation rates.

The database used in this research contains an estimate of PAUC growth for 192 MDAPs that entered EMD during FY 1965–FY 2010. We follow the convention of not including in the database any MDAP that was not at least five years beyond EMD, so that cost growth would have time to appear. The most recent Selected Acquisition Reports (SARs) available for this paper were those for December 2015; consequently, MDAPs that passed MS B during FY 2010 were the most recent included in the database.

The estimates mainly are drawn from the database developed for IDA Paper P-5330 (Revised), which in turn evolved from the database for IDA Paper P-5126.[1] The cost growth observations for FY 1965–FY 1969, however, and a few of the observations for FY 1965–FY 1989, are drawn from other studies, as is discussed below.

Figure B-1 is a histogram of the cost growth estimates in the database used for this paper. The paper used the 152 completed MDAPs that passed MS B during the period FY 1965–FY 2009 for which both an Average Procurement Unit Cost (APUC) and a PAUC estimate were available.

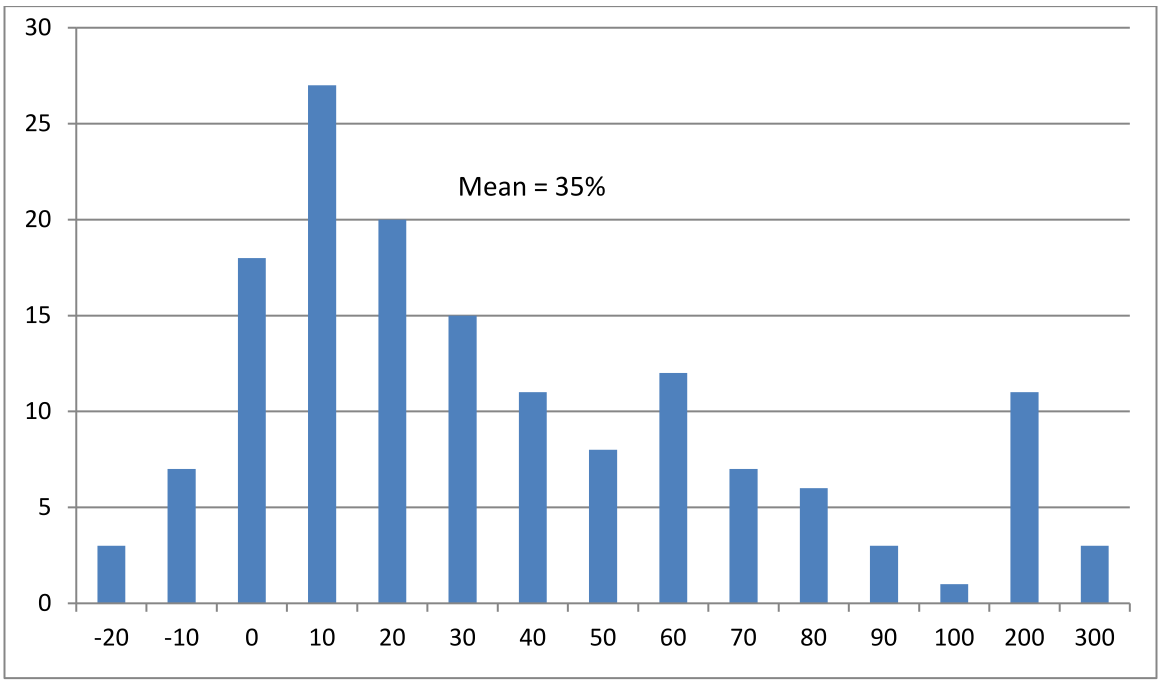

Figure B-1. Histogram of Quantity Normalized PAUC Growth from the MS B Baseline

B. Business Rules

Almost all of the data used in this research were taken directly or indirectly from SARs. SARs filed in FY 1997 and subsequent years are available through the Defense Acquisition Management Information Retrieval (DAMIR) system. Many SARs filed before FY 1997 are available on an Office of the Under Secretary of Defense

1 David L. McNicol et al., "Further Evidence on the Effect of Acquisition Policy on Cost Growth of Major Defense Acquisition Programs," IDA Paper P-5330 (Revised) (Alexandria, VA: Institute for Defense Analyses, August 2016); David L. McNicol and Linda Wu, "Evidence on the Effect of DoD Acquisition Policy and Process on Cost Growth of Major Defense Acquisition Programs," IDA Paper P-5126 (Alexandria, VA: Institute for Defense Analyses, September 2014).

(Acquisition, Technology and Logistics) (OUSD(AT&L)) SIPRNet site. These two sources provided SARs under about 345 distinct labels.

Not all of these distinct labels are distinct programs. Three steps are needed to get from the list of distinct SAR labels to a list of MDAPs:

1. During the 1970s, each Component involved in a joint program sometimes filed a SAR. These SARs reported the same program data. The database used in this research includes only the data reported (for the entire program) in the SAR filed by the lead Component.
2. The program name used on the SAR often changes over the acquisition cycle for a given program. For example, the OH-58D Kiowa Warrior was first reported as the Army Helicopter Improvement Program (AHIP). In most cases the database uses the name under which the last (or, for ongoing programs, most recent) SAR was filed.
3. Multiple MDAPs that have passed MS B are sometimes combined into a single MDAP. Conversely, a single MDAP that has passed MS B is sometimes split into two or more separate MDAPs. If the data permitted (and they often did not), our rule was to maintain the program(s) as they had been defined at MS B.

For the reasons noted above, the database does not include any MDAPs that passed MS B after FY 2010. In addition, the following were excluded from the main database:

- Major Automated Information Systems (MAIS),
- Chemical Demilitarization Programs,
- Ballistic Missile Defense programs managed by the Ballistic Missile Defense Agency and its predecessors,
- Programs that filed a SAR but were never designated as an MDAP, and
- Programs cancelled before they passed MS B or before they were designated as an MDAP.

These exclusions were indicated by the purpose of the analysis, which is to gauge the effect of different OSD-level acquisition regimes and funding climates on MDAP outcomes. The database then should include only programs subject to OSD-level acquisition policy and process. To at least a significant extent, the excluded programs differed from the MDAP norm. The exclusions therefore resulted in a main database that includes 316 MDAPs that entered development during the period FY 1965–FY 2010.

Most of the MDAPs in the database passed MS B at the OSD level. Some, however, entered at MS III/C, obtained both MS B and Low Rate Initial Production authority in a single OSD-level review, or passed MS B at the Service level and later became Acquisition Category (ACAT) I programs. These cases are noted in the database for programs that became MDAPs in FY 1989 or later, but not reliably noted for programs begun earlier.

Finally, it proved to be necessary to adopt a clear criterion for program cancellation. In the database, a program is classified as cancelled if:

- The program did not result in production of any fully configured end items, or
- Any fully configured end items produced were used only for testing and development.

Application of this definition was not clear-cut for six programs that passed MS B at the Service level, later filed SARs, and subsequently were cancelled. We retained on the list of cancelled programs the five that had been designated as an ACAT I program and excluded the one that had not.[2]

Two other programs were counted as cancelled, although they did not exactly satisfy the criteria stated. The C-27J was included on the list of cancelled programs because the 21 C-27Js produced were placed directly in long-term storage and later transferred to Special Operations Command and the US Coast Guard. Roland was included, although the system was produced in the United States in limited quantities and issued to a single National Guard battalion, which falls into a gray area between issue of the system to active duty units and its use only for development, experiment, and training.

The file "Program Notes" (provided on the included CD) provides some information bearing on each of the 58 cancellations we identified. We found 16 additional programs that filed one or more SARs during FY 1959–FY 2009 and were cancelled. These 16 were not included on the list of cancelled programs because they were either cancelled before passing MS B, were never designated an ACAT I program, or were cancelled after they fell below the ACAT I level. They appear as numbers 59–74 in "Program Notes."

C. Coverage

As was noted above, the database includes 58 MDAPs that were cancelled (as an ACAT I program) after passing MS B and includes 258 programs that went into production. We have APUC and PAUC estimates for 184 of the MDAPs that went into production, of which 32 were still underway as of the December 2015 SARs. Table B-1 reports the relevant data broken down by the nine time periods used in the statistical

[2] AN/WQR-Advanced Deployable System, AQM-127A Supersonic Low Altitude Target, Advanced Seal Delivery System, ASM-135A Air-Launched Anti-Satellite System, and Land Warrior were retained on the list of cancelled programs. Extended Range Munition was cancelled before it was designated an ACAT I program.

analysis. Overall, the database reports a cost growth estimate for about 70 percent of the MDAPs that went into production.

Table B-1. MDAPs in the Database Not Cancelled, with an APUC and a PAUC Estimate, by Bust/Boom Time Periods

Period (FY)	Went into Production	No. with APUC & PAUC	Percent with APUC & PAUC
1965–1969	21	16	76%
1970–1980	63	48	76%
1987–1989	16	10	63%
1990–1993	14	11	78%
1994–2000	40	30	75%
2001–2002	11	6	55%
2010	3	4	75%
Total	**168**	**125**	**74%**
1981–1982	14	7	50%
1983–1986	45	31	69%
2003–2009	31	21	68%
Total	90	59	66%
Grand Total	**258**	**184**	**71%**

D. Sources of Cost Growth Estimates

Table B-2 reports the sources of the APUC and PAUC estimates used in this paper. Nearly half of the total was taken from an MDAP cost growth database developed and maintained by the Office of Program Analysis and Evaluation (PA&E) Resource Analysis deputate. The PA&E cost growth database is documented in a briefing by John McCrillis given at the 2003 Annual DoD Cost Analysis Symposium.[3] The briefing is included on the CD provided on the inside back cover of this paper.

[3] John McCrillis, "Cost Growth of Major Defense Programs," Briefing (presented at the Department of Defense Cost Analysis Symposium, Williamsburg, VA, January 30, 2003).

Table B-2. Sources of the APUC and PAUC Growth Estimates Used in Different Periods

Period (FY)	PA&E	P-2722	RAND	In-House	Total
1964–1969	0	16	0	0	16
1970–1979	36	8	2	0	46
1980–1989	45	0	4	1	51
1990–1999	7	0	0	32	36
2000–2009	0	0	0	30	25
2010	0	0	0	3	3
Total	**88**	**24**	**6**	**66**	**184**

APUC and PAUC growth estimates for an additional 24 MDAPs were taken from IDA Paper P-2722.[4] The provided CD includes the main volume of P-2722, as well as an Excel workbook with the data. The next section of this appendix describes how the P-5126 cost growth estimates were made.

Communication from the RAND Corporation provided updates to the FY 2015 SARs of estimates for six MDAPs published in a 1996 study[5] of APUC and PAUC growth estimates normalized to the MS B baseline.

Finally, APUC and PAUC growth estimates for 66 MDAPs were made in-house as part of the work on this project. Fifty-eight of the MDAPs in the PA&E cost growth database were still ongoing at the time of the final PA&E update (that is, when the December 2004 SARs were filed). These were updated with data from the December 2015 SARs. In addition, APUC and PAUC growth estimates for MDAPs that passed MS B during FY 2008–FY 2010 were made, again using the December 2015 SARs.

The PA&E estimates were constructed through a detailed examination of the SAR variances. The IDA P-2722, IDA P-5126, and RAND estimates were made with data at a much more aggregated level. The methods used were essentially the same, but it is reasonable to assume that they differ in detailed ways not captured by the general characterization each offers of the method used. P-2722 did not in all cases follow the business rules used in P-5126 and this paper.

These four sources use the same definitions of the relevant cost terms and are based on SAR data. Each also, in most instances, measures cost growth from the MS B baseline when it is available and reports quantity normalized unit cost growth. Thus, a PAUC

[4] Karen Tyson et al., "The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs, Vol. I: Main Report," IDA Paper P-2722 (Alexandria, VA: Institute for Defense Analyses, 1992).

[5] Jeanne M. Jarvaise, Jeffrey A. Drezner, and Dan Norton, "The Defense System Cost Performance Database: Cost Growth Using Selected Acquisition Reports," RAND Report MR-625-OSD (Santa Monica, CA: The RAND Corporation, 1996).

estimate from, for example, P-2722 means the same thing as an APUC estimate from the other three sources.

There were several MDAPs from the 1960s and 1970s for which we had two APUC and PAUC growth estimates. The decisions on which of the alternative estimates to use was entirely rules-based. The PA&E database did not provide estimates for MDAPs that entered EMD during FY 1965–FY 1969. The unit cost growth estimates used for FY 1965–FY 1969 are from P-2722. In addition to the SAR data, P-2722's estimates in many cases reflected other sources of information, including material provided by the program office and contractors. For FY 1970 and beyond, we used the PA&E estimate in all cases in which the last SAR for the program had been filed by the time of the final update of the PA&E database (which used the December 2004 SARs). In a few cases, P-2722 had a cost growth estimate for a program not included in the PA&E database. In these instances, we used the estimate from P-2722 if the program was reported complete in the most recent SARs used in making the estimate; otherwise, we used the RAND estimate if available.

E. Computation of the P-5126 (Main Database) V 5.2 Estimates

This section briefly describes how the 66 in-house estimates were made. The relevant data and computations are in the "Data and Computations for In-house Cost Growth Estimates.xlsx" file on the CD.

1. RDT&E

The SARs report fully configured units acquired with RDT&E funds and those acquired with procurement funds. Only the former are used in computing quantity-adjusted RDT&E cost growth. Our procedure was simply to compute the ratio of the Current Estimate (CE) of RDT&E cost and the baseline RDT&E cost (both in program base year dollars) and scale that by the ratio of baseline quantity to CE quantity. Suppose, for example, that the number of fully configured units purchased with RDT&E funds has increased from four to five and that CE RDT&E cost is 50 percent larger than the baseline cost. Our computation of unit RDT&E cost growth is then (4/5) x 1.5 - 1, or 20 percent.

2. APUC

The method used to normalize APUC for quantity change depended, first, on the extent to which quantity changed between MS B and the final SAR and, second, on whether a useable estimate of the slope of the learning curve was available.

a. No Quantity Change (NQC)

The SAR CE quantity was within ±1 percent of the MS B quantity for 12 of the MDAPs for which estimates were required. No quantity normalization is needed for these programs; their APUC growth is computed by dividing the CE APUC in the final SAR (or the December 2012 SAR for an ongoing program) by the MS B APUC and subtracting 1. The APUC growth for SBIRS-High also falls under this heading. The total number of SBIRS-High satellites to be acquired decreased from five (at MS B) to four (the December 2012 SAR). The decrease, however, was in a satellite purchased with RDT&E funds, and we did not put these on a learning curve. There was no change in the number of SBIRS-High satellites purchased with procurement funds. Finally, although the PAC-3 quantity change fell outside the ±1 percent boundary, data limitations made it necessary to compute the PAC-3 APUC growth as the ratio of the CE and MS II APUCs.

b. Defense Acquisition Management Information Retrieval System (DAMIRS) Learning Curve (DLC)

The DoD contractor staff for DAMIRS provided us with their estimates of learning curve parameters that we were able to use to compute APUC growth for 13 MDAPs that passed MS B during FY 1989–FY 2001. We refer to these as the DAMIRS Learning Curve (DLC) APUC growth estimates. For each of these, we took the CE APUC growth in program base year dollars from the last SAR for the program or the December 2015 SAR (for ongoing programs). The task was to normalize this APUC estimate to the MS B quantity, which was done as follows:

- We used the learning curve to compute the recurring flyaway cost at the MS B baseline quantity.
- The CE estimates of RDT&E and non-recurring flyaway cost were taken from the final SAR for the program or from the December 2012 SAR (for ongoing programs).
- Support costs paid for with procurement dollars are, for many programs, primarily initial spares and support equipment, although other items may also fall into this category. Initial spares and support equipment normally scale with the number of units of the system purchased. For that reason, we used the CE support cost reported in the last or most recent SAR scaled to the MS B baseline quantity.

c. Calibrated Learning Curve (CLC)

Twenty-nine MDAPs did not have a PA&E estimate or estimated learning curve parameters, and their CE quantity was significantly different from the MS B quantity.

The approach we used in those cases rested on a cost progress curve of the conventional form:

$$C = TQ^{\beta}. \tag{B-1}$$

In this expression, C is recurring flyaway cost, T is first unit cost, Q is cumulative production, and β is the cost progress parameter. We solved this and used the CE for recurring flyaway to get:

$$\hat{T} = CQ^{-\beta}. \tag{B-2}$$

This will be referred to as the calibrated learning curve (CLC) method. A value of β = 0.94 was used for each of the programs. From this point, the computations were the same as those for MDAPs for which DAMIRS staff provided the learning curve parameters.

3. PAUC

Quantity PAUC is simply the sum of quantity normalized RDT&E and Procurement, divided by the baseline quantity, less 1.

4. Summary

Table B-3 provides an overview of the number of estimates in P-5126 made with each of the methods.

Table B-3. Sources of the Quantity Normalized Unit Cost Growth Estimates Used in Different Periods

Period (FY)	NQC	DLC	CLC	Total
1989–2001	5	13	21	39
2002–2010	7	0	20	27
Total	**12**	**13**	**41**	**66**

F. Comparison of the PA&E and CLC/DLC PAUC Growth Estimates

P-5126 compared the PA&E estimates for 23 MDAPs with estimates made using the CLC and DLC methods.[6] That material is repeated here without substantial changes.

The obvious approach is to compare the PA&E PAUC growth for systems that have been completed with PAUC growth for those same systems computed using the DLC and CLC methods. Unfortunately, there are no MDAPs that have been completed and for

[6] McNicol and Wu, "Evidence on the Effect of DoD Acquisition Policy and Process," A-7, A-9.

which we have both a PA&E PAUC growth estimate and the data needed to compute a DLC or CLC estimate. The best we can do is to examine the 23 MDAPs that passed MS II/B during FY 1989–FY 2001 and for which we have a PA&E PAUC growth estimate, a DLC estimate, and a CLC estimate.

The PA&E estimates were most recently updated with the 2004 SARs. The DLC and CLC estimates, in contrast, incorporated more recent data—either the final SAR for the program or, for ongoing programs, the December 2012 SAR. Consequently, in most cases we would expect the DLC and CLC PAUC growth estimates to be larger than the corresponding PA&E estimate. That is the test: A method fails if it yields estimates that are "too often" and by "too much" less than the PA&E estimates. Clearly, this is a weak test.

The relevant estimates are presented in Table B-4. The comparison of the PA&E estimates and CLC estimates is on the left, and the comparison of the PA&E and DLC estimates is on the right. The CLC estimates are larger than the PA&E estimates for 17 of the 23 MDAPs—in most cases, considerably larger. They are smaller in six cases (shaded rows). In all but one of these cases (Joint Direct Attack Munition, or JDAM) the differences are absolutely or relatively small. The average of CLC PAUC growth estimates is 77 percent, in comparison to an average of 60 percent for the PA&E estimates. The DLC estimates exhibit the same pattern. The average of the DLC estimates is 73 percent, and four of them (shaded rows) are less than the PA&E estimate for the program, three by a substantial amount.

Table B-4. Comparison of PA&E, CLC, and DLC PAUC Growth Estimates for 23 MDAPs

Program	PA&E	CLC	Program	PA&E	DLC
Longbow Apache	78%	117%	Longbow Apache	78%	133%
F-22	41%	71%	F-22	41%	55%
F/A-18E/F	6%	12%	F/A-18E/F	6%	9%
Bradley Upgrade	39%	54%	Bradley Upgrade	39%	86%
MIDS	30%	72%	MIDS	30%	68%
CEC	48%	62%	CEC	48%	62%
H-1 Upgrades	124%	192%	H-1 Upgrades	124%	197%
LPD 17	43%	71%	LPD 17	43%	72%
CH-47F	147%	173%	CH-47F	147%	156%
GMLRS/GMLRS AW	125%	249%	GMLRS/GMLRS AW	125%	243%
MH-60S	62%	69%	MH-60S	62%	70%
Tactical Tomahawk	24%	28%	Tactical Tomahawk	24%	27%
GBS	10%	31%	GBS	10%	33%
Stryker	21%	25%	Stryker	21%	22%
UH-60M Black Hawk	49%	62%	UH-60M Black Hawk	49%	61%
WGS	28%	55%	WGS	28%	42%
C-130J	70%	84%	C-130J	70%	70%
JPATS	43%	40%	JPATS	43%	44%
SSN 774	35%	33%	SSN 774	35%	37%
JDAM	18%	-10%	JDAM	18%	-13%
Javelin	229%	197%	Javelin	229%	134%
MH-60R	95%	74%	MH-60R	95%	80%
NAS	25%	21%	NAS	25%	1%
Average	**60%**	**77%**		**60%**	**73%**

Note: The PA&E estimates were updated only through the 2004 SARs. The CLC and DLC estimates incorporate information from the last SAR for the program or the December 2012 SAR (for ongoing programs).

Appendix C.
Boom Effects for McNamara-Clifford, Acquisition Reform (AR), and the Bust Phase of the DAB Post AR

Table C-1 presents average Program Acquisition Unit Cost (PAUC) growth and average program duration data for the McNamara-Clifford and the Acquisition Reform (AR) periods.

Table C-1. Average PAUC Growth and Program Duration for Completed Programs for McNamara-Clifford and AR

		Average PAUC Growth	Average Duration
McNamara-Clifford	**Bust0**	87% (12)	9.3
	Bust1	34% (4)	20.5
Acquisition Reform	**Bust0**	2% (1)	7
	Bust1	38% (18)	14.6

* Quantity APUC from the MS B baseline.

** From MS B through the year in which the program's last SAR was filed.

In contrast to what was found for the DSARC/DAB-Bust period, for McNamara-Clifford, average PAUC growth for Bust0 programs is about two and one-half times that of Bust1 programs. The difference is statistically significant.[1] This may be due to the fact that the Bust1 programs continued into at least the early 1980s and therefore presumably were more strongly influenced by the 1969 Packard acquisition reforms, which are associated with a significant reduction in PAUC growth.

The cost growth data for AR are not useful for statistical analysis because only one program that passed MS B during that period (AV-8B Remanufacture) had been completed by the December 2015 SARs.

[1] K-S and A-D find the distributions of PAUC growth in Bust0 and Bust 1, respectively, to be consistent with a normal distribution. P = 0.048 for a two-tailed t-test with correction for unequal variances.

Appendix D. RDT&E Cost Growth for the DSARC/DAB Period

Table D-1 presents data on Research, Development, Test and Evaluation (RDT&E) cost growth and duration in the DSARC/DAB period that parallel the PAUC and duration data presented in Table 2 (on page 5), Table 3 (on page 6), and Table 4 (on page 7). The number of observations in some cells differs from that given for PAUC because the database does not have an RDT&E estimate for all programs for which there is a PAUC growth estimate.

Table D-1. Average RDT&E Growth and Average Program Duration by Number of Boom Periods Encountered for Bust and Boom Climates

Bin		Average RDT&E Growth[a]	Average Duration[b]
1st Bust Period	**Bust0**	5% (5)	6.7
	Bust1	53% (38)	14.1
2nd Bust Period	**Bust0**	37% (7)	8.0
	Bust1	45% (17)	15.8
1st Boom Period	**Boom0**	41% (26)	9.6
	Boom1	65% (7)	22.3
2nd Boom Period	**Boom0**	1% (9)	66.1
	Boom1	n/a (0)	n/a

[a] Quantity APUC from the MS B baseline.
[b] From MS B through the year in which the program's last SAR was filed.

The pattern of growth in RDT&E in the first bust period is consistent with that observed for PAUC growth: (1) average RDT&E growth for programs in Bust1 is significantly higher than the average for Bust0; and (2) the proportion of programs of Bust1 that fall into the right tail of the distribution also is significantly higher than it is for Bust0.[1]

[1] M-W U P = 0.025 (U = 35.5, $n_1 = 38$, $n_2 = 5$). P = 0.051 for Fisher's Exact Test (FET) using the number of programs in Bust0 and Bust1 with an RDT&E growth of at least 40 percent.

Average RDT&E growth in the second bust period is noticeably higher in Bust1 than in Bust0, but the difference is not statistically significant. The proportion of programs with RDT&E cost growth of more than 40 percent also is not significantly higher in Bust1 than in Bust0.[2]

In the first boom period, average RDT&E cost growth is significantly higher for MDAPs in Boom1 than for those in Boom0, and the proportion of MDAPs with RDT&E growth of at least 40 percent also is significantly higher in Boom1 than in Boom0.[3]

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2 M-W U P = 0.308 (U = 43, $n_1 = 17$, $n_2 = 7$). P = 1.000 for FET using the number of programs in Bust0 and Bust1 with an RDT&E growth of at least 40 percent.

3 M-W U P = 0.075 (U = 132, $n_1 = 26$, $n_2 = 7$). P = 0.027 for FET using the number of programs in Bust0 and Bust1 with an RDT&E growth of at least 40 percent.

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Abbreviations

ACAT	Acquisition Category
A-D	Anderson-Darling Test
AHIP	Army Helicopter Improvement Program
ANOVA	Analysis of Variance
APUC	Average Procurement Unit Cost
AR	Acquisition Reform
ATM	Asynchronous Transfer Mode
BA	Budget Authority
CAIG	Cost Analysis Improvement Group
CAPE	Cost Assessment and Program Evaluation
CD	Compact Disc
CE	Current Estimate
CLC	Calibrated Learning Curve
CPIF	Cost Plus Incentive Fee
CY	Calendar Year
DAB	Defense Acquisition Board
DAMIRS	Defense Acquisition Management Information Retrieval System
DCP	Development Concept Paper/Decision Coordinating Paper
DDR&E	Director, Defense Research and Engineering
DLC	DAMIRS Learning Curve
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DSARC	Defense Systems Acquisition Review Council
EMD	Engineering and Manufacturing Development
FET	Fisher's Exact Test
FFP	Firm Fixed Price
FPIF	Fixed Price Incentive Fee
FY	Fiscal Year
GBS	Global Broadcast System

GRH	Gramm-Rudman-Hollings
IDA	Institute for Defense Analyses
IFF	Iraqi Freedom Funds
IP	Internet Protocol
JDAM	Joint Direct Attack Munition
K-S	Kolmogorov-Smirnov Test
MAIS	Major Automated Information System
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MILPERS	Military Personnel
MS	Milestone
M-W U	Mann-Whitney U Test
NQC	No Quantity Change
O&M	Operations and Maintenance
OASD(SA)	Office of the Assistant Secretary of Defense for Systems Analysis
OLS	Ordinary Least Squares
OSA	Office of Systems Analysis
OSD	Office of the Secretary of Defense
PA&E	Program Analysis and Evaluation
PAUC	Program Acquisition Unit Cost
P-C	Post-Carlucci
PPBS	Planning, Programming, and Budgeting System
RDT&E	Research, Development, Test and Evaluation
SAR	Selected Acquisition Report
SBIRS-High	Space-Based Infrared Satellite-High
TPP	Total Package Procurement
US	United States
USD(AT&L)	Under Secretary of Defense (Acquisition, Technology and Logistics)
VCJCS	Vice Chairman, Joint Chiefs of Staff
WSARA	Weapon Systems Acquisition Reform Act of 2009

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14. ABSTRACT
This paper is the fourth in a series that examines the association between outcomes of Major Defense Acquisition Programs (MDAPs) and changes in acquisition policy and process and funding climate. Like an earlier paper in the series, it finds that quantity normalized Program Acquisition Unit Cost (PAUC) growth measured from Milestone (MS) B is significantly higher in programs that passed MS B in bust climates than in boom climates. Moreover, among MDAPs that passed MS B in a bust phase, only those that continued into a boom climate showed significantly higher PAUC growth than programs that passed MS B in a boom climate. This conclusion is important because it implies that much of the observed PAUC growth may have causes other than flaws in MS B baselines. The conclusion tells us less than might be hoped, however. This is so because the PAUC growth associated with the boom climate may reflect the purchase of capability beyond that specified in the MS B baseline or, alternatively, may reflect PAUC increases that occur when programs take advantage of a boom climate to “get well.”

15. SUBJECT TERMS
Acquisition reform; acquisition policy; acquisition process; cancellation; termination; cost growth; APUC growth; PAUC growth; funding climate

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