The question asked in this article is whether the shared intellectual property of the acquisition community includes an adequate theory of cost growth in major defense acquisition programs (MDAPs). This question is given concrete form by cost growth data for 123 MDAPs. These data are grouped into categories, which range from very small—negative, in fact—cost growth to cost growth in excess of 100%. Potential explanations for this broad range of cost growth considered are: the conventional wisdom about cost growth; a recent RAND study that closely examined cases at both ends of the distribution, along with some possible extensions of that study; and a recent model of the root causes of cost growth. The author argues that each of these falls short; in particular, it seems that the defense acquisition community at large does not have a good explanation of cost growth in the broad range of 30% to 100%.

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This article examines whether the shared intellectual property of the acquisition community includes an adequate theory of cost growth in major defense acquisition programs (MDAPs), and—having concluded that it does not—characterizes the largest gap in our collective understanding of MDAP cost growth. The term “shared intellectual property” is used to mean an understanding that is possessed to an important extent by the experienced members of the Department of Defense (DoD) acquisition community.

Three alternative explanations of cost growth are examined. The first of these is the author’s understanding, based on decades of experience, of the acquisition community’s conventional wisdom about cost growth. The second is the widespread belief that the proximate cause of the largest part of cost growth in MDAPs is due to unrealistic elements included in Milestone (MS) B baselines. Over the years, this idea has been explored by several major studies, most recently a 2017 RAND study by Lorell et al. (2017). The third, and by far least well known, is a theory of the root causes of cost growth proposed by McNicol (2020).

The exam question used to test these theories is novel: Does the theory provide a plausible explanation of the full range of cost growth observed, from the very small—negative, in fact—to the very large. The means used to test how well an idea explains the data varies from one case to the next.

**FIGURE 1. RANGE OF COST GROWTH DATA**

![Figure 1](https://www.dau.edu)

**Note.** The data in this figure are for 123 MDAPs that passed Milestone (MS) B during the bust funding climates Fiscal Year (FY) 1965–FY 1980 and FY 1987–FY 2002. In these climates, competition among MDAPs for funding was particularly intense. Programs that passed MS B in boom climates are set aside initially. The measure of cost used is Program Acquisition Unit Cost (PAUC) in program base-year dollars. Cost growth is the ratio of actual PAUC observed at the end of the acquisition cycle adjusted to the MS B base-line quantity procured divided by MS B PAUC.

The average quantity adjusted PAUC growth and number of observations by category are Category I: -8% (13); Category IIa: 15% (44); Category IIb: 39% (20); Category IIc: 68% (31); Category III: 171% (15).
The Data

Figure 1 displays the cost growth data used, grouped into five categories of average cost growth:

- **Category I:** MDAPs with negative unit cost growth—that is, for which, when the acquisition was completed, unit cost, adjusted to the Milestone (MS) B quantity, was less than had been projected at MS B.

- **Category II:** MDAPs that had cost growth between zero and 100%. This category is divided into three subcategories:
  a. Cost growth of less than 30%
  b. Cost growth of 30% to 50%
  c. Cost growth of more than 50% but no more than 100%

- **Category III:** Cost growth of more than 100%

The observations are based on the cost estimates in the programs’ MS B baselines. These distinguish development, procurement, and military construction, and generally follow the lines of the program work breakdown structure currently provided by DoD Military Standard 881E. The individual supervising the estimate decides how many levels down into the structure to go. Typically, the Office of the Secretary of Defense (OSD)-level independent cost estimate is made at a relatively high level and will be composed from, say, 10 to 50 distinct cost categories. An estimate is made for each of these categories, covering the program’s entire acquisition cycle. The estimates made by program offices often are considerably more detailed.

This article uses the only publicly available database with cost growth data for a substantial number of MDAPs. The database includes at least some data on all MDAPs that entered what is now called Engineering and Manufacturing Development (EMD) during the period Fiscal Year (FY) 1965–FY 2009. DoD offices and specific parts of the DoD Decision Support System process are referred to by the names that were commonly used for them during FY 2000–FY 2009. Cost growth data are included in the database for 123 MDAPs that passed MS B during one
of two “bust” periods, when competition for acquisition funding was relatively intense (FY 1965–FY 1980 and FY 1987–FY 2002). Omission of MDAPs that passed MS B during boom periods (FY 1981–FY 1986 and FY 2003–FY 2009) removes a complication: the very large difference in average Program Acquisition Unit Cost (PAUC) growth between MDAPs that passed MS B in bust periods and those that passed MS B in boom periods. (On the association of funding climate and cost growth, see McNicol and Wu [2014] and McNicol [2018].) This problem is too large to include within the scope of this article. Omitting the 62 MDAPs that passed MS B in boom periods does not, however, eliminate the problem illustrated in Figure 1: It is still reasonable to ask whether current conceptions can explain the full range of cost growth presented by 123 MDAPs that passed MS B in bust periods.

The cost growth figures used are based on PAUC. Acquisition cost is the sum of Research, Development, Test, and Evaluation (RDT&E) cost; procurement cost, that is, the cost of buying units once they are developed; and system-specific military construction costs. PAUC is the ratio of acquisition cost to units acquired. The denominator of PAUC growth is the PAUC in the MS B baseline (in program base-year dollars). The numerator is the PAUC reported in the program’s final Selected Acquisition Report (SAR) (also in program base-year dollars), adjusted to the MS B baseline quantity by moving quantity acquired up or down the cost progress curve, as appropriate. This adjustment removes changes in quantity acquired as a factor that needs to be considered. The resulting cost growth figures are estimates of what cost growth would have been had the MS B baseline quantity been acquired. Of the 123 MDAPs in the sample, 110 were completed by the end of FY 2016. Actual PAUC was known for these programs; for the other 13, the 2016 SARs include forecasts of the acquisition costs of the program when completed.
Conventional Wisdom and the Data

The initial impulse of someone who approaches Figure 1 in terms of the conventional wisdom probably is to question the data. It is mainly the 13 MDAPs (all of which were completed by FY 2016) with negative cost growth that trigger this response. A comment often heard is that “all major acquisition programs” show cost growth. They do not. Virtually all programs do show growth in RDT&E cost at the contract level during the Technology Maturation and Risk Reduction phase that precedes EMD. Further, most (but not all) programs show growth in RDT&E for the EMD phase. This does not imply, however, growth in acquisition costs. In the author’s experience, procurement characteristically accounts for 70% to 80% of acquisition cost, and in some cases, procurement cost declines by enough to yield a quantity-adjusted PAUC growth that is negative.

Once the shock of Figure 1 has worn off, further discussion probably would tacitly assume that MDAPs increased in cost over time and offer reasons for this presumed increase. Examples of such reasons often heard are increased use of advanced technologies, more programs that are systems of systems, and greater use of software. An explanation of Figure 1 in these terms would be that the higher cost growth systems tend to be the more recent MDAPs and/or those with problematic program features. A look at the data is enough to call such an explanation into question. The earliest of the MDAPs in Category III is the M-60 A2 Patton tank, which entered EMD about 1965, and the median program in Category III entered EMD in 1987. While Category III includes programs of each of the Services, Army programs are significantly overrepresented (11 of 15), which may reflect unique aspects of Army policy.

More generally, the conventional wisdom conflates two distinct assertions—one accurate and one not. The preponderance of evidence supports the conclusion that average unit acquisition costs at completion of successive generations of particular system types (destroyers, for example) have increased over time (Arena et al., 2006a, 2008). However, average PAUC growth of annual cohorts of MDAPs has shown no persistent tendency to increase over time (Arena, 2006b).
Finally, conventional wisdom tends to ignore the MS B review. A MS B review involves examinations of the proposed program by Service and OSD staff elements, and each MS B baseline is approved by a senior DoD official. It is the nominal intent of the MS B review to ensure that, at that stage, the MDAP conforms to DoD acquisition policy, which provides that the elements of the baseline, including the cost estimate, should be realistic. Consequently, substantial cost growth in an MDAP necessarily involves some degree of policy or institutional failure.

### 2017 RAND Study

Lorell et al. (2017) is the culmination of several studies undertaken at RAND. It differs from other case studies in that it is a comparative examination of cost growth in six MDAPs with extremely high growth and four with very low growth. Such a comparison is important because some program characteristics associated with cost growth are common. Most MDAPs, for example, have some degree of concurrency between EMD and procurement, and critical technologies that are to some degree immature at MS B.

Lorell et al. (2017) find that programs with extremely high-cost growth each possessed all or nearly all of five characteristics:

1. Immature technology; integration complexity
2. Unclear, unstable, or unrealistic requirements
3. Unrealistic cost estimates
4. Acquisition strategy and program structure not tailored for level of risk
5. MS B and MS C approved at the same time

These characteristics were found to be entirely absent in two of the low-cost growth programs, and the remaining two programs possessed, respectively, one and two of the five factors that cause extremely high-cost growth. So, to the extent that Lorell et al. (2017) is accepted, we know very high-cost growth (Category III) is associated with the program characteristics listed previously, and that those are largely absent in programs with lower cost growth (Categories I and IIa).

The significance that can be attached to Lorell et al. (2017) is, however, constrained by its inclusion only of Air Force programs that passed MS B during the years 1991–2001 and its small sample size. More concretely, several of the high-cost growth programs included were acquired with contracts that limited government oversight and, instead, placed more responsibility on
the contractor for system performance. This approach was called Total System Performance Responsibility (TSPR), which, in retrospect, was associated with high-cost growth. As the authors note, use of TSPR was strongly encouraged by senior DoD leadership. A new administration ended the TSPR experiment in 2002 (McNicol, 2018). Consequentially, to the extent that TSPR drove the high-cost growth cases, it is necessary to be wary of using Lorell et al. (2017) to interpret cost growth in earlier and later periods.

In addition, a feature that Lorell et al. (2017) shares with most other well-known studies of cost growth complicates its application to acquisition policy. In words that are just beginning to be used commonly, Lorell et al. (2017) implicitly attributed cost growth to Errors of Inception, which are unrealistic features of the program approved at MS B. There are, however, two other major categories of cost growth:

- Errors of Execution: management errors made during program execution by government or contractor program managers (PMs); and
- Program Changes: changes made to the program post-MS B that are not forced by internal program developments, such as schedule slips or cost growth.

The meager evidence available suggests that cost growth due to Errors of Execution is small—on average, only a few percentage points—but that cost growth due to Program Changes is, on average, a bit more than 30% of average cost growth (McNicol, 2018). Note that a Program Change is conceptually different from “unclear, unstable, or unrealistic requirements” (Lorell et al., 2017), but the two are difficult to separate if the capabilities to be acquired were loosely defined at MS B. This author’s judgment is that
Errors of Execution and Program Changes probably are relatively unimportant for the high-cost growth cases considered by Lorell et al., but this does not imply that they can be ignored in other cases.

Finally, Lorell et al. (2017) does not provide an explanation of the full range of cost growth we see in Category II. There are 95 programs in Category II—the bulk of the sample used here—and even if all of Category IIa is dropped out, the cost growth of the remaining 51 programs ranges from 30% to 100%. These programs are the dandelions of cost growth—not the most noxious of weeds but the most common.

Conjectures Motivated by 2017 RAND Study

No published study has tried to explain the differences in the magnitudes of cost growth across Category II programs. In fact, the topic has barely been noticed.

The most practical way forward on this problem is to hypothesize an explanation and then, to the extent possible, test it against data. The three possibilities considered here all concern Errors of Inception:

1. PAUC growth increases with the number of unrealistic elements in the MS B baseline; it is the number of poisons administered that counts.
2. The crucial cause of cost growth variation is the magnitude of the unrealistic elements in the MS B baseline—the sizes of the doses of poisons administered are crucial.
3. The extent of cost growth is determined by toxic combinations of MS B elements. That is, the poison is not any one substance alone, but is created by the interaction of several substances.

The first of these hypotheses can be tested easily, although crudely. Relevant data are presented in Figure 2. The data are drawn from Diehl et al. (2012), which provides a synthesis of the results of the 15 root cause analyses (RCAs) undertaken by RAND or IDA, as required by the Weapon Systems Acquisition Reform Act of 2009. (The RAND studies are reported in Blickstein et al. [2011, 2012]; Diehl et al. [2012] provide the references to the individual IDA studies.) Only 12 data points appear in Figure 2 because three of the 15 programs for which RCAs were done were major automated
information systems, not MDAPs. There is no visible association in Figure 2 between PAUC growth and the number of issues found in the RCAs and, in fact, the correlation between the observations on PAUC growth and the number of issues for these 12 MDAPs is statistically insignificant. The appropriate conclusion is that, at least for this sample, the magnitude of cost growth was determined by more than just the number of unrealistic elements in the baseline.

**FIGURE 2. PAUC GROWTH AND NUMBER OF UNREALISTIC ELEMENTS IN THE MS B BASELINE**

![Graph showing PAUC growth and number of issues](image)

*Note.* Adapted from Diehl et al. (2012), Table 4, p. 12.

This brings us to the second hypothesis—that what matters for cost growth is the *extent* to which one or more features of the baseline approved at MS B are unrealistic. The obvious suspect is the cost estimate. If the cost estimate is, say, half of the realistic cost for the program, cost growth of at least 100% is almost certain to emerge. Cost estimates this unrealistic (and worse) are sometimes adopted. Another relevant example is the assumption in the MS B baseline on the annual buy rate during full-rate production; this also can be seriously unrealistic and have a substantial effect on PAUC growth. The SARs report MS B baseline unit costs. Unfortunately, the independent cost estimates, which would provide an indicator of the realism of the MS B baseline cost estimates, are not published. The situation is no better for other features of the program approved at MS B. In short, the data required to test the second hypothesis for a reasonably sized sample of MDAPs are not publicly available.

Finally, PAUC growth in the middle ranges—30% to 100%—may reflect the interaction of two or more features of the MS B baseline. The readiest example of this possibility is provided by immaturity of a critical technology and EMD schedule. The fact that a critical technology is somewhat
immature at the start of EMD will not cause substantial cost growth if
the technology is not required until relatively late in EMD. Schedule, of
course, determines when “late” arrives. If the schedule is unrealistically
short, it may force decisions on the immature technology that concatenate
into a serious problem and cost growth. A similar example is provided by
concurrence between the EMD portion of the program and the production
portion. Concurrence is costly to the extent that it forces retrofits, and this,
in turn, depends on how optimistic the EMD schedule is and, if EMD slips,
just what parts are delayed.

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cost for the program, cost growth of at least
100% is almost certain to emerge. Cost
estimates this unrealistic (and worse) are
sometimes adopted.

A painstakingly careful study of an individual MDAP, ideally with cost
growth in Category IIc, should be able to identify the causes of PAUC growth,
estimate the magnitude of each, and characterize how interactions between
various factors influenced PAUC growth. This would be a difficult, data-in-
tensive, time-consuming task, but it could, and perhaps should, be done. The
truly daunting prospect is that of accumulating a sufficient number of such
studies to provide a sound basis for policy recommendations.

Root Causes of Cost Growth

This section takes up the question of whether recent work on the root
causes of cost growth in MDAPs explains the clustering of cost growth
observed in Figure 1, especially Category IIc. The term “root cause analysis”
is defined further on.

The Senate Committee on Homeland Security and Governmental Affairs
staff report on acquisition reform provides a convenient place to begin the
discussion (Senate Report No. 113-28, 2014). This report provided—and
probably still does—a fair representation of the opinions on the causes
of cost growth from people who have been associated with DoD or the
Congress. None of the experts proposed a theory of cost growth. However,
two—Thomas Christie and Paul Francis—in the course of their remarks, point to the basic elements of a theory of the root causes of cost growth based on incentives. These elements are as follows:

1. The context is long-standing criticisms of the results of the DoD acquisition process for MDAPs—cost growth, schedule slips, performance shortfalls.
2. Christie asserts that these problematic results are largely due to unrealistic assumptions embedded in the baselines approved at MS B. Francis takes a less definitive position on the extent to which cost growth is due to unrealistic elements in MS B baselines.
3. Christie and Francis both observe that competition for funding provides the PM of an MDAP with an incentive to propose unrealistic program assumptions for inclusion in the MS B baseline. Christie seems to suggest that this incentive applies to all MDAPs in all periods; again, Francis takes a less definite position.
4. Christie and Francis both assert that sometimes the Milestone Decision Authority (MDA) accepts a proposed MS B baseline in the face of creditable evidence developed during the MS B review that it contains some program assumptions that are significantly unrealistic.

Note that items 3 and 4 are sufficient conditions for the occurrence of cost growth: The unrealistic baseline is proposed, presumably by the PM, and then accepted by the MDA. In this context, “program manager” should be understood to refer to the PM, the Program Executive Officer (PEO), and any other, more senior officials who participate directly in the decisions.

It is important not to conflate a failure to fully fund the cost estimate in the MS B baseline and the realism of that estimate. The issue here is the realism of the MS B cost estimate; it is taken for granted that the cost estimate in the MS B baseline will be fully funded.
A root cause model is, as the label suggests, a model of the causes of cost growth, but it goes at least one stage upstream from the immediate, or proximate, causes of cost growth. For example, one common proximate cause of cost growth is an unrealistic EMD schedule. A root cause analysis attempts to say something useful about why the unrealistic EMD schedule was adopted. The obvious approach is to start with the decision to adopt an unrealistic EMD schedule and work back up the decision stream to identify the succession of decisions that yielded the unrealistic EMD schedule. This is an extremely ambitious, data-intensive, and in many respects analytically difficult approach. In contrast, McNicol (2020) takes an approach that is far easier and uses much less data. It seeks only to characterize the circumstances in which a decision to adopt a MS B baseline with substantial unrealistic elements is likely to occur.

The model is built on the premise that an unrealistic MS B baseline is more likely to be proposed by the PM and adopted by the MDA when competition for funds is more rather than less intense. The question then becomes: What governs the intensity of competition for funds and the ability of the PM to respond by proposing a MS B baseline with unrealistic elements? McNicol (2020) proposes: (a) funding climate—this is determined by several factors, the most volatile of which is the relative availability of funding for MDAP new starts; (b) a measure of the priority of the program—high priority programs are closer to the front of the line for funding; and (c) measures of changes over time in acquisition policy—the more stringent acquisition policy is, the less scope a PM has to propose an unrealistic MS B baseline. (A “high priority” program was defined as one that acquired a platform intended to play a major role in one of the Service’s major warfighting missions, e.g., the F-22.) These variables are in the portion of the model concerned with cost growth due to unrealistic elements in the MS B baseline.
McNicol (2020) would excel at a more challenging version of the test that included (a) the difference in cost growth between MDAPs that passed MS B in bust periods and those that passed in boom periods; and (b) the difference in cost growth between high- and low-priority programs. These differences are substantial. For example, for the first bust-boom phase (FY 1965–FY 1986), the difference is 28 percentage points: 46% for the bust phase and 18% for the boom phase (McNicol, 2018). The model in McNicol (2020) provides a cogent explanation of these differences, which finds substantial statistical support. The conventional wisdom and the model implicit in Lorell et al. (2017) have no explanation to offer for either the large difference between bust and boom periods and the smaller, but still substantial, difference between high- and low-priority programs.

McNicol (2020) does not do any better than the other models in explaining the data in Figure 1, however. At first glance it appears that it might. In particular, high-priority MDAPs might be expected to be in Categories I and IIa and low-priority programs in Category IIc and III. Plausible though this conjecture may be, it is not consistent with the data. Thirty-one MDAPs are in Category IIc. Of these, 23 (about 74%) were low-priority programs. (Recall that all the programs in Figure 1 passed MS B in a bust period.) Low-priority programs, however, account for about 77% of the sample behind Figure 1. Using a standard chi-square test, these two proportions are not significantly different.

**Conclusions**

The general answer to the question posed in this article is this: The acquisition community has major parts, but not all, of an explanation of the proximate causes of cost growth in MDAPs due to Errors of Inception. A great deal of effort has gone into Category III over the years. We probably understand the causes of extremely high-cost growth reasonably well. As well as making a major contribution to our understanding of Category III
programs, Lorell et al. (2017) give us a start on MDAPs with negative cost growth, and it probably would be easy to find additional factors involved. Overall, the literature has progressed to the point that deficiencies in understanding of Categories I, IIa, and III largely could be remedied by careful and judicious reading and synthesis. At present, however, no explanation satisfactorily accounts for the causes of cost growth in Categories IIb and, especially, IIc. Together, these two categories include over 40% (51 of 123) of the MDAPs in the sample used in this study.

The absence is important because an explanation of the proximate causes of cost growth due to Errors of Inception provides a foundation for recommendations for changes in acquisition regulations and policies. Stripped to its essentials, the presumption is that if a cause of cost growth can be seen, solutions can be found in additions to, or modifications of, acquisition policies and regulations. But most important for Categories IIb and IIc, significant uncertainty prevails throughout the defense acquisition community about just what is causing the relatively large cost growth observed and, consequently, the appropriate policy response.

The leading possibilities are (a) the magnitude by which one or more elements in the MS B baseline (for example, the cost estimate) is unrealistic; and (b) the interactions of two or more elements. These have different policy implications. If the problem is that large errors in particular elements occur with some frequency, attention is directed to the staff organizations at the OSD level responsible for review of those elements. Alternatively, if the problem is a toxic interaction of two or more elements of the baseline, the spotlight falls on the Overarching Integrated Product Team (OIPT), or—beginning in 2018 for most MDAPs—whatever body plays the role of the OIPT at the Service level. The OIPT’s established roles are to organize milestone reviews, ensure that the required documentation is available and meets quality standards, identify the issues raised in staff reviews, and resolve issues that can be resolved below the MDA level. On the assumption that a major proximate cause of cost growth is a toxic combination of
elements in the baseline, it also presumably would fall to the OIPT to identify these elements and propose alterations of them in a way that avoids the problem of large cost growth.

A deeper insight into this topic is found in a comparison of comments made by Tom Christie and Paul Francis in the Senate Staff Compendium (Senate Report No. 113-28, 2014). Both assert that in a significant proportion of cases, the MDA accepts a MS B baseline in the face of creditable evidence that some of its elements are unrealistic, which is to say that in these instances, the MDA did not fully enforce DoD’s acquisition rules. Christie’s evident remedy is for MDAs to apply established acquisition policy. Francis, in contrast, takes the view that the acquisition rules and policies actually followed by MDAs have evolved over time under the pressure of events. From this perspective, the fault is not in the failure of successive MDAs to apply the rules as written, but in a lack of flexibility and realism in the written rules themselves. Having made this intriguing and provocative point, Francis unfortunately does not go on to identify what rules he has in mind and how, over time, they evolved into something more permissive than written acquisition regulations.

**Implications for Further Study**

This article can be read as suggesting further research on the extent to which the magnitude of cost growth of MDAPs reflects:

- The degree of unrealism in elements of the MS B baseline (e.g., how unrealistic is the cost estimate?); and
- The interaction of two or more elements of the MS B baseline.

These suggestions are not offered with enthusiasm because at best it would be extremely difficult to capture the data required for a creditable study. Anyone interested in the results of such studies should not be in a hurry.
In the face of this obstacle, someone interested in ongoing events in the acquisition process might decide to accept the limitations of the empirical literature, take what is useful, and go directly to a policy problem. The two empirical issues listed previously direct attention to the effectiveness of the MS B review process. In 1964, Robert McNamara established the first OSD-level process for oversight of MDAPs. This provided the trellis on which the MS B process and its institutions grew for the next half century and more. It perhaps is time to identify and then evaluate fundamentally different approaches. A topic that would be approached similarly, but which is different in substance, could take off from the premise that in some cases the MDA accepts a proposed MS B baseline in the face of creditable evidence that some elements are significantly unrealistic. It would be reasonable to assume further that such decisions are much more likely to occur in bust periods. During bust periods, senior officials were constrained to select from a menu that offered only unpalatable choices: delay new starts; stretch ongoing programs; truncate or cancel ongoing programs; launch new programs that will provide less capability than the threat warrants; or adopt unrealistically optimistic assumptions at MS B—especially on cost—for major acquisition programs. One question never asked, but which should be, is this: Given the circumstances assumed, was it at least sensible if not cost-effective to adopt a baseline with unrealistic features? And then, depending on the answer to this question, it is reasonable to ask whether the formal acquisition regulations should be modified to recognize the discretionary authority that senior officials may choose to exercise.
References


Can We Explain Cost Growth in Major Defense Acquisition Programs?

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