Is the Ratio of Investment between Research and Development to Production in Major Defense Acquisition Programs Experiencing Fundamental Change?

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A Report of the CSIS DEFENSE-INDUSTRIAL INITIATIVES GROUP

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II

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Abstract

With the advent of the information age, both commercial industry and the Department of Defense are moving towards complex R&D-intensive systems over the simpler, mass-produced systems of the industrial age. This paper uses budgetary and program data to better understand the historical trends in the relationship of production costs to development costs in complex acquisition programs.
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Chapter 1: Introduction

This paper presents analysis of the historical trends in the relationship of production costs to development costs in complex acquisition programs. To understand this phenomenon, the study team examines it at two different levels. The first is the macro investment level where portfolio management trade-offs are made between aggregate development and procurement and between programs. The second level is individual programs where the ambitions of the program and the underlying technology shape the resources required for a program to complete development.

Starting with the macro level, for all militaries, finding the proper investment balance between the needs of the current force structure and the potential future force structures is a recurring challenge. Militaries must find a balance between the procurement of existing systems with the development of new platforms and technologies. In the United States, this dynamic has followed a cyclical historical pattern in the ratio of procurement to research, development, test, and evaluation (RDT&E) in the Department of Defense (DoD) budgets. When the overall DoD budget increases, procurement would rise disproportionately and thus the ratio of procurement to RDT&E would also increase. Inversely, when the defense budget would fall, procurement spending would fall faster than the overall budget, and the ratio of procurement to RDT&E would also fall. Since Fiscal Year (FY) 1955 DoD has spent an average of 2.2 dollars on procurement for every dollar spent on RDT&E. However, as shown in Figure 1, the center of the range of this cycle abruptly shifted downwards following the peak of the Reagan buildup when DoD was spending 3.25 dollars on procurement.
for every dollar spent on RDT&E, a level that has not been approached again in subsequent years.

Following the peak of the Reagan buildup, the ratio of procurement to RDT&E fell as the overall defense budget declined, but this time it fell more sharply than previous drawdowns and failed to rebound to expected levels during subsequent budget increases. The ratio of procurement to RDT&E fell to a historic low of 1.22 in FY 1998, compared to the previous historic low of 1.95 in FY 1975, as a result of the 1990s “procurement holiday” that led to sharp cuts in procurement spending and only relatively modest declines to RDT&E. Furthermore, after defense contracting rebounded in the 2000s, the 2.17 ratio of procurement to RDT&E in FY 2008 remained well below the historical average and significantly below the 3.24 to 3.64 ratios of previous peak buildup periods. The historically low ratio of procurement to RDT&E seen during the 1990s can be explained by the decisions made following the end of the Cold War and the success of the Gulf War to prioritize the development of next-generation weapon systems and the 1990s procurement holiday that slashed procurement budgets. But why did the ratio of procurement to RDT&E remain below historical averages during the mid-to-late 2000s despite historic modernization budgets? Is there something different about this generation of major defense acquisition programs (MDAP) or are there other factors at play?

**Figure 1-1: DoD Ratio of Procurement to RDT&E, 1955-2018**

Weapon systems, and other complex acquisition programs, have always grown in complexity from generation to generation, but has the information age brought about a fundamental change in the relationship between R&D and production? Compared to the simpler mass-produced systems of earlier generations, today’s systems are exponentially more complex and heavily leveraged on software. In 1960, software performed only 8 percent of an F-4’s functions. By 1982, that rose to 45 percent in the F-16, and by 2000, software performed 80 percent of the functions in the F-22.\(^1\) DoD’s software development and maintenance requirements have been estimated to be growing somewhere between 15 to 20 percent annually.\(^2\) These trends are not unique to defense. Boeing’s 787 Dreamliner requires 14 million source lines of code (SLOC) and some of today’s premium-class cars utilize up to 100 million SLOC. When compared to the 400,000 SLOC in the original Space Shuttle, the importance of software is evident.

The growth in software requirements are staggering, but is a fundamental change in the relationship between production and development underway? For companies, the answer to this question could have business–altering dynamics. For firms like Boeing and others in the defense marketplace, the business model has been to conduct development and early production at a monetary loss before turning a profit as production ramps up. However, if a fundamental change in the relationship between development and production is underway, these business models may no longer be sustainable.

This paper begins by analyzing the literature on MDAPs to examine whether there are noticeable differences in the acquisition of MDAPs today compared to historical trends. Next, the paper outlines the research approach and methodology to be used in this study. The paper then explores the historical R&D trends, both within DoD and the broader economy. Within DoD, this paper looks at the trends in the composition of the DoD R&D portfolio, while the economy–wide analysis looks at the trends in R&D intensity by economic sector. Following this look at the historical R&D patterns, the paper looks at the trends in the ratio of procurement to RDT&E across DoD for the components and select platform portfolios. Finally, this paper concludes by summarizing the trends across the different categories to assess whether there is an ongoing change in the ratio of investment between R&D to production in MDAPs.


Chapter 2: Declining Procurement-RDT&E Ratios: The Result of a Broken Acquisition System?

The problems with the current MDAP portfolio are well-known to defense acquisition observers and have led many to state that the defense acquisition system is broken. However, are there truly significant differences between this generation of MDAPs and previous generations? In 2008, the Government Accountability Office (GAO) made headlines when it reported that 70 percent of DoD’s MDAPs were over budget and behind schedule. Cumulative MDAP cost-growth totaled $295 billion, and the average MDAP was 21 months behind schedule. Are the delays and cost growth associated with today’s MDAPs higher than historic rates?

Policymakers and analysts have been concerned about the development and procurement of major weapon system platforms since the advent of the modern defense industrial base at the end of World War II. Despite the ever-increasing complexity of weapon systems from generation to generation, studies of the changes to the procurement system show that the management problems have been remarkably consistent. Multiple studies have shown that weapon system cost growth, during development

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and procurement, and schedule growth has remained largely consistent over time. Additionally, recent analysis both in and out of government show that cost growth today is similar to historical rates. These studies suggest that most of cost growth in MDAPs occurs during the development phase. For example, Younossi et al. found that “the average adjusted total cost growth for a completed program was 46 percent from [Milestone] B and 16 percent from [Milestone] C.”

Concerning cycle times, David Tate found that “highly-visible programs,” those with the greatest total acquisition costs, are driving a false perception that cycle times have been increasing over the past 25-plus years. Instead, Tate found that for all commodity types, including “highly-visible programs,” cycle growth over the past 25 years has been statistically insignificant. Scholars have found a difference in the cost growths of programs resulting from the differing conditions of the funding climate for when programs achieve Milestone B status. David McNicol and Linda Wu found that if a program attained Milestone B status when the budget climate is relatively constrained, the program could be burdened by overly optimistic costing assumptions. When these optimistic assumptions fail to pan out, the result is significant cost growth. Thus, McNicol and Wu conclude that programs that attain Milestone B status in “bust” periods are more likely

7 Younossi et al., Is Weapon System Cost Growth Increasing?, 17.
to experience cost growth than programs that attain Milestone B status in “boom” periods.9

The literature suggests that the cost and schedule growth in MDAPs since the 1990s are not beyond historical norms and do not explain the topline trends in the declining ratio of procurement to RDT&E. Although these previous studies extensively studied cost and schedule growth in MDAPs, there has been little analysis of the ratio of procurement to RDT&E. Previous analysis has largely focused on the topline budget trends previously highlighted or topline MDAP data.10 The 2015 Performance of the Defense Acquisition System reported that for the 76 active MDAPs, “[a]t the median, the procurement share is more than six times larger than the RDT&E share.”11 However, these reports contained no further breakdowns of the data service or platform.

Chapter 3: Methodology and Study Design

Given the literature suggests that these trends are not necessarily the result of a broken acquisition system but rather the result of other factors, this paper seeks to further investigate the potential sources of the declining ratio of procurement to RDT&E across the DoD. Additionally, given the software growth trends occurring in defense and non-defense complex acquisition programs, this paper looks to see if there are similar trends occurring in the broader economy. Specifically, this paper seeks to answer the following questions:

- Has the relative importance of R&D changed across the broader economy over the past four decades?
- What are the historical trends in the ratio of procurement to RDT&E funding for MDAPs?
- What are the historical trends in the ratio of procurement to R&D funding in the DoD components? Are there significant differences between the DoD components?
- What are the historical trends in the ratio of procurement to R&D among MDAPs between the DoD components? Are there significant differences between the DoD components?
- What are the historical trends in the ratio of procurement to R&D among MDAPs between the different platform portfolios? Are there significant differences between platform portfolios?
3.1 | Data Methodology

To compare the DoD budget trends to broader economic trends, this paper looks at the historical R&D intensity trends in select manufacturing and non-manufacturing industries. The study team selected industries that are similar in nature to the defense industry. R&D intensity is measured by total expenditure of all firms on R&D over total net sales in an industry. Although R&D intensity is not perfectly analogous to the DoD budgetary trends, it provides a rough approximation given limited visibility into more specific budgetary trends within private companies. Additionally, while R&D intensity is not without issues,\(^\text{12}\) it is a commonly used method of measuring “the relative importance of R&D across industries and among firms in the same industry.”\(^\text{13}\)

To measure the topline historical ratio trends for the MDAP portfolio, this paper uses the data from Selected Acquisition Reports (SAR). The issues associated with SARs have been well-documented,\(^\text{14}\) but they still provide the most reliable source of data.\(^\text{15}\) This paper created a dataset using the annual SAR data accessed through Defense Acquisition Management Information Retrieval (DAMIR) and the Defense Acquisition Visualization Environment (DAVE) for MDAPs from FY 1997 to FY 2017. To enable historical comparisons, the DAMIR SAR data are supplemented with historical data from RAND’s Defense System Cost Performance Database (DSCPD) made available in The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports, which provides a summary of SAR data from the 1960s to FY 1994.\(^\text{16}\)

Using this combined dataset, this paper then took several steps to filter and categorize data to enable more granular statistical analysis. First, this paper excluded Ships & Submarines from this analysis due to the foundational

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14 Some of the problems with utilizing SARs include but are not limited to: inconsistent baseline cost estimates, exclusion of some significant cost elements, exclusion of special access programs, constantly changing preparation guidelines of SARS, and inconsistent interpretations of preparation guidelines across programs.
differences in acquisition approaches between shipbuilding and other MDAPs.\textsuperscript{17} Second, this paper filtered out MDAPs that were exclusively RDT&E or Production. From this dataset, MDAPs were then categorized into one of the 11 CSIS platform portfolio categories.\textsuperscript{18} Finally, MDAPs were categorized into decades based on when their first baseline estimate was approved. Accordingly, most MDAPs are categorized into the appropriate decade according to their original development baseline estimate. Programs without a development baseline estimate are categorized according to their baseline production estimate.

From this refined dataset, this paper looks at the MDAP data, further broken down by component and platform portfolio, in three ways. First, it analyzes the ratio of procurement to RDT&E estimated at development for all MDAPs with a development baseline. Using the development estimate baseline data, this view provides an assessment of what DoD expects the ratio of procurement to RDT&E for MDAPs to be at the start of the development process. Next, it considers the ratio of procurement to RDT&E estimated at production for all MDAPs with a production baseline. Using the production estimate baseline data, this shows what DoD anticipates the ratio of procurement to RDT&E to be during actual production. Finally, this paper analyzes the trends for only the MDAPs that have both a development and production baseline to assess how the estimate ratio of procurement to RDT&E changed between the start of development and production. This approach was chosen in part to make transparent that much of the differences between RDT&E estimate trends and procurement estimate trends could be attributed to the differences in the MDAPs comprising the two samples.

For the entire sample and for the components, the study team also created simple pairs of regression models with the ratio of procurement to RDT&E at Milestone B and Milestone C as dependent variables. These models include only a small number of inputs, but they provide a way of checking whether differences over time may simply be attributable to having more aircraft programs in one decade or the next or whether the proportion of MDAPs with both forms of estimates proved decisive.

\begin{thebibliography}{99}
\end{thebibliography}
Chapter 4: Historical R&D Trends

This paper presents analysis of the historical trends in the relationship of production costs to development costs in complex acquisition programs. To understand this phenomenon, the study team examines two different levels. The first is the macro investment level where portfolio management trade-offs are made between aggregate development and procurement and between programs. The second level, covered in Chapter 5, are individual programs where the ambitions of the program and the underlying technology shape the resources required for a program to complete development.

4.1 | Historical R&D Intensity Trends by Industry

How do these trends compare to the broader marketplace? Although software and high-tech intensive devices get much of the media attention, are we seeing shifts in the importance of R&D to industry more generally? These questions are challenging to address. The available data on civilian firms are not as thorough as the information provided in the defense budget, which makes perfectly analogous comparisons difficult for outside researchers. Instead, the study team looks to R&D intensity, which reports domestic R&D spending as a percentage of domestic sales, an economic metric that aids in understanding the general importance of R&D to firms in a certain sector. Straightforwardly, a higher level of R&D intensity means proportionally greater R&D activity in the sector in question.

Evaluating historical analysis of R&D intensity trends within industries is complicated by the creation of the North American Industry Classification...
System (NAICS) in 1997 and subsequent move away from, and eventually elimination of, the Standard Industrial Classification (SIC) system. This results in a split data set. This report uses the R&D intensity data from the National Science Foundation, which used SIC codes up until 1998 before switching to NAICS codes in 1999. Given the shift from SIC codes to NAICS codes, this paper focuses on the general trends from 1970 to 1998 and then from 1998 to 2014.


Figure 4-1: R&D Intensity in Manufacturing and Select Industries, 1970-1998

The data show that R&D intensity in the manufacturing sector did not follow a singular long-term trend but a series of intermediate trends, as shown in Figure 4-1 above. Throughout the 1970s, manufacturing R&D intensity gradually fell from approximately 3.7 in 1970 to 2.6 in 1979. Then from 1980 to 1986, manufacturing R&D intensity grew at 7.68 percent Compound Annual Growth Rate (CAGR). Finally, from 1986 to 1996 manufacturing R&D declined at 2.84 percent CAGR.

Beyond the topline manufacturing R&D intensity trends, the data show that the trends could vary between industries. Across the broader Transportation industry, the data show that R&D intensity was on a downward trend since
the late 1980s. R&D intensity in the Transportation industry declined at 6.3 percent CAGR from 1987 to 1998. Comparatively, the Electrical Equipment industry followed a more cyclical pattern but remained relatively steady.

Aircraft and Missiles is one subset of the Transportation industry of particular interest to this paper. The data show that R&D intensity trends in the Aircraft and Missile industry followed a cyclical pattern, relatively similar to DoD’s trend in the ratio of procurement to RDT&E. In the Aircraft and Missiles sector, R&D had cyclical periods of growth followed by periods of decline and vice versa but has been broadly trending downward since the mid-1980s.

4.1.2 | R&D INTENSITY: 1999-2014

The data show that there is not an economy-wide trend in the importance of R&D, as measured g sector and has seen steady growth but remains below historical averages since 1999.

Figure 4-2: Manufacturing and Nonmanufacturing R&D Intensity, 1999-2014

The data show that below the Manufacturing industry level, there are no obvious trends in the data. Among the selected manufacturing industries and sub-industries (Computer and Electronics; Transportation Equipment; Aerospace Products and Parts) the data are often noisy, with significant variance year-to-year.
The data for selected industries in the Nonmanufacturing sector is less noisy overall and does suggest more definitive trends. Figure 4-3 shows the selected industries within the Manufacturing and Nonmanufacturing sectors from 1999 to 2014. The data show that, in general, R&D intensity in the Professional, Scientific, and Technical Services industry (NAICS code 54) is on a downward trend since 2000. From a peak of 18.7 intensity in 2001, R&D intensity for that sector fell as low as 3.2 in 2010 and is currently 7.8 in the latest available data. In Information, the other selected Nonmanufacturing industry, R&D intensity has been trending slightly upward in the past few years after holding steady throughout earlier years of reporting data. However, similar to the trend for the broader Manufacturing sector, it is too early to draw definitive conclusions.

Figure 4-3: R&D Intensity in Select Industries, 1999-2014

Source: National Science Foundation Business Research and Development Innovation Survey; CSIS analysis.

Note: Gaps in the data in certain years are due to the NSF masking that year’s data.

In general, the data do not show an overall shift in the importance of R&D across the broader market over the past 40 years when measured using R&D intensity. There are certain trends in the broader Manufacturing sector and the Information industry that suggest a shift could be occurring, but it remains too early to draw definitive conclusions.
4.2 | Defense R&D Trends

The budget data show that the ratio of procurement to RDT&E spending has been declining in recent years, but has the composition of the R&D portfolio changed? The following sections analyze the trends in R&D by type of R&D to examine whether changes in the composition of DoD’s R&D portfolio can explain the declining budgetary ratio of procurement to RDT&E.¹⁹

4.2.1 | Weapons Development v. Science & Technology

Figure 4-4 shows the trends in defense R&D budgets for Weapons Development and Other (WD&O) and Science and Technology (S&T) from FY 1976 to FY 2016.²⁰

The data show that DoD R&D spending on both WD&O and S&T has increased since FY 1976, but there have been some notable differences between the two R&D categories. WD&O spending growth has outpaced S&T spending.


since FY 1976 but has been more cyclically volatile, experiencing periods of more extreme growth and declines compared to the modest swings in S&T funding levels. From FY 1976 to FY 2008, WD&O grew at a 3.3 percent CAGR compared to the 2.3 CAGR for S&T. However, from FY 2008 to FY 2016, WD&O declined at a 3.9 percent CAGR, while S&T marginally grew at a 0.1 percent CAGR.

**Figure 4-5: Share of Defense Research & Development, 1976-2016**

As shown in Figure 4-5 above, despite WD&O spending outpacing S&T growth from FY 1976 to FY 2016, their share of total DoD R&D spending has remained relatively steady, with only a marginal increase in WD&O’s share. There have been some fluctuations, particularly in the more volatile WD&O periods, but WD&O has historically accounted for approximately 74 percent of DoD R&D from FY 1976 to FY 2016, while S&T accounted for 19 percent.\(^\text{21}\)

These trends show that despite external factors such as war, budget pressure, and changing priorities R&D reflects a relatively fixed cost for DoD. There have been some cyclical shifts in the composition of the R&D portfolio, but there has not been a massive shift in the composition of the DoD R&D portfolio between developing weapons and science and technology research.

\(^{21}\) These percentages do not add up to 100 percent because this analysis excludes the following R&D categories: DoD 2009 Recovery Act, DHS Defense-Related Activities, and DOE Atomic Defense.
4.2.2 | DoD Science & Technology Trends

As shown in Figure 4-6 below, while DoD S&T declined at a 0.1 percent CAGR between FY 1990 and FY 2016, there were notable differences within the three S&T accounts, Basic (6.1) and Applied Research (6.2), and Advanced Technology Development (6.3). Between FY 1990 and FY 2016, Advanced Technology Development (6.3) declined at a 2.1 percent CAGR. Comparatively, Basic Research (6.1) and Applied Research (6.2) increased at a 1.4 percent and 0.8 percent CAGR, respectively.

Figure 4-6: DoD Science & Technology Trends, 1990-2016

As shown in Figure 4-7 below, Advanced Technology Development (6.3) has unsurprisingly fallen sharply as a share of total DoD S&T spending and total DoD R&D spending. In FY 1990, Advanced Technology Development (6.3) accounted for 64 percent of S&T spending and 14 percent of total DoD R&D spending compared to 7 percent and 38 percent in FY 2016, respectively. Although Basic Research (6.1) and Applied Research (6.2) grew at equal rates as a share of S&T spending, Applied Research declined as a share of total DoD R&D spending while Basic Research held relatively steady.
In conclusion, these trends show significant shifts in the composition of DoD’s S&T portfolio over the past three decades away from more specialized mid-tier R&D to early-stage R&D. Although Advanced Technology Development largely involves pre-Milestone B efforts, this mid-tier R&D stage is more focused on developing the specific subsystems and components that inform MDAPs than the more generic developments stemming from Basic and Applied Research.\(^\text{22}\)

Chapter 5: Ratio of Procurement to RDT&E Trends

The macro-level historical R&D trends do not show definitive shifts in the relative importance of R&D, but what are the historical trends in the ratio of procurement to RDT&E funding for MDAPs? Furthermore, are there significant differences between the military services or the type of MDAP being procured? The following sections examine the trends in the ratio of procurement to RDT&E for MDAPs in three ways: overall DoD; the three military services; and the Aircraft, Ordnance & Missile, and Electronics, Comms, & Sensors platform portfolios. For each unit of analysis, the following sections look at the development baseline estimate trends, the production baseline estimate trends, and a comparison between the two estimates for MDAPs. For the military services, this analysis is complimented by analysis of the procurement and RDT&E budgetary trends.

5.1 | Overall DoD Ratio of Procurement to RDT&E

The following sections show the trends for all DoD MDAPs with an original approved development or production estimate, excluding those filtered out for the reasons listed in the methodology section.

DEVELOPMENT ESTIMATE

The data show that the estimated ratio of procurement to RDT&E during the development phase has fallen over the past decades by nearly every measurement. Except for the 2000s, the median development estimate (DE) estimated ratio of procurement to RDT&E was lower than the
previous decade’s ratio median. However, even the 2000’s median ratio of procurement to RDT&E (3.20) was lower than that of the total population (3.43). Furthermore, the upper quartile value has been on the decline since the 1980s, signaling a decline in the estimated ratio of procurement to RDT&E for at least three-fourths of MDAPs. Finally, variability, as measured by the interquartile range (IQR), has been declining since the 1980s, but there has been notably smaller variability in the two most recent decades.

Figure 5–1 below shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate (DE) baseline for all MDAPs.

**Figure 5-1: Overall DoD MDAPs Development Estimate Baseline by Decade**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>19</td>
<td>58</td>
<td>56</td>
<td>40</td>
<td>50</td>
<td>22</td>
<td>245</td>
</tr>
<tr>
<td># Outliers</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>9</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>Max Value</td>
<td>80.80</td>
<td>97.67</td>
<td>112.49</td>
<td>38.00</td>
<td>37.88</td>
<td>22.64</td>
<td>112.49</td>
</tr>
</tbody>
</table>

Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis.
Note: Outliers not shown on graph.

**PRODUCTION ESTIMATE**

The production baseline estimate data for all MDAPs are less conclusive. Measuring by the median, the production estimate ratio fell sharply during the 2000s (2.93) after holding steady the previous two decades (4.92). Although the median subsequently rose during the 2010s (3.76), it
remains below historical averages (4.14). The upper quartile trends show a
different trend, however. The upper quartile for production (PdE) estimates
experienced a whipsaw over the past three decades. The upper quartile rose
during the 1990s (12.3) from the 1980s level (10.26) before falling sharply
during the 2000s (9.71) which was then followed by a rebound to relatively
new historic levels during the 2000s (12.62).

These two trends suggest contradictory explanations for whether the ratio of
procurement to RDT&E estimated at production is experiencing fundamental
change. The median trends suggest that the ratio of procurement to RDT&E
estimated at production for a “typical” MDAP is declining. However, this
trend does not appear to be consistent across the sample. Those MDAPs
that are more procurement intense appear to be moving in the opposite
direction, as shown by the apparent growth in the upper quartile ratio of
procurement to RDT&E estimated at production. Figure 5-2 shows the
statistical distribution of the estimated ratio of procurement to RDT&E at
the production estimate baseline for all MDAPs.

**Figure 5-2: Overall DoD MDAPs Production Estimate Baseline
by Decade**

<table>
<thead>
<tr>
<th>Decade Program Began</th>
<th>1960s</th>
<th>1970s</th>
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<th>2000s</th>
<th>2010s</th>
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<tr>
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<td>7</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td><strong>Max Value</strong></td>
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<td>287.00</td>
<td>94.19</td>
<td>689.86</td>
<td>510.97</td>
<td>258.38</td>
<td>689.86</td>
</tr>
</tbody>
</table>

Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis.
Note: Outliers not shown on graph.
DEVELOPMENT ESTIMATE V. PRODUCTION ESTIMATE

Figure 5-3 shows the statistical distribution of the ratio of procurement to RDT&E for MDAPs at the development estimate versus the production estimate.

Figure 5-3: Comparison of Estimated Ratio of Procurement to RDT&E at Development v. Production for Only MDAPs with Both Estimates by Decade

Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis.
Note: Outliers not shown on graph.
Looking only at the MDAPs with both development and production estimates, two key trends emerge: (1) optimistic development estimates and (2) a declining ratio of procurement to RDT&E.

The data show that estimates are more optimistic at the start of development than those at the beginning of production. For the total population of MDAPs in this dataset across all six decades, the median estimated ratio of procurement to RDT&E was 4.05 during development compared to 3.64 during production. Development’s higher ratio of procurement to RDT&E also held true at both the lower and upper quartiles compared to production.

The data further show that the estimated ratio of procurement to RDT&E is declining for MDAPs with both development and production estimates by most measures. The median ratio of procurement to RDT&E estimated during development has been falling since the 1980s, while the ratio estimated during production started declining during the 1990s. The upper quartile for both development and production has declined since the 1980s. Finally, the lower quartile data show that production’s lower quartile has declined since the start of the century, while the trends are more inconclusive in development. The lower quartile grew from the 1.51 in the 1980s to 2.15 in the 2000s but fell to 1.47 during the 2010s. Although some of the decline can be accounted for by the 2010s smaller population count, there was a similar decline in the topline development estimate trends.

Of note, the median development estimate ratio of procurement to RDT&E for programs with both a development and production estimate is higher (4.05) than the topline development estimate ratio median (3.43). Meanwhile, the median production estimate ratio of procurement to RDT&E for programs with both a development and production estimate is lower (3.64) than the topline production estimate ratio median (4.14).

**REGRESSION MODEL**

The results show some support for the findings above, but do not reach the 95 percent significance level. For development, the ratio of production to RDT&E correlates negatively with the year but is only significant at the 90 percent level. The coefficient suggests a one-unit change in year (~23 years) correlates to a 27.3 percent reduction in ratio, all else being equal. For production, the relationship is also negative, though not significant. As discussed below in the Component sections, the more focused model for individual components does find some significant relationships between years, the time variable, and the ratio of procurement to RDT&E. This difference suggests that military organizations’ strategic choices remain a critical factor even in a time of technological transformation.
The model also sheds light on the difference in composition between those MDAPs with both development and production estimates and those with only one. The strongest result is tied to the presence or absence of a development estimate. Namely, when estimating the log of the ratio at production, those MDAPs with a development estimate correlate with a 71.3 percent lower ratio at the 99.9 percent significance level, assuming all other factors are held constant.

For platform portfolios, the baseline used in the model is aircraft, so the other five categories are relative to aircraft rather than an average of all MDAPs. Electronics, Communications, and Sensors proved significant for ratios at development and production, with ratios estimated to be respectively 52.2 percent to 57.8 percent lower than those for aircraft. The results are even stronger for Space Systems, with ratios that are estimated to be 77.0 percent to 74.2 percent lower, respectively. These discussed differences between platforms are significant at the 99 percent level or higher, assuming that all other factors are constant.

<table>
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<th>Table 5-1: Regression Model of Entire Sample</th>
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***p < 0.001, **p < 0.01, *p < 0.05, p < 0.1.
Overall DoD Takeaways:

- The development estimate ratio of procurement to RDT&E is declining by nearly all measurements. A simple regression model supports this finding but only at the 90 percent level.

- The production estimate ratio of procurement data is more inconclusive as to whether the declines during the 2000s were an anomaly or the beginnings of an emerging trend. The data show that while the median ratio of procurement to RDT&E in the 2010s remains below historical levels the upper quartile is higher than historical levels.

- For MDAPs with both development and production estimates:
  - The development estimated ratio is more optimistic than production.
  - The ratio of procurement to RDT&E has declined for both development and production.

5.2 | Ratio of Procurement to RDT&E by Component

The following sections show the trends in the ratio of procurement to RDT&E across the military components measured at both the budgetary level and by MDAPs.

5.2.1 | DEPARTMENT OF THE ARMY

The budget data show that the Army, unlike either the Navy or the Air Force, has continued to follow cyclical historical patterns, with a high ratio during buildups which then declines during drawdowns. Since FY 1955, the Army has spent on average 2.36 dollars on procurement for every dollar spent on RDT&E. Figure 5-4 shows the ratio of procurement to RDT&E in the Army’s budget from FY 1955 to FY 2018.
The Army was the only service that returned to the historical cyclical pattern during the mid-2000s. This trend was driven in large part by the operations in Iraq and Afghanistan, but these trends are interesting given the failures of nearly all the Army’s marquee acquisition programs over that period. Additionally, as the wars in Iraq and Afghanistan began to wind down and end, the ratio of procurement to RDT&E remained above historical averages, contrary to previous cycles. During this most recent drawdown, Army RDT&E fell much more sharply than in previous cycles.

Development Estimate

Figure 5–5 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate baseline for Army MDAPs.
The data show that unlike the Overall DoD trends, the ratio of procurement to RDT&E for Army MDAP’s estimated during development has been increasing over the past 30 years. The median ratio of procurement was declining between the 1960s and the 1980s but has been rising since. The median went from 6.00 during the 1960s to 3.13 during the 1980s before rising to 5.64 during the 2010s. The lower quartile trends follow a similar pattern, going from 2.97 during the 1960s to 1.16 during the 1980s before rising to 4.55 during the 2010s. Although the upper quartile trends differ slightly, they still support the overall trend of an increase in the estimated ratio of procurement to RDT&E for Army MDAP programs during the development phase. Even though Army development estimated upper quartile values declined during the 2000s before rebounding during the 2010s, the 2000s upper quartile (12.77) is higher than the upper quartile for the total population (11.24).

**Production Estimate**

Figure 5-6 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate baseline for Army MDAPs.
There has been a significant increase in the production baseline’s estimated ratio of procurement to RDT&E for Army MDAPs in recent decades. Absent a period of decline during the 1990s, the median Army production estimated ratio increased between the 1970s and 2000s. The lower quartile gradually increased between the 1980s and 1990s before further acceleration during the 2000s. Finally, the upper quartile has been declining since the 1980s, but all other measures show an increase in the ratio of procurement to RDT&E for Army MDAPs at production.

The data for the most recent decade (2010s) are more inconclusive, given the smaller sample size, as to whether this trend has reversed itself or is more analogous to the downturn in the 1990s. The statistical measures show decline in the ratio of procurement to RDT&E, but the small sample size makes it difficult to distinguish whether this is a broader trend or more representative of those five MDAPs.

**Development Estimates v. Production Estimates**

The Army trends for MDAPs with both development and production estimates
follow the Overall DoD finding of optimistic development estimates but are not experiencing the same fundamental change in the ratio of procurement to RDT&E.

The data show that the Army’s ratio of procurement to RDT&E estimated at development was higher than the ratio of procurement to RDT&E estimated at production in each decade going back to the 1970s. Furthermore, using the median for the total populations, the difference between the two estimates was 73 percent higher in the Army than Overall DoD. For Overall DoD, the difference between the total population’s development and production estimates median was 0.41 compared to 0.88 in the Army. The abnormally high difference between the Army’s 2000s development and production estimates only partially accounts for why the Army’s difference was 73 percent higher than Overall DoD as in every decade except the 2010s, the Army had a higher difference between the median of its development and production estimates than Overall DoD.

The median, lower quartile, and upper quartile data all show that the Army is not experiencing a fundamental change in the ratio of procurement to RDT&E for programs with both a production and development estimate. The data show that the median ratio of procurement to RDT&E estimated both at development and production is generally up since the 1990s. The data show similar trends through a general increase in the lower quartile values for both development and production since the 1990s. Finally, the data show that after an abnormally high upper quartile for both development and production during the 1980s the upper quartile held steady throughout the 1990s and 2010s at levels over twice that of the 1970s before seeing an up-tick in the 2010s.

Figure 5–7 shows the statistical distribution of the ratio of procurement to RDT&E for MDAPs at the development estimate versus the production estimate.
Regression Model

In keeping with the above results, the model of Army programs shown in Table 5–2 finds that the ratio of procurement to RDT&E is increasing over time, a trend in stark contrast to the other two military departments and the overall sample. For the sake of comparison, both overall models are included to highlight where the results align and where they diverge. This
model finds that a shift of 23 years correlates with a 183 percent increase in the ratio estimated at development and an even larger increase for ratio estimated at production. That said, both results are only significant at the 95 percent level, and the lower bound of their 95 percent confidence interval is only an increase of 13.7 and 12.9 percent, respectively. Given the wide range, the study team has confidence in the finding that Army is increasing its ratio of procurement to RDT&E in recent decades but does not provide an estimate for the rate of increase.

### Table 5-2: Regression Model of Army Programs

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<th>Log (Ratio at Development)</th>
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<td>Estimating History</td>
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<tr>
<td>Available at Development</td>
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<td></td>
</tr>
<tr>
<td>Available at Production</td>
<td></td>
<td>0.26 (0.16)</td>
</tr>
<tr>
<td>Platform Portfolio</td>
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</tr>
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<td>Elec., Comms, &amp; Sensors</td>
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<td>-1.16 (0.41)**</td>
</tr>
<tr>
<td>Ordnance and Missiles</td>
<td>-0.75 (0.40)</td>
<td>-0.37 (0.20)</td>
</tr>
<tr>
<td>Land Vehicles</td>
<td>0.40 (0.46)</td>
<td>0.49 (0.36)</td>
</tr>
<tr>
<td>Missile Defense</td>
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<td>-0.22 (0.37)</td>
</tr>
<tr>
<td>Space Systems</td>
<td></td>
<td>-1.47 (0.35)**</td>
</tr>
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<td>AIC</td>
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<td>597.71</td>
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<td>BIC</td>
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<td>Log Likelihood</td>
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<td>-288.85</td>
</tr>
<tr>
<td>Deviance</td>
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<td>Num. obs.</td>
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***p < 0.001, **p < 0.01, *p < 0.05, p < 0.1.
The Army’s development estimate data show that, unlike Overall DoD trends, the Army’s ratio of procurement to RDT&E estimated at development has been increasing over the last 30 years. The simple regression model also supported this finding, significant at the 95 percent level.

The Army’s production data is inconclusive as to whether there is a fundamental ongoing change in the ratio of procurement to RDT&E. The median data suggests that the investment ratio is steady despite whipsaw, while the lower quartile trends show an increase and the upper quartile trends show a decrease. The simple regression model aligns with the median, finding an increase that is significant at the 95 percent level.

For MDAPs with both development and production estimates:

- Similar to Overall DoD, Army development estimates are more optimistic than production estimates. However, the difference between Army development and production estimates is nearly 50 percent higher than Overall DoD.

- Unlike Overall DoD, the ratio of procurement to RDT&E has increased over the last three decades.

### 5.2.2 | DEPARTMENT OF THE AIR FORCE

Of the three military services, the Air Force has the lowest historical ratio of procurement to RDT&E, spending one dollar on development for every 2.05 dollars spent on production. This is not surprising given the Air Force’s cultural preference for new, high-tech solutions even before it became its own military service in 1947. Furthermore, the National Reconnaissance Office’s budget falls under the Air Force. Figure 5-8 shows the ratio of procurement to RDT&E in the Air Force’s budget from FY 1955 to FY 2018.
Is the Ratio of Investment between Research and Development to Production in Major Defense Acquisition Programs Experiencing Fundamental Change?

Figure 5-8: Air Force Ratio of Procurement to RDT&E, 1955-2018


The Air Force differs from the other services in a few notable ways. First, whereas the other services saw a rapid spike followed by a quick decline during the Reagan buildup, the Air Force experienced a smaller spike earlier, followed by a more gradual rise. Second, the Air Force ratio fell lower than any of the other services during the 1990s, falling to as low as 1.07 in 1997. That year, the Air Force spent nearly one dollar on RDT&E for every dollar that it spent on procurement.

After hitting a historic low in FY 1997, the Air Force’s ratio of procurement to RDT&E gradually grew from FY 1998 to FY 2008. The ratio then began to fall again from FY 2008 to FY 2014 before increasing from FY 2014 to FY 2017.

Development Estimate

Figure 5–9 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate (DE) baseline for Air Force MDAPs.
The data show that the ratio of procurement to RDT&E for Air Force MDAPs' development estimates has been declining since the 1980s. The DE median ratio fell from 3.60 during the 1970s to 2.46 in 1990 before the sharp decline to 0.78 during the 2000s. The median ratio slightly increased to 1.07 during the 2010s but is still well below the total population's 2.59 median. Similarly, the upper and lower quartile went from 1.84 and 11.16 during the 1970s to 0.36 and 3.48 during the 2010s, respectively.

**Production Estimate**

Figure 5-10 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate baseline for Air Force MDAPs.
The Air Force data show that after peaking during the 1990s, the ratio of procurement to RDT&E estimated at development has been trending downward during the past two decades. The median went from 5.20 during the 1990s to 1.14 during the 2010s, well below the 3.16 median for the total Air Force population. Similarly, the upper quartile fell to 3.26 during the 2010s compared to 23.35 during the 1990s and 8.85 for the total population. Finally, the lower quartile declined from 1.85 during the 1980s to 0.36 during the 2000s but held steady at that level during the 2010s.

*Development Estimates v. Production Estimates*

Figure 5–11 shows the statistical distribution of the ratio of procurement to RDT&E for Air Force MDAPs at the development estimate versus the production estimate.
Figure 5-11: Comparison of Estimated Ratio of Procurement to RDT&E at Development v. Production for Only Air Force MDAPs with Both Estimates by Decade

The data show that although the difference between the Air Force’s total population development estimate median and production estimate median (0.37) are roughly equivalent to the Overall DoD trends (0.41), the decade-by-decade data tell a different story. Between the 1970s and 2000s, production’s median estimated ratio was higher than development’s in the Air Force.
except for during the 1990s. Even when the development estimates were
more optimistic than production during the 1990s, the difference was not
sizable (0.07). However, this changed during the 2010s when the Air Force
had a more sizable difference between the development and production
medians (0.52), which matched the Overall DoD data (0.74) more closely
than ever before.

The development estimate baseline and production estimate baseline data
show that the ratio of procurement to RDT&E for Air Force MDAPs declined
between the 1980s and 2000s but could be experiencing a rebound during
the 2010s. Between the 1980s and 2000s, the median Air Force ratio of
procurement to RDT&E estimated at development and production declined
from 4.05 and 4.64 to 0.78 and 0.81, respectively. Similarly, the Air Force
lower and upper quartile estimated ratio of procurement to RDT&E went
from 1.22 to 0.30 and 7.15 to 4.58 for development estimates and from 1.22
to 0.29 and 5.33 to 3.14 for production estimates, respectively.

During the 2010s the declining ratio of procurement to RDT&E halted. For
the development baseline data, the lower quartile and median rose to 0.48
and 1.47, respectively. For the production baseline data, the lower quartile,
median, and upper quartile all rose to 0.31, 0.94, and 4.18, respectively.
However, given the generation’s population relative to the other generations,
it is too early to determine whether this data indicate a reversal in trends
or are just characteristic of these four MDAPs.

Regression Model

The simple regression model for Air Force programs, summarized in Table
5-3, shows a negative correlation between year and the ratio of procurement
to RDT&E at both development and production. The former result is the
significant one, with a change of 23 years associated with an 87.2 percent
decrease in ratio at development, with a decrease of only 45.1 percent at
the lower bound of the confidence interval. This result is significant at the
99 percent level. However, the similar finding for the ratio at production
is only significant at the 90 percent level. Given the large standard errors
for each of the findings, the study team is not confident in estimating the
magnitude of the relationship.
Table 5-3: Regression Model of Air Force Programs

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</tr>
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<td>Available at Production</td>
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***p < 0.001, **p < 0.01, *p < 0.05, p < 0.1.

Air Force Takeaways:

- The Air Force’s development estimate ratio of procurement to RDT&E has sharply fallen since the 1970s by nearly every measure, including a simple model significant at the 99 percent level.

- The Air Force’s production estimate data show that the Air Force is experiencing a fundamental change in the ratio of procurement to RDT&E in production estimates.

- For MDAPs with both development and production estimates:
  - Unlike the topline trend, the Air Force routinely had a higher ratio of procurement to RDT&E estimated at production than development from the 1970s to the 2000s. However, the Air Force’s more optimistic development estimates during 2010s more closely resembled the topline trend.
  - The Air Force experienced a meaningful change in the ratio of procurement to RDT&E between the 1980s and 2000s but could be experiencing a rebound during the 2010s. However, it is too early to definitively conclude whether this reversal is the start of a new trend or characteristic of the 2010s small count relative to the other decades.
Among the military services, the Navy has the highest historical average ratio of procurement to RDT&E (3.38). Figure 5-12 shows the ratio of procurement to RDT&E in the Navy’s budget from FY 1955 to FY 2018.

Figure 5-12: Navy Ratio of Procurement to RDT&E, 1955-2018


The Navy ratio trends have generally followed the Overall DoD trends, with a few notable differences. After the ratio of procurement to RDT&E in the Navy peaked in 1983, that ratio fell precipitously in the following years despite near-historic procurement budgets. Whereas the Overall DoD budget trends in those years were largely driven by procurement funding declining quicker than RDT&E funding, that was not the case in the Navy. Instead, the declining ratio in the Navy was driven by a $5 billion increase in RDT&E over a five-year period while the procurement budgets stayed relatively flat. In recent years, the ratio of procurement to RDT&E in the Navy fell from FY 2000 to FY 2005, during which time Navy RDT&E funding grew at nearly three times the rate of procurement funding. Since FY 2005, the Navy’s ratio of procurement to RDT&E has been on a stable but gradual growth path.
Development Estimate

Figure 5-13 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate baseline for Navy MDAPs.

Figure 5-13: Navy MDAPs Development Estimate Baseline by Decade

![Box plot showing the ratio of procurement to RDT&E by decade.]

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Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis.
Note: Outliers not shown on graph.

Similar to the topline DoD trends, the ratio of procurement to RDT&E for Navy MDAP’s estimated during development has declined since the 1990s. For all Navy MDAP development estimates, the median has gone from 4.24 during the 1980s to 1.24 during the 2010s, well below 3.16 median for the total Navy population. The lower quartile started declining during the 1970s, going from 5.22 in the 1960s to 2.61 in the 1970s before falling over the next four decades to 0.65 in the 2010s. The upper quartile decline lagged behind the median and lower quartile, only starting during the 1990s. The 15 percent decline in the upper quartile values from the 1980s to the 1990s was followed by a 60 percent decline during the 2000s. In total, Navy’s MDAP DE upper quartile went from 9.01 during the 1980s to 2.15 during the 2010s.
**Production Estimate**

Figure 5-14 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the production estimate baseline for Navy MDAPs.

**Figure 5-14: Navy Production Estimate Baseline by Decade**

![Box plot showing the ratio of procurement to RDT&E for Navy MDAPs by decade.](image)

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Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis.

Note: Outliers not shown on graph.

Navy MDAP data show a clear decline in the ratio of procurement to RDT&E estimated at production. The median trends show a gradual decline from the 1970s to the 1990s before a significant freefall during the 2000s. The median ratio of procurement to RDT&E for Navy MDAPs went from 6.98 during the 1970s to 5.11 during the 1990s to 1.93 during the 2000s. Navy production’s lower quartile started modestly declining during the 1990s, but similar to the median, there was a significant decline between the 1990s (2.84) and the 2000s (1.42). Finally, the upper quartile started declining during the 1990s similarly to the lower quartile, but unlike the lower quartile’s initial relatively modest decline, the upper quartile started immediately declining sharply. For Navy production estimates, the upper quartile went from 11.71 during the 1980s to 6.19 during the 1990s and then to 3.23 during the 2000s, a 47 and 48 percent decrease, respectively.
Development Estimates v. Production Estimates

The Navy trends for MDAPs with both development and production estimates follow the Overall DoD finding of optimistic development estimates and are experiencing fundamental change in the ratio of procurement to RDT&E.

For the total MDAP population, the Navy’s ratio of procurement to RDT&E estimated at development is higher than the ratio estimated at production just like the Overall DoD trend. However, unlike Overall DoD where development estimates have been roughly equivalent or higher than production since the 1970s, Navy production estimates have been higher than development estimates during the 1970s and 1990s. During the 1970s and 1990s, the Navy’s median ratio of procurement to RDT&E estimated at development was 3.73 and 3.91 compared to 3.31 and 4.75 at production, respectively. Additionally, for the total population, the difference between the ratio estimated at development and production is closer in the Navy (0.27) than the overall topline trend (0.41).

The descriptive statistics for Navy MDAPs with both a development and production estimate all show a decline in the ratio of procurement to RDT&E. In both the development and production estimates, the median has been on a downward trajectory since the 1980s. The development estimated ratio median has gone from 7.57 in the 1980s to 2.81 during the 2000s, while the production estimated ratio median went from 6.50 to 2.12. The upper quartile trends followed that same trend, going from 9.27 to 3.10 in development and 10.26 to 3.21 in production. Finally, the production estimate lower quartile trends followed these trends, but the development estimate quartile trends were more inconclusive given their increase during the 2000s. The lower quartile of the development estimate had been on a downward trend during the 1980s and 1990s but rebounded during the 2000s. However, despite this rebound, the declines in the median and upper quartile suggest that Navy MDAPs might be experiencing a fundamental change in the ratio of procurement to RDT&E.

Figure 5-15 shows the statistical distribution of the ratio of procurement to RDT&E for MDAPs at the development estimate versus the production estimate.
Figure 5-15: Comparison of Estimated Ratio of Procurement to RDT&E at Development v. Production for Only Navy MDAPs with Both Estimates by Decade

Source: RAND DSCP; SARs accessed through DAMIR; CSIS analysis.
Note: Outliers not shown on graph.

Regression Model

The regression results for Navy, as shown in Table 5-4, show a negative relationship between the year and the ratio of procurement to RDT&E spending at development but not at production. The relationship at development is significant at the 95 percent level. The model correlates a
23-year change in start year with a reduction of 76.6 percent in the ratio, although 26.5 percent falls within the 95 percent confidence interval for these results. As with Air Force, the study team is confident in the direction of the relationship but not in its magnitude.

<table>
<thead>
<tr>
<th>Table 54: Regression Model of Navy Programs</th>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>(Intercept)</td>
</tr>
<tr>
<td>Navy</td>
</tr>
<tr>
<td>Overall</td>
</tr>
<tr>
<td>Log(Ratio at Development)</td>
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<tr>
<td>-2.45 (0.32)**</td>
</tr>
<tr>
<td>1.85 (0.22)**</td>
</tr>
<tr>
<td>3.08 (0.49)**</td>
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<tr>
<td>3.02 (0.37)**</td>
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<tr>
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<tr>
<td>-1.46 (0.59)*</td>
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<tr>
<td>0.18 (0.29)</td>
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<td>0.26 (0.16)</td>
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<tr>
<td>-1.41 (0.39)**</td>
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<td>-1.25 (0.26)**</td>
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<tr>
<td>Platform Portfolio</td>
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<td>Elec., Comms, &amp; Sensors</td>
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<tr>
<td>-0.89 (0.32)**</td>
</tr>
<tr>
<td>-0.74 (0.22)**</td>
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<tr>
<td>-0.78 (0.47)</td>
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<tr>
<td>-0.86 (0.32)**</td>
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<tr>
<td>Ordnance and Missiles</td>
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<td>-0.76 (0.30)*</td>
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<td>-0.22 (0.42)</td>
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<td>-0.09 (0.29)</td>
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<td>Land Vehicles</td>
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<td>0.49 (0.36)</td>
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<td>0.08 (0.88)</td>
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<tr>
<td>47</td>
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<tr>
<td>144</td>
</tr>
</tbody>
</table>

**p < 0.001, *p < 0.01, *p < 0.05, p < 0.1.

**Navy Takeaways:**

- The Navy’s development baseline data show that the ratio of procurement to RDT&E estimated at development has sharply declined since the 1980s. The simple regression model aligns with these results over the entire period and is significant at the 95 percent level.

- The median, lower quartile, and upper quartile of the Navy’s production baseline estimate data have all fallen since the 1990s, albeit at different rates.

- For MDAPs with both development and production estimates:
  - Similar to Overall DoD, Navy development estimates are more optimistic than production estimates. However, there is a smaller difference between Navy development and production estimates and the overall trend. Additionally, unlike Overall DoD, the Navy’s production estimates were higher than its development estimates during the 1970s and 1990s.
  - Navy’s MDAPs are experiencing a fundamental change in the ratio of procurement to RDT&E. Except for the development estimate baseline’s lower quartile increasing during the 2000s, all other measurements show a declining ratio of procurement to RDT&E since the 1980s.
5.3 | Ratio of Procurement to RDT&E by Platform Portfolio

The following sections show the ratio of procurement to RDT&E in the following platform portfolios: Aircraft; Ordnance & Missiles; and Electronics, Comms, & Sensors. The study team explored regression models for the three categories of platform portfolios. However, these models added little that was not already found in the initial ratio regression model in the Overall DoD Trends section, which already includes a categorical variable for platform portfolios.

5.3.1 | AIRCRAFT

Development Estimate

The data show that the Aircraft platform portfolio is currently experiencing a change in the ratio of production to investment at the development estimate. After the median grew throughout the 1970s and 1980s, the median Aircraft ratio of procurement to RDT&E declined during the 2000s and 2010s. The median Ordnance & Missiles ratio went from 7.81 during the 1990s to 3.32 during the 2000s and 3.12 during the 2010s. The lower and upper quartile trends show that the distribution of the development estimate ratio for Ordnance & Missiles MDAPs shrunk over the past two decades. The upper quartile went from 17.52 during the 1990s to 4.63 during the 2000s. There was a slight uptick during the 2010s, as the upper quartile rose to 4.86, but it remains well below the total population’s upper quartile (7.79). Finally, the lower quartile data declined starting during the 1990s, dropping from 4.07 during the 1980s to 2.63. The lower quartile rebounded slightly to 2.81 during the 2000s but cratered during the 2010s to 0.40. Together, these three measurements show a declining ratio of procurement to RDT&E since the 1990s.

Figure 5–16 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate baseline of the Aircraft platform portfolio.
Figure 5-16: Aircraft Development Estimate Baseline by Decade

![Figure 5-16: Aircraft Development Estimate Baseline by Decade]

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<td>16</td>
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<td>1</td>
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<tr>
<td>Max Value</td>
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<td>34.37</td>
<td>40.19</td>
<td>38.00</td>
<td>4.31</td>
<td>2.39</td>
<td>80.80</td>
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</tbody>
</table>

Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis.

Note: Outliers not shown on graph.

Production Estimate

Figure 5–17 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the production estimate baseline of the Aircraft platform portfolio.
Is the Ratio of Investment between Research and Development to Production in Major Defense Acquisition Programs Experiencing Fundamental Change?

The Aircraft data show a more definitive decline in the production baseline’s ratio of procurement to RDT&E during the 2000s, where the median, lower quartile, and upper quartile ratio of development to production estimated for Aircraft MDAPs at production declined. During the 1990s, the typical ratio of procurement to RDT&E for an Aircraft program, as measured by the median, was 6.38 compared to 3.04 and 2.45 during the 2000s and 2010s, respectively. Both the upper and lower quartiles suffered similarly sharp declines during the 2000s. The lower quartile went from 4.48 during the 1990s to 1.15 during the 2000s, while the upper quartile went from 36.26 during the 1990s to 10.72 during the 2000s.

**Development Estimates v. Production Estimates**

The trends for Aircraft programs with both development and production estimates follow the Overall DoD finding of optimistic development estimates. While there is evidence to suggest a likely ongoing fundamental change in the ratio of procurement to RDT&E, the data are not definitive.

Figure 5-18 shows the statistical distribution of the ratio of procurement to RDT&E for Aircraft at the development estimate versus the production estimate.
The data show that since the 1990s the ratio of procurement to RDT&E estimated at development for Aircraft has been higher than the ratio estimated at production. During the 1990s, the estimated development median was 31 percent higher than the production estimate. Furthermore, the 2.81 difference between the two estimates was significantly higher than the 0.34 difference between Overall DoD estimates that decade. More optimistic Aircraft development estimates continued during the 2000s and 2010s, but the difference shrunk to 5 percent and 17 percent, respectively.

By every metric, the data show a dramatic drop in the ratio of procurement to RDT&E for Aircraft during the 2000s in both the production and
development estimates. The “typical” estimated ratio of procurement to RDT&E for an Aircraft program, as measured by the median, fell from 9.00 and 6.19 for development and production during the 1990s to 3.04 and 2.87, respectively. The declines from the 1990s to the 2000s in the upper quartile were more extreme, going from 30.13 to 3.26 in development and 13.95 to 3.26 in production.

The 2010s data show some rebound from these declines, but even with that rebound, the ratio of procurement to RDT&E is lower during the 2010s than for the total study population. Furthermore, because there are only a handful of Aircraft programs beginning during the 2010s that now have both a development and production estimate, it is difficult to draw robust conclusions from these trends. Instead, the data suggest that there is likely still an ongoing change in the ratio of procurement to RDT&E for Aircraft, but perhaps not to the same degree as suggested by the 2000s data.

**Aircraft Takeaways:**

- The Aircraft development estimate data show a declining ratio of procurement to RDT&E estimated since the 1990s.
- The Aircraft production estimate data show a declining ratio of procurement to RDT&E estimated between the 1980s and 2000s.
- For MDAPs with both development and production estimates:
  - Aircraft development estimates started becoming more optimistic than production estimates during the 1990s, but the gap between the two estimates has since shrunk.
  - There is likely an ongoing change in the ratio of procurement to RDT&E for Aircraft since the turn of the century but perhaps not to the same magnitude as suggested by the dramatic decline between the 1990s and 2000s.

**5.3.2 | ORDNANCE & MISSILES**

**Development Estimate**

Figure 5-19 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate baseline of the Ordnance & Missiles platform portfolio.
It is inconclusive whether there has been a change in the ratio of procurement to RDT&E in the Ordnance & Missiles platform portfolio over the past two decades given the volatility in the data. The 2000s data mostly show a rising Ordnance & Missiles ratio of procurement to RDT&E, with only the lower quartile declining. The median and upper quartile values rose from 3.10 and 5.33 during the 1990s to 5.24 and 11.52 during the 2000s, respectively. However, during the 2010s, the Ordnance & Missiles ratio of procurement to RDT&E estimated at development plummeted. The median fell from 5.24 to 0.58, the lower quartile went from 1.64 to 0.28, and the upper quartile went from 11.52 to 3.05. Given the whipsaw between the two decades, it is inconclusive whether one of the two trends are more relevant moving forward. Furthermore, the more limited number of Ordnance & Missiles programs only compounds the difficulty in drawing more significant trends from the data.

**Production Estimate**

Figure 5–20 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate baseline of the Ordnance & Missiles platform portfolio.
Is the Ratio of Investment between Research and Development to Production in Major Defense Acquisition Programs Experiencing Fundamental Change?

The data are insufficient to form conclusions on the ratio of procurement to RDT&E in Ordnance & Missiles production estimates. In the two most recent decades, there are not enough programs to make any trends sufficiently robust. Going back further, the data mostly suggest that by most measures the ratio of procurement to RDT&E increased during the 1990s, but the ratio of procurement to RDT&E metrics remained lower than those for the total Ordnance & Missiles production population.

**Development Estimates v. Production Estimates**

Figure 5-21 shows the statistical distribution of the ratio of procurement to RDT&E for the Ordnance & Missiles platform portfolio at the development estimate versus the production estimate.
Similar to Ordnance & Missile production estimates above, there is not sufficient data in recent years to draw conclusions about whether there has been a fundamental change in the ratio of procurement to RDT&E for Ordnance & Missiles. Although there are still some limitations, there is evidence suggesting more optimistic Ordnance & Missiles development estimates than production estimates.
The data show there is minimal difference between the Ordnance & Missiles platform’s ratio of procurement to RDT&E estimated at development versus production and the Overall DoD trends. Furthermore, there were more differences in two of the three relevant decades. For MDAPs beginning during the 1970s, the estimated ratio of procurement increased between development and production in the Ordnance & Missiles platform (-0.30) but remained roughly equal across DoD (-0.01). There was near equivalence between the two estimate baselines in the Ordnance & Missiles (-0.01) compared to the more optimistic Overall DoD development estimates (0.34) for the 1990s MDAPs.

Given the limited robustness of the two-most recent decades, even attempting to draw conclusions from the 1990s is inconclusive and depends on the measure used. Looking at the development estimates, the median suggests that the ratio for a typical Ordnance & Missiles program was comparable to that of the total population, while the upper quartile data suggest that the ratio of procurement to RDT&E was decreasing for “most” programs. The production data similarly suggest that the ratio declined for most programs but that was increasing for a typical program. Given these, at times, contradictory trends, the data are inconclusive.

**Ordnance & Missiles Takeaways:**

- The Ordnance & Missiles development estimate data has been volatile for the past two decades and are inconclusive as to whether there is a change in the ratio of procurement to RDT&E.

- The Ordnance & Missiles development production data is insufficient to form conclusions about the investment ratio trends.

- For MDAPs with both development and production estimates:
  - For the total Ordnance & Missile population, development estimates are more optimistic than production estimates. The difference between the two estimates in Ordnance & Missiles is in-line with the Overall DoD trends.

- There is not sufficient data in recent years to draw conclusions about whether there is an ongoing fundamental change in the ratio of procurement to RDT&E. The historical data is also inconclusive, at times showing contradictory trends.
5.3.3 | ELECTRONICS, COMMS, & SENSORS

Development Estimate

Figure 5-22 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate baseline of the Electronics, Comms, & Sensors (EC&S) platform portfolio.

Figure 5-22: Electronics, Comms, & Sensors Development Estimate Baseline by Decade

The data show that although there has been fluctuation in the ratio of procurement to RDT&E in the development estimates for the Electronics, Comms, & Sensors (EC&S) platform portfolio, it is not experiencing a fundamental change in the ratio of production to development. From the 1970s to the 1990s, the median EC&S development estimate declined from 2.62 to 1.13 before rising to 2.77 during the 2000s. The upper quartile trends follow a similar pattern going from 3.92 in the 1970s to 3.20 in the 1990s and then rising significantly to 13.28 during the 2000s. Meanwhile, the lower quartile rose from the 1980s to the 2000s before decreasing during the 2010s. During the 2010s, all three of these values declined, but this trend is not sufficiently robust to draw conclusions given the small population.
Is the Ratio of Investment between Research and Development to Production in Major Defense Acquisition Programs Experiencing Fundamental Change?

Production Estimate

Figure 5-23 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the production estimate baseline of the EC&S platform portfolio.

Figure 5-23: Electronics, Comms, & Sensors Production Estimate Baseline by Decade

![Box and Whisker Plot]

Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis.
Note: Outliers not shown on graph.

The production estimate data show significant whipsaws between the 1980s and 2000s. The median value went from 7.24 in the 1980s to 1.27 in the 1990s, an 83 percent decline, before increasing to 3.84, a 204 percent increase. The upper quartile experienced an even more intense whipsaw, decreasing from 22.04 during the 1980s to 5.10 during the 1990s before rising to 53.56 during the 2000s. With only two EC&S programs in the 2010s, there is insufficient data to gather conclusions from these trends.

Development Estimates v. Production Estimates

Figure 5–24 shows the statistical distribution of the ratio of procurement to RDT&E for MDAPs at the development estimate versus the production estimate.
Figure 5-24: Comparison of Estimated Ratio of Procurement to RDT&E at Development v. Production for Only Electronics, Comms, & Sensors with Both Estimates by Decade

The EC&S trends for MDAPs with both development and production estimate follow the Overall DoD finding of optimistic development estimates, and there is some limited evidence to suggest that the ratio between development and production is increasing, not decreasing like Overall DoD.
The data show that the difference between development and production estimates is higher in EC&S (0.79) than the Overall DoD Topline (0.41).

The ratio of procurement to RDT&E for EC&S programs with both development and production estimates shows some evidence, albeit limited, of an increase in the ratio of procurement to RDT&E in recent times. Between the 1970s and 1990s, the median development to production ratio declined during both development and production. However, there was a sharp uptick during the 2000s. During development, the median rose from 1.43 to 9.24; in production, the median rose from 1.27 to 3.84. This comparison shows that, while the investment increase didn’t grow as much as planned at development, there was still an increase in the ratio of procurement to RDT&E at production compared to the previous decade. There were similar rises across the two estimates in both the lower and upper quartiles. While the absolute value suggests an ongoing significant shift, the small populations across all decades limits the robustness of this finding. Although relatively comparable in number, individual programs’ outsized influence limit the application to systemic findings.

**Electronics, Comms, & Sensors Takeaways:**
- The Electronics, Comms, & Sensors development estimate data show fluctuation in the estimated ratio of procurement but only negligible fundamental changes.
- The Electronics, Comms, & Sensors production data show significant whipsaws between the 1980s and 2000s and insufficient data in the 2010s to use for comparison.
- For MDAPs with both development and production estimates:
  - Similar to Overall DoD, Army development estimates are more optimistic than production estimates. However, the difference between development and production estimates is higher in Electronics, Comms, & Sensors than the Overall DoD topline.
  - There is some evidence, albeit limited, that the ratio of procurement to RDT&E has increased in recent years.
Conclusion

Has the relative importance of R&D, as measured by R&D intensity, changed across the broader economy over the past four decades?

The R&D intensity trends shows no consistent overall trend in the change of importance of R&D across the broader economy over the past four decades. The data show that from 1970 to 1998, R&D intensity in the manufacturing sector followed a series of cyclical up and down intermediate trends but remained relatively steady in the aggregate. During that period, R&D intensity in the Aircraft and Missiles industry followed a cyclical pattern not dissimilar from DoD’s ratio of procurement spending to RDT&E and had been on a downward trend since the mid-1980s.

Since 1999, there has been no change in the overall R&D intensity trends, but there is more volatility at lower levels of the economy that provides less clarity at the subsector level. R&D intensity within the manufacturing sector had been increasing before plummeting during the fiscal crisis. The R&D intensity in this sector has since recovered in recent years and begun to rise again, but additional data are still necessary to confirm that these current trends are not an anomaly. The information industry in the nonmanufacturing sector has also shown a similar positive trend in recent years, but additional data are also still required.

There has been a more definitive downward trend in the Professional, Scientific, and Technical Services industry. At the start of the century, R&D intensity in the Professional, Scientific, and Technical Services industry was comparable
to the Computer and Electronics industry but has since fallen sharply. From 2000 to 2014, R&D intensity in the Professional, Scientific, and Technical Services industry declined at -5.7 percent CAGR.

What are the historical trends in the ratio of procurement to r&d funding in the military services? Are there significant differences between the military services?

The data show that there are significant differences between the different military services. Across DoD historically, the Navy has the highest ratio of procurement to RDT&E among the military services. The Navy’s 3.38 ratio of procurement to RDT&E is 43 percent higher than the Army’s (2.36) and 65 percent higher than the Air Force’s (2.05).

The Navy and the Air Force generally followed the same cyclical historical trends as the Overall DoD, but with a few points of interest worth noting. In the Navy, the ratio of procurement to RDT&E began to decline despite continued, near-historic procurement budgets as a result of increases to the RDT&E budget. In the other services, the declining ratio was largely the result of procurement funding falling more sharply than RDT&E funding, but that wasn’t the case with the Navy. Of note in the Air Force, the ratio of procurement to RDT&E fell as low as 1.07 in 1997.

Meanwhile, the Army did not see a shift away from the historical cyclical pattern, unlike the Navy or the Air Force, and returned to levels above historical averages during the mid-2000s. These trends are heavily influenced by operations in Iraq and Afghanistan but are still interesting given the failure of the Army modernization’s programs since the end of the Cold War. The Army, more so than any other service, has been maligned with failures and problems in its acquisition system.

What are the historical trends in the ratio of procurement to rdt&e funding for mdaps?

Looking only at the MDAPs with both development and production estimates, two key trends emerge: (1) optimistic development estimates and (2) a declining ratio of procurement to RDT&E.

The data show that estimates are more optimistic at the start of development than those at the beginning of production. For the total population of MDAPs in this dataset across all six decades, the median estimated ratio of procurement to RDT&E was 4.05 during development compared to 3.64 during production.

The data further show that the estimated ratio of procurement to RDT&E is declining for MDAPs with both development and production estimates by
most measures. The median ratio of procurement to RDT&E estimated during development has been falling since the 1980s, while the ratio estimated during production started declining during the 1990s.

What are the historical trends in the ratio of procurement to R&D among MDAPs between the military services? Are there significant differences between the military services?

The data show that among the military services the ratio of procurement to RDT&E declined in the Navy and Air Force but increased in the Army.

The Air Force data show that by nearly every measure the Air Force is experiencing a meaningful change in the ratio of procurement to RDT&E. The ratio of procurement to RDT&E has declined in all production estimates, all development estimates, and across both estimates for MDAPs with both estimates. While there was some rebound during the 2010s, it is too early to definitively conclude whether this reversal is the start of a new trend or a characteristic of the 2010s small count relative to the other decades.

The Navy data show a nearly universal decline in the ratio of procurement to RDT&E in recent decades. With limited exceptions, measurements of the ratio of procurement to RDT&E have been on the decline, albeit at varying rates. The Navy and Air Force tracking with one another is largely consistent with the trend observed in their budget.

Unlike the other two services, the Army data show an increasing ratio of procurement to RDT&E. The Army’s development estimate data show that unlike overall DoD trends, the Army’s ratio of procurement to RDT&E estimated at development has been increasing over the last 30 years. Similarly, for programs with both a development and production baseline, the ratio of procurement to RDT&E has increased over the last three decades. Finally, the Army’s production data show a significant increase in the ratio of procurement to RDT&E between the 1970s and 2000s.

What are the historical trends in the ratio of procurement to R&D among MDAPs between the different platform portfolios? Are there significant differences between platform portfolios?

The data show that among the platform portfolios, the trends were more inconclusive.

The Aircraft data show that by nearly every measure Aircraft is experiencing a meaningful change in the ratio of procurement to RDT&E. The ratio of procurement to RDT&E has declined in all production estimates, all development estimates, and across MDAPs with both estimates.
The data were inconclusive as to whether the ratio of procurement to RDT&E has changed in the Ordnance & Missiles platform portfolio. The Ordnance & Missiles development estimate data have been volatile for the past two decades and are inconclusive as to whether there is a change in the ratio of procurement to RDT&E while the Ordnance & Missiles production estimate data were insufficient to form conclusions about the ratio of procurement to RDT&E trends. Similarly, for Ordnance & Missiles programs with both development and production estimates, there is insufficient data in recent years to draw conclusions about whether there is an ongoing fundamental change in the ratio of procurement to RDT&E. Furthermore, the historical data are also inconclusive, at times showing contradictory trends.

The Electronics, Comms, & Sensors data show that there is some evidence, albeit limited, that the ratio of procurement to RDT&E has increased in recent years for MDAPs with both a development and production estimate. The Ec&S development estimate data show fluctuation in the estimated ratio of procurement but negligible fundamental change while there was insufficient data in recent years to compare against the significant whipsaws between the 1980s and 2000s.

**Figure 6-1: Summary of Key Findings**
6.1 | CONCLUDING THOUGHTS

The data show that although there has been no change in the overall importance of R&D across the broader economy, as measured by R&D intensity, there were more meaningful changes in DoD. For the topline DoD budget, although the ratio of procurement to RDT&E rebounded slightly during the mid-to-late 2000s compared to the 1990s, the ratio remains below the historical average despite historic modernization budgets. Similar to the topline budgetary trends, the MDAP data show that across Overall DoD the estimated ratio of procurement to RDT&E has declined by most measures, particularly for development estimates. Furthermore, the Air Force and Navy follow a similar trend, one that achieves statistical significance in a simple regression model. Unlike the other two services, the Army’s ratio of procurement to RDT&E increased in recent decades. However, the platform portfolio data show that only the Aircraft platform portfolio experienced a meaningful change in the ratio of procurement to RDT&E while the Ordnance & Missiles and Electronics, Comms, & Sensors portfolios were more inconclusive, either due to contradictory trends or insufficient data.

This paper presents a novel analysis of the ratio of procurement to RDT&E within MDAPs, but this topic remains relatively underexplored and holds promise for future research. Moving forward, the CSIS study team plans to continue exploring this area to better understand the dynamics at play. Potential areas of new analysis on this topic include but are not limited to: whether the program had a prototyping phase, whether the program was a follow-on or had a clean start, the current estimate at last submitted SAR or production maturity, whether the program was cancelled or curtailed, and the effects of program size and program length. These additional variables can provide important insights into the dynamics at play in the ratio of procurement to RDT&E in MDAPs.
About the Authors

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