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Is the Ratio of Investment Between R&D to Production in Major Defense Acquisition Programs Experiencing Fundamental Change?

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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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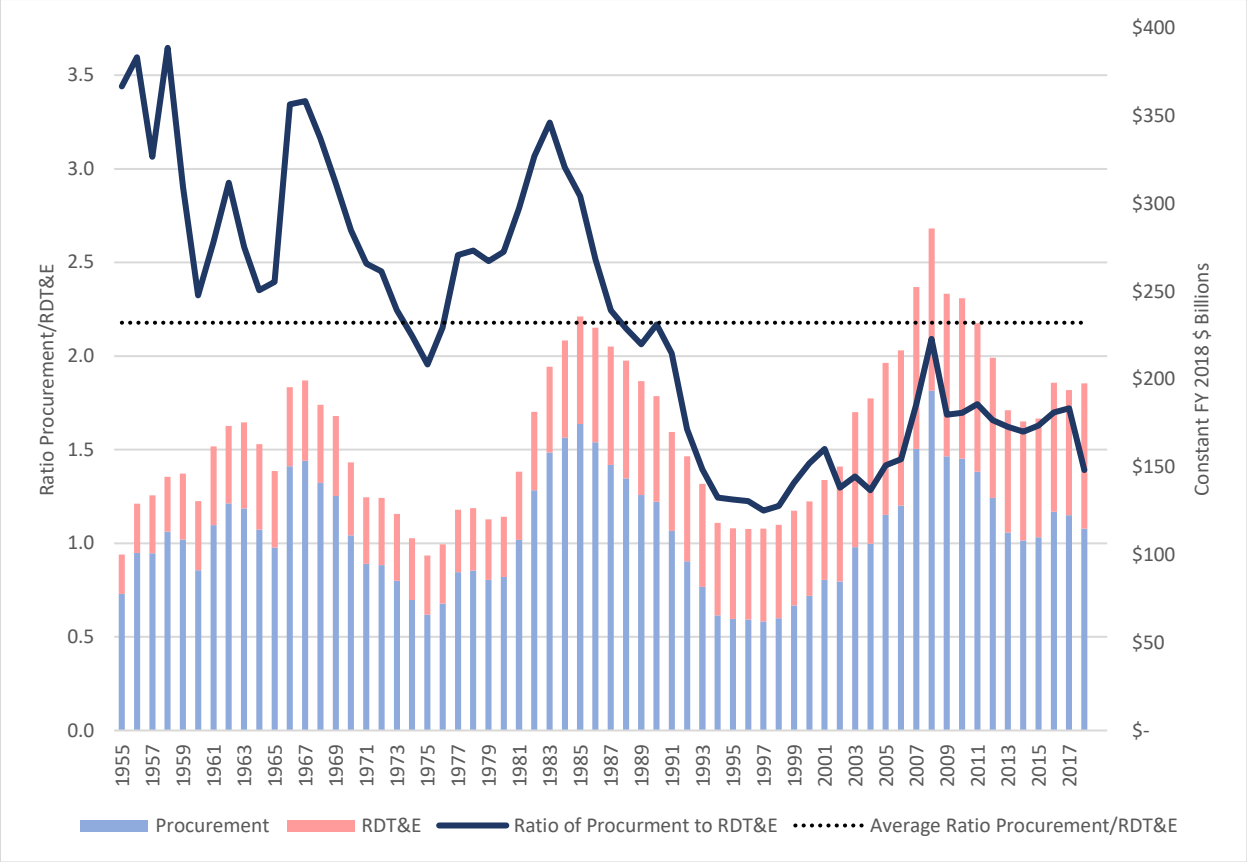
1. | Introduction

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 are 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 RD&TE also would fall. Overall, since Fiscal Year (FY) 1955 DoD has spent an average of 2.2 dollars on procurement for every dollar it 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 Regan buildup when DoD was spending 3.25 dollars on procurement to one dollar 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: 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, when defense contracting rebounded in the 2000s, the 2.17 ratio of procurement to RDT&E in FY 2008, remains 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



Source: Department of Defense, "National Defense Budget Estimates for Fiscal Year 2018 (Green Book)," Office of the Undersecretary of Defense (Comptroller), Revised August 2017; CSIS analysis

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, the percent of functions performed by software 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

[1] Marc Hansen and Robert F. Nesbit, *Report of the Defense Science Board Task Force on Defense Software,* (*Washington, DC*: Defense Science Board, 2000), http://www.dtic.mil/dtic/tr/fulltext/u2/a385923.pdf.

[2] David M. Tate, *Software Productivity Trends and Issues (Conference Paper),* (Alexandria, VA: Institute for Defense Analyses, March 2017), https://www.ida.org/idamedia/Corporate/Files/Publications/IDA_Documents/CARD/2017/D-8367.pdf.

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. 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 trends, the paper looks at the trends in the ratio of procurement to RDT&E for across DoD, the components, and select platform portfolios. Finally, this paper concludes by summarizing the trends across the different variables to assess whether there is an ongoing changing in the Ratio of Investment Between R&D to Production in MDAPs.

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.[3] 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.[4] 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 and procurement and schedule growth has remained largely consistent over time.[5] Additionally, recent analysis both in and out of government show that cost-growth today is similar to historical rates.[6] 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] MS B and 16 percent from MS C.[7]"

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[3] Senate Permanent Subcommittee on Investigations, *Defense Acquisition Reform: Where Do We Go From Here? A Compendium of Views by Leading Experts?,* (Washington, DC: Senate Committee on Homeland Security and Governmental Affairs, 2014), https://www.hsgac.senate.gov/imo/media/doc/REPORT%20-%20DEFENSE%20ACQUISITION%20REFORM-A%20Compendium%20of%20Views%20(10-2-14)1.pdf.

[4] Government Accountabililty Office, *Defense Acquisitions: Assessments of Selected Weapon Programs*, (Washington, DC: GAO, March 2008), https://www.gao.gov/new.items/d08467sp.pdf.

[5] Joseph G. Bolten, Robert S. Leonard, Mark V. Arena, Obaid Younossi, and Jerry M. Sollinger, *Sources of Weapon System Cost Growth: Analysis of 35 Major Defense Acquistioin Programs,* (Santa Monica, CA: RAND, 2008), http://www.rand.org/content/dam/rand/pubs/monographs/2008/RAND_MG670.pdf; Jeffery A. Dreazner, Jeanne M. Jarvaise, Ronn Hess, Daniel M. Norton, and Paul G. Hough, *An Analysis of Weapon System Cost Growth*, (Santa Monica, CA: RAND, 1993), https://www.rand.org/pubs/monograph_reports/MR291.html; Gene Porter, Brain Gladstone, C. Vance Gordon, Nicholas Karvonides, R. Royce Kneece, Jr., Jay Mandelbaum, Jay Mandelbaum, and William D. O'Neil, *The Major Causes of Cost Growth in Defense (IDA Paper P-4531),* (Alexandria, VA: Institute for Defense Analyses, December 2009), http://www.dtic.mil/dtic/tr/fulltext/u2/a519884.pdf; Andy W. Marshall and William Meckling, *Predictability of the Costs, Time, and Success of Development,* (Santa Monica, CA: RAND, 1959), https://www.rand.org/pubs/papers/P1821.html; Obaid Younossi, Mark V. Arena, Robert S. Leonard, Charles Robert Roll, Arvind Jain, and Jerry M. Sollinger, *Is Weapon System Cost Growth Increasing? A Quantitative Assessment of Completed and Ongoing Programs,* (Santa Monica, CA: RAND, 2007), http://www.rand.org/pubs/monographs/MG588.html.

[6] Office of the Undersecretary of Defense for Acquisition Technology and Logistics, *Performance of the Defense Acquisition System: 2016 Annual Report. Performance of The Defense Acquisition System*, (Washington, DC: DoD, October 2016), https://dod.defense.gov/Portals/1/Documents/pubs/Performance-of-Defense-Acquisition-System-2016.pdf; Barry D. Watts and Todd Harrison, *Sustaining Critical Sectors of the U.S. Defense Industrial Base*, (Washington, DC: Center for Strategic and Budgetary Assessment, 2011), http://csbaonline.org/uploads/documents/2011.09.20-Defense-Industrial-Base.pdf

[7] Younossi, et al., *Is Weapon System Cost Growth Increasing?*, p. 17.

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.[8] 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 to experience cost growth then 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 top-line 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.

[8] David M. Tate, *Acquisition Cycle Time: Defining the Problem (Revised)*, (Alexandria, VA: Institute for Defense Analyses, October 2016), https://www.ida.org/idamedia/Corporate/Files/Publications/IDA_Documents/CARD/2016/D-5762.ashx.

[9] David L. McNicol and Linda Wu, *Evidence on the Effect of DoD Acquisition Policy and Process on Cost Growth of Major Defense Acquisition Programs*, (Alexandria, VA: Institute for Defense Analyses, September 2014), https://www.acq.osd.mil/parca/docs/ida-p5126.pdf.

[10] Todd Harrison, *Chaos and Uncertainty: The FY2014 Defesne Budget and Beyond*, (Washington, DC: Center for Strategic and Budgetary Assessment, October 2013), http://csbaonline.org/uploads/documents/Analysis-of-the-FY-2014-Defense-Budget.pdf; Todd Harrison, *Analysis of the FY2017 Defense Budget*, (Washington, DC: Center for Strategic and International Studies, April 2016), https://csis-prod.s3.amazonaws.com/s3fs-public/publication/Analysis%20of%20the%20FY%202017%20Budget.pdf.

[11] Office of the Undersecretary of Defense for Acquisition Technology and Logistics, *Performance of the Defense Acquisition System: 2015 Annual Report,* (Washington, DC: DoD, September 2015), p. 5, https://dod.defense.gov/Portals/1/Documents/pubs/Performance-of-Defense-Acquisition-System-2015.pdf.

3. | Methodology and Study Design

Given the literature suggesting that these trends are not necessarily the result of a broken acquisition system, but other factors, this paper seeks to further investigate the potential sources of the declining ratio of procurement to RDT&E across 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 amongst 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 amongst 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 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;[12] it is a commonly used method of measuring "the relative importance of R&D across industries and among firms in the same industry."[13]

To measure the top-line 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-noted[14], but they still provide the most reliable source of data.[15] This paper created a dataset using the annual SAR data accessed through Defense Acquisition Management Information Retrieval (DAMIR) and the Defense

[12] Kirsty Hughes, "The interpretation and measurement of R&D intensity — A note," *Research Policy*, *17*(5), 301–307.
[13] National Science Board, 2008, Science and Engineering Indicators 2008, Two volumes,
Arlington, VA: National Science Foundation (volume 1, NSB 08-01; volume 2, NSB 08-01A), https://wayback.archive-it.org/5902/20150818072353/http://www.nsf.gov/statistics/seind08/pdf/c04.pdf.
[14] Some of the problems with utilizing SAR's 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, inconsistent interpretations of preparation guideline across programs.
[15] Paul G. Hough, *Pitfalls in Calculating Cost Growth from Selected Acquisition Reports*, (Santa Monica, CA: RAND, 1992), http://www.rand.org/pubs/notes/N3136.html.

Acquisition Visualization Environment (DAVE) for MDAPs from FY 1997 to FY 2017. To enable historical comparisons, the DAMIR SAR data is 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.[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 differences in acquisition approaches between shipbuilding and other MDAPs.[17] Second, this paper filtered out MDAPs that had were exclusively RDT&E or Production. From this dataset, MDAPs were then categorized into one of the eleven CSIS platform portfolio categories.[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, threefold. First, it analyzes the ratio of procurement to RD&TE 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 development process. Next, it considers the ratio of procurement to RD&TE estimated at production for all MDAPs 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 that 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.

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[16] Jeanne M. Jarvaise, Jeffery A. Drezner, and Daniel M. Norton, *The Defense System Cost Performance Database: Cost Growth Analysis Using Selected Acquisition Reports,* (Santa Monica, CA: RAND, 1996), https://www.rand.org/pubs/monograph_reports/MR625.html.

[17] Mark V. Arena, Robert S. Leonard, Sheila E. Murray, Obaid Younossi, *Historical Cost Growth of Completed Weapon System Programs,* (Santa Monica, CA: RAND, 2006), p. 43, https://www.rand.org/content/dam/rand/pubs/technical_reports/2006/RAND_TR343.pdf; Jeffery A. Drezner, Mark V. Arena, Megan McKernan, Robert Murphy, Jessie Riposo, *Are Ships Different? Policies and Procedures for the Acquisition of Ship Programs,* (Santa Monica, CA: RAND, 2011), p. xii-xiii, https://www.rand.org/content/dam/rand/pubs/monographs/2011/RAND_MG991.pdf,

[18] Rhys McCormick, Andrew P. Hunter, and Gregory Sanders, *Measuring the Impact of Sequestration and the Drawdown on the Defense Industrial Base,* (Washington, DC: Center for Strategic and International Studies, December 2017), https://www.csis.org/analysis/measuring-impact-sequestration-and-drawdown-defense-industrial-base.

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 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, 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.

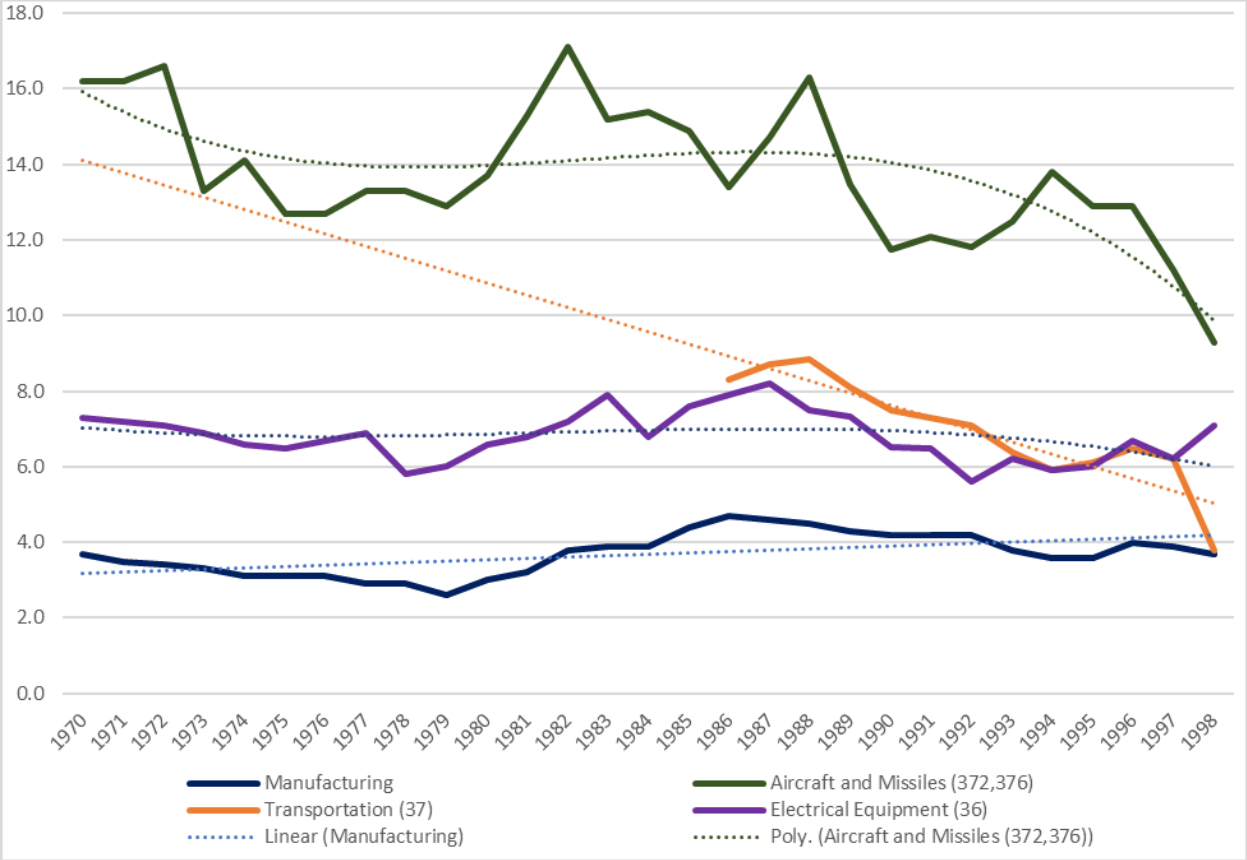
4.1. Historical R&D Intensity Trends by Industry

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 generally? These questions are challenging to address. The available data on civilian firms is 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, which splits the data set. This report uses the R&D intensity data from the National Science Foundation who 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.

4.1.1. R&D Intensity: 1970 – 1998

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



Source: National Science Foundation Industrial Research and Development Information System; CSIS analysis

The data show that R&D intensity in the manufacturing sector did not following 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 top-line 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.

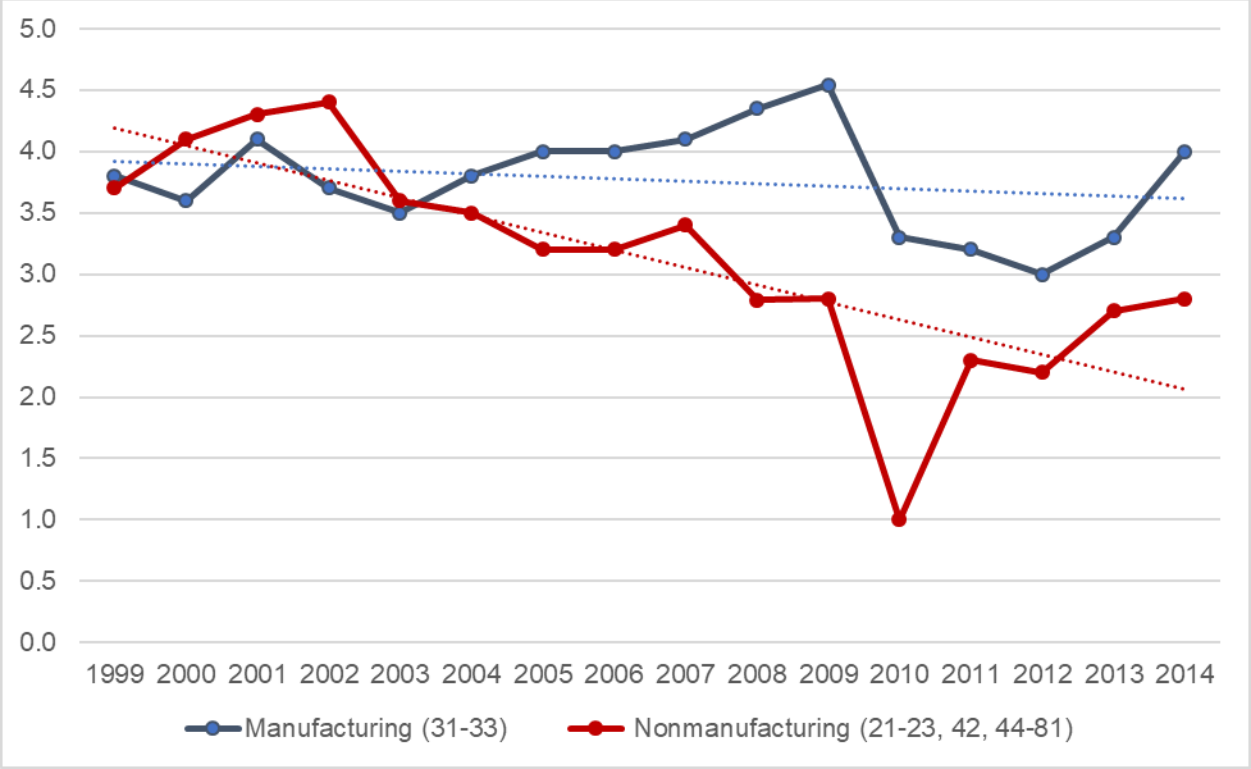
One subset of the Transportation industry is of particular interest to this paper, Aircraft and Missiles. Of note, the data show that R&D intensity trends in the Aircraft and Missile industry followed a cyclical pattern, relatively similar to DoD's trend in the ratio of procurement to RDT&E. In the Aircraft 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 by R&D intensity, but that there is more uncertainty at lower levels.

As shown in Figure 4-2, R&D intensity in the manufacturing industry was on an upward trajectory until the onset of the fiscal crisis but fell sharply the following years. Manufacturing R&D intensity has started trending back upwards in the last two years of available data, but sustained growth is necessary before drawing any definitive conclusions can be drawn. Comparatively, R&D intensity in the non-manufacturing sector had been gradually declining even prior to the fiscal crisis, and the one-year sharp decline. However, R&D intensity in the non-manufacturing industry rebounded quicker than the manufacturing sector and has been on a steady growth pass since but remains below historical averages since 1999.

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



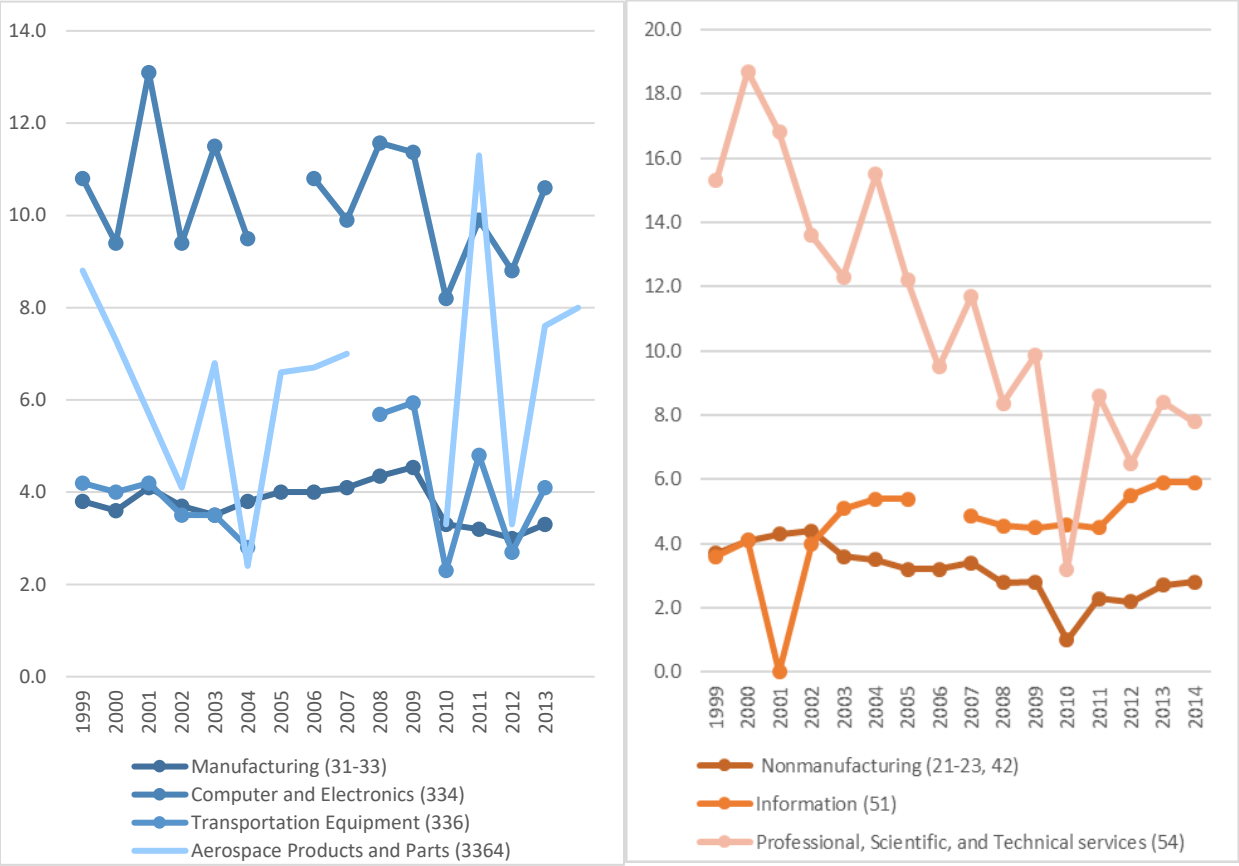
Source: National Science Foundation Business Research and Development Innovation Survey; CSIS analysis

The data show that below the Manufacturing industry level, there are no obvious trends in the data. Amongst the selected manufacturing industries and sub-industries, (Computer and Electronics; Transportation Equipment; Aerospace Products and Parts) the data is often noisy, with significant variance year-to-year.

The data for selected industries in the non-manufacturing sector is less noisy overall and does suggest more definitive certain trends. Figure 4-3 shows the selected industries within the Manufacturing and Non-Manufacturing sectors from 1999 to 2014. The data show that, in general, R&D intensity in the Professional, Scientific, 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 last available data. In the other selected non-manufacturing industry, information, after holding steady throughout the years reporting data, R&D intensity has been slightly trending upward in the past few years. However, just as 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 as measured using R&D intensity. There are certain trends in the broader Manufacturing sector and the Information industry that suggests a shift could be occurring, it remains too early to draw definitive conclusions.

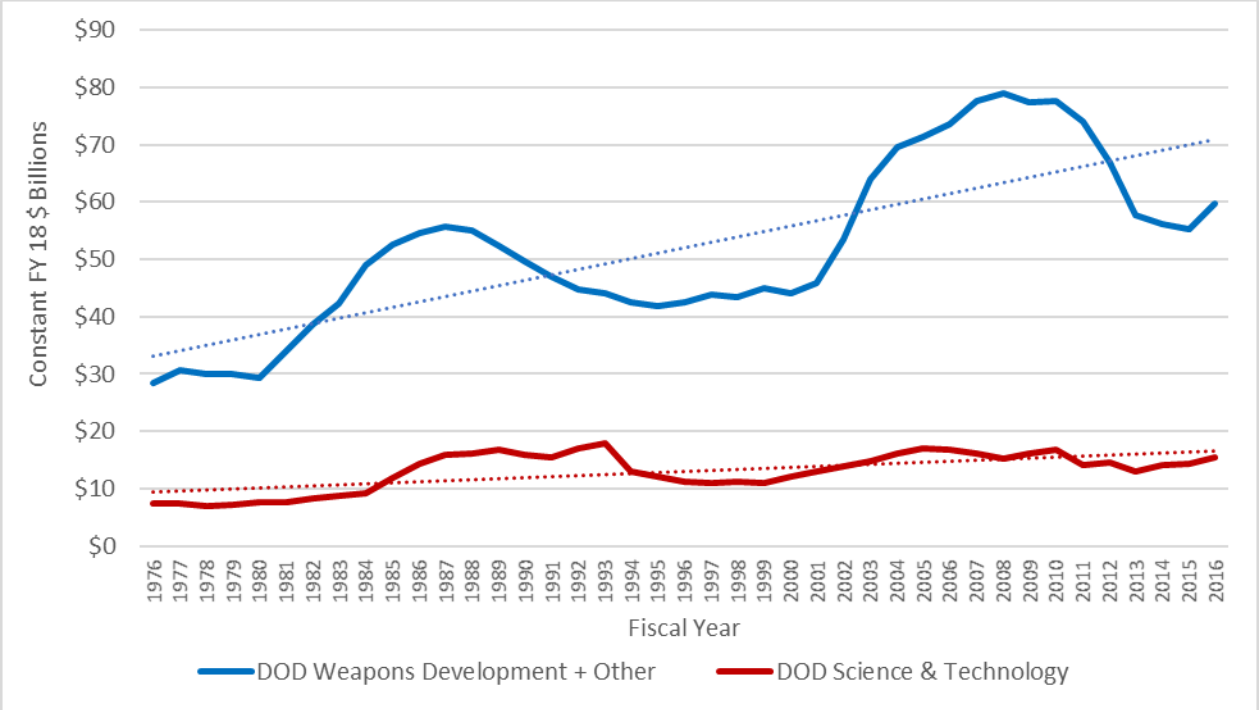
4.2. Defense R&D Trends

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 in 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 & Other and Science and Technology (S&T) from FY 1976 to FY 2016.[20]

Figure 4-4: Trends in Defense Research & Development, 1976-2016



Source: American Association for the Advancement of Science; CSIS analysis

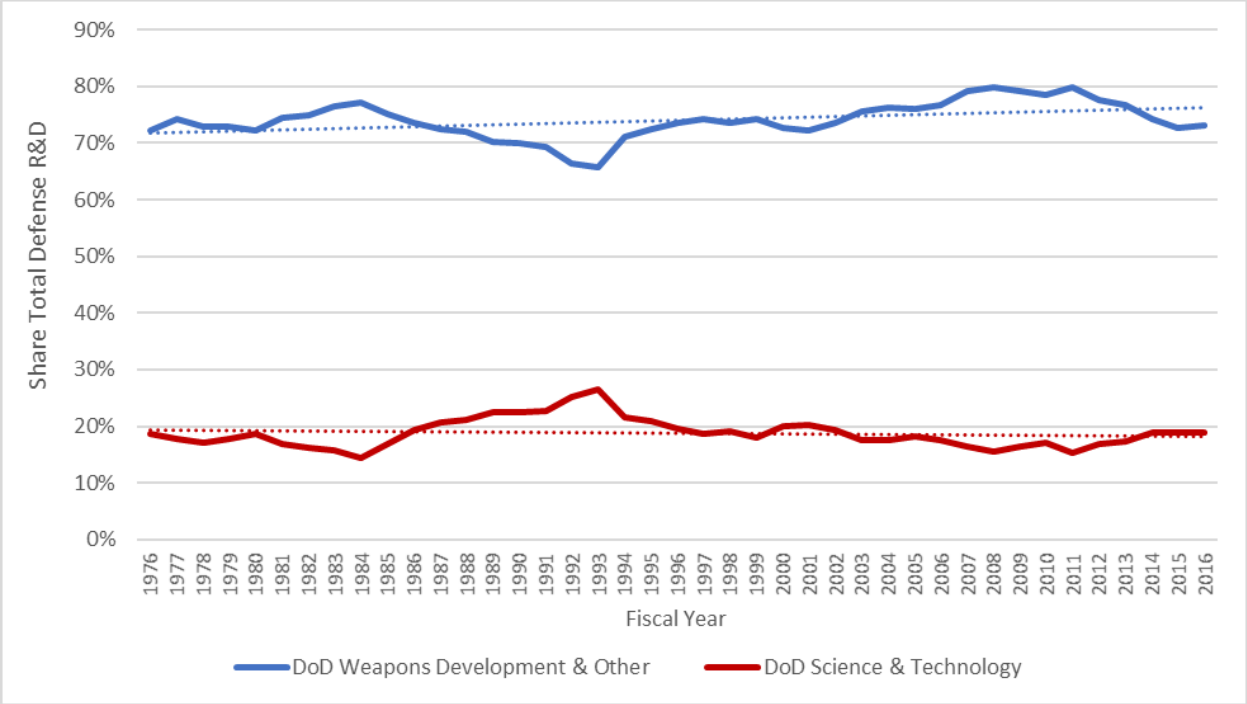
The data show that spending on both DoD R&D spending on both Weapons Development & Other and S&T has increased since FY 1976, but there have been some notable differences between the two R&D categories. DOD Weapons Development & Other spending growth has outpaced DoD S&T spending since FY 1976, but has been more cyclically volatile, experiencing periods of large growth and declines compared to the more modest swings in S&T funding levels. From FY 1976 to FY 2008, DoD Weapons

[19] The data for this section comes from the American Association for the Advancement of Science's "Historical Trends in Federal R&D" dataset available at https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd.

[20] Science and Technology is defined by DoD as budget activities 6.1 (Basic Research), 6.2 (Applied Research), and 6.3 (Advanced Technology Development. Weapons Development & Other includes the other R&D activities: 6.4 (Advanced Component Development and Prototypes), 6.5 (System Development and Demonstration), 6.6 (RDT&E Management Support), and 6.7 (Operational Systems Development). See: John F. Sargent Jr., Department of Defense Research, Development, Test, and Evaluation (RDT&E): Appropriations Structure, (Washington, DC: Congressional Research Service, December 2016), https://fas.org/sgp/crs/natsec/R44711.pdf.

Development & Other grew at a 3.3 percent CAGR compared to the 2.3 CAGR for DoD S&T. However, from FY 2008 to FY 2016, DoD Weapons Development & Other declined at a -3.9 percent CAGR, while DoD S&T marginally grew at a 0.1 percent CAGR.

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



Source: American Association for the Advancement of Science; CSIS analysis

As shown in Figure 4-5 above, despite DoD Weapons Development & Other 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 Weapon Development & Other's share. There have been some fluctuations, particularly in the more volatile Weapons Development & Other periods, but Weapons Development & Other has historically accounted for approximately 74 percent of DoD R&D from FY 1976 to FY 2016, while S&T accounted for 19 percent.[21]

These trends show that despite external factors such as war, budget pressure, 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 hasn't been a massive shift in the composition of the DoD R&D portfolio between developing weapons and S&T research.

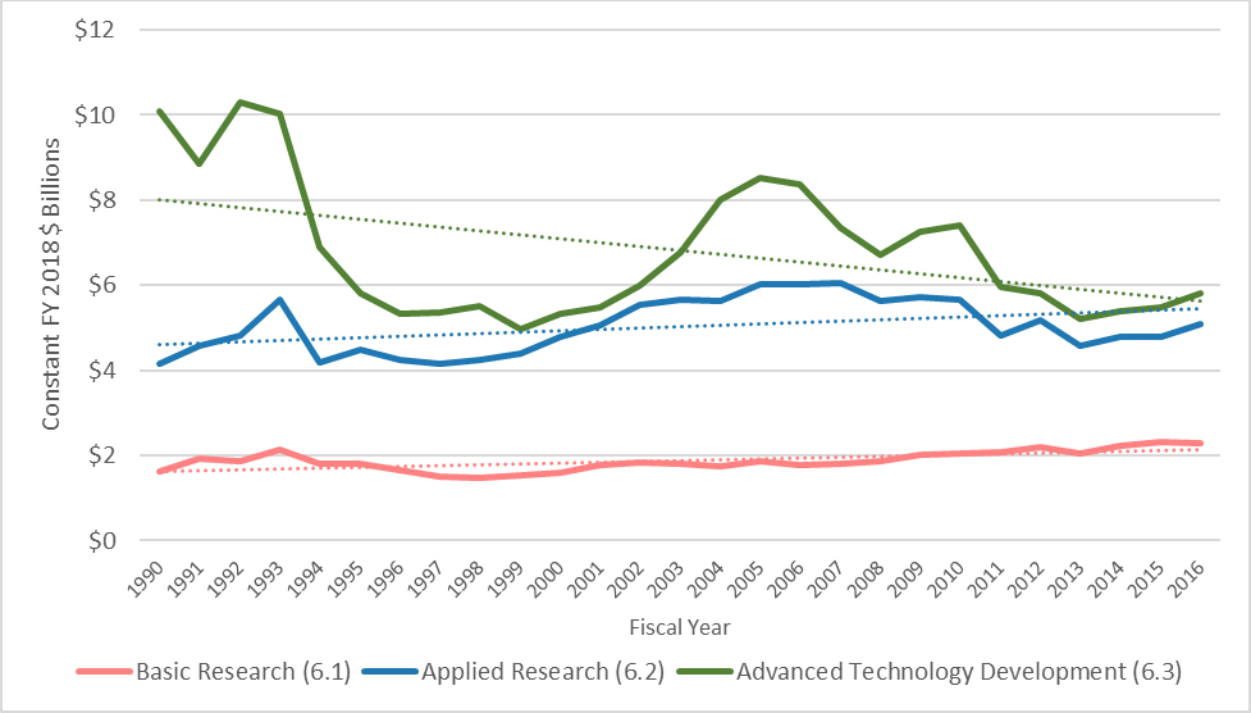
4.2.2. DoD Science & Technology Trends

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 S&T accounts, particularly between the two seed-corn categories, 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

[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.

CAGR. Comparatively, Basic Research (6.1) and Applied Research (6.2) increased at a 1.4 percent and 0.8 percent CAGR respectively.

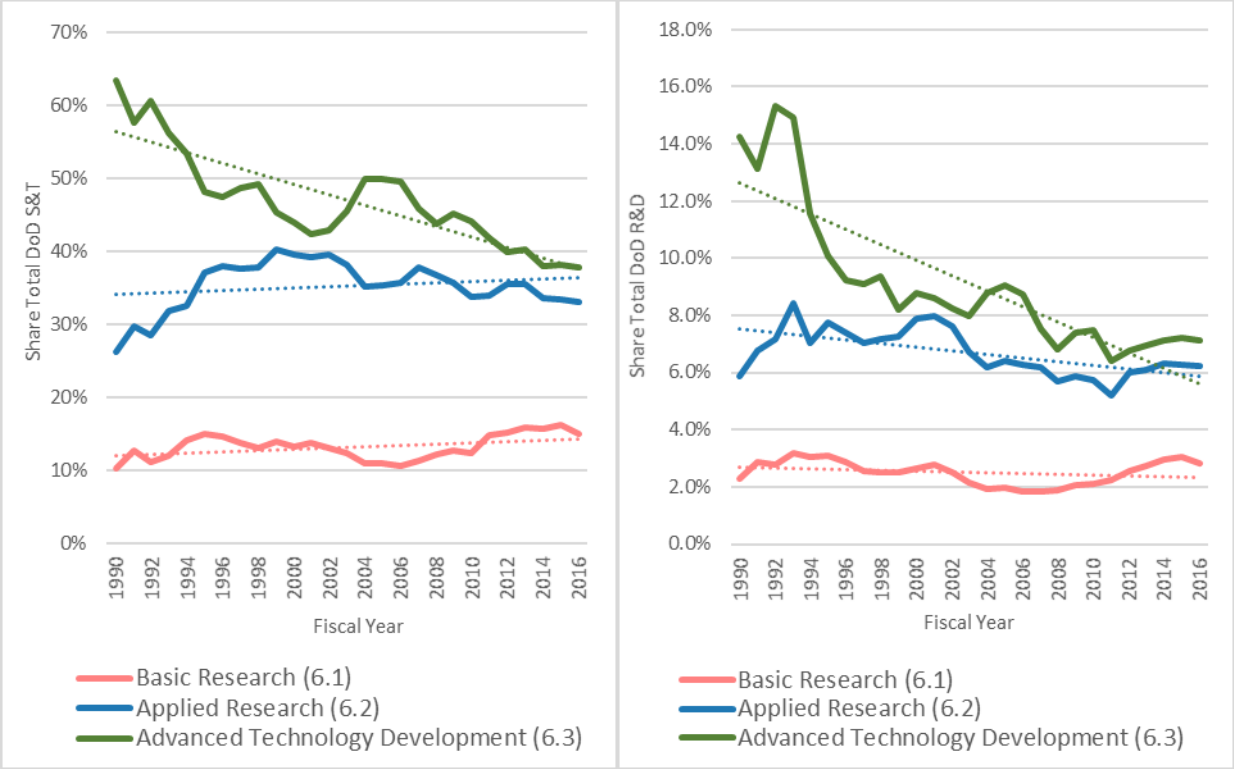
Figure 4-6: DoD Science & Technology Trends, 1990-2016



Source: American Association for the Advancement of Science; CSIS analysis

As shown in Figure 4-7 below, Advanced Technology Development (6.3) has unsurprisingly fallen sharply 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 DoD S&T spending and 14 percent of total DoD R&D spending compared to 7 percent and 38 percent respectively in FY 2016. Although Basic Research (6.1) and Applied Research (6.2) grew at equal rates as a share of DoD S&T spending, Applied Research declined as a share of total DoD R&D spending while Basic Research held relatively steady.

Figure 4-7: DoD Science & Technology as Share Total DoD Research & Development, 1990-2016



Source: American Association for the Advancement of Science; CSIS analysis

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.[22]

[22] Defense Acquisition University, "Advanced Technology Development (ATD)", Defense Acquisition Glossary, https://www.dau.mil/glossary/pages/1415.aspx.

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 RD&TE 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 threefold: overall DoD; the three military services; and the Aircraft, Ordnance & Missile, and Electronics, Comms, & Sensors platform portfolio. 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 with both estimates. 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

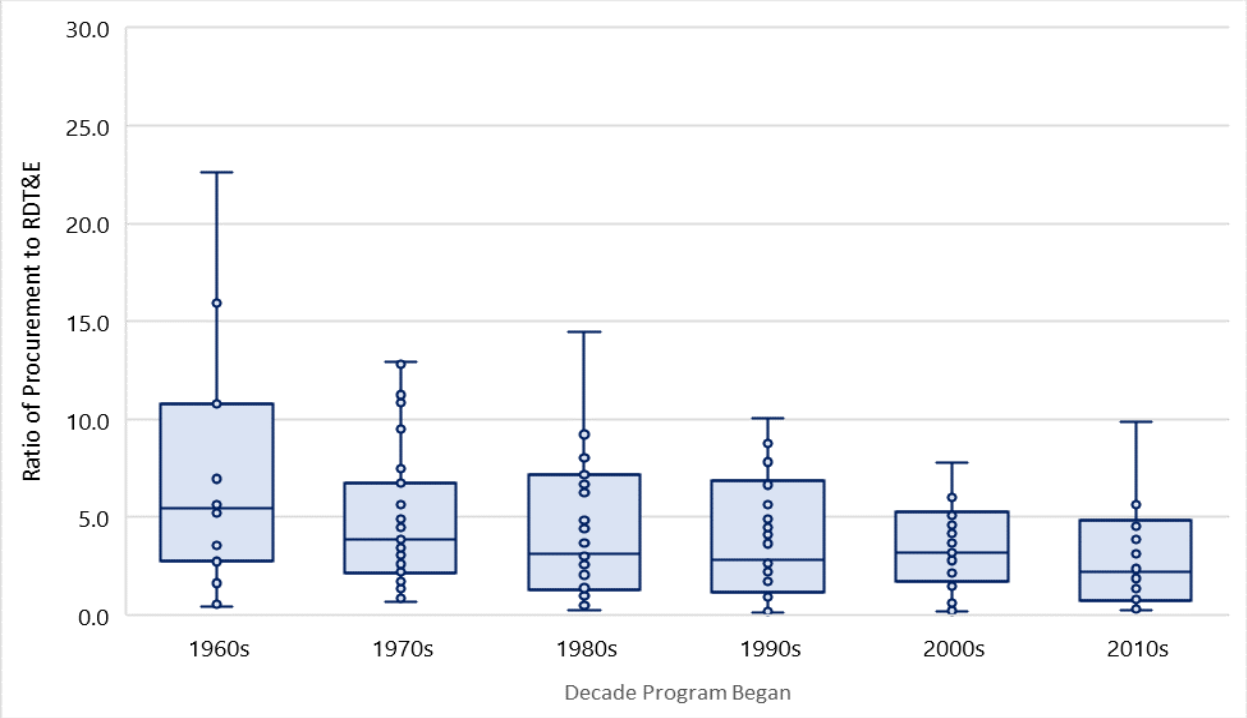
The following sections show the trends for all DoD MDAPs, excluding those filtered out for the reasons listed in the methodology section, with an original approved development or production estimate.

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 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



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	19	58	56	40	50	22	245
Q1	2.72	2.15	1.26	1.17	1.70	0.73	1.64
Median	5.47	3.84	3.11	2.83	3.20	2.22	3.43
Q3	10.77	6.76	7.16	6.84	5.25	4.81	6.69
IQR	8.04	4.61	5.90	5.67	3.54	4.08	5.05
# Outliers	2	5	7	4	9	2	28
Max Value	80.80	97.67	112.49	38.00	37.88	22.64	112.49

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

Production Estimate

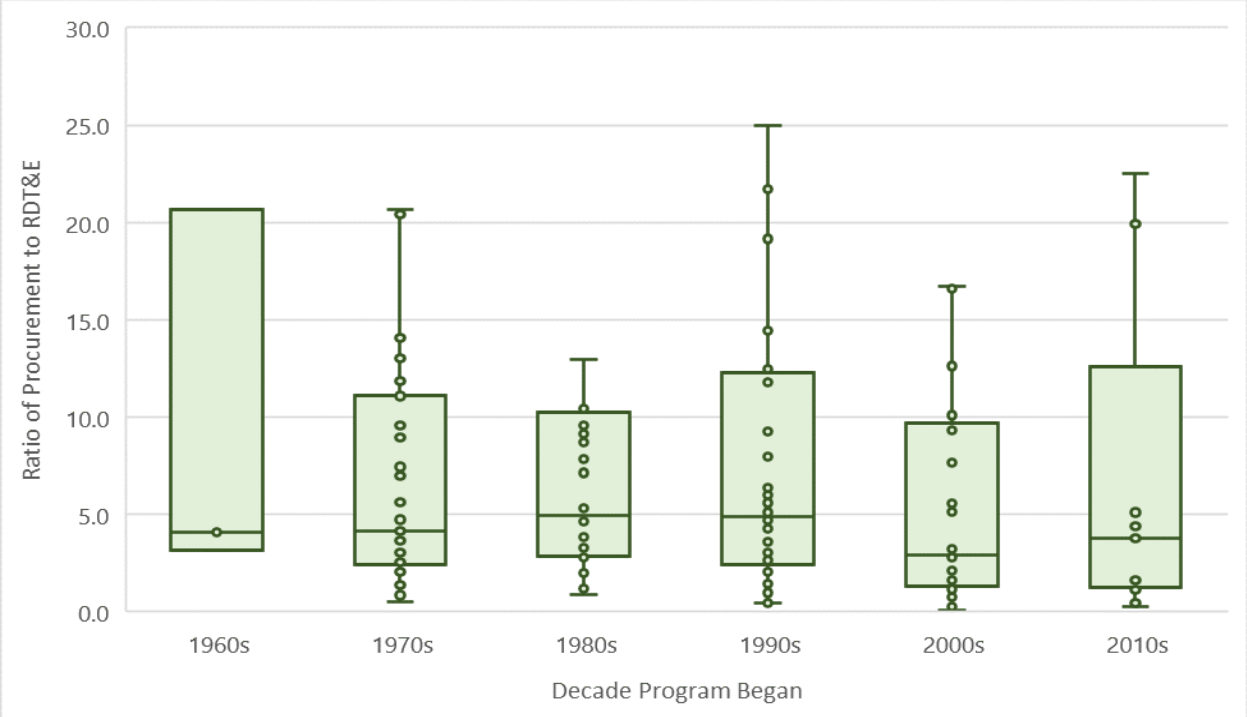
The production baseline estimate data for all MDAPs are less conclusive. Measuring by the median, the production estimate ratio fell sharply during the 2000s (2.93) after holding steady the previous two decades (4.92). Although the median subsequently rose during the 2010s (3.76), it remains below historical averages (4.14). The upper quartile trends show a different trend however. The upper quartile for 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 a sharp fall sharply during the 2000s (9.71) that was followed by a rebound to relatively-new historic levels during the 2000s (12.62).[23]

[23] In terms of raw numbers, the upper quartile was higher during the 1960s (20.68), but the 1960s small population size limits the usefulness when comparing to other periods.

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



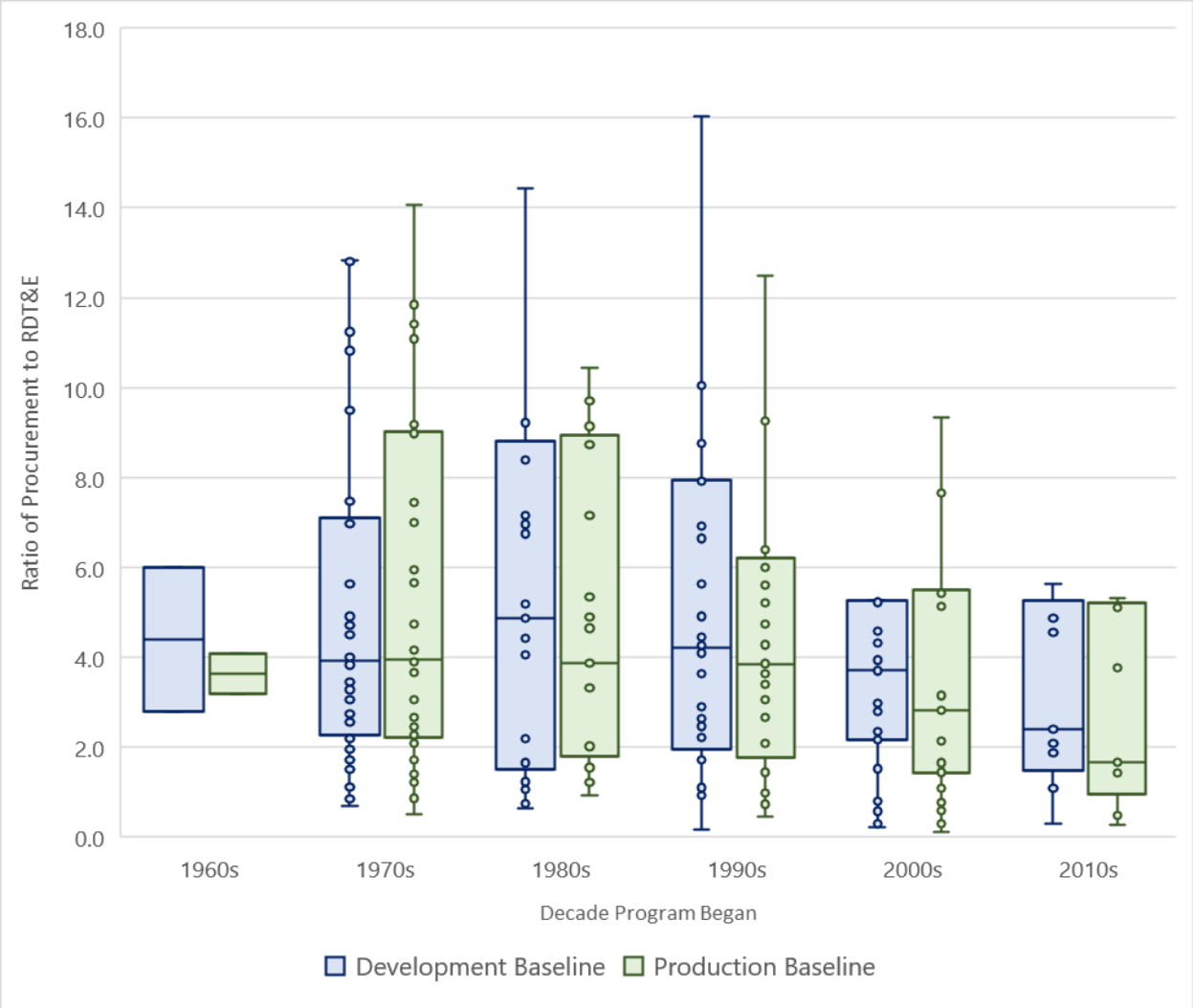
Production (PdE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	3	47	36	40	37	13	176
Q1	N/A	2.45	2.86	2.40	1.30	1.28	1.81
Median	4.08	4.14	4.92	4.92	2.93	3.76	4.14
Q3	20.68	11.08	10.26	12.30	9.71	12.62	10.35
IQR	N/A	8.63	7.40	9.91	8.41	11.34	8.55
# Outliers	0	5	7	5	5	1	23
Max Value	20.68	287.00	94.19	689.86	510.97	258.38	689.86

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

Development Estimates v. Production Estimates

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



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	2	38	21	29	27	9	126
Q1	N/A	2.25	1.51	1.95	2.15	1.47	2.13
Median	N/A	3.92	4.86	4.19	3.69	2.39	4.05
Q3	N/A	7.09	8.80	7.93	5.27	5.25	7.01
IQR	N/A	4.84	7.29	5.98	3.11	3.78	4.87
# Outliers	N/A	3	2	3	6	1	15
Max Value	6.00	97.67	112.49	38.00	37.88	22.64	112.49

Production (PdE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	2	38	21	29	27	9	126
Q1	N/A	2.22	1.77	1.75	1.43	0.94	1.65
Median	N/A	3.93	3.86	3.85	2.81	1.65	3.64
Q3	N/A	9.03	8.93	6.21	5.50	5.21	6.53
IQR	N/A	6.81	7.16	4.46	4.07	4.26	4.89
# Outliers	N/A	4	2	4	3	1	15
Max Value	4.08	287.00	94.19	58.07	22.42	19.93	287.00

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

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 RD&TE is declining for MDAPs with both development and production estimates by most measures. The median ratio of procurement to RD&TE 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 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

Table 5-1: Regression Model of Entire Sample

	Log(Ratio at Development)	**Log(Ratio at Production)**
(Intercept)	**1.53** (0.17)***	**2.89** (0.27)***
Study Variable		
rescale(Year)	-0.32 (0.16).	-0.13 (0.23)
Estimating History		
Available at Development		**-1.25** (0.26)***
Available at Production	0.26 (0.16)	
Platform Portfolio		
Elec., Comms, & Sensors	**-0.74** (0.22)**	**-0.86** (0.32)**
Ordnance and Missiles	-0.37 (0.20).	-0.09 (0.29)
Land Vehicles	0.49 (0.36)	0.72 (0.50)
Missile Defense	-0.22 (0.37)	-0.24 (0.51)
Space Systems	**-1.47** (0.35)***	**-1.36** (0.42)**
AIC	597.71	498.30
BIC	630.44	528.00
Log Likelihood	-288.85	-239.15
Deviance	220.90	233.57
Num. obs.	195	144

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

The results at this 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% level. The coefficient suggests a one-unit change in year (~23 years)

correlates to a 27.3 percent to reduction in ratio, all else being equal. For production, the relationship is also negative, though not significant. As is 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 level of significance, 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 Sensor 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 platform are significant at the 99 percent level or higher and assume that all other factors are constant.

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:
    - Development estimated ratio is more optimistic than production
    - The ratio of procurement to RDT&E has declined for both development and production

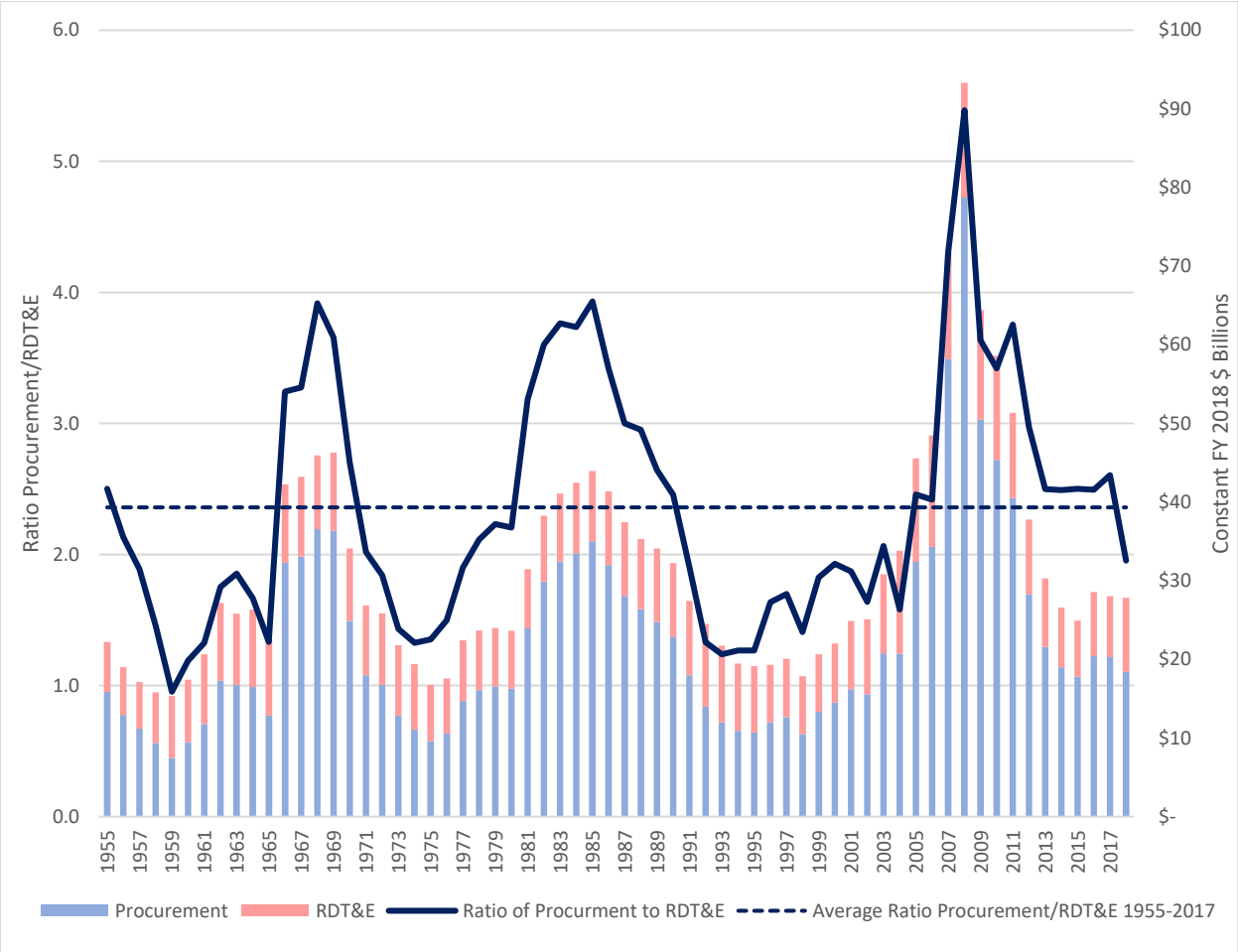
5.2. Ratio of Procurement to RDT&E by Component

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 build ups dropping down 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.

Figure 5-4: Army Ratio of Procurement to RDT&E, 1955-2018



Source: Department of Defense, "National Defense Budget Estimates for Fiscal Year 2018 (Green Book)," Office of the Undersecretary of Defense (Comptroller), Revised August 2017; CSIS analysis

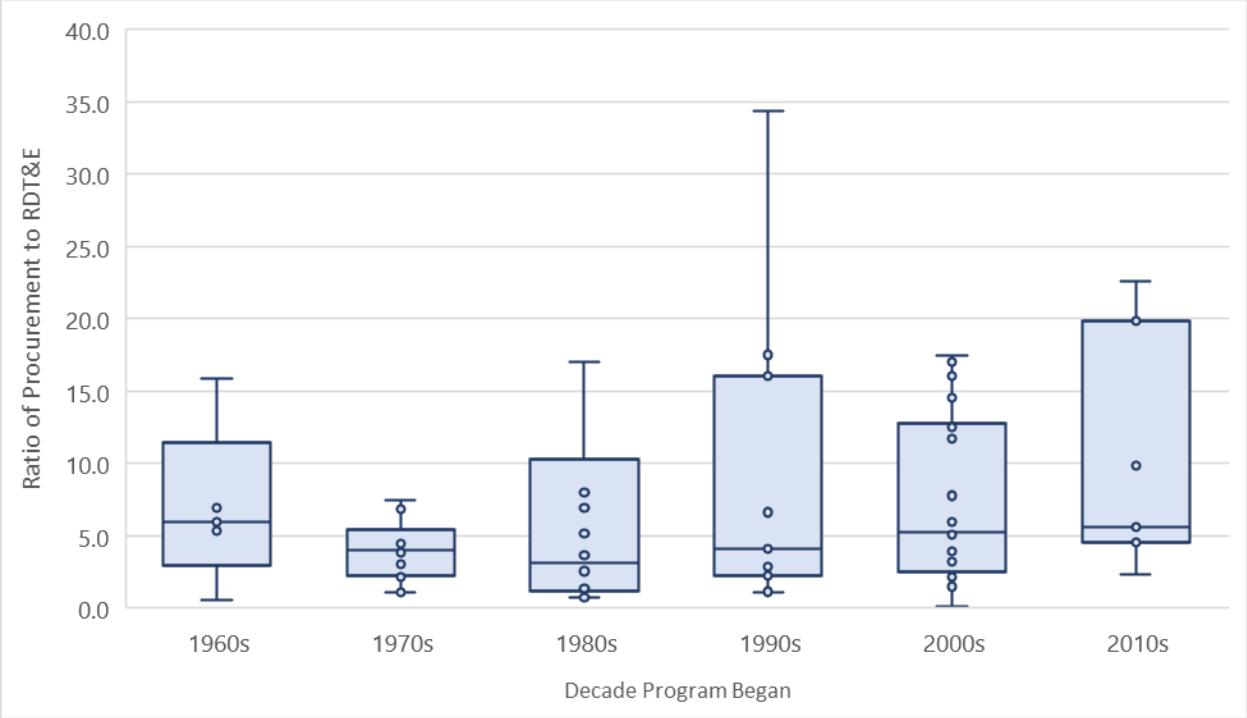
The Army was the only service that returned to the historical cyclical pattern during the mid-2000s. This trend was driven, in large part due to the operations in Iraq and Afghanistan, but these trends are interesting given the failures of nearly all the Army's marquee acquisition programs over that 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.

Figure 5-5: Army MDAPs Development Estimate Baseline by Decade



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	5	18	14	11	24	7	79
Q1	2.97	2.25	1.16	2.25	2.55	4.55	2.29
Median	6.00	3.99	3.13	4.09	5.25	5.64	4.59
Q3	11.43	5.40	10.27	16.04	12.77	19.85	11.24
IQR	8.46	3.15	9.11	13.80	10.22	15.30	8.95
# Outliers	0	2	2	0	1	0	4
Max Outlier	15.92	12.81	112.49	34.33	37.88	22.64	112.49

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

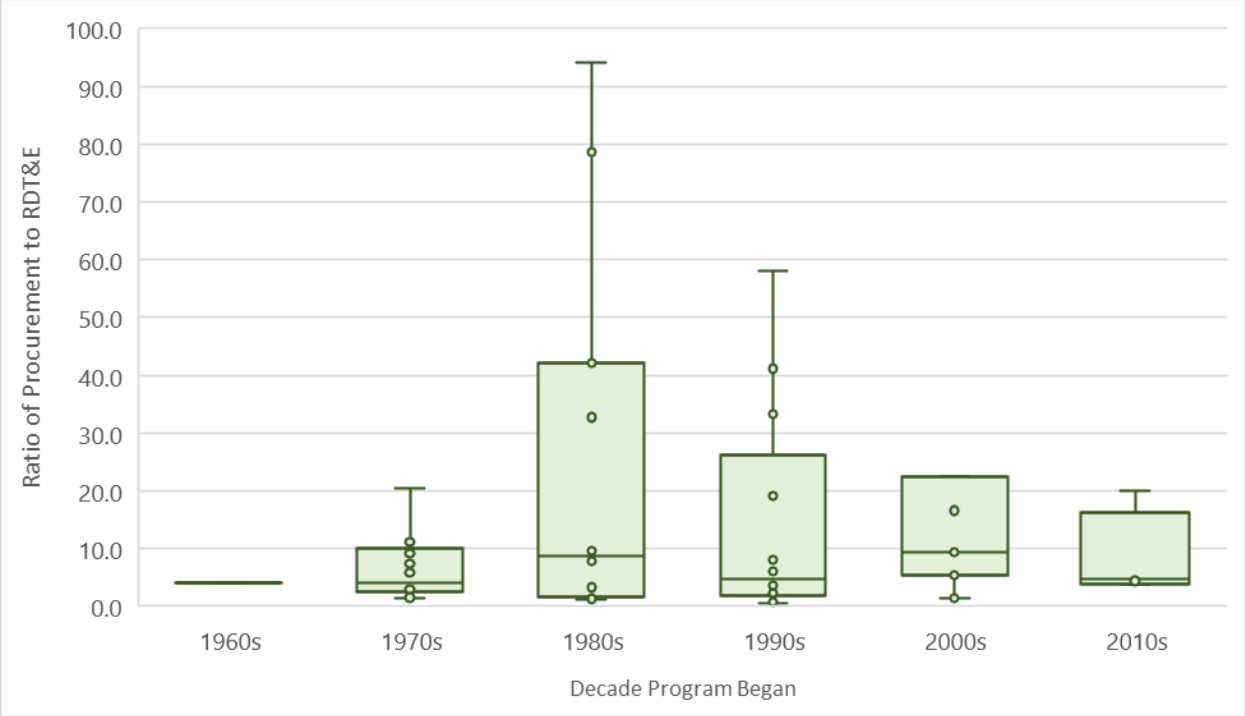
The data show that unlike the Overall DoD trends, the ratio of procurement to RDT&E for Army MDAP's estimated during development has been increasing over the past thirty years. The median ratio of procurement was declining between the 1960s and the 1980s but has been rising since. The median went from 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.

Figure 5-6: Army MDAPs Production Estimate Baseline by Decade



Production (PdE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	1	18	11	13	11	5	57
Q1	N/A	2.49	1.54	1.87	5.41	3.92	2.60
Median	N/A	4.14	8.72	4.72	9.32	4.85	5.50
Q3	N/A	10.13	42.07	26.19	22.42	16.27	17.93
IQR	N/A	7.64	40.53	24.31	17.01	12.35	15.33
# Outliers	N/A	1	0	0	2	0	7
Max Outlier	4.08	25.88	94.19	58.07	510.97	19.93	510.97

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

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 more accelerating 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 decades, 2010s, is more inconclusive as to whether this trend has reversed itself is more analogous to the downturn in the 1990s given the smaller sample size. 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

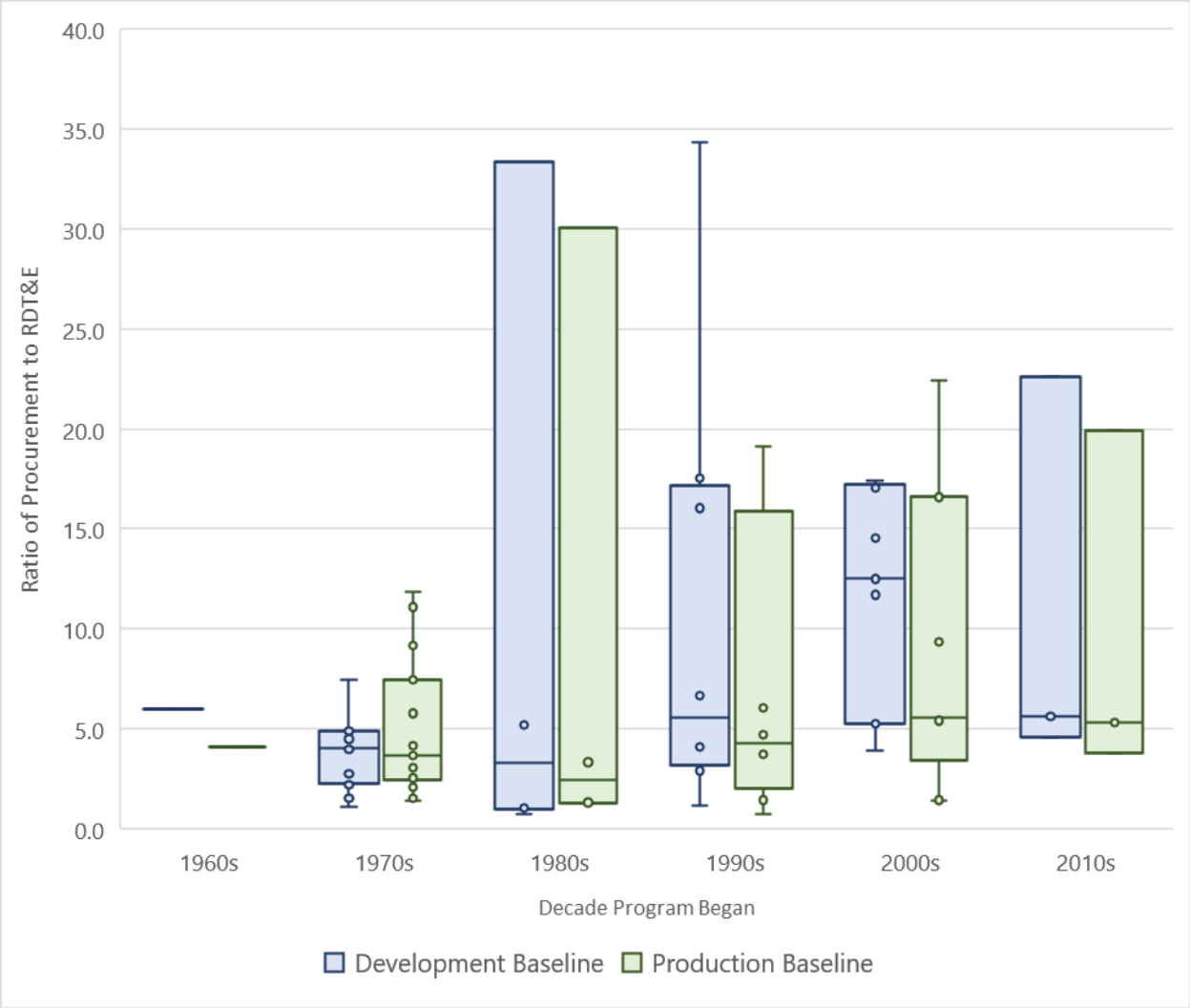
The Army trends for MDAPs with both development and production estimate follow the Overall DoD finding of optimistic development estimates, but are not experiencing the same fundamental change in the ratio of procurement to RDT&E.

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 in 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 as high as 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.

Figure 5-7: Comparison of Estimated Ratio of Procurement to RDT&E at Development v. Production for only Army MDAPs with both estimates, by decade



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	1	15	6	8	9	3	42
Q1	N/A	2.27	0.97	3.20	5.25	4.55	3.01
Median	N/A	4.00	3.28	5.54	12.50	5.64	5.04
Q3	N/A	4.90	33.34	17.15	17.24	22.64	12.58
IQR	N/A	2.63	32.37	13.95	11.99	18.08	9.57
# Outliers	N/A	2	1	0	1	0	3
Max Outlier	6.00	12.81	112.49	34.33	37.88	22.64	112.49

Production (PdE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	1	15	6	8	9	3	42
Q1	N/A	2.45	1.30	2.00	3.42	3.76	2.36
Median	N/A	3.65	2.43	4.29	5.57	5.31	4.16
Q3	N/A	7.44	30.09	15.87	16.64	19.93	9.22
IQR	N/A	4.99	28.79	13.87	13.22	16.17	6.86
# Outliers	N/A	0	1	1	0	0	4
Max Outlier	4.08	11.84	94.19	58.07	22.42	19.93	94.19

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

Regression Model

In keeping with the above results, the model of Army programs shown in Table 5-2 finds that he 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 comparison sake, both overall models are included and 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

	Log (Ratio at Development)		**Log (Ratio at Production)**	
	Army	**Overall**	**Army**	**Overall**
(Intercept)	**1.35** (0.46)**	**1.85** (0.22)***	**3.13** (0.58)***	**3.02** (0.37)***
Study Variable				
rescale(Year)	**1.04** (0.46)*	-0.73 (0.37)$^{\cdot}$	**1.35** (0.62)*	-0.30 (0.53)
Estimating History				
Available at Development			**-1.83** (0.37)***	**-1.25** (0.26)***
Available at Production	0.23 (0.27)	0.26 (0.16)		
Platform Portfolio				
Elec., Comms, & Sensors	**-1.16** (0.41)**	**-0.74** (0.22)**	**-1.32** (0.43)**	**-0.86** (0.32)**
Ordnance and Missiles	-0.75 (0.40)$^{\cdot}$	-0.37 (0.20)$^{\cdot}$	-0.78 (0.43)$^{\cdot}$	-0.09 (0.29)
Land Vehicles	0.40 (0.46)	0.49 (0.36)	0.39 (0.52)	0.72 (0.50)
Missile Defense	-0.52 (0.49)	-0.22 (0.37)	-0.42 (0.54)	-0.24 (0.51)
Space Systems		**-1.47** (0.35)***		**-1.36** (0.42)**
AIC	179.50	597.71	144.20	498.30
BIC	198.49	630.44	160.85	528.00
Log Likelihood	-80.75	-288.85	-63.10	-239.15
Deviance	50.42	220.90	40.34	233.57
Num. obs.	61	195	47	144

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$.

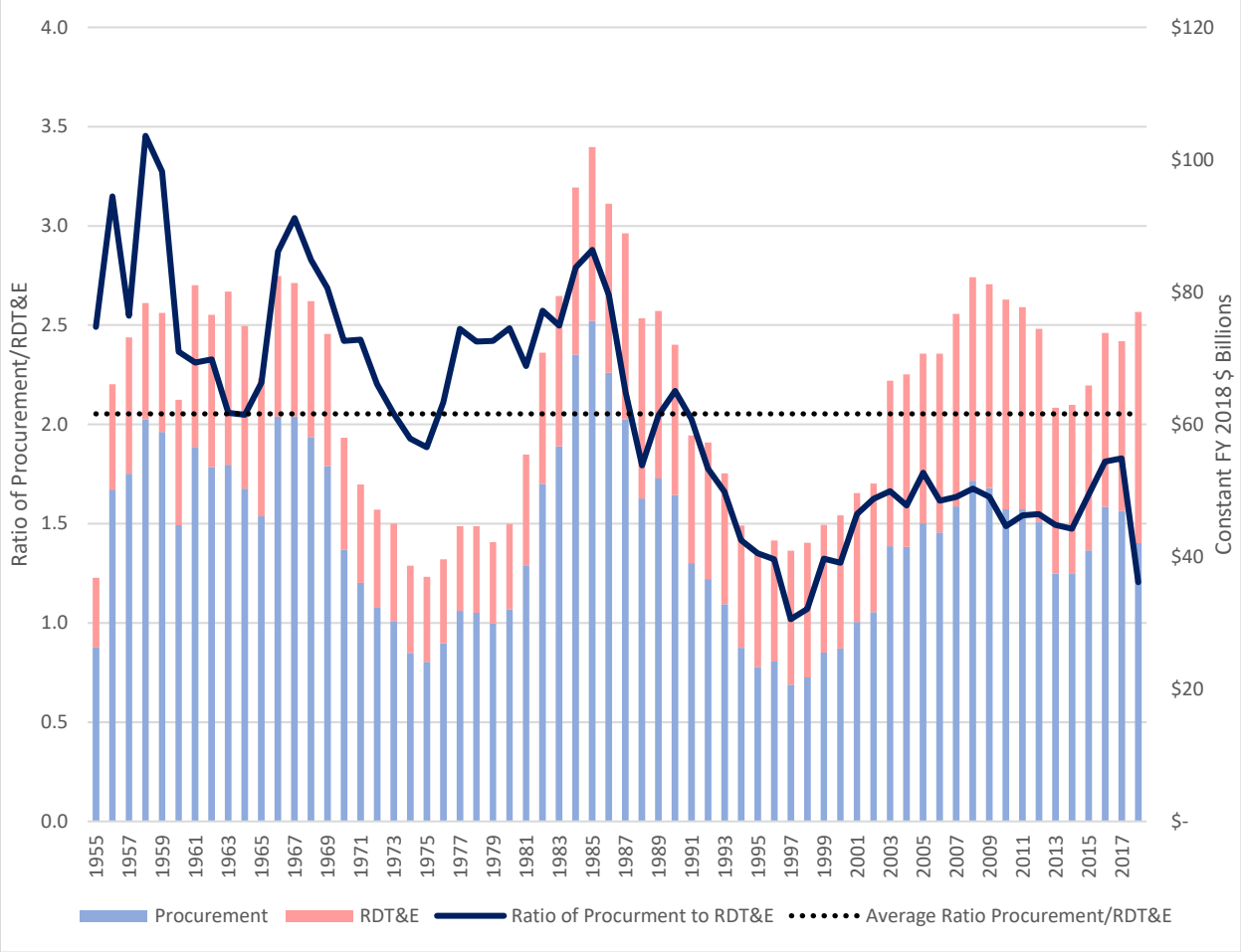
Army Takeaways:

- 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 thirty 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 change in the ratio of procurement to RDT&E ongoing. The median data suggests that the investment ratio is steady despite whipsaw, while the lower quartile trends are increasing 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 1 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.

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



Source: Department of Defense, "National Defense Budget Estimates for Fiscal Year 2018 (Green Book)," Office of the Undersecretary of Defense (Comptroller), Revised August 2017; CSIS analysis

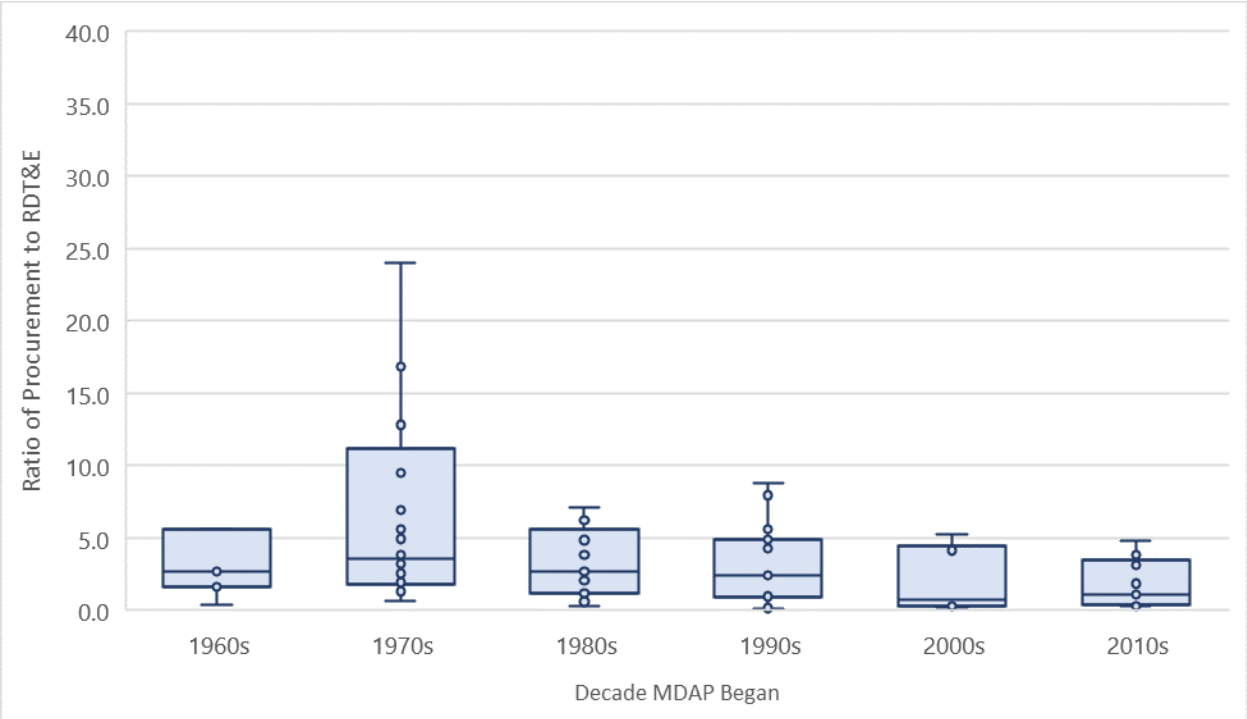
The Air Force differs from the other services in a few notable ways. First, whereas the other services saw a rapid spike followed by a quick decline during the Reagan buildup, the Air Force experienced a smaller spike earlier, followed by a more gradual rise to its crescendo. Second, the Air Force ratio fell lower than any of the 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 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.

Figure 5-9: Air Force MDAPs Development Estimate Baseline by Decade



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	7	21	25	15	9	9	86
Q1	1.62	1.84	1.17	0.96	0.29	0.36	1.09
Median	2.72	3.60	2.68	2.46	0.78	1.07	2.59
Q3	5.63	11.16	5.59	4.90	4.45	3.48	4.93
IQR	4.00	9.31	4.43	3.94	4.16	3.13	3.85
# Outliers	1	2	4	0	0	0	10
Max Value	22.63	97.67	50.62	8.76	5.22	4.86	97.67

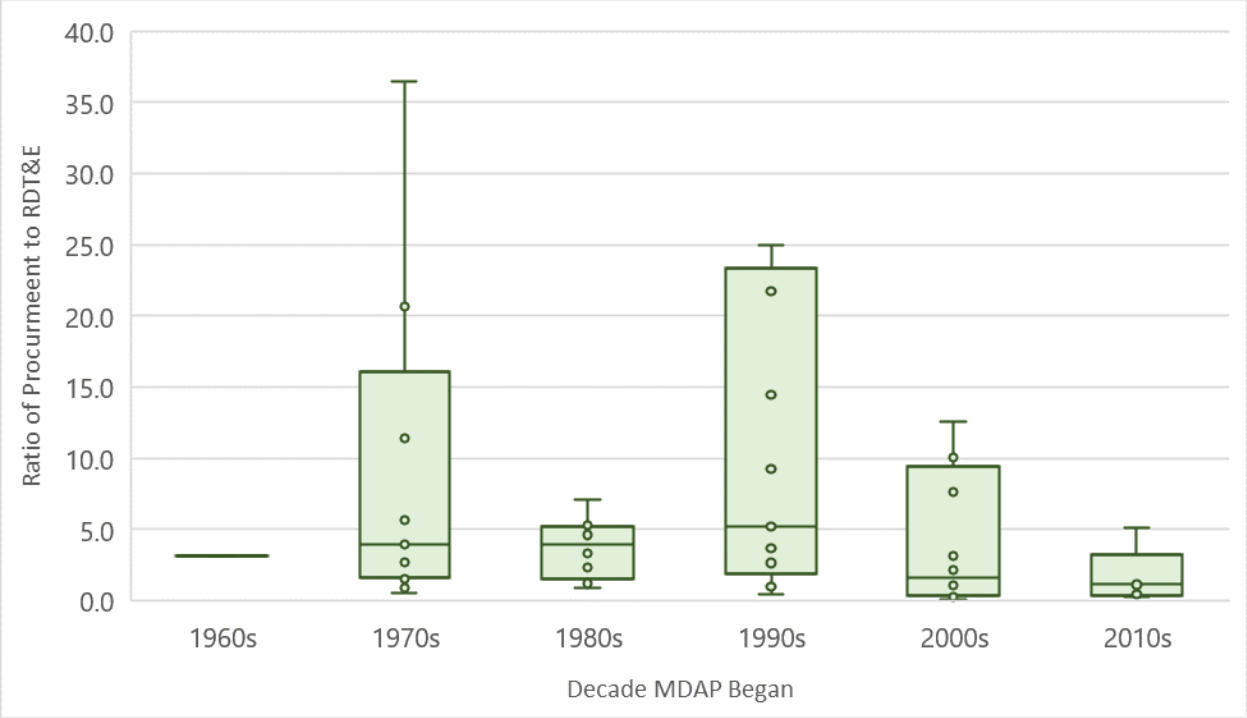
Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis
Note: Outliers not shown on graph

The data show that the ratio of procurement to RDT&E for Air Force MDAP's 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 respectively during the 1970s to 0.36 and 3.48 during the 2010s.

Production Estimate

Figure 5-10 shows the statistical distribution of the estimated ratio of procurement to RDT&E at the development estimate (DE) baseline for Air Force MDAPs.

Figure 5-10: Air Force MDAPs Production Estimate Baseline by Decade



Production (PdE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	1	17	12	13	12	5	60
Q1	N/A	1.63	1.50	1.85	0.36	0.36	1.16
Median	3.17	3.97	3.97	5.20	1.64	1.14	3.16
Q3	N/A	16.05	5.24	23.35	9.48	3.26	8.85
IQR	N/A	14.42	3.73	21.50	9.12	2.90	7.69
# Outliers	0	2	1	2	1	0	10
Max Value	3.17	287.00	56.53	689.86	50.24	5.10	689.86

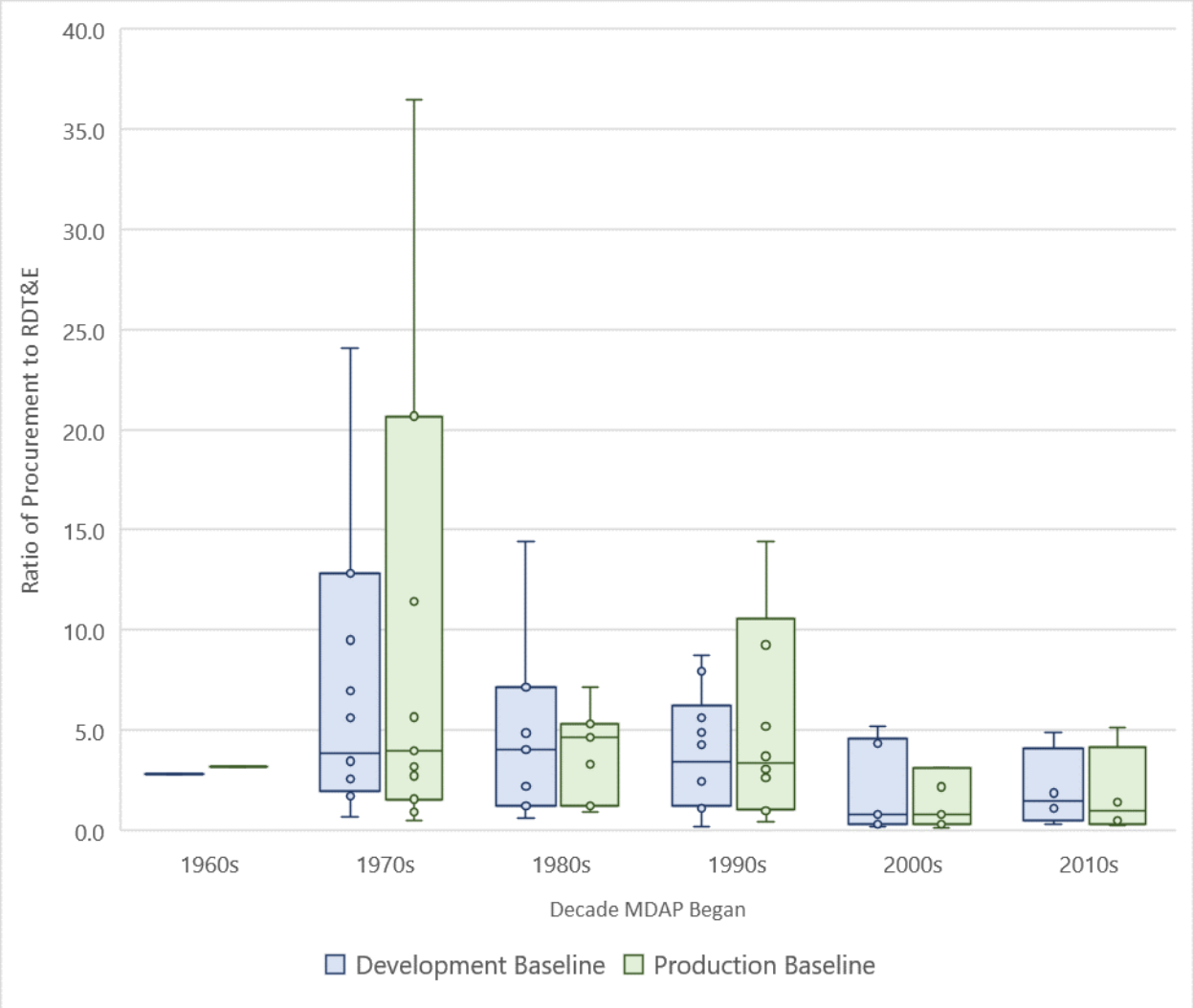
Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis
Note: Outliers not shown on graph

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 the past two decades. The median went from 5.20 during the 1990s to 1.14 during the 2010s, well below 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



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	1	15	7	10	7	4	44
Q1	N/A	1.95	1.22	1.21	0.30	0.48	1.22
Median	N/A	3.82	4.05	3.45	0.78	1.47	3.52
Q3	N/A	12.82	7.15	6.20	4.58	4.11	5.62
IQR	N/A	10.87	5.93	5.00	4.28	3.63	4.40
# Outliers	N/A	2	0	0	0	0	5
Max Value	2.79	97.67	14.43	8.76	5.22	4.86	97.67

Production (PdE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	1	15	7	10	7	4	44
Q1	N/A	1.55	1.22	1.04	0.29	0.31	1.00
Median	N/A	3.97	4.64	3.37	0.81	0.94	3.15
Q3	N/A	20.68	5.33	10.55	3.14	4.18	5.87
IQR	N/A	19.12	4.11	9.51	2.86	3.87	4.87
# Outliers	N/A	2	0	1	1	0	6
Max Value	3.17	287.00	7.14	24.98	7.65	5.10	287.00

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

The data show that although the difference between the Air Force's total population's 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 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 period 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 just characteristic of these four MDAPs.

Regression Model

Table 5-3: Regression Model of Air Force Programs

	Log(Ratio at Development)		Log(Ratio at Production)	
	Air Force	**Overall**	**Air Force**	**Overall**
(Intercept)	**1.84** (0.39)***	**1.85** (0.22)***	**3.25** (0.80)***	**3.02** (0.37)***
Study Variable				
rescale(Year)	**-2.06** (0.74)**	-0.73 (0.37)·	-2.09 (1.17)·	-0.30 (0.53)
Estimating History				
Available at Development			-0.84 (0.56)	**-1.25** (0.26)***
Available at Production	0.51 (0.31)	0.26 (0.16)		
Platform Portfolio				
Elec., Comms, & Sensors	-0.46 (0.44)	**-0.74** (0.22)**	-1.06 (0.70)	**-0.86** (0.32)**
Ordnance and Missiles	0.13 (0.36)	-0.37 (0.20)·	0.29 (0.61)	-0.09 (0.29)
Land Vehicles		0.49 (0.36)		0.72 (0.50)
Missile Defense		-0.22 (0.37)		-0.24 (0.51)
Space Systems	**-0.98** (0.45)*	**-1.47** (0.35)***	-0.82 (0.64)	**-1.36** (0.42)**
AIC	234.34	597.71	198.00	498.30
BIC	252.33	630.44	211.38	528.00
Log Likelihood	-109.17	-288.85	-92.00	-239.15
Deviance	92.74	220.90	116.06	233.57
Num. obs.	70	195	50	144

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

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.

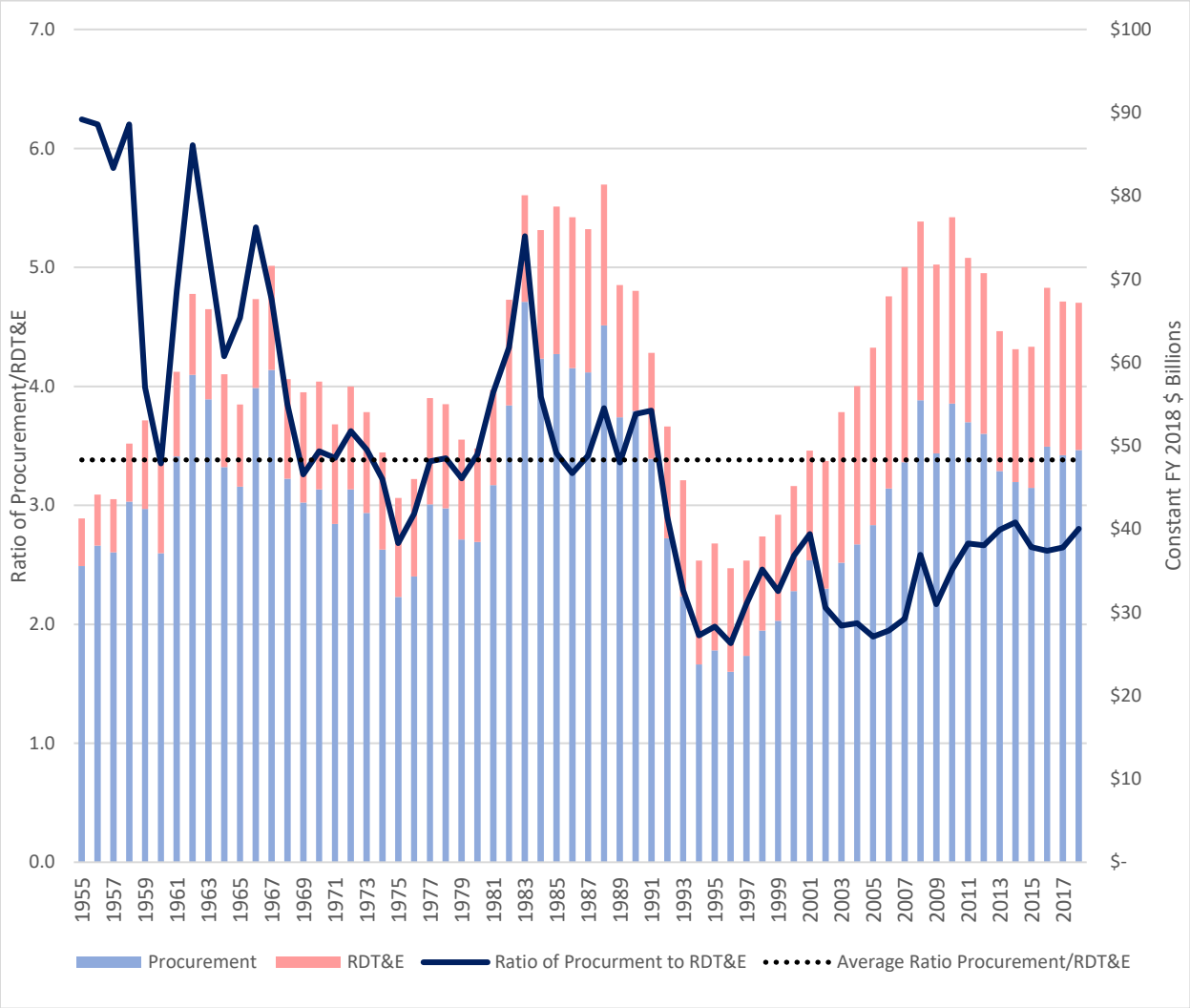
Air Force Takeaways:

- 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.

5.2.3. Department of the Navy

Amongst 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



Source: Department of Defense, "National Defense Budget Estimates for Fiscal Year 2018 (Green Book)," Office of the Undersecretary of Defense (Comptroller), Revised August 2017; CSIS analysis

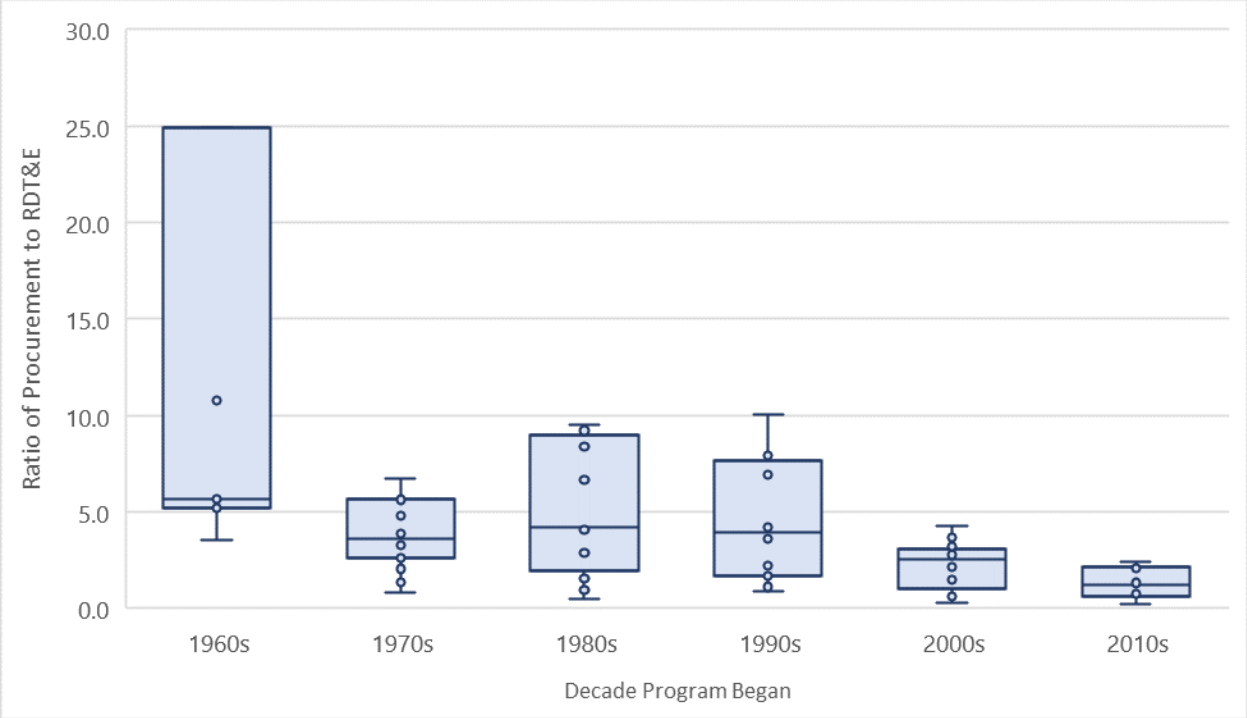
The Navy ratio trends has generally followed the overall DoD trends, with a few notable differences. After the ratio of procurement to RDT&E in the Navy peaked in 1983, that ratio fell precipitously in the following years despite near-historic procurement budgets. Whereas the Overall DoD budget trends in those years was 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



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	7	19	16	12	16	6	76
Q1	5.22	2.61	1.95	1.71	1.06	0.65	1.71
Median	5.66	3.59	4.24	3.91	2.55	1.24	3.16
Q3	24.89	5.64	9.01	7.67	3.07	2.15	5.65
IQR	19.67	3.04	7.06	5.96	2.01	1.50	3.94
# Outliers	1	3	1	1	0	0	6
Max Value	80.80	34.37	40.19	38.00	4.31	2.39	80.80

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

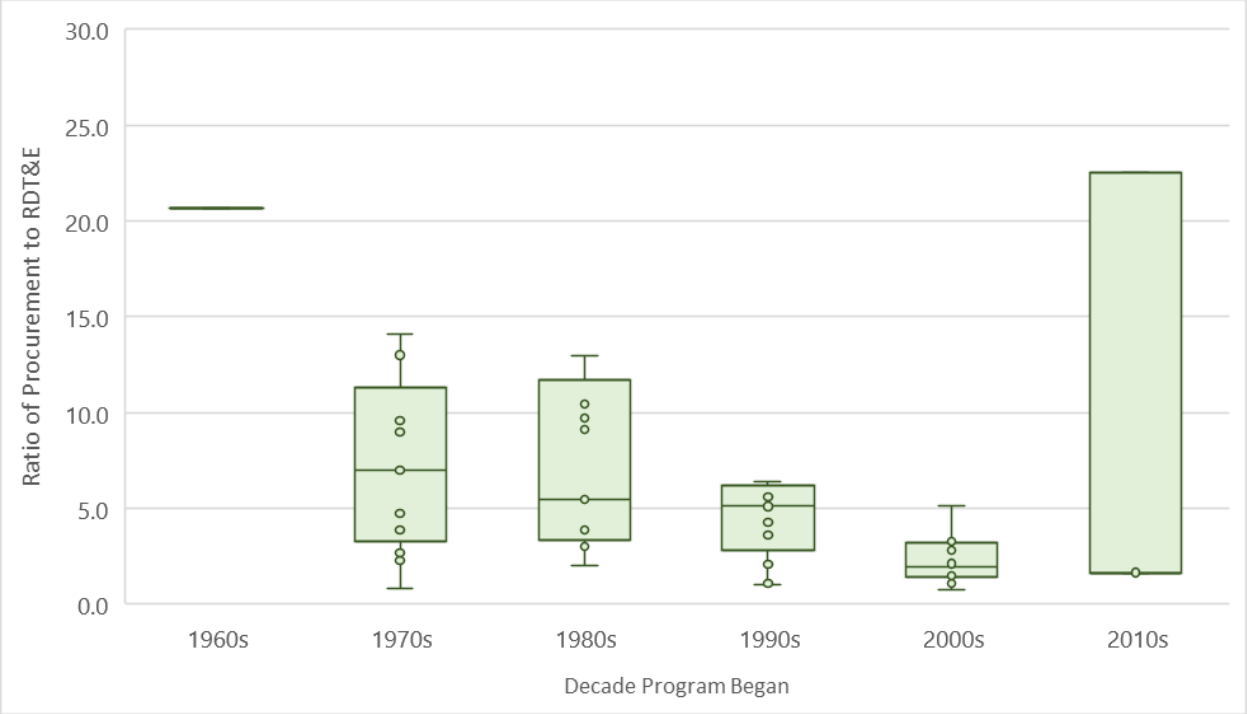
Similar to the topline DoD trends, the ratio of procurement to RDT&E for Navy MDAP's estimated during development has declined since the 1990s. For all Navy MDAP development estimates, the median has gone from 4.24 during the 1980s to 1.24 during the 2010s, well below 3.16 median for the total Navy population. 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 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 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



Production (PdE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	1	13	13	13	14	3	57
Q1	N/A	3.29	3.34	2.84	1.42	1.65	2.09
Median	20.68	6.98	5.46	5.11	1.93	1.65	3.91
Q3	N/A	11.30	11.71	6.19	3.23	22.50	9.36
IQR	N/A	8.00	8.36	3.35	1.80	20.86	7.27
# Outliers	N/A	1	2	2	1	0	6
Max Value	20.68	201.07	49.26	12.48	91.43	22.50	201.07

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 shown 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 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 like

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

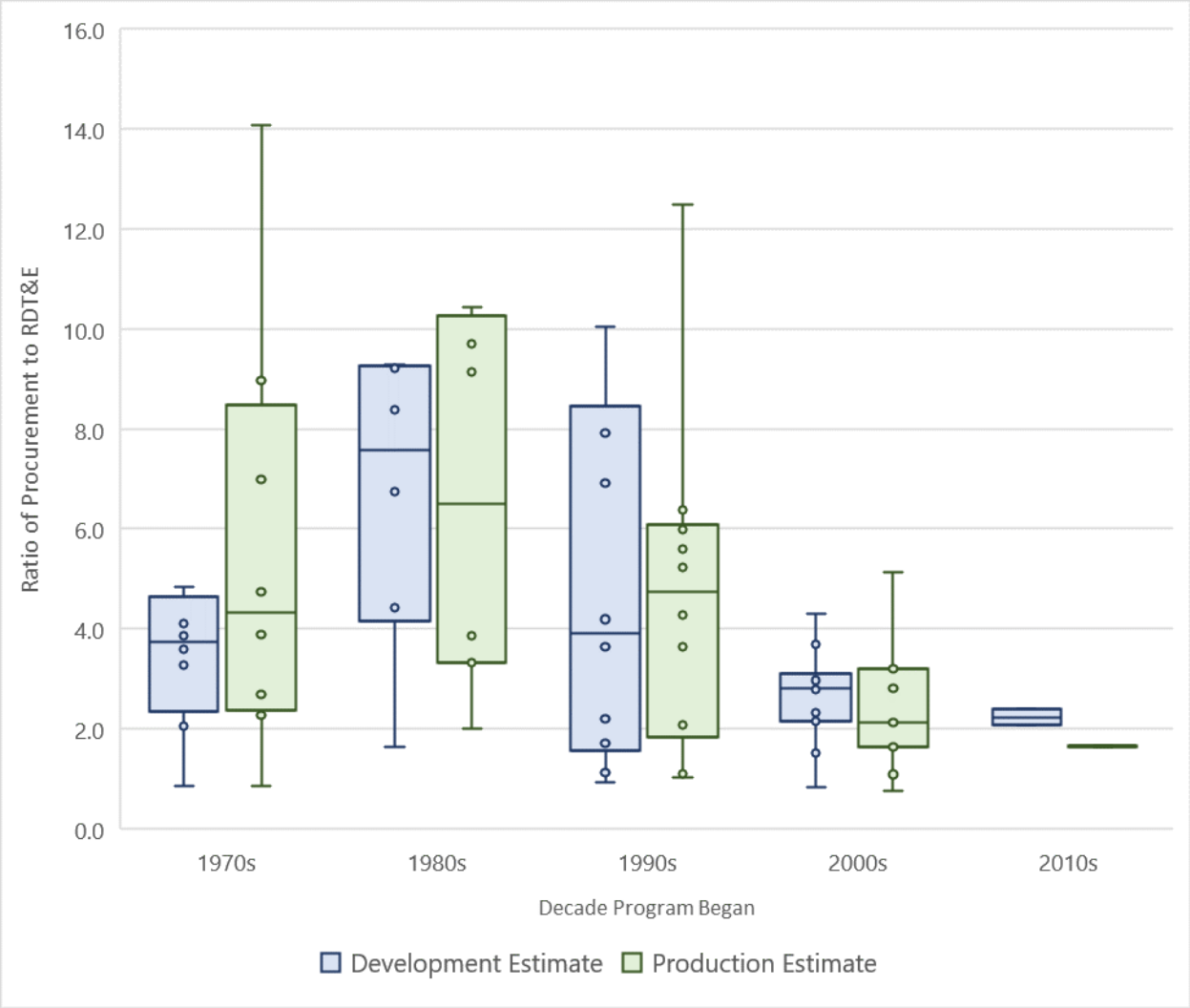
The Navy trends for MDAPs with both development and production estimate follow both the Overall DoD finding of optimistic development estimates and are experiencing fundamental change in the ratio of procurement to RDT&E.

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



Development (DE) Baseline						
	1970s	1980s	1990s	2000s	2010s	Total Population
Count	8	8	10	11	2	39
Q1	2.36	4.15	1.55	2.15	N/A	2.15
Median	3.73	7.57	3.91	2.81	2.23	3.59
Q3	4.65	9.27	8.45	3.10	N/A	6.74
IQR	2.29	5.12	6.90	0.95	N/A	4.59
# Outliers	1	1	1	0	0	2
Max Value	10.82	40.19	38.00	4.31	2.39	40.19

Production (PdE) Baseline						
	1970s	1980s	1990s	2000s	2010s	Total Population
Count	8	8	10	11	2	39
Q1	2.37	3.33	1.83	1.64	N/A	1.74
Median	4.31	6.50	4.75	2.12	1.65	3.32
Q3	8.48	10.26	6.09	3.21	N/A	6.00
IQR	6.11	6.93	4.27	1.57	N/A	4.26
# Outliers	0	1	0	0	0	3
Max Value	14.07	43.60	12.48	5.13	1.65	43.60

Source: RAND DSCPD; 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 procurement. 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 of relationship, but not in its magnitude.

Table 5-4: Regression Model of Navy Programs

	Log(Ratio at Development)		Log(Ratio at Production)	
	Navy	**Overall**	**Navy**	**Overall**
(Intercept)	**2.45** (0.32)***	**1.85** (0.22)***	**3.08** (0.49)***	**3.02** (0.37)***
Study Variable				
rescale(Year)	**-1.46** (0.59)*	-0.73 (0.37)·	-0.09 (0.70)	-0.30 (0.53)
Estimating History				
Available at Development			**-1.41** (0.39)***	**-1.25** (0.26)***
Available at Production	0.18 (0.29)	0.26 (0.16)		
Platform Portfolio				
Elec., Comms, & Sensors	**-0.89** (0.32)**	**-0.74** (0.22)**	-0.78 (0.47)	**-0.86** (0.32)**
Ordnance and Missiles	**-0.76** (0.30)*	-0.37 (0.20)·	-0.22 (0.42)	-0.09 (0.29)
Land Vehicles	-0.84 (0.71)	0.49 (0.36)	0.08 (0.88)	0.72 (0.50)
Missile Defense	-0.46 (0.59)	-0.22 (0.37)	-0.80 (0.83)	-0.24 (0.51)
Space Systems	-1.54 (0.98)	**-1.47** (0.35)***	**-1.90** (0.83)*	**-1.36** (0.42)**
AIC	174.78	597.71	152.01	498.30
BIC	193.78	630.44	168.66	528.00
Log Likelihood	-78.39	-288.85	-67.01	-239.15
Deviance	46.67	220.90	47.64	233.57
Num. obs.	61	195	47	144

***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 are 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.

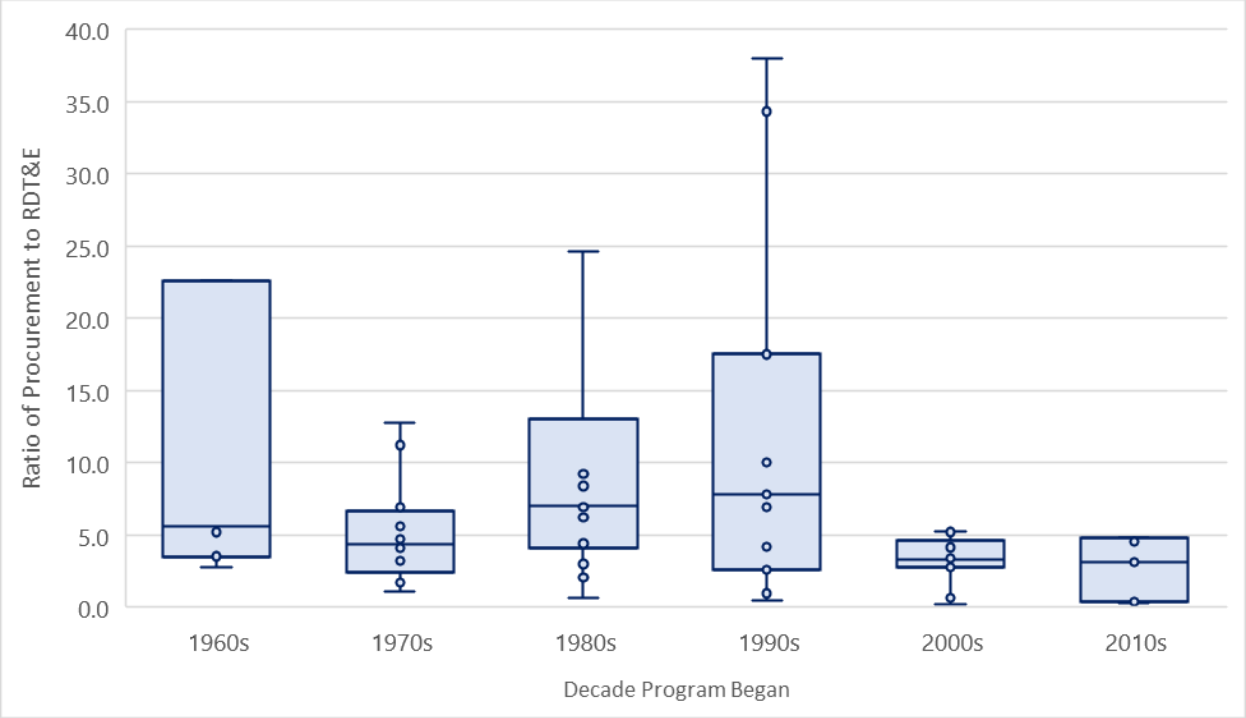
5.3.1. Aircraft

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 up-tick during the 2010s as the upper quartile rose to 4.86 but is still well below the total's population upper quartile 7.79. Finally, the lower quartile data declined starting during the 1990s when the lower quartile went 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



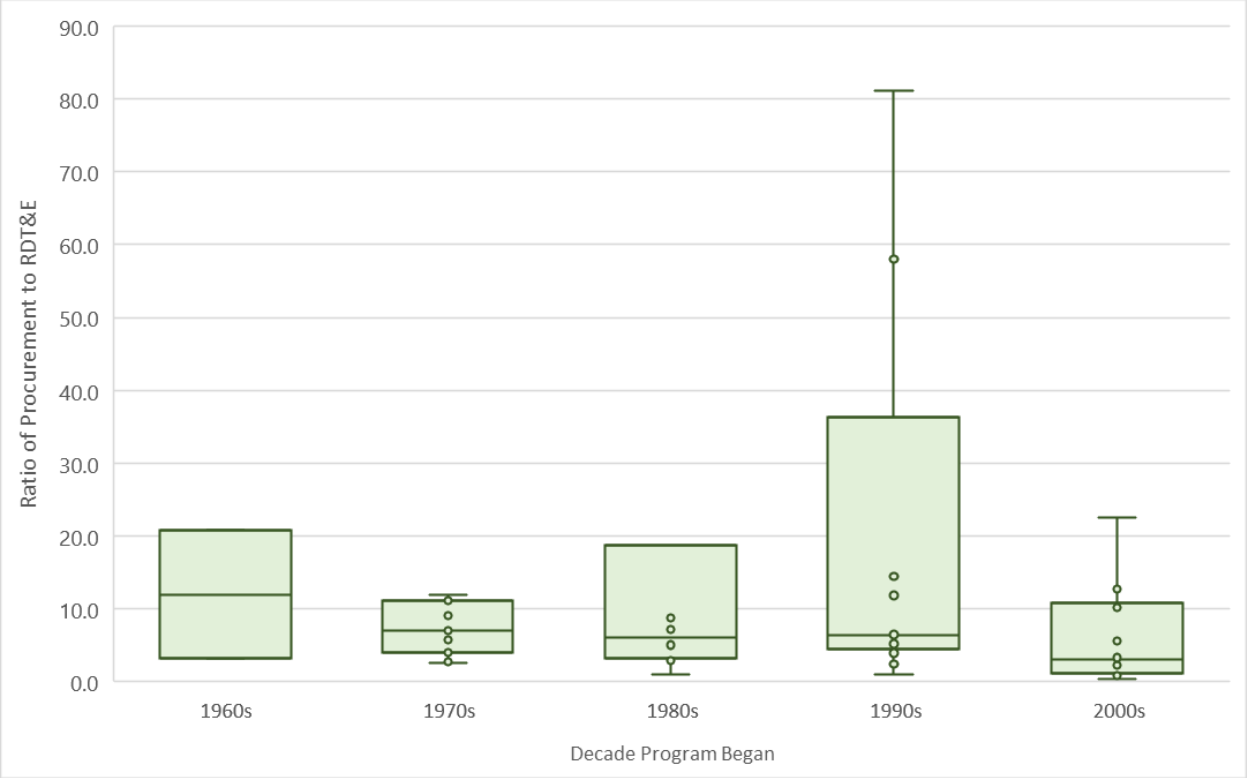
Development (DE) Baseline							
	1960s	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**	**Total Population**
Count	7	16	14	11	18	7	73
Q1	3.53	2.45	4.07	2.63	2.81	0.40	2.83
Median	5.63	4.40	7.05	7.81	3.32	3.12	4.55
Q3	22.63	6.63	13.08	17.52	4.63	4.86	7.79
IQR	19.10	4.18	9.01	14.89	1.83	4.45	4.97
# Outliers	1	1	2	0	2	1	11
Max Value	80.80	34.37	50.62	38.00	37.88	19.85	80.80

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.

Figure 5-17: Aircraft Production Estimate Baseline by Decade



Production (PdE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	2	11	10	13	18	4	58
Q1	N/A	3.97	3.19	4.48	1.15	0.48	2.77
Median	11.93	6.98	6.05	6.38	3.04	2.45	5.11
Q3	N/A	11.08	18.73	36.26	10.72	4.77	11.50
IQR	N/A	7.12	15.55	31.78	9.56	4.29	8.73
# Outliers	N/A	0	2	1	2	0	7
Max Value	20.68	11.84	56.53	689.86	510.97	5.10	689.86

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

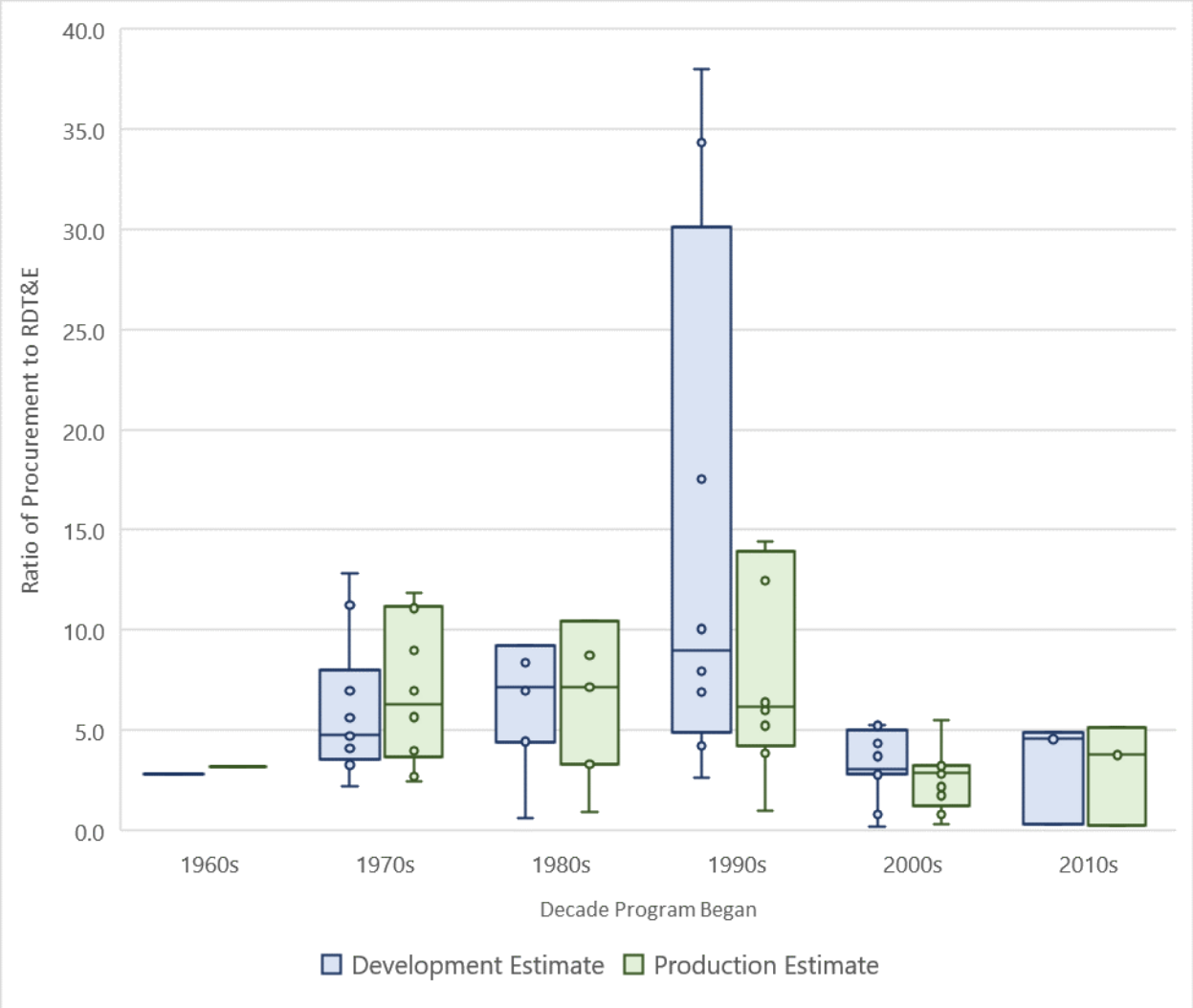
The Aircraft data show a more definitive decline in the production baseline's ratio of procurement to RD&TE during the first decade of the new century. During the 2000s, the median, lower quartile, and upper quartile ratio of development to production estimated for Aircraft MDAPs at production has declined. 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 similar sharp declines during the 2000s. The lower quartile went from 4.48 during the 90s to 1.15 during the 2000s, while the upper quartile went from 36.26 during the 1990s to 10.72.

Development Estimates v. Production Estimates

The trends for Aircraft programs with both development and production estimate follow the Overall DoD finding of optimistic development estimates, but while there is evidence to suggest an ongoing fundamental change in the ratio of procurement to RDT& is likely, the data is 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.

Figure 5-18: Comparison of Estimated Ratio of Procurement to RDT&E at Development v. Production for Aircraft with both estimates, by decade



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	1	10	7	8	12	3	41
Q1	N/A	3.52	4.42	4.87	2.79	0.28	2.90
Median	N/A	4.77	7.15	9.00	3.04	4.55	4.70
Q3	N/A	8.03	9.21	30.13	5.00	4.86	8.17
IQR	N/A	4.51	4.79	25.25	2.21	4.57	5.26
# Outliers	N/A	0	1	0	1	0	5
Max Value	2.79	12.81	40.19	38.00	37.88	4.86	40.19

Production (PdE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	1	10	7	8	12	3	41
Q1	N/A	3.65	3.32	4.19	1.25	0.26	2.75
Median	N/A	6.31	7.14	6.19	2.87	3.76	3.97
Q3	N/A	11.17	10.44	13.95	3.26	5.10	8.85
IQR	N/A	7.52	7.13	9.76	2.01	4.85	6.10
# Outliers	N/A	0	1	1	1	0	3
Max Value	3.17	11.84	43.60	58.07	22.42	5.10	58.07

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

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, from 9.00 and 6.19 during development and production respectively during the 1990s to 3.04 and 2.87. 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:

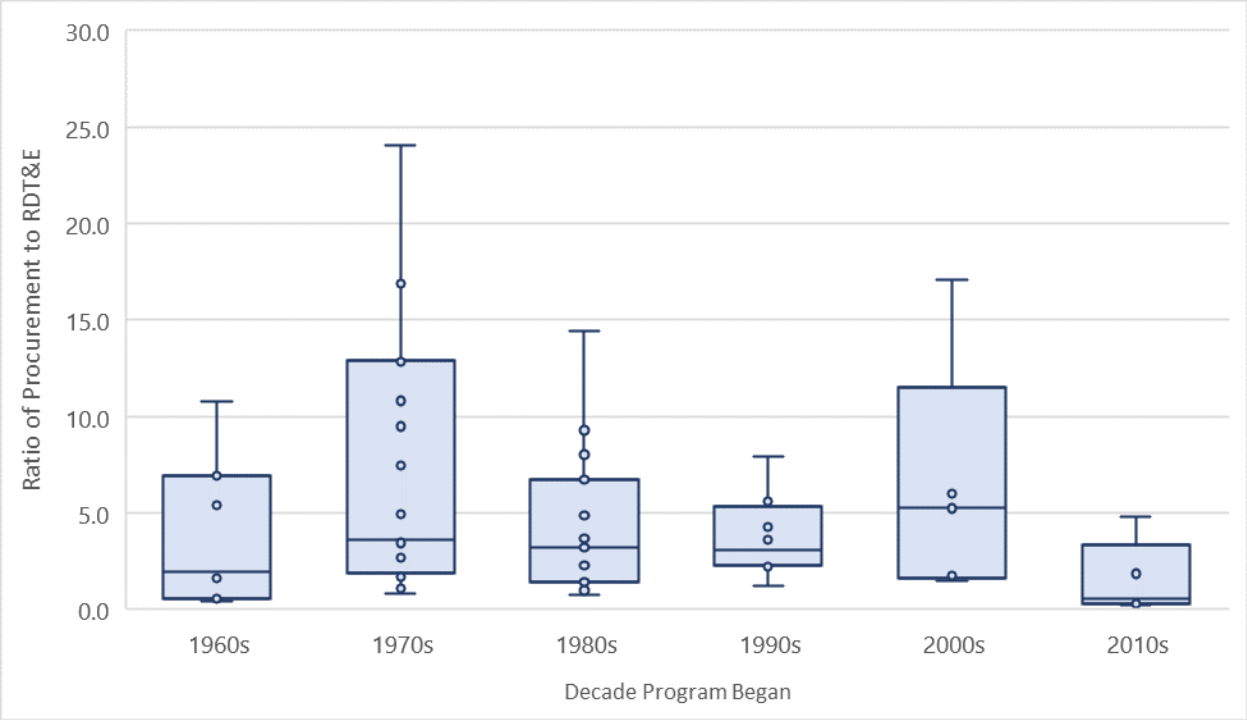
- The Aircraft development estimate data show a declining ratio of procurement to RDT&E estimated since the 1990s.
- The Aircraft development estimate data show a declining ratio of procurement to RDT&E estimated between the 1980s and 2000s.
- For MDAPs with both development and production estimates:
    - Aircraft development estimates started becoming more optimistic than production estimates during the 1990s, but the gap between the two estimates has shrunk since then.
    - 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.

Figure 5-19: Ordnance & Missiles Development Estimate Baseline by Decade



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	7	21	19	12	5	5	69
Q1	0.56	1.88	1.44	2.30	1.64	0.28	1.58
Median	1.96	3.59	3.22	3.10	5.24	0.58	3.22
Q3	6.95	12.88	6.74	5.33	11.52	3.33	7.20
IQR	6.38	11.00	5.30	3.03	9.88	3.05	5.62
# Outliers	0	2	1	1	0	0	7
Max Value	10.77	97.67	20.85	16.04	17.05	4.79	97.67

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

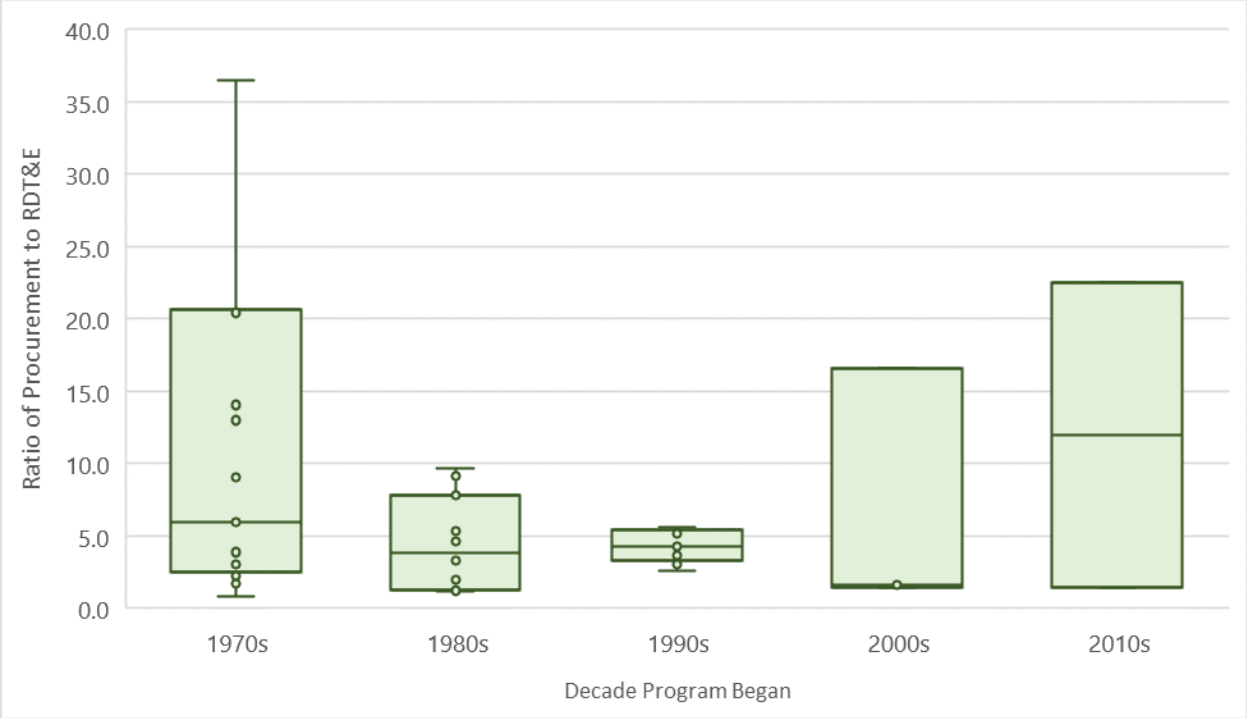
It is inconclusive whether has been a change in the ratio of ratio of procurement to RDT&E in the Ordnance & Missiles platform portfolio over the past two decades given the volatility in the data. The 2000s data mostly show a rising Ordnance & Missiles ratio of procurement to RDT&E, with only the lower quartile declining. The median and upper quartile values respectively rose from 3.10 and 5.33 during the 1990s to 5.24 and 11.52 during the 2000s. However, during the 2010s 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.

Figure 5-20: Ordnance & Missiles Production Estimate Baseline by Decade



Production (PdE) Baseline						
	1970s	1980s	1990s	2000s	2010s	Total Population
Count	19	11	9	3	2	44
Q1	2.54	1.31	3.35	1.43	N/A	2.33
Median	5.94	3.86	4.27	1.64	11.96	4.21
Q3	20.68	7.83	5.40	16.58	N/A	12.18
IQR	18.14	6.52	2.05	15.15	N/A	9.85
# Outliers	3	0	1	0	0	4
Max Value	287.00	9.70	19.15	16.58	22.50	287.00

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

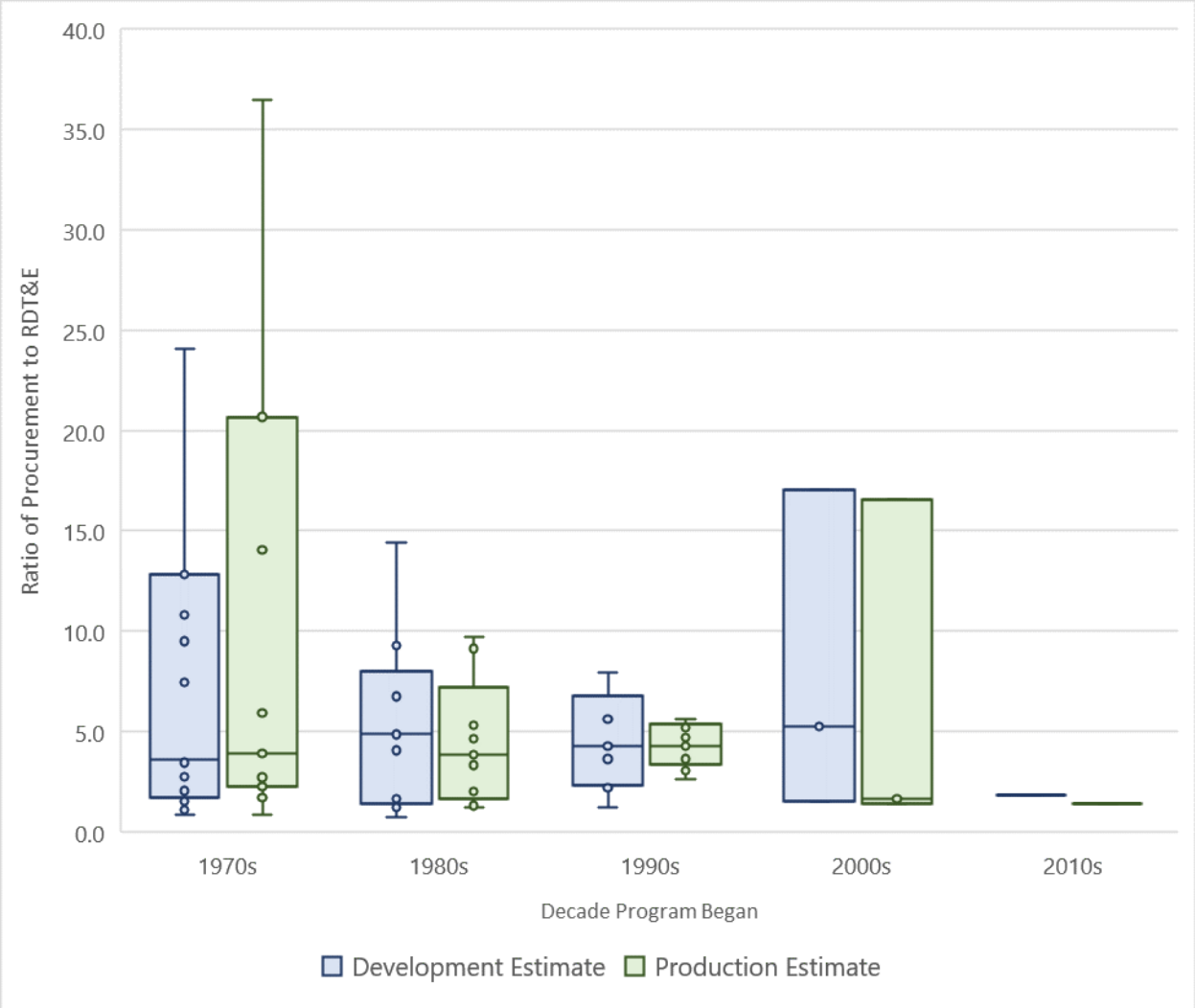
The data is insufficient data to form conclusions on the ratio of procurement to RDT&E trends in Ordnance & Missiles production estimates. In the two most-recent decades, there are not enough programs to make any trends sufficiently robust. Going back further, the data mostly suggests that, by most measures, 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.

Figure 5-21: Comparison of Estimated Ratio of Procurement to RDT&E at Development v. Production for only Ordnance & Missiles with both estimates, by decade



Development (DE) Baseline						
	1970s	1980s	1990s	2000s	2010s	Total Population
Count	15	9	9	3	1	37
Q1	1.71	1.43	2.33	1.51	N/A	1.79
Median	3.59	4.86	4.26	5.24	1.86	4.26
Q3	12.82	8.02	6.77	17.05	N/A	9.39
IQR	11.11	6.59	4.44	15.54	N/A	7.60
# Outliers	2	0	1	0	0	3
Max Value	97.67	14.43	16.04	17.05	1.86	97.67

Production (PdE) Baseline						
	1970s	1980s	1990s	2000s	2010s	Total Population
Count	15	9	9	3	1	37
Q1	2.26	1.66	3.35	1.43	N/A	2.17
Median	3.89	3.86	4.27	1.64	1.42	3.86
Q3	20.68	7.23	5.40	16.58	N/A	7.54
IQR	18.41	5.57	2.05	15.15	N/A	5.37
# Outliers	2	0	1	0	0	6
Max Value	287.00	9.70	19.15	16.58	1.42	287.00

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

Note: Outliers not shown on graph

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 more evidence showing 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, 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 similar suggest the ratio declined for most programs, but that was increasing for a typical program. Given these, at-times, contradictory trends, the data is inconclusive.

Ordnance & Missiles Takeaways:

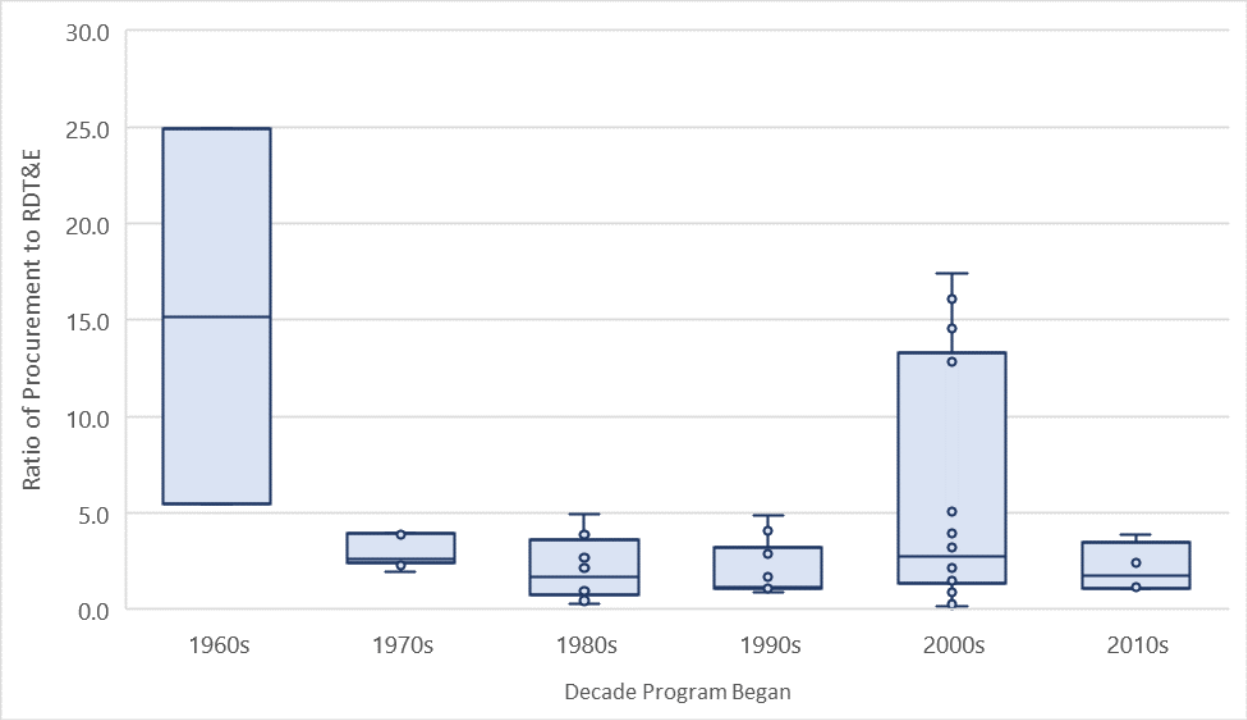
- The Ordnance & Missiles development estimate data has been volatile the past two decades and are inconclusive as to whether there is a change in the of procurement to RDT&E.
- The Ordnance & Missiles development production data is insufficient to form conclusions about the investment ratio trends.
- 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 platform portfolio.

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



Development (DE) Baseline							
	1960s	1970s	1980s	1990s	2000s	2010s	Total Population
Count	2	9	16	10	14	4	55
Q1	N/A	2.41	0.77	1.09	1.34	1.10	1.09
Median	15.18	2.62	1.69	1.13	2.77	1.78	2.39
Q3	N/A	3.92	3.62	3.20	13.28	3.49	3.98
IQR	N/A	1.51	2.85	2.11	11.94	2.39	2.89
# Outliers	0	1	1	0	0	0	6
Max Value	24.89	6.72	9.50	4.90	17.43	3.85	24.89

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

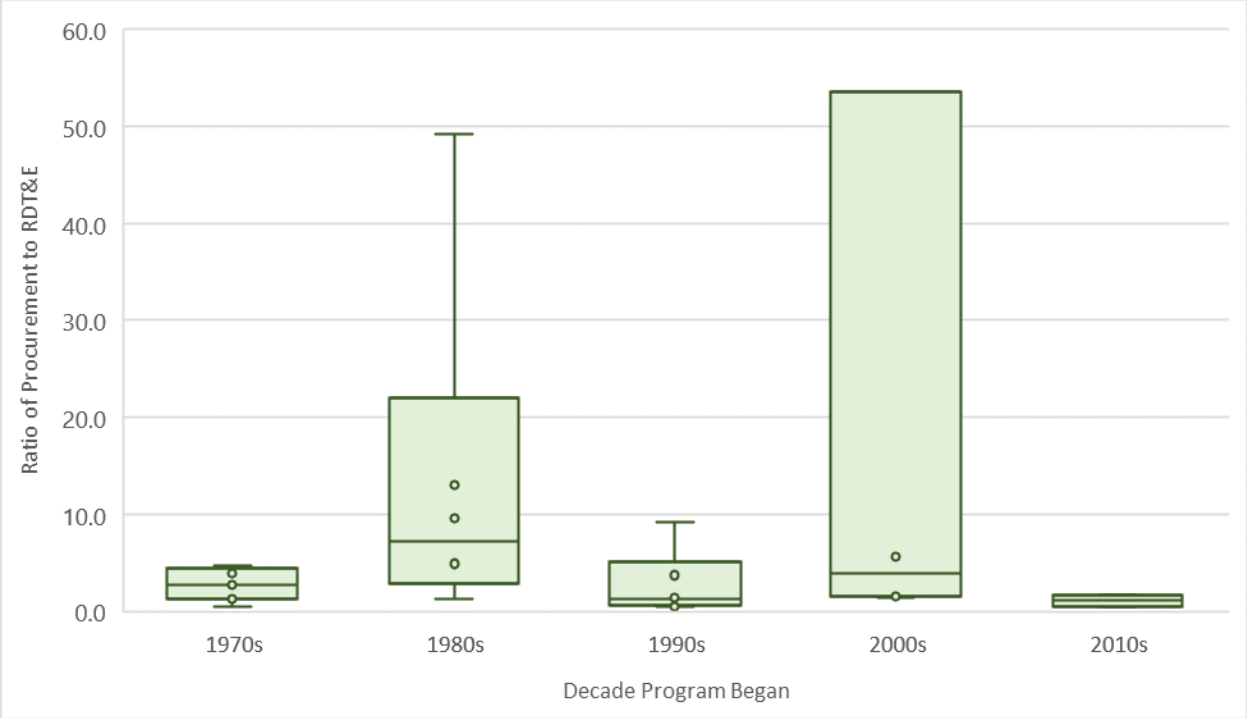
The data show that although there has been fluctuation in the ratio of procurement to RDT&E in the development estimates for the Electronics, Comms, & Sensors platform portfolio, it is not experiencing a fundamental change in the ratio of production to development. From the 1970s to the 1990s the median 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, however this trend is not sufficiently robust to draw conclusions given the small population.

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 Electronics, Comms, & Sensors platform portfolio.

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



Production (PdE) Baseline						
	1970s	1980s	1990s	2000s	2010s	Total Population
Count	9	6	10	6	2	33
Q1	1.31	2.80	0.66	1.49	N/A	1.24
Median	2.66	7.24	1.27	3.84	1.06	2.12
Q3	4.44	22.04	5.10	53.56	N/A	7.41
IQR	3.13	19.25	4.44	52.07	N/A	6.16
# Outliers	1	0	1	1	0	5
Max Value	25.88	49.26	33.22	164.13	1.65	164.13

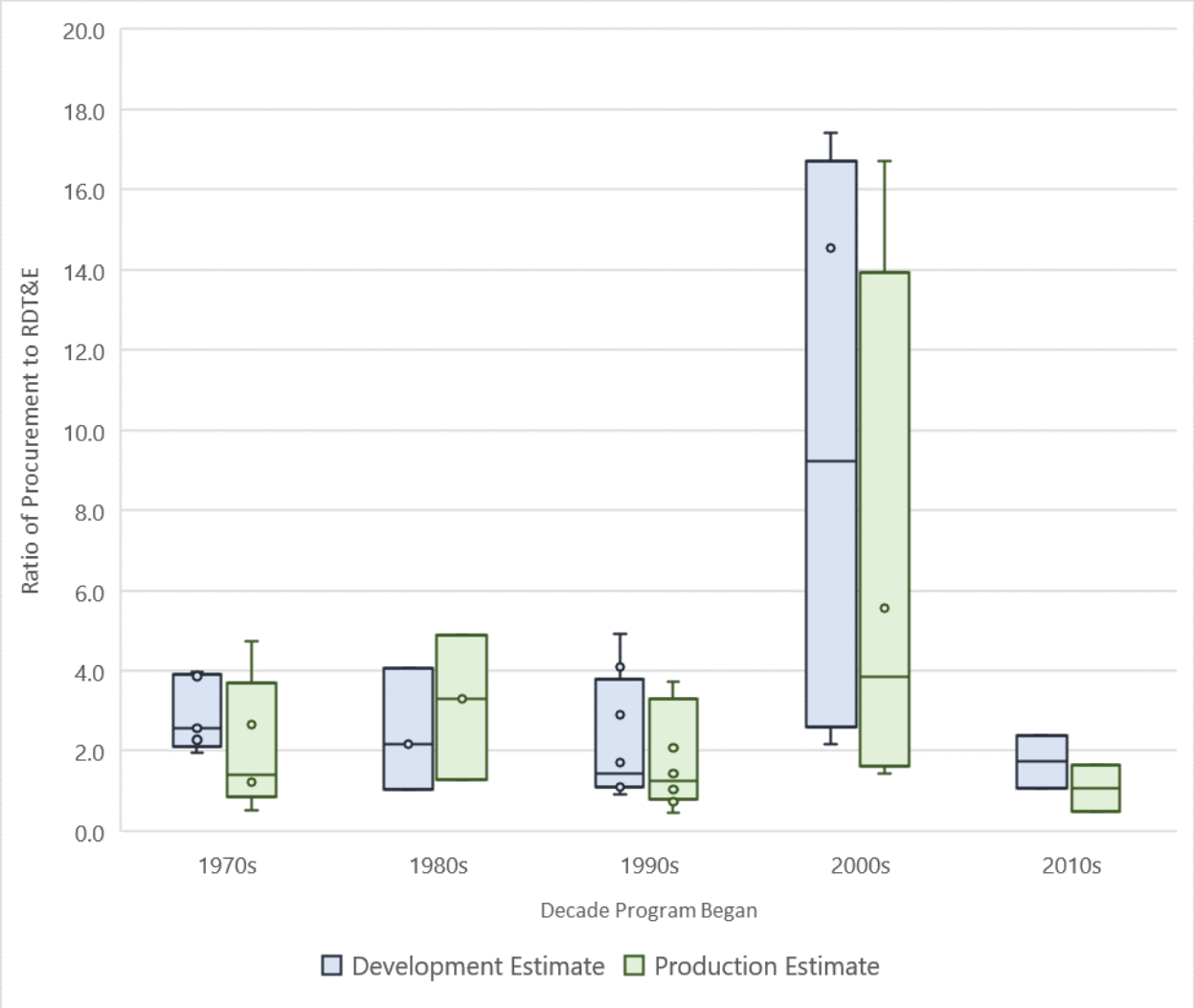
Source: RAND DSCPD; SARs accessed through DAMIR; CSIS analysis
Note: Outliers not shown on graph

The production estimate data shows 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 5.10 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 this whipsaw.

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



Development (DE) Baseline						
	1970s	1980s	1990s	2000s	2010s	Total Population
Count	5	3	8	4	2	22
Q1	2.11	1.05	1.10	2.60	N/A	1.14
Median	2.55	2.18	1.43	9.24	1.73	2.33
Q3	3.92	4.05	3.79	16.71	N/A	3.99
IQR	1.81	3.00	2.70	14.11	N/A	2.85
# Outliers	0	0	1	0	0	2
Max Value	3.98	4.05	4.90	17.43	2.39	17.43

Production (PdE) Baseline						
	1970s	1980s	1990s	2000s	2010s	Total Population
Count	5	3	8	4	2	22
Q1	0.86	1.27	0.80	1.61	N/A	1.08
Median	1.40	3.30	1.27	3.84	1.06	1.54
Q3	3.70	4.89	3.30	13.92	N/A	3.97
IQR	2.84	3.62	2.50	12.31	N/A	2.89
# Outliers	0	0	1	0	0	2
Max Value	4.73	4.89	9.25	16.70	1.65	16.70

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

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 Electronics, Comms, & Sensors (0.79) than the overall DoD topline (0.41).

The ratio of procurement to RDT&E for Electronics, Comms, and Sensors programs with both development and production estimates shows some, albeit limited, evidence 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 up-tick 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, gives individual programs out-sized influence limiting 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 negligible fundamental changes.
- The Electronics, Comms, & Sensors production data show significant whipsaws between the 1980s and 2000s and insufficient data 2010s data to compare against.
- 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 RD&TE has increased in recent years.

6. | 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 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 uncertainty at lower levels. Prior to the fiscal crisis, R&D intensity within the manufacturing sector was 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 is still necessary to confirm that these current trends are not an anomaly. The information industry in the non-manufacturing sector has also shown a similar positive trend in recent years, but additional data is 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 amongst the military. 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 trends, 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 the 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 for the failures and problems of 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 RD&TE is declining for MDAPs with both development and production estimates by most measures. The median ratio of procurement to RD&TE 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 amongst MDAPs between the military services? Are there significant differences between the military services?

The data show that amongst 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 RD&TE 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 characteristic of the 2010s small count relative to the other decades.

The Navy data shows 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 thirty 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 shows 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 amongst MDAPs between the different platform portfolios? Are there significant differences between platform portfolios?

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

The Aircraft data show that by nearly every measure that Aircraft is experiencing a meaningful change in the ratio of procurement to RDT&E. The ratio of procurement to RD&TE has declined in all production estimates, all development estimates, and across both estimates for MDAPS with both estimates.

The data was 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 has been volatile 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 was 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 is 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 RD&TE 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

	Development	Production	Combined	
	DE Ratio Change	*PdE Ratio Change*	*DE v. PdE*	*Ratio Change*
Overall DoD	↗	↗	DE More Optimistic	↗
Components				
Army	↗	↗	DE More Optimistic; Army 50% higher than Overall DoD	↗
Navy	↗	↗	DE More Optimistic; Smaller Difference than Overall DoD	↗
Air Force	↗	↗	DE More Optimistic; Roughly in-line with Overall DoD	↗
Platform Portfolio				
Aircraft	↗	↗	DE More Optimistic; since 1990s	↗
Ordnance & Missiles	?	—	DE More Optimistic; In-line with Overall DoD	—
Electronics, Comms & Sensors	↗	?	DE More Optimistic; In-line with Overall DoD	↗

Legend

- — Insufficient Data
- ? Inconclusive Result
- .05 Significance Level
- .01 Significance Level

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 RD&TE 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 RD&TE 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 was 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 try and 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 clean start, the current estimate at last submitted SAR or production maturity, whether the program was cancelled or curtailed, effects of program size, and program length. These additional variables can provide important insights into better under the dynamics at play in the ratio of procurement to RDT&E in MDAPs.

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