United States Government Accountability Office

Report to Congressional Committees

April 2018

WEAPON SYSTEMS ANNUAL ASSESSMENT

Knowledge Gaps Pose Risks to Sustaining Recent Positive Trends

Accessible Version

GAO-18-360SP

Contents

Foreword 1

Letter 3

Background 5

Ten Observations on the Cost and Schedule Performance of DOD's 2017 Major Defense Acquisition Program Portfolio 8

Four Observations on DOD's Implementation of Key Acquisition Reform Initiatives 29

Eight Observations from Our Assessment of Knowledge Attained by Programs at Key Junctures and Related Implications for Testing and Software Development 34

Assessments of Individual Programs 50

Agency Comments 163

Appendix I: Major Defense Acquisition Programs' Individual Subcontracting Reports in the Electronic Subcontracting Reporting 166

Appendix II: Objectives, Scope, and Methodology 170

Appendix III: Knowledge-Based Acquisition Practices 184

Appendix IV: Comparison of December 2016 and First Full Estimates of Total Acquisition Cost for Programs in the Department of Defense 187

Appendix V: Cost and Schedule Changes over 5 Years and since First Full Estimates for the 86 Programs in DOD's 2017 Portfolio 191

Appendix VI: Technology Readiness Levels 192

Appendix VII: Comments from the Department of Defense 194

Appendix VIII: GAO Contact and Staff Acknowledgments 195

Appendix IX: Accessible Data 198

Data Tables 198

Agency Comments 204

Related GAO Products 206

Tables

Table 1: DOD Estimates that its 2017 Portfolio Will Cost More and Take Longer to Deliver as Compared to the 2016 Portfolio (Fiscal year 2018 dollars in billions) 12
Table 2: Programs that Comprise DOD's 2017 Portfolio Gained $2.3 Billion in Buying Power since 2016 (IFiscal year 2018 dollars in millions) 16
Table 3: DOD Estimates That Its 2017 Sub-portfolio of Programs Initiated since 2010 Will Cost Less, but Take Longer to Deliver, as Compared to 2016 (Fiscal year 2018 dollars in billions) 23
Table 4: DOD Estimates That Its 2017 Sub-portfolio of Programs Initiated before 2010 Will Cost More and Take Slightly Longer to Deliver, as Compared to 2016 (Fiscal year 2018 dollars in billions) 23
Table 5: DOD Programs Initiated since 2010 Gained Nearly $5.0 Billion in Buying Power, Which Was Offset by $2.7 Billion in Buying Power Decreases among Programs Initiated before 2010 (IFiscal year 2018 dollars in millions) 27
Table 6: Plans to Promote Competition among 57 Selected Programs in DOD's 2017 Portfolio 30
Table 7: Implementation of Knowledge-Based Practices for Programs in System Development 37
Table 8: Projected Implementation of Knowledge-Based Practices at Development Start for Future Programs 38
Table 9: Implementation of Knowledge-Based Practices for Selected Programs at Critical Design Review 40
Table 10: Implementation of Knowledge-Based Practices for Selected Programs at Production Decision 44
Table 11: Major Defense Acquisition Programs' Individual Subcontracting Reports in the Electronic Subcontracting Reporting System (eSRS) 166

Table 12: Best Practices for Knowledge-based Acquisitions 184
Table 13: December 2016 Cost Estimates and First Full Estimates for DOD's 2017 Portfolio of Major Defense Acquisition Programs (Fiscal year 2018 dollars in millions) 187
Table 14: Cost and Schedule Changes for Programs in DOD's 2017 Portfolio (Fiscal year 2018 dollars) 191
Table 15: Technology Readiness Levels and Descriptions 192
Table 16: GAO Staff Responsible for Individual Program Assessments 195
Data for Figure 2: DOD's Major Defense Acquisition Program Portfolio's Gains and Losses between 2016 and 2017 198
Data for Figure 3: DOD's Portfolio Cost and Size Have Increased Since 2016, but Remain within Historic Ranges 199
Data for Figure 4: Between 2016 and 2017, 23 DOD Programs Experienced Total Acquisition Cost Increases or Decreases of Greater than 5 Percent 199
Data for Figure 5: When Controlling for Quantity Changes, 16 DOD Programs Experienced Total Acquisition Cost Increases or Decreases of Greater than 5 Percent between 2016 and 2017 200
Data for Figure 6: DOD's 2017 Portfolio Shows Changes in Funding Requirements and Sunk Costs that Indicate Programs Are Further Along in the Acquisition Process 200
Data for Figure 7: DOD's 2017 Portfolio Reflects a Decline in Performance against 1- and 5-Year Cost Growth Metrics, but Demonstrates Improvement in Meeting the Metric for Cost Growth since First Full Estimate 201
Data for Figure 8: Programs in DOD's 2017 Portfolio Incurred Most of Their Cost Growth after Production Start 201
Data for Figure 9: Over 85 Percent of the 2017 Portfolio's Estimated Total Acquisition Cost Is for 61 Programs That DOD Initiated Prior to 2010 202
Data for Figure 10: Programs Initiated since 2010 Show Fewer Significant Year-to-Year Cost Changes as Compared to the Programs Initiated Prior to 2010 202
Data for Figure 11: When Controlling for Quantity Changes, the Programs Initiated since 2010 Incurred an Overall Cost Decrease while Programs Initiated Prior to 2010 Experienced an Overall Cost Increase 203
Data for Figure 12: Programs in DOD's 2017 Portfolio Initiated since 2010 Incurred Their Cost Growth before Critical

Design Review, while Programs Initiated Prior to 2010 Incurred Most of Their Cost Growth after Production 203
Data for Figure 13: Actions Programs Reported They Have Taken to Achieve “Should-Cost” Savings 204
Data for Figure 14: Eighteen Current Programs Completed, or Plan to Complete, Software Development after Production Start204
Data for Figure 15: Sixteen Programs Declared or Plan to Declare Initial Operational Capability before Completing Initial Operational Test and Evaluation 204

Figures

Figure 1: Defense Acquisition Cycle and GAO-Identified Knowledge Points 6
Figure 2: DOD’s Major Defense Acquisition Program Portfolio’s Gains and Losses between 2016 and 2017 10
Figure 3: DOD’s Portfolio Cost and Size Have Increased Since 2016, but Remain within Historic Ranges 11
Figure 4: Between 2016 and 2017, 23 DOD Programs Experienced Total Acquisition Cost Increases or Decreases of Greater than 5 Percent 14
Figure 5: When Controlling for Quantity Changes, 16 DOD Programs Experienced Total Acquisition Cost Increases or Decreases of Greater than 5 Percent between 2016 and 2017 15
Figure 6: DOD’s 2017 Portfolio Shows Changes in Funding Requirements and Sunk Costs that Indicate Programs Are Further Along in the Acquisition Process 18
Figure 7: DOD’s 2017 Portfolio Reflects a Decline in Performance against 1- and 5-Year Cost Growth Metrics, but Demonstrates Improvement in Meeting the Metric for Cost Growth since First Full Estimate 20
Figure 8: Programs in DOD’s 2017 Portfolio Incurred Most of Their Cost Growth after Production Start 21
Figure 9: Over 85 Percent of the 2017 Portfolio’s Estimated Total Acquisition Cost Is for 61 Programs That DOD Initiated Prior to 2010 22
Figure 10: Programs Initiated since 2010 Show Fewer Significant Year-to-Year Cost Changes as Compared to the Programs Initiated Prior to 2010 25

Figure 11: When Controlling for Quantity Changes, the Programs Initiated since 2010 Incurred an Overall Cost Decrease while Programs Initiated Prior to 2010 Experienced an Overall Cost Increase 26
Figure 12: Programs in DOD's 2017 Portfolio Initiated since 2010 Incurred Their Cost Growth before Critical Design Review, while Programs Initiated Prior to 2010 Incurred Most of Their Cost Growth after Production 28
Figure 13: Actions Programs Reported They Have Taken to Achieve "Should-Cost" Savings 34
Figure 14: Eighteen Current Programs Completed, or Plan to Complete, Software Development after Production Start 49
Figure 15: Sixteen Programs Declared or Plan to Declare Initial Operational Capability before Completing Initial Operational Test and Evaluation 50
Figure 16: Illustration of Program Two-Page Assessment 52
Figure 17: Illustration of Program One-Page Assessment 53
Figure 18: Examples of Knowledge Scorecards 55

Abbreviations

AMDR	Air and Missile Defense Radar
BMDS	Ballistic Missile Defense System
CH-53K	CH-53K Heavy Lift Replacement Helicopter
CRH	Combat Rescue Helicopter
DAMIR	Defense Acquisition Management Information Retrieval
DOD	Department of Defense
eSRS	Electronic Subcontracting Reporting System
F-15 EPAWSS	F-15 Eagle Passive Active Warning and Survivability System
F-35	F-35 Lightning II Joint Strike Fighter
IFPC Inc 2-I Block 1	Indirect Fire Protection Capability Increment 2—Intercept Block 1
KC-46A	KC-46 Tanker Modernization Program
MDAP	Major Defense Acquisition Program
MRL	manufacturing readiness level
NA	not applicable
NGJ Inc 1	Next Generation Jammer Increment 1
SAR	Selected Acquisition Report
T-AO 205	John Lewis Class Fleet Replenishment Oiler
TBD	to be determined
TRL	technology readiness level

WSARA	Weapon Systems Acquisition Reform Act

This is a work of the U.S. government and is not subject to copyright protection in the United States. The published product may be reproduced and distributed in its entirety without further permission from GAO. However, because this work may contain copyrighted images or other material, permission from the copyright holder may be necessary if you wish to reproduce this material separately.

U.S. GOVERNMENT ACCOUNTABILITY OFFICE

441 G St. N.W.
Washington, DC 20548

Comptroller General
of the United States

April 25, 2018

Congressional Committees

I am pleased to present our 16th annual assessment of the Department of Defense's (DOD) major weapon system acquisition programs—an area on GAO's high-risk list.[1] This year's report offers observations on the performance of DOD's 2017 portfolio of 86 major programs, which the department expects to cost $1.66 trillion in total.[2] This significant financial investment demands keen oversight and continued implementation of key legislative and policy reforms, as well as knowledge-based acquisition practices developed and recommended by GAO.[3]

This year's assessment offers a mixed message for DOD acquisition. On the one hand, we observed positive cost performance in the programs that DOD has initiated since 2010, when acquisition reforms began to take root—a trend we first highlighted in our 2016 assessment. Yet, like so many programs before them, most of these newer programs have continued to proceed without the requisite knowledge that our prior work has shown underpins good program outcomes.

Our work has found that when programs enter development with insufficient knowledge, negative effects can cascade throughout the acquisition cycle. These knowledge shortfalls, or gaps, often begin with program decisions to accept immature technologies at the start of system development, but then later manifest in other forms as the program approaches production. In this environment, decision makers are

[1]GAO, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others*, GAO-17-317 (Washington, D.C.: Feb. 15, 2017).

[2]Our assessment of DOD's portfolio does not include the cost of the Ballistic Missile Defense System (BMDS), as the program and its elements lack acquisition program baselines needed to support our assessment of cost and schedule change. For more information on BMDS and its elements, see GAO, *Missile Defense: Some Progress Delivering Capabilities, but Challenges with Testing Transparency and Requirements Development Need to Be Addressed,* GAO-17-381 (Washington, D.C.: May 30, 2017). 10 U.S.C. § 225 requires the Missile Defense Agency (MDA) to establish and maintain an acquisition baseline for certain elements of the BMDS, but these baselines are not the same as the acquisition program baselines developed pursuant to 10 U.S.C. § 2435 and DOD acquisition policies. For example, they do not include service-funded operations and sustainment costs needed to support GAO's assessment of cost and schedule change.

[3]See, e.g., Weapon Systems Acquisition Reform Act of 2009, Pub. L. No. 111-23.

confronted with the choice of increasing program investments, despite lacking visibility on whether the program's cost and schedule estimates are achievable, or truncating the program, and subsequently depriving warfighters of a needed capability. We have made numerous recommendations over the years to address these knowledge gaps in DOD's programs.[4] This year, for the first time, we conducted an exploratory statistical analysis of a small sample of 15 programs in production that begins to validate a linkage between the attainment of knowledge and the real-life cost and schedule outcomes that programs deliver. This analysis showed that programs that attained certain knowledge at key points had lower cost and schedule growth than other programs.

Therefore, it is troubling to observe the knowledge gaps that persist in DOD programs, especially in those initiated after 2010. Many of these later programs are only now on the cusp of entering production, or are in early production. As we first observed in 2017, production is the acquisition phase most closely associated with cost growth. Consequently, DOD's continued willingness to accept knowledge gaps in these newer programs—now over 8 years after the implementation of acquisition reforms—indicates that reforms have not yet taken hold to the extent that Congress intended.

Gene L. Dodaro
Comptroller General of the United States

[4]See the Related GAO Products page at the end of this report for examples of products where we have recommended application of knowledge-based acquisition practices within DOD acquisition programs.

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

April 25, 2018

Congressional Committees

In response to the joint explanatory statement accompanying the Department of Defense Appropriations Act, 2009, this report provides insight into the department's $1.66 trillion portfolio of major weapon programs.[1] It includes observations on (1) the cost and schedule performance of DOD's 2017 portfolio of 86 major weapon programs, (2) the implementation of key acquisition reform initiatives within 57 current and future programs, and (3) the knowledge that 57 current and future programs attained at key decision points in the acquisition process. This report also includes information related to small business participation, pursuant to a provision in a report to the National Defense Authorization Act for Fiscal Year 2013.[2] Specifically, we determined whether individual subcontracting reports from a program's prime contractor or contractors were accepted within the Electronic Subcontracting Reporting System (eSRS).[3] Results from this analysis can be found in appendix I.

Our observations in this report are based on three sets of programs:

- We assessed 86 major defense acquisition programs (MDAP) in DOD's 2017 portfolio for cost and schedule performance.[4] We obtained cost, schedule, and quantity data from DOD's December

[1]See Explanatory Statement, 154 Cong. Rec. H 9427, 9526 (daily ed., Sept. 24, 2008), to the Department of Defense Appropriations Act, 2009, contained in Division C of the Consolidated Security, Disaster Assistance, and Continuing Appropriations Act, 2009, Pub. L. No. 110-329 (2008).

[2]H.R. Rep. No. 112-479, at 284 (2012). The National Defense Authorization Act for Fiscal Year 2013, Pub. L. No.112-239.

[3]The government uses individual subcontracting reports on eSRS as one method of monitoring small business participation, as the report includes goals for small business subcontracting.

[4]Major defense acquisition programs (MDAP) are those identified by DOD or that have a dollar value for all increments estimated to require eventual total expenditure for research, development, test, and evaluation of more than $480 million, or for procurement of more than $2.79 billion, in fiscal year 2014 constant dollars. DOD maintains a list of programs designated as future major defense acquisition programs. These programs have not formally been designated as MDAPs; however, DOD plans for these programs to enter system development, or bypass development and begin production, at which point DOD will likely designate them as MDAPs. We refer to these programs as future or planned major defense acquisition programs throughout this report.

2016 Selected Acquisition Reports (SAR)—which detail initial cost, schedule, and performance baselines and changes over the past year—and from the Defense Acquisition Management Information Retrieval (DAMIR) system, a DOD repository for program data. We conducted our own assessment of data reliability by comparing the SAR data we entered into our weapon system database and the DAMIR data and determined the data were sufficiently reliable for the purposes of our report.

- We also assessed 45 MDAPs currently between the start of development and the early stages of production. We developed a questionnaire to obtain information on the extent to which these programs are following knowledge-based acquisition practices for technology maturity, design stability, and production readiness. The questionnaire asked programs to provide information about systems engineering, design drawings, manufacturing planning and execution, and the implementation of specific acquisition reforms. In addition, the questionnaire requested that programs provide details on scheduling, critical technology levels, major development and early procurement contract data, and other information. We received questionnaire responses from all 45 current programs from October 2017 through December 2017.
- We also assessed 12 future MDAPs not yet in the portfolio to gain additional insights into knowledge they plan to attain before starting development and their plans for implementing key acquisition reforms. We provided a questionnaire to program offices to collect information on schedule events, costs, and numerous acquisition reforms, and received responses from all 12 future programs from October 2017 through January 2018.

In addition, we present individual assessments of 57 MDAPs, which include the 45 MDAPs currently in development or early production, as well as the 12 future programs. Appendix II provides additional information on our objectives, scope, and methodology.

We conducted this performance audit from May 2017 to April 2018 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

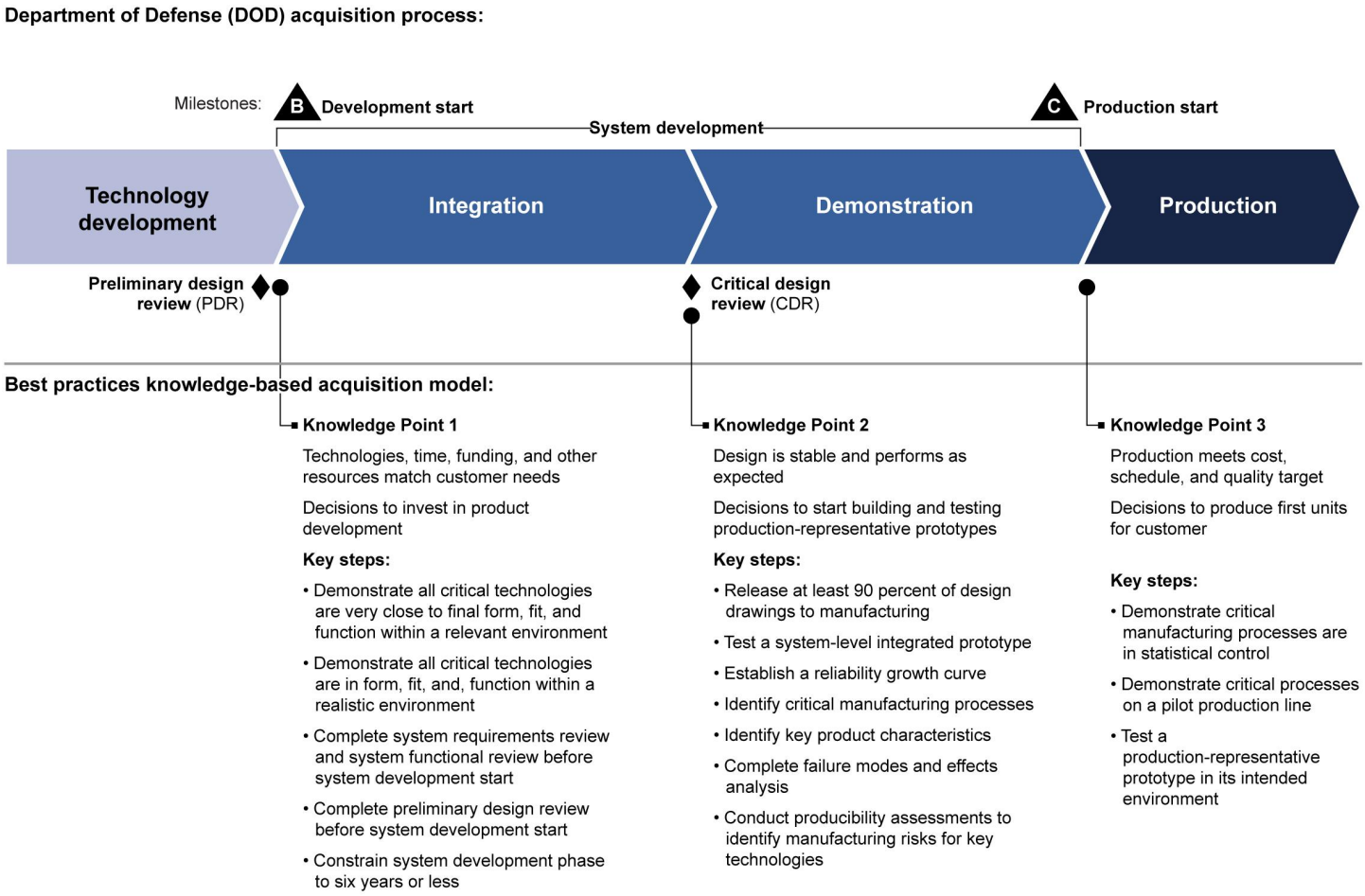
DOD acquires new weapons for its warfighters through a management process known as the Defense Acquisition System.[5] This system generally requires defense acquisition programs to proceed through three phases that are (1) technology maturation and risk reduction, (2) engineering and manufacturing development, and (3) production and deployment. In this report we refer to these three phases more simply as technology development, system development, and production. Programs typically complete a series of milestone reviews and other key decision points that authorize entry into a new acquisition phase.

Our body of work has shown that attaining high levels of knowledge before significant commitments are made during product development drives positive acquisition outcomes.[6] We have found that in order to reduce risk there are three key points where programs should demonstrate critical levels of knowledge before proceeding to the next acquisition phase: development start, system-level critical design review, and production start. Figure 1 aligns the acquisition milestones described in DOD Instruction 5000.02, which establishes policy for the management of acquisition programs, with these three key decision points.

[5]Department of Defense Directive 5000.01, *The Defense Acquisition System* (Nov. 2007); Department of Defense Instruction 5000.02, *Operation of the Defense Acquisition System* (Jan. 2015) [incorporating change 3 (Aug. 2017)] ("DOD Instruction 5000.02").

[6]GAO, *Best Practices: DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed*, GAO-10-439 (Washington, D.C.: Apr. 22, 2010); *Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding*, GAO-09-322 (Washington, D.C.: May 13, 2009); *Defense Acquisitions: A Knowledge-Based Funding Approach Could Improve Major Weapon System Program Outcomes*, GAO-08-619 (Washington, D.C.: July 2, 2008); *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, GAO-02-701 (Washington, D.C.: July 15, 2002); *Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes*, GAO-01-288 (Washington, D.C.: Mar. 8, 2001); and *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999).

Figure 1: Defense Acquisition Cycle and GAO-Identified Knowledge Points



Source: GAO analysis of DOD-provided data, DOD Instruction 5000.02, and best practices. | GAO-18-360SP

Knowledge associated with these three points builds over time. Our prior work on knowledge-based approaches shows that a knowledge deficit early in a program can cascade through design and production, leaving decision makers with less knowledge to support decisions about when and how to move into subsequent acquisition phases that require more budgetary resources. Under a knowledge-based approach, demonstrating technology maturity is a prerequisite for moving forward into system development, during which time the focus should be on design and integration. Similarly, a stable and mature design is also a prerequisite for moving into production, where the focus should be on efficient manufacturing. Appendix III provides additional details about key practices at each of the knowledge points.

Our work has led to multiple recommendations that DOD has generally or partially agreed with and made progress in implementing. For example, our previous work recommended DOD ensure programs conduct a preliminary design review prior to starting development, and DOD's policy now reflects this. Further, our work has influenced efforts within DOD and Congress to address some of the challenges in the defense acquisition system—primarily, that it takes longer and costs more to develop and produce the systems required to perform DOD's various missions and operations. Notably, the Weapon Systems Acquisition Reform Act of 2009 (WSARA) sought to improve the way DOD acquires major weapon systems and incorporated many of our related recommendations.[7] WSARA revised the certifications that programs were expected to complete before being approved for system development start. Programs are currently required to make certain determinations and certifications that they have met the following requirements, among others, prior to entering system development:[8]

- The program has conducted appropriate trade-offs among cost, schedule, and performance objectives;
- The program has demonstrated a high likelihood of accomplishing its intended mission based on a preliminary design review and formal post-preliminary design review assessment; and
- The Under Secretary of Defense for Research and Engineering has independently verified that critical technologies are mature and demonstrated in a relevant environment.[9]

[7]Pub. L. No. 111-23.

[8]This requirement is codified as amended at 10 U.S.C. § 2366b. Since WSARA was implemented in late 2009, Congress has revised or repealed some of its original requirements. For example, the National Defense Authorization Act for Fiscal Year 2016 repealed the requirement for programs to conduct competitive prototyping prior to starting system development. Pub. L. No. 114-92, § 822(b). Now, program acquisition strategies generally are to include the use of competitive prototypes before the start of system development to the maximum extent practicable and consistent with the economical use of available financial resources. 10 U.S.C. § 2431b(c).

[9]Demonstration in a relevant environment is Technology Readiness Level (TRL) 6. Demonstration in an operational environment is TRL 7 and this is the level of maturity GAO's knowledge-based acquisition practices work has determined constitutes a low risk for starting a product development program. See appendix VI for detailed descriptions of TRLs. In addition, a major defense acquisition program generally may not receive approval for development start until the milestone decision authority certifies that the technology in the program has been demonstrated in a relevant environment. 10 U.S.C. § 2366b(a)(2). Under certain circumstances this requirement may be waived. *Id.* § 2366b(d).

In 2010, DOD started its own acquisition reform initiatives, as outlined in its "Better Buying Power" memorandums.[10] These reforms included the requirement that programs conduct affordability and "should-cost" analyses to encourage program managers to find cost savings.[11]

Our work has shown that DOD, through its Instruction 5000.02, has incorporated WSARA and other initiatives to address sound management practices, such as realistic cost estimates, use of prototypes, and systems engineering.

Ten Observations on the Cost and Schedule Performance of DOD's 2017 Major Defense Acquisition Program Portfolio

Our analysis of DOD's 2017 MDAP portfolio shows that programs initiated since 2010 performed better than the remainder of the portfolio and realized a cost decrease of $5.6 billion between 2016 and 2017. However, these savings were not big enough to avert an overall cost increase of $54.7 billion across the entire portfolio last year, the majority of which was due to quantity increases. It is too early to say whether these savings could curb that level of growth in future years. We will likely gain visibility into that prospect as more programs that began after 2010 enter production.

[10]DOD's Better Buying Power memorandums are an initiative to strengthen DOD's purchasing practices, improve industry productivity, and provide an affordable military capability to the warfighter. According to DOD, it encompasses a set of fundamental acquisition principles to achieve greater efficiencies through affordability, cost control, elimination of unproductive processes and bureaucracy, and promotion of competition.

[11]Affordability analyses promote responsible and sustainable investment decisions by examining the implications of today's capability requirements choices and investment decisions based on reasonable projections of future needs before substantial resources are committed. "Should-cost" analyses inform the management of all costs throughout the acquisition life cycle, as well as negotiations with industry over contract costs and incentives. "Should-cost" analyses are also focused on eliminating non-value-added overhead and unnecessary reporting requirements.

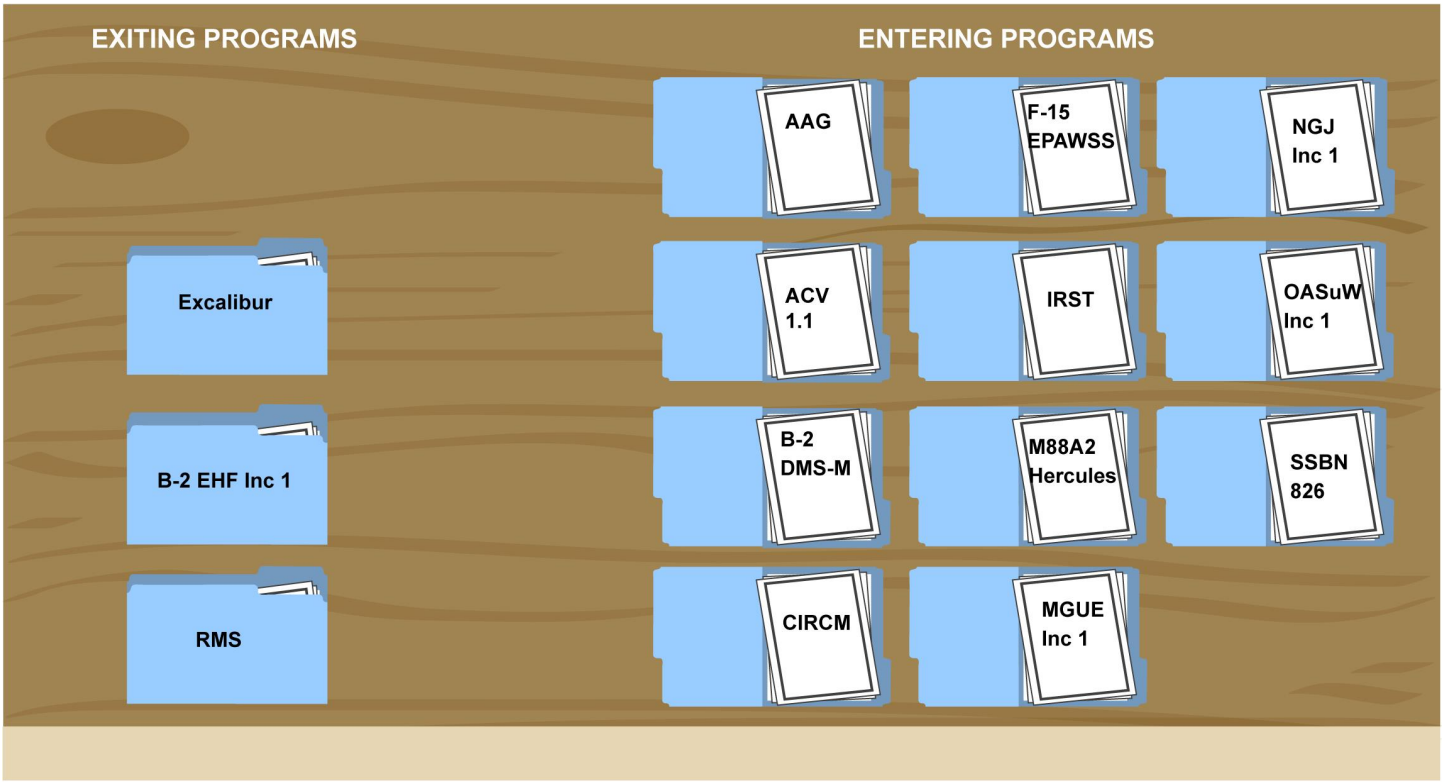
DOD's 2017 Portfolio Has Grown in Number of Programs and Cost

1. **The 2017 portfolio consists of 86 programs, which will cost over $1.66 trillion to acquire.**[12]

   Three programs exited the portfolio in 2017, after they completed their planned procurements or were cancelled, and 11 new programs were added, which resulted in the largest number of programs within the portfolio since 2011. Figure 2 shows the programs exiting and entering between 2016 and 2017.

[12]All dollar figures are in fiscal year 2018 constant dollars, unless otherwise noted.

Figure 2: DOD's Major Defense Acquisition Program Portfolio's Gains and Losses between 2016 and 2017



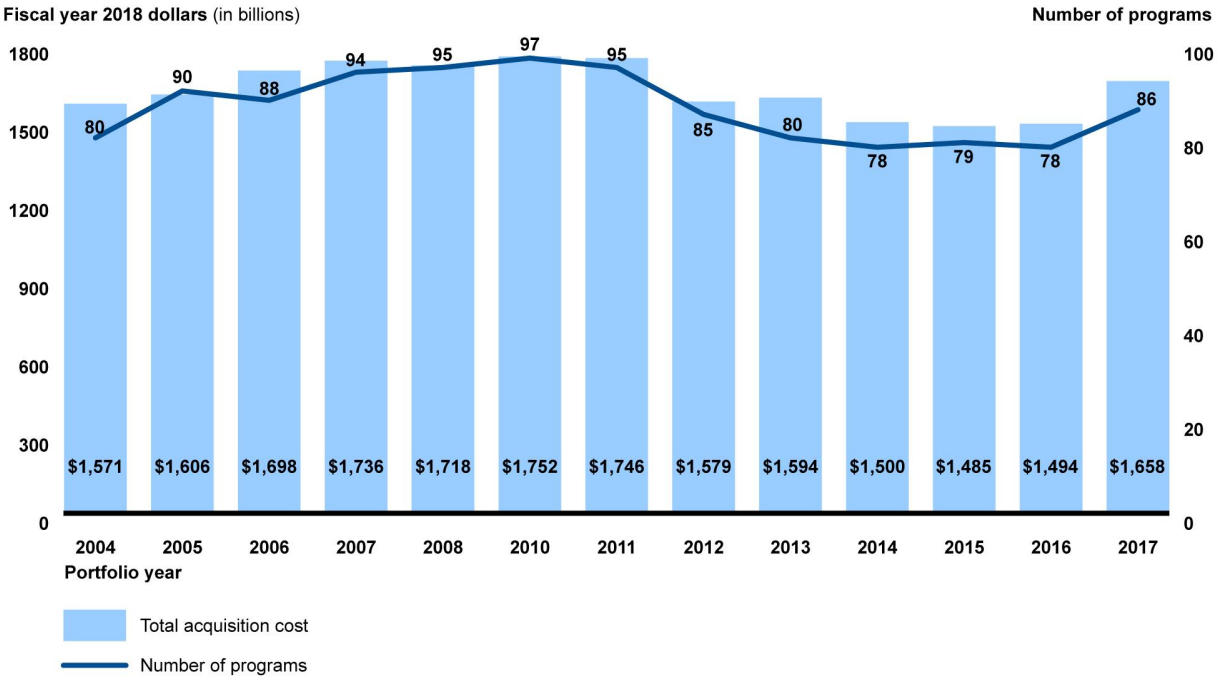
AAG	Advanced Arresting Gear
ACV 1.1	Amphibious Combat Vehicle Phase 1 Increment 1
B-2 DMS-M	B-2 Defensive Management System-Modernization
B-2 EHF Inc 1	B-2 Extremely High Frequency SATCOM and Computer Increment 1
CIRCM	Common Infrared Countermeasure
Excalibur	Excalibur Precision 155mm Projectiles
F-15 EPAWSS	F-15 Eagle Passive Active Warning Survivability System
IRST	Infrared Search and Track
M88A2 Hercules	M88A2 Heavy Equipment Recovery Combat Utility Lift Evacuation System
MGUE Inc 1	Military Global Positioning System User Equipment Increment 1
NGJ Inc 1	Next Generation Jammer Increment 1
RMS	Remote Minehunting System
OASuW Inc 1	Offensive Anti-Surface Warfare Increment 1
SSBN 826	Columbia Class Submarine

Source: GAO analysis of Department of Defense data. | GAO-18-360SP

- DOD's net gain of eight programs was a contributing factor in the 2017 portfolio's total cost change of $164 billion and marks the second year of increases after 4 years of decreasing annual costs with one small increase between 2010 and 2017.

Figure 3 shows the number of programs and total cost of this year's portfolio compared to previous years.

Figure 3: DOD's Portfolio Cost and Size Have Increased Since 2016, but Remain within Historic Ranges



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Note: DOD did not issue Selected Acquisition Reports (SAR) in 2009, which precludes us from having the cost baseline information necessary to include 2009 in this analysis.

- For other analyses, detailed below, we added the first full estimates for the 11 programs that entered the 2017 portfolio to the 2016 portfolio. We also subtracted the funding associated with the three programs that exited the portfolio from 2016 to 2017. We took these steps in order to make the two portfolios comparable before measuring cost and schedule differences.
- Under this approach, over the past year, DOD's cost estimates for these programs have increased by $54.7 billion, or 3.4 percent, of which approximately $47.7 billion is attributed to quantity increases.
- This leaves $7 billion in cost increases that were likely caused by an increase in the time and effort required to complete development and procurement of several programs.

- In comparison to last year, the 2017 portfolio's development costs increased by $8.8 billion and procurement costs increased $45.4 billion.[13]

Three programs—the Navy's MQ-4C Triton Unmanned Aircraft System and P-8A Poseidon Multi-Mission Maritime Aircraft and the Air Force's Next Generation Operational Control System—account for $3.5 billion, or nearly 40 percent, of the aggregate development cost increase. One program, the Navy's SSN 774 Virginia Class Submarine, accounts for $38 billion, or nearly 84 percent, of the aggregate procurement cost growth due to an increase in procurement quantity.

Source: GAO analysis of Department of Defense (DOD) data. | GAO-18-360SP

- In addition, the 2017 portfolio's average time to deliver capability increased by just over a month in the past year—an improvement over the delays incurred in the previous two portfolios we reviewed.

Table 1 details changes in funding and average cycle times to deliver initial capabilities for the current portfolio.

Table 1: DOD Estimates that its 2017 Portfolio Will Cost More and Take Longer to Deliver as Compared to the 2016 Portfolio (Fiscal year 2018 dollars in billions)

	2016 portfolio estimates[a]	2017 portfolio estimates	Net change between 2016 and 2017	Percentage change between 2016 and 2017
Total estimated research and development cost	305.2	313.9	8.8	2.9
Total estimated procurement cost	1,284.6	1,330.0	45.4	3.5
Total estimated acquisition cost[b]	1,603.1	1,657.8	54.7	3.4
Average cycle time (in months) to deliver initial capabilities	121.7	123.0	1.3	1.1

Source: GAO analysis of Department of Defense (DOD) data. | GAO-18-360SP

[a]For the 2016 portfolio, we included $132.3 billion in first full estimates for the 11 programs that entered the 2017 portfolio and subtracted $23.2 billion for the three programs that exited the portfolio between 2016 and 2017. These adjustments made the portfolios comparable for measurement of cost and schedule differences.

[b]In addition to research and development and procurement costs, total acquisition cost includes acquisition-related operation and maintenance and system-specific military construction costs.

Appendix IV outlines the cost performance of individual programs over the past year, 5 years, and since first full estimate. Appendix V provides portfolio-level information on cost and schedule changes over the past 5 years and since programs' first full estimates.

[13]In addition, the 2017 portfolio includes a total of $500 million in military construction and acquisition operations and maintenance costs.

- Forty-three programs, or half the 2017 portfolio, incurred cost growth that totaled $74.8 billion ($47.7 billion of which was due to quantity increases), while the other 43 programs experienced cost decreases that totaled $20.1 billion.
- Most programs' cost changes were between 0 and 5 percent, whether they were decreases or increases.

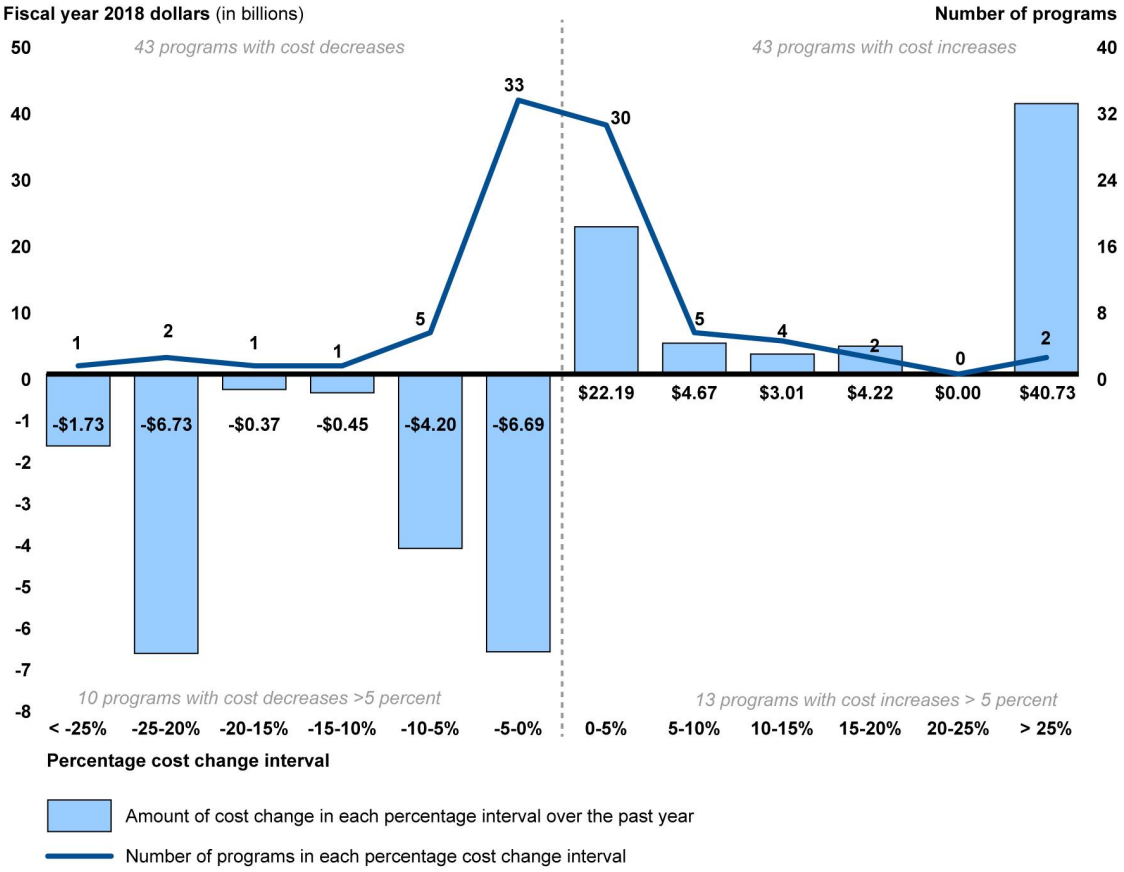
We identified three programs with cost changes greater than 25 percent, two of which were mainly driven by quantity changes:

- the Navy's SSN 774 Virginia Class Submarine, which incurred 40.6 percent cost growth attributable to a quantity increase;
- the Air Force's Next Generation Operational Control System, which experienced 25.4 percent cost growth without a quantity increase; and
- the Air Force's F-15 Eagle Passive Active Warning Survivability System, which reduced its planned cost by 39.3 percent following a quantity decrease.

Source: GAO analysis of Department of Defense (DOD) data. | GAO-18-360SP

Figure 4 displays the portfolio's total acquisition cost change from 2016 to 2017 for each program distributed among percentage change intervals irrespective of changes to quantity.

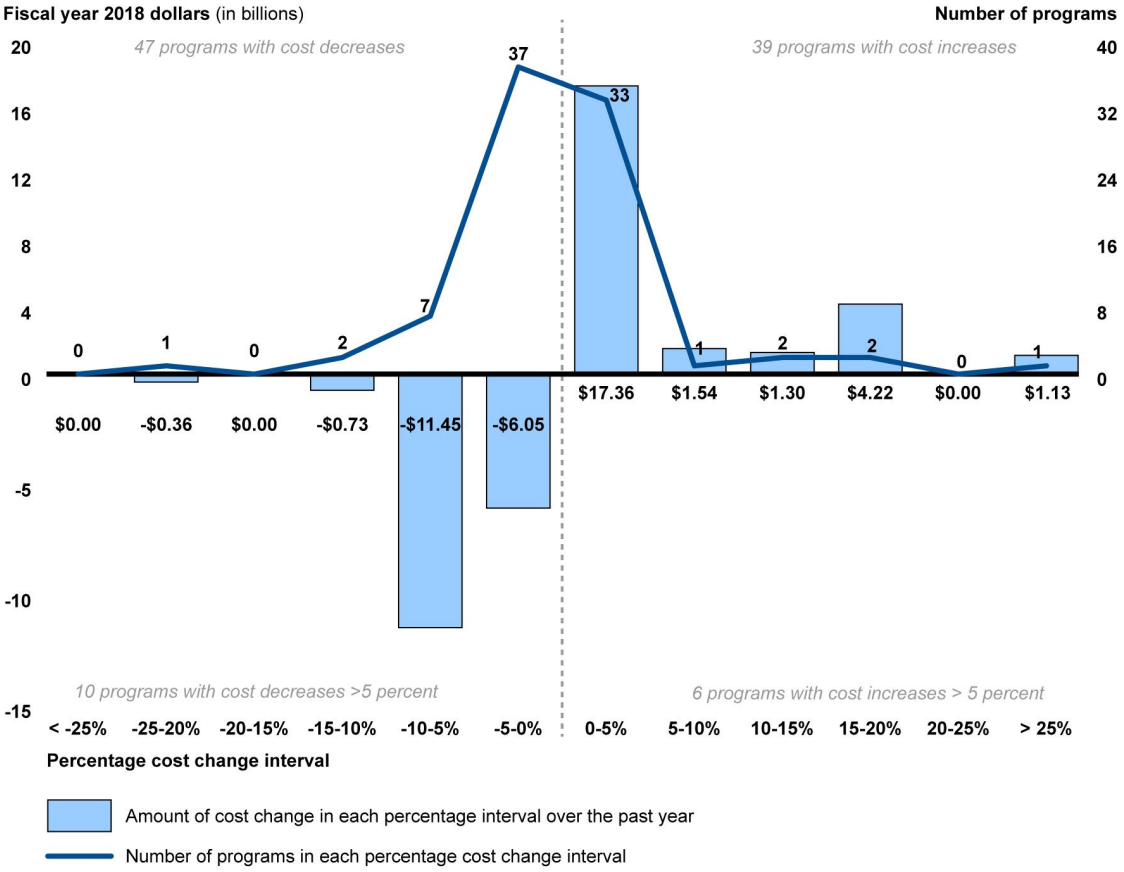
Figure 4: Between 2016 and 2017, 23 DOD Programs Experienced Total Acquisition Cost Increases or Decreases of Greater than 5 Percent



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Figure 5 shows the portfolio's total acquisition cost change not due to quantity changes from 2016 to 2017 for each program distributed among percentage change intervals.

Figure 5: When Controlling for Quantity Changes, 16 DOD Programs Experienced Total Acquisition Cost Increases or Decreases of Greater than 5 Percent between 2016 and 2017



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Programs in DOD's 2017 Portfolio Gained More Buying Power

2. Since last year's assessment, programs in DOD's 2017 portfolio realized a combined $2.3 billion gain in buying power—meaning DOD is able to buy more goods or services for the same level of funding. Nonetheless, this gain was significantly less than the $10.7 billion increase in buying power achieved by the 2016 portfolio.

Buying power is the amount of goods or services that can be purchased given a specified level of funding. To determine changes in

buying power, the effects of quantity changes must be isolated from other factors that affect cost.

- A program's cost can increase because of additional quantities. While that does represent a cost increase, it does not necessarily indicate acquisition problems or a loss of buying power. Alternatively, a program's cost can decrease due to a reduction in quantity and may still experience a buying power gain or loss.

Table 2 details the buying power changes reflected in the 2017 portfolio. Negative numbers indicate decreased costs and a gain in buying power. Positive numbers indicate the opposite.

Table 2: Programs that Comprise DOD's 2017 Portfolio Gained $2.3 Billion in Buying Power since 2016 (IFiscal year 2018 dollars in millions)

	Number of programs	Actual procurement cost change since 2016	GAO calculated cost change attributable to quantity changes	GAO calculated cost change not attributable to quantity changes
Increased buying power	**51**	**25,243.10**	**45,497.35**	**-20,254.25**
Procurement cost decreased with no quantity change	31	-6,295.70	0.00	-6,295.70
Quantity increased with less cost increase than anticipated	14	39,933.88	52,531.44	-12,597.56
Quantity decreased with more cost decrease than anticipated	6	-8,395.08	-7,034.09	-1,360.99
Decreased buying power	**29**	**20,182.98**	**2,191.24**	**17,991.74**
Procurement cost increased with no quantity change	21	5,716.15	0.00	5,716.15
Quantity increased with more cost increase than anticipated	5	14,428.03	3,386.03	11,042.00
Quantity decreased with less cost decrease than anticipated	3	38.80	-1,194.79	1,233.59
No change in buying power	**6**	**0.00**	**0.00**	**0.00**
Portfolio totals	**86**	**45,426.08**	**47,688.59**	**-2,262.51**

Source: GAO analysis of Department of Defense (DOD) data. | GAO-18-360SP

Note: We calculated buying power by comparing the actual procurement cost changes against our calculated cost changes attributable to quantity increases or decreases. To do this, we multiplied the quantity change by the program's acquisition procurement unit cost.

Future Funding Requirements Have Increased

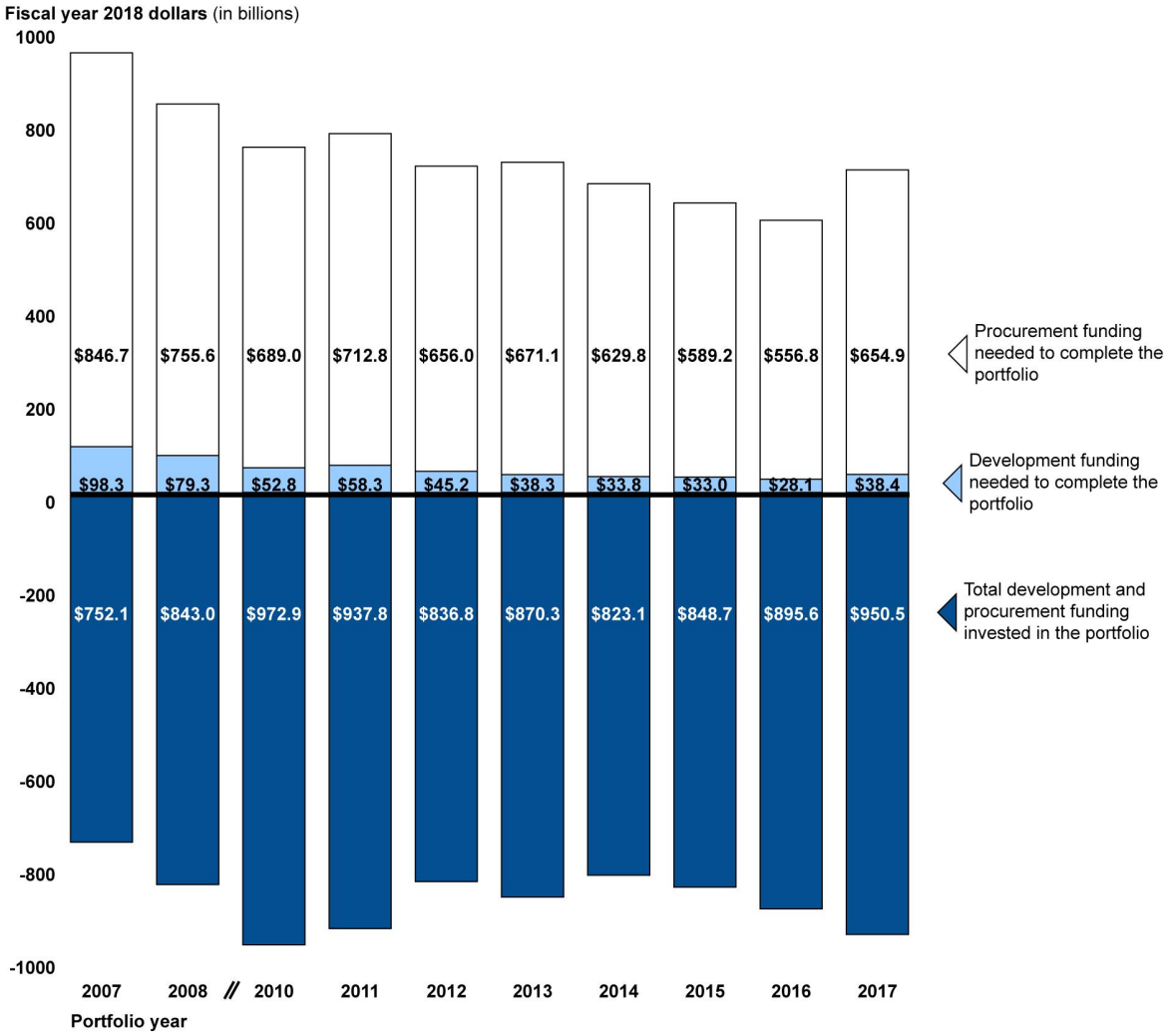
3. The amount of future funding needed to complete the 2017 portfolio's planned development and procurement activities totals $693.3 billion—almost $108 billion more than last year's portfolio.

While this year's increase in future funding requirements can be explained, in part, by the 11 programs added to the portfolio, it also signifies a reversal of the trend we have reported for the past 3 years of decreases in future funding required for both development and procurement.

- Future funding details the amount of investment required beyond the current fiscal year for all programs to complete their development and procure all planned quantities.
- Of the 2017 portfolio's future funding requirements, $38.4 billion is slated for development and $654.9 billion for procurement.
- The $38.4 billion required for future development is an increase of $10.3 billion over last year's assessment and, beyond just an increase in new programs, could be an indicator that current programs have added additional requirements that carry greater risk, are taking more complex acquisition approaches, or are relying on less mature technologies. Nevertheless, the 2017 portfolio's future funding need, for both development and procurement, is $251.7 billion less than the amount that the 2007 portfolio was estimated to have required a decade ago.
- Notably, the 2007 portfolio had fewer sunk costs than it had future funding needs. That ratio has reversed for the current portfolio. Sunk costs in the 2017 portfolio are around the same amount now as they were in 2011, shortly after acquisition reforms were implemented.
- Further, the amount of future development funding needed in the current portfolio is 60 percent less than the amount the 2007 portfolio required ($38.4 billion compared to $98.3 billion). This decrease indicates that, on average, programs in the current portfolio might be further along in the acquisition process than programs in the 2007 portfolio were at the same juncture.

Figure 6 further compares the cost differences between the current and previous years' portfolios each year from 2007 to 2017.

Figure 6: DOD's 2017 Portfolio Shows Changes in Funding Requirements and Sunk Costs that Indicate Programs Are Further Along in the Acquisition Process



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Note: DOD did not issue SARs in 2009, which precludes us from having the cost baseline information necessary to include 2009 in this analysis.

4. Fewer DOD programs meet 1-year and 5-year cost growth metrics, but over half of the current programs show less than 15 percent cost growth since initial estimates.

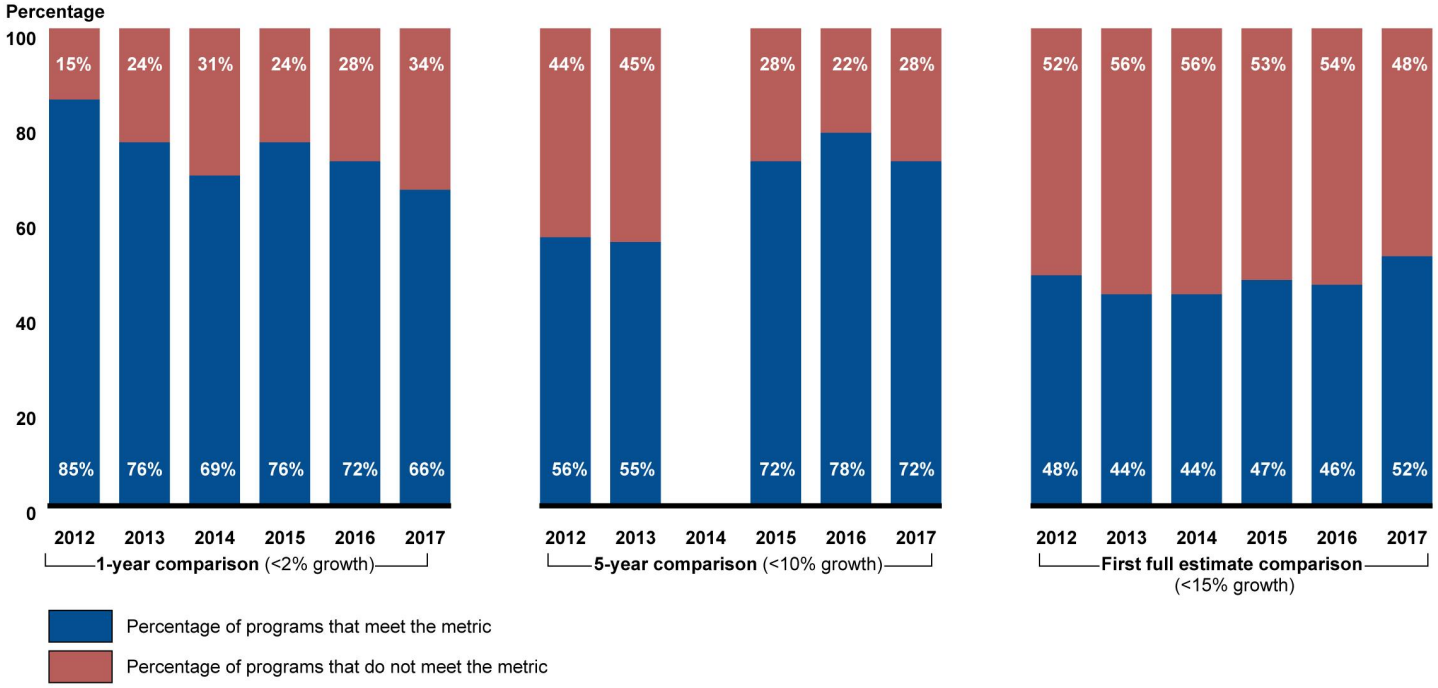
In December 2008, GAO, DOD, and the Office of Management and Budget agreed on a set of metrics, which we have been reporting on since 2011, to measure DOD program cost growth over time.

Although DOD no longer supports the use of these metrics, we continue to believe the current metrics have value.

- The metrics measure cost performance over three defined periods: the preceding year, the preceding 5 years, and since first full estimates were established. If programs exceed these metrics, they are experiencing higher than normal cost growth and if a high percentage of programs exceed these metrics, it is an indication of excessive portfolio cost growth. For DOD's 2017 portfolio, we observed:
  - Less than 2 percent cost growth over the past year: 66 percent of programs met this metric, down from 72 percent in last year's portfolio. This continues a general trend downward since 2012.
  - Less than 10 percent cost growth over the past 5 years: 72 percent of programs met this metric, down from 78 percent in last year's portfolio. This represents a significant improvement over 2012.
  - Less than 15 percent cost growth since first full estimate: 52 percent of programs met this metric, which is an improvement over all previous portfolios dating back to 2012.
- These results indicate that short-term cost growth is increasing in some programs, while longer-term cost growth is slowing.

Figure 7 illustrates the 2017 portfolio's performance against the three aforementioned metrics and how that performance compares to other portfolios since 2012.

Figure 7: DOD's 2017 Portfolio Reflects a Decline in Performance against 1- and 5-Year Cost Growth Metrics, but Demonstrates Improvement in Meeting the Metric for Cost Growth since First Full Estimate



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Note: DOD did not issue Selected Acquisition Reports in 2009, which precluded us from having the cost baseline information necessary to assess the 5-year performance of the 2014 portfolio.

Appendix IV provides additional detail on historic cost performance in individual programs, which informed this analysis.

5. The 2017 portfolio has experienced about $537 billion in cost growth from original estimates. However, $464 billion of this growth occurred 5 or more years ago. The 2017 portfolio realized 51 percent of its cost growth, or $272 billion, after programs started production.

Approximately 86 percent of the total acquisition cost growth reflected in DOD's 2017 portfolio occurred prior to 2012.

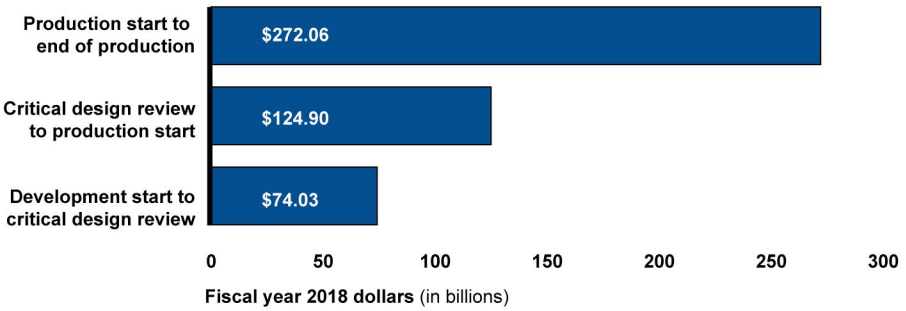
- We observed that costs for the 2017 portfolio have grown throughout the program acquisition cycle, and a majority of this cost growth occurred after programs began production.
- Our prior work has shown that cost increases incurred during production may indicate programs entered production prior to attaining key knowledge related to technology maturity, design

stability, or production readiness. In other cases, production cost growth can be attributed to decisions to increase quantities or improve capabilities, often years after DOD has developed and approved a first full estimate for the program.

- Our analysis found that 62 of 86 programs in DOD's 2017 portfolio are in production.

Figure 8 shows the 2017 portfolio's cost growth throughout the various acquisition phases.

Figure 8: Programs in DOD's 2017 Portfolio Incurred Most of Their Cost Growth after Production Start



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Notes: To accommodate shipbuilding programs in this analysis, we correlated detail design contract awards, fabrication starts, and lead ship deliveries with development start, critical design review, and production start, respectively. Approximately $66 billion in cost growth occurred in programs either prior to starting system development or prior to the program being designated as a major defense acquisition program, or was included in older Selected Acquisition Reports we do not have, all of which prevented us from allocating that total in our analysis.

Programs Initiated since 2010 Currently Demonstrate Better Cost Performance than Older Programs

6. **DOD has initiated 25 programs since 2010, when the government implemented significant acquisition reforms. These 25 programs represent 29 percent of the 86 programs in the current portfolio, but only account for about 15 percent of the portfolio's total acquisition cost.**

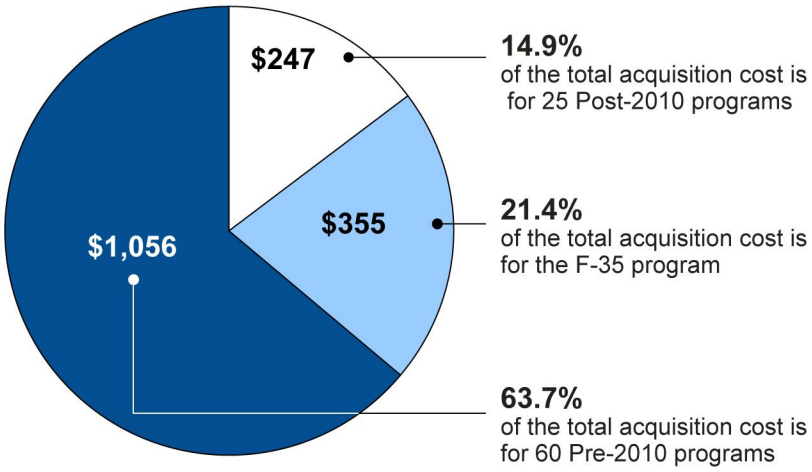
   The current portfolio can be divided into two sub-portfolios—25 programs that DOD initiated since 2010 and 61 programs initiated prior to 2010. The 25 programs initiated since 2010 have followed updated procedures that incorporated WSARA reforms and "Better Buying Power" initiatives.

- The lower total acquisition cost in the post-2010 sub-portfolio may be due, in part, to the acquisition strategies that these programs have adopted. For instance, acquisition strategies that employ lower-risk, less complex approaches to system development—such as new increments of existing capabilities or affordability-based capability trades—can produce better cost outcomes.

Figure 9 illustrates how the current portfolio's total acquisition cost is apportioned between programs that began before and since 2010 and as compared to DOD's largest acquisition program, the $355 billion F-35 Lightning II Joint Strike Fighter, which entered development in 2001.

Figure 9: Over 85 Percent of the 2017 Portfolio's Estimated Total Acquisition Cost Is for 61 Programs That DOD Initiated Prior to 2010

Fiscal year 2018 dollars (in billions)



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

7. Our analysis of the 2017 portfolio showed differences in cost performance between programs that began before and since 2010. We found that the acquisition reforms that DOD began to implement that year were a driving factor behind the cost changes.

Between December 2015 and December 2016:

- the sub-portfolio of programs initiated since 2010, overall, decreased their estimated total acquisition costs by $5.6 billion.
- the sub-portfolio of programs initiated before 2010 incurred an estimated aggregate total acquisition cost increase of $60.3 billion.

- At the same time, the average time to deliver capability increased by just under 1 month for the sub-portfolio of programs initiated before 2010, but increased by 2.6 months for the sub-portfolio of programs initiated since 2010. This difference could be attributed to older programs being much further along in production and having schedules less prone to change.

Table 3 details the changes in estimated funding needs and average cycle time to deliver initial capabilities for the sub-portfolio of programs initiated since 2010.

Table 3: DOD Estimates That Its 2017 Sub-portfolio of Programs Initiated since 2010 Will Cost Less, but Take Longer to Deliver, as Compared to 2016 (Fiscal year 2018 dollars in billions)

	2016 sub-portfolio estimates[a]	2017 sub-portfolio estimates	Net change between 2016 and 2017	Percentage change between 2016 and 2017
Total estimated research and development cost	53.2	54.1	0.9	1.7
Total estimated procurement cost	195.8	189.4	-6.3	-3.2
Total estimated acquisition cost[b]	252.4	246.8	-5.6	-2.2
Average cycle time (in months) to deliver initial capabilities	92.4	95	2.6	2.8

Source: GAO analysis of Department of Defense (DOD) data. | GAO-18-360SP

[a]For the 2016 sub-portfolio, we included $126.9 billion in first full estimates for the 9 programs initiated since 2010 that entered the 2017 sub-portfolio. This adjustment made the sub-portfolios comparable for measurement of cost and schedule differences.

[b]In addition to research and development and procurement costs, total acquisition cost includes costs for acquisition-related operations and maintenance and system-specific military construction.

Table 4 details the changes in estimated funding needs and average cycle time to deliver initial capabilities for the sub-portfolio of programs initiated before 2010.

Table 4: DOD Estimates That Its 2017 Sub-portfolio of Programs Initiated before 2010 Will Cost More and Take Slightly Longer to Deliver, as Compared to 2016 (Fiscal year 2018 dollars in billions)

	2016 sub-portfolio estimates[a]	2017 sub-portfolio estimates	Net change between 2016 and 2017	Percentage change between 2016 and 2017
Total estimated research and development cost	252.0	259.8	7.9	3.1
Total estimated procurement cost	1,088.8	1,140.6	51.8	4.8
Total estimated acquisition cost[b]	1,350.7	1,411.0	60.3	4.5
Average cycle time (in months) to deliver initial capabilities	133.9	134.8	0.9	0.7

Source: GAO analysis of Department of Defense (DOD) data. | GAO-18-360SP

[a]For the 2016 sub-portfolio, we included $5.4 billion in first full estimates for the 2 programs initiated before 2010 that entered the 2017 sub-portfolio and subtracted $23.2 billion for the three programs

that exited the sub-portfolio between 2016 to 2017. These adjustments made the sub-portfolios comparable for measurement of cost and schedule differences

[b]In addition to research and development and procurement costs, total acquisition cost includes costs for acquisition-related operations and maintenance and system-specific military construction.

In fiscal year 2017, we compared the cost growth of weapon systems development programs for a 5-year period after WSARA's implementation to the 10-year period prior to the act—estimating about a 75 percent, or $36.0 billion, reduction in the rate of development cost growth. While it is not certain that the act's implementation was the sole reason for this reduction in cost growth, we found that it was the driving factor.[14]

8. Between 2016 and 2017, a similar percentage of DOD programs initiated before and since 2010 experienced cost changes of 5 percent or less. However, these 1-year cost changes are, on average, smaller in the programs initiated since 2010.

A few programs in each of the two sub-portfolios (prior to 2010 and since 2010) drive a majority of the overall cost changes within the 2017 portfolio.

These programs include:

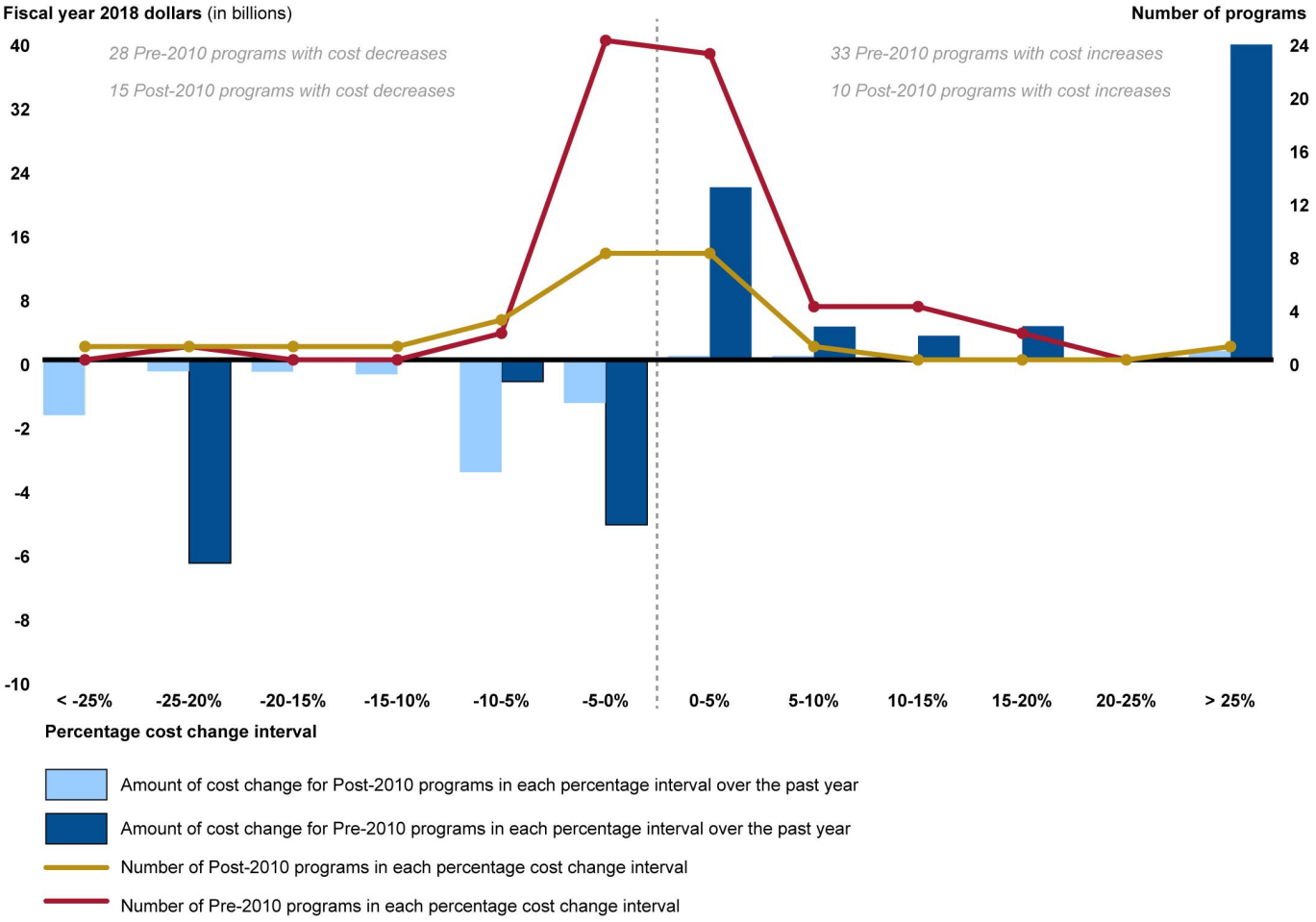
- Programs since 2010: the Air Force's Next Generation Operational Control System, F-15 Eagle Passive Active Warning Survivability System, and KC-46A Tanker Modernization Program.
- Pre-2010 programs: the Navy's Littoral Combat Ship and SSN 774 Virginia Class Submarine and the DOD-wide F-35 Lightning II Joint Strike Fighter program.

Source: GAO analysis of Department of Defense (DOD) data. | GAO-18-360SP

Figure 10 details the distribution of total acquisition cost changes in each percentage interval over the past year within the two sub-portfolios.

[14]GAO, *Performance and Accountability Report: Fiscal Year 2017*, GAO-18-2SP (Washington, D.C.: Nov. 15, 2017).

Figure 10: Programs Initiated since 2010 Show Fewer Significant Year-to-Year Cost Changes as Compared to the Programs Initiated Prior to 2010

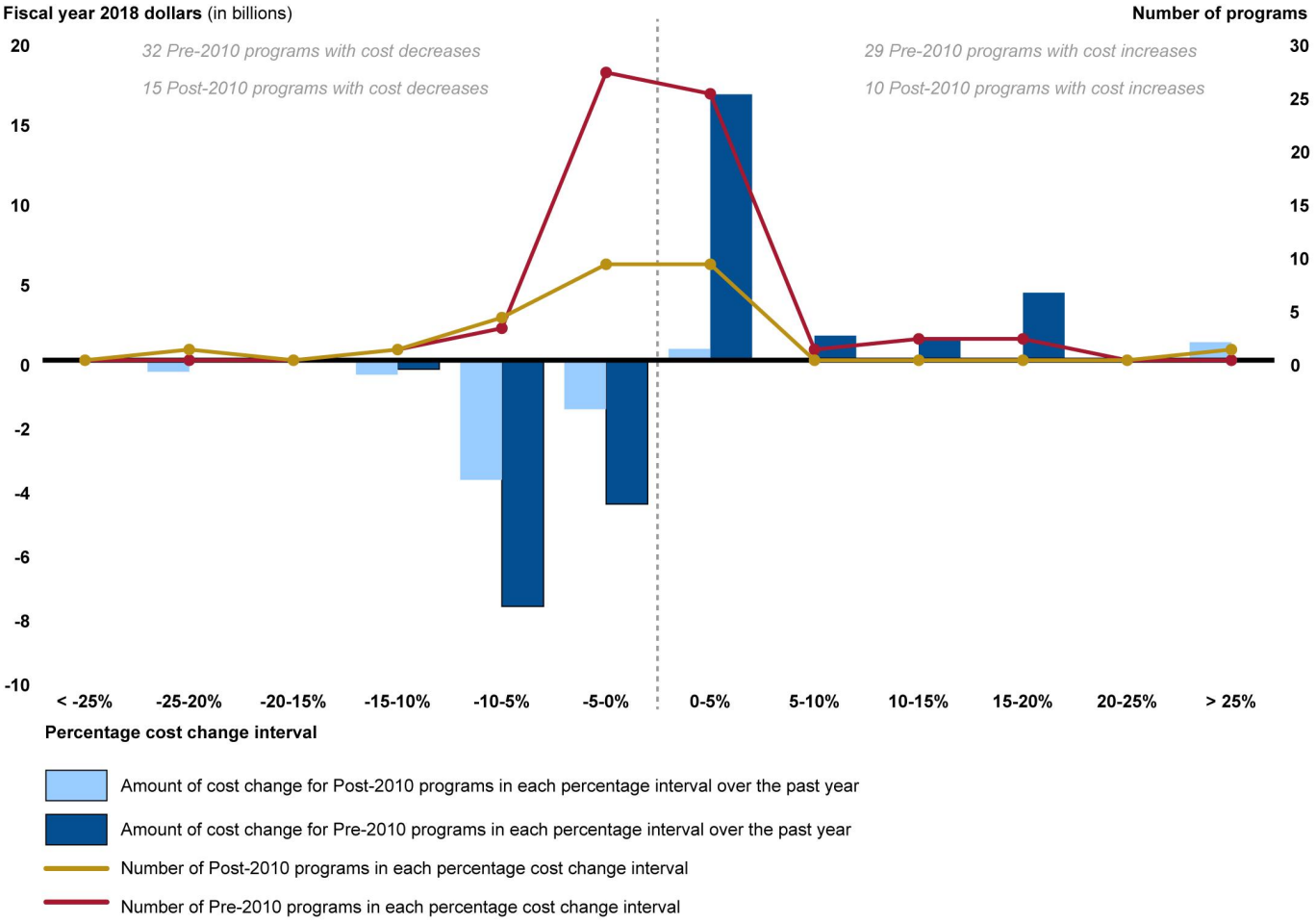


Source: GAO analysis of Department of Defense data. | GAO-18-360SP

- When controlling for quantity changes, the programs initiated since 2010 experienced a cost decrease of $4.2 billion while the older programs incurred an $11.2 billion cost increase. This again indicates that, over a shorter period of time, the programs initiated since 2010 have managed cost growth more effectively than the older programs.

Figure 11 also details the distribution of the total acquisition cost changes over the past year within the two sub-portfolios, but controls for quantity changes.

Figure 11: When Controlling for Quantity Changes, the Programs Initiated since 2010 Incurred an Overall Cost Decrease while Programs Initiated Prior to 2010 Experienced an Overall Cost Increase



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Programs Initiated since 2010 Gained Buying Power and Experienced Overall Cost Decreases

9. Programs initiated since 2010 gained buying power, while earlier programs incurred an overall loss in buying power.

The 2017 portfolio's overall buying power gain of $2.3 billion was driven by the sub-portfolio of 25 programs initiated since 2010, which together realized a buying power increase of almost $5 billion. On the other hand, the sub-portfolio of 61 programs initiated prior to 2010 produced a buying power decrease of $2.7 billion.

- The disparity in buying power performance between the two sub-portfolios could indicate that acquisition reforms may be yielding dividends in the form of cost efficiencies in newer programs.

Table 5 details the buying power changes reflected in the aforementioned sub-portfolios. Negative numbers indicate decreased costs and a gain in buying power. Positive numbers indicate the opposite.

Table 5: DOD Programs Initiated since 2010 Gained Nearly $5.0 Billion in Buying Power, Which Was Offset by $2.7 Billion in Buying Power Decreases among Programs Initiated before 2010 (IFiscal year 2018 dollars in millions)

Programs initiated since 2010	Number of programs	Actual procurement cost change since 2016	GAO calculated cost change attributable to quantity changes	GAO calculated cost change not attributable to quantity changes
Increased buying power	15	-6,808.08	-1,454.67	-5,353.41
Decreased buying power	8	464.93	$70.58	394.36
No change in buying power	2	0.00	0.00	0.00
Sub-portfolio totals	**25**	**-6,343.15**	**-1,384.10**	**-4,959.05**
Programs initiated before 2010				
Increased buying power	36	32,051.18	46,952.02	-14,900.84
Decreased buying power	21	19,718.05	2,120.66	17,597.39
No change in buying power	4	0.00	0.00	0.00
Sub-portfolio totals	**61**	**51,769.23**	**49,072.69**	**2,696.54**

Source: GAO analysis of Department of Defense (DOD) data. | GAO-18-360SP

10. Current cost estimates for programs initiated since 2010 have decreased from their original estimates. These programs experienced cost decreases after both critical design review and production start.

DOD's current sub-portfolio of programs initiated since 2010 has achieved cost and schedule outcomes that, when measured cumulatively against the programs' original estimates, have outperformed other DOD programs.

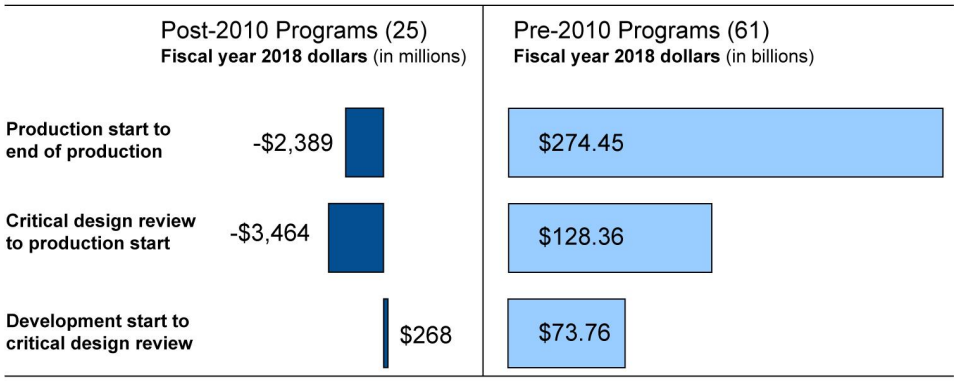
- These 25 programs have achieved a 2.1 percent, or $5.3 billion, cost decrease and, on average, a 9-month delay in delivering capabilities, as compared to their original estimates.
- In comparison, DOD's other 61 programs, which were all initiated before 2010, have experienced cost growth of 62.4 percent, or $542.1 billion, and schedule delays totaling 35 months on average since those programs developed their original estimates.

- Forty percent of the programs initiated since 2010 (10 out of 25) are in production while 85 percent (52 out of 61) initiated before 2010 are in production.
- Cumulative cost growth experienced by the programs initiated before 2010 occurred during all phases of the acquisition process, although most occurred after the start of production.

Conversely, we observed that programs initiated since 2010 have, over a shorter period of time, reduced their planned costs after critical design review and the start of production with a small amount of cost growth ($268 million) before their critical design reviews. It is important to recognize that this cost trend may reverse over time, because many of the post-2010 programs are still early in production or have yet to start production.

Figure 12 provides information on these cost changes specific to the sub-portfolios of programs initiated before 2010 and since 2010.

Figure 12: Programs in DOD's 2017 Portfolio Initiated since 2010 Incurred Their Cost Growth before Critical Design Review, while Programs Initiated Prior to 2010 Incurred Most of Their Cost Growth after Production



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Note: To accommodate shipbuilding programs in this analysis, we correlated detail design contract awards, fabrication starts, and lead ship deliveries with development start, critical design review, and production start, respectively. Approximately $66 billion in cost growth occurred in programs either prior to starting system development or prior to a program being designated as a major defense acquisition program, or was included in older Selected Acquisition Reports we do not have, all of which prevented us from allocating that total in our analysis.

Four Observations on DOD's Implementation of Key Acquisition Reform Initiatives

We observed that weapon acquisition programs that consistently implement acquisition reform initiatives—such as affordability constraints, "should-cost" analyses, and acquisition strategies that promote competition throughout the lifecycle of the program—tend to gain buying power and report less cost growth on average than programs that do not implement these initiatives. This year, our analysis of 57 selected programs shows that programs have implemented measures to promote competition consistently. However, only 61 percent of programs in this year's assessment that awarded contracts for development, test, or production did so competitively. The current programs that reported implementing acquisition strategies that promote competition by awarding contracts competitively also reported less estimated total acquisition cost growth across the program, on average, than others, after accounting for quantity changes. While our analysis is limited to this assessment, the information from these programs shows a possible correlation between a reduction in estimated total acquisition cost growth and a program's use of acquisition strategies that promote competition. We also observed indications this year that the efficacy of affordability constraints and "should-cost" analyses has been reduced, although these initiatives remain largely untested. Therefore, it is premature to conclude whether the changes we observed this year will continue in the long run.

Most Programs Plan to Promote Competition during the Acquisition Process, Which Can Improve Prospects for Eventual Buying Power Gains

1. **Of the 57 current and future programs we assessed, 55 reported they intend to promote competition during the acquisition process, while 2 future programs reported they currently have no plans for competition either before or after development start.**

   Measures to promote competition that program offices reported they use, among others, include the following:

   - use of "modular open architecture", which focuses on design of highly cohesive, loosely coupled, and severable modules for a system that can be competed separately and acquired from independent vendors;

- acquisition of the contractor's "technical data package", which may provide the government the drawings and specifications needed to produce and support the system;
- competitive prototypes;
- dual sources of manufacturing; and
- competition for future upgrades.

- As we have previously found, competition is a critical tool for achieving the best return on the government's investment.[15] DOD shares this view and has reported that competition is a central tenet in acquisition reform and the single best way to motivate contractors to provide the best value.
- The two future programs with no current plans for competition—the Air Force's B-2 Extremely High Frequency Satellite Communications and UH-1N Utility Helicopter Replacement programs—could change their plans to promote competition as they move further along the acquisition process and their acquisition strategies continue to evolve.

The total of 55 programs that plan to promote competition represents an increase from last year's assessment, when only 41 programs signaled such plans. Table 6 outlines the extent to which and when current and future programs plan to promote competition.

Table 6: Plans to Promote Competition among 57 Selected Programs in DOD's 2017 Portfolio

	For the 12 future programs	For the 45 current programs	Total
Number of programs that plan to promote competition	**10**	**45**	**55**
Throughout acquisition life cycle	3	28	**31**
Only prior to start of system development	2	5	**7**
Only after the start of system development	5	12	**17**
Number of programs that do not plan to promote competition	**2**	**0**	**2**

Source: GAO Analysis of Department of Defense (DOD) data | GAO-18-360SP

2. Sixty-one percent of programs that awarded contracts for development, test, or production reported implementing

[15]GAO, Defense Acquisitions: Assessments of Selected Weapon Programs, GAO-17-333SP (Washington, D.C.: Mar. 30, 2017).

acquisition strategies that promote competition that included awarding contracts competitively. Overall, the current programs that awarded contracts competitively incurred less estimated total acquisition cost growth than others after accounting for quantity changes, both since last year and as compared to their initial cost estimates.

DOD Instruction 5000.02 generally requires programs to have an acquisition strategy that addresses how program management will create and sustain a competitive environment, from program inception through sustainment.[16]

- Forty-six of the 57 current and future programs reported awarding contracts for product development, test, initial production, or production using either competitive or non-competitive procedures. The other 11 programs have yet to award any contracts for these types of activities as they predominately have yet to start system development.[17]
- Of these 46 programs, 28 reported awarding contracts for development, test, or production competitively, while 18 programs reported awarding contracts non-competitively.
- After controlling for quantity changes, our analysis showed that the current programs that reported implementing acquisition strategies to promote competition that included awarding competitive contracts decreased their estimated total acquisition costs by an average of $67 million since 2016. Conversely, the current programs that awarded non-competitive contracts increased their estimated total acquisition costs by an average of $50 million since 2016.
- Our analysis showed similar trends when we measured current programs against their original cost estimates. Specifically, after controlling for quantity changes, we observed an average total acquisition cost decrease of $1.01 billion for the current programs that implemented acquisition strategies to promote competition that included awarding competitive contracts. On the other hand, the current programs that reported awarding their contracts non-

[16]Programs reported awarding competitive contracts, which in some cases may have been through full and open competition pursuant to the Federal Acquisition Regulation part 6, or in other cases, may have been a more limited competition, such as a down-select competition between two contractors.

[17]For this observation, we relied on the programs self-reporting, via our questionnaire, whether or not they awarded their contracts competitively. We did not independently confirm this information as part of the analysis.

competitively accounted for an average total acquisition cost increase of $3.56 billion.

- One notable exception to the aforementioned reductions in estimated total acquisition costs was the DOD-wide F-35 Lightning II Joint Strike Fighter program, which awarded a competitive development contract, but realized significant program cost growth during development. We excluded the F-35 program from this analysis.[18]

Programs with Affordability Constraints and "Should-Cost" Analyses Report Progress with Cost Containment, but the Effectiveness of the Constraints Remains Untested

3. Of the 57 current and future programs we assessed, 34 reported that they operate under an affordability constraint while another 23 do not. Of the 34 programs with established affordability constraints, all but one reported that they were on track to stay under their identified cost constraint.

DOD Instruction 5000.02 requires DOD components to develop life-cycle affordability goals early in the acquisition process, as well as affordability caps before starting system development, for major defense acquisition programs. These goals and caps, also referred to as constraints, should be stated in terms of procurement unit cost and sustainment costs.

Affordability constraints are intended to ensure that capability requirements prioritization and cost tradeoffs occur as early as possible and throughout a program's life cycle, as well as to keep unaffordable programs from entering or remaining within the acquisition process. DOD policy instructs that when approved affordability constraints cannot be met, a program's technical requirements, schedule, and required quantities must be revisited by DOD. Under the policy, if the program still cannot meet its constraints, and DOD cannot raise the program's affordability constraints by obtaining approval to lower constraints elsewhere, the program is to be canceled.

[18]The F-35 Lightning II Joint Strike Fighter program's approximately $118.8 billion in cost growth since its original cost estimate has an outsized effect when calculating average cost changes for groups of acquisition programs. Consequently, we excluded the F-35 program from certain analyses in this report, where noted.

- The 23 programs that do not have established affordability constraints include those that:
  - have not started system development,
  - were already in production prior to the affordability constraint requirement,
  - currently operate under legislatively mandated cost caps, or
  - are a nonstandard program or a development-only program with no planned procurement phase.
- Of the 34 programs that report establishing affordability constraints, 33 of them are currently performing within their identified constraints.
  - The only program that did not report performance in line with its affordability constraints was the Air Force's Next Generation Operational Control System.
- The effectiveness of affordability constraints has yet to be widely tested, and use of affordability constraints does not preclude programs from incurring cost growth. In fact, when we excluded the DOD-wide F-35 Lightning II Joint Strike Fighter program, we observed that the other 33 programs with affordability constraints have slightly higher average cost growth from their initial estimates ($1.66 billion) than what programs without established affordability constraints have cumulatively incurred ($1.52 billion).

4. Of the 57 current and future programs we assessed, 42 reported that they conducted "should-cost" analyses. These programs, along with two other programs which do not yet have approved "should-cost" targets, reported anticipated savings of $51 billion, of which $33.2 billion has been realized to date.

In accordance with DOD Instruction 5000.02, every major defense acquisition program should conduct a "should-cost" analysis as a management tool to help control and reduce program costs before the program starts system development.

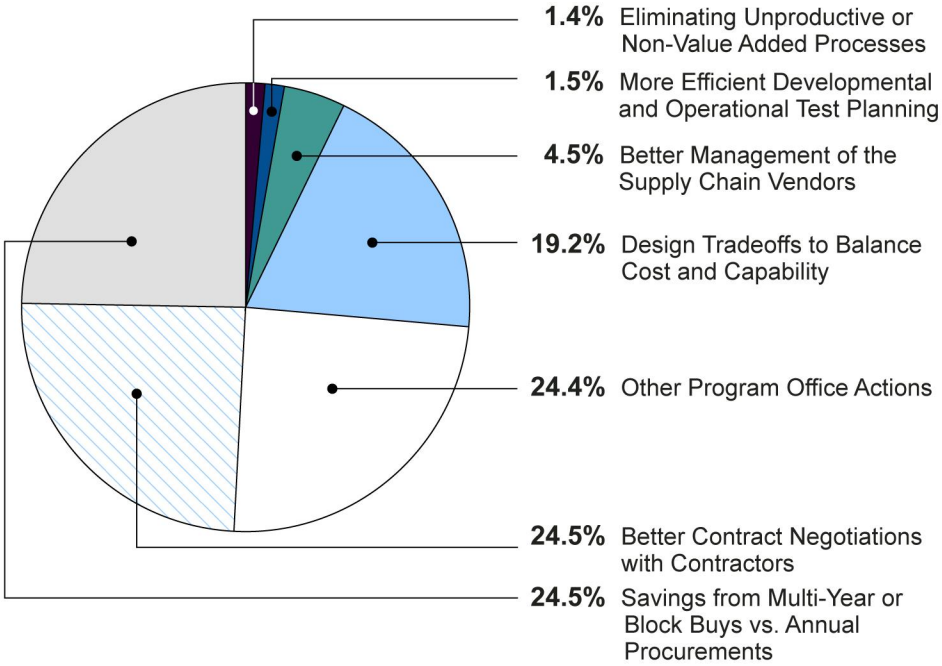
- The aim is to scrutinize every cost under the program's control, reduce negotiated prices for contracts, and obtain other efficiencies in program execution to bring costs below what is budgeted for the program. Any savings achieved can then be reallocated within the program or for other priorities.
- Of the 45 current programs, 40 reported completing "should-cost" analyses. Of the other 5 programs, three reported that they are in the process of establishing "should-cost" targets, one reported it is using "will-cost" targets in their acquisition program baseline instead, and

one programs reported being restructured and had not established new “should-cost” targets yet.

- Of the 12 future programs, only 2 reported completing a “should-cost” analysis. The other 10 programs should complete their analyses before they start system development, which is consistent with DOD policy.
- As compared to our March 2017 assessment, we observed significantly fewer anticipated savings in this year’s assessment—$51 billion versus $111.5 billion.

Programs can take several different actions that lead to “should-cost” savings. Figure 13 shows the predominant actions programs take.

Figure 13: Actions Programs Reported They Have Taken to Achieve “Should-Cost” Savings



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Eight Observations from Our Assessment of Knowledge Attained by Programs at Key

Junctures and Related Implications for Testing and Software Development

Our analysis of 57 selected programs shows that DOD programs continue to not fully implement knowledge-based acquisition practices. We observed several current and future programs have proceeded, or plan to proceed, into system development, through critical design reviews, and into production without meeting key acquisition practices, thereby increasing their risk of undesirable cost, schedule, and performance outcomes. At the same time, based on an exploratory statistical analysis of our previous work dating back to 2003, we observed MDAPs that implemented one or more of three specific knowledge-based acquisition practices had lower cost and schedule growth than those that did not.[19] This analysis provides additional insight as to the importance of following a knowledge-based acquisition approach, yet this pattern remains the exception, not the norm. We observed that programs frequently accept knowledge shortfalls, even if it impairs performance in the near-term, in order to produce or deliver their capability in accordance with their schedules. In addition to the shortfalls at our three knowledge points, we also observed acceptance of knowledge shortfalls in program schedules for (1) developmental testing and production, (2) software development, and (3) initial operational test and evaluation.

Most Programs Did Not Fully Demonstrate Mature Technology and Complete System Engineering Reviews before System Development Start

1. **The one program that began system development during our assessment period met all but one of the five knowledge-based acquisition practices applicable to development start. In addition, most of the 44 programs that previously began system development did not meet all knowledge-based acquisition practices.**

[19]Our exploratory statistical analysis examined eight key knowledge-based acquisition practices, which we have annually assessed individual programs on since 2003, and select programs' cost and schedule changes. We found that three of the eight key practices held a statistically significant relationship to programs' cost and schedule changes. See appendix II for more information.

The knowledge-based acquisition practices require (1) full demonstration of critical technologies, (2) completion of key systems engineering reviews, and (3) constraint of system development to 6 years or less. [20]

- The Navy's T-AO 205 John Lewis Class Fleet Replenishment Oiler program is a shipbuilding program, for which we measure detail design contract award as the point in system development where knowledge-based acquisition practices should be met. We observed that the T-AO 205 program fully matured all its critical technologies before it awarded a detail design contract in 2016. However, the program did not complete a preliminary design review prior to this award—an approach inconsistent with knowledge-based acquisition practices.[21]

Table 7 shows the extent to which DOD has implemented knowledge-based acquisition practices for knowledge point 1, or system development start, for the Navy's T-AO 205 program as well as for the other 44 current programs we assessed, which entered system development prior to 2017.

[20]Demonstration in a relevant environment is Technology Readiness Level (TRL) 6. Demonstration in an operational environment is TRL 7. See appendix VI for detailed descriptions of TRLs. In addition, a major defense acquisition program generally may not receive approval for development start until the milestone decision authority certifies that the technology in the program has been demonstrated in a relevant environment. 10 U.S.C. § 2366b(a)(2). Under certain circumstances, this requirement may be waived. *Id.* § 2366b(d).

[21]A major defense acquisition program generally may not receive approval for development start until the milestone decision authority has received a preliminary design review, conducted a formal assessment of the preliminary design review, and certifies, based on that assessment, that the program has a high likelihood of accomplishing its intended mission. 10 U.S.C. § 2366b(a)(1). Under certain circumstances, this requirement may be waived. *Id.* § 2366b(d).

Table 7: Implementation of Knowledge-Based Practices for Programs in System Development

Knowledge Based Practices at System Development Start	T-AO 205	Other 44 Programs Practice implemented	Other 44 Programs Practice not implemented	Other 44 Programs No Data	N/A	Trend from 2016 to 2017
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment. (TRL 6)	Practice implemented	23	11	4	6	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Demonstrate all critical technologies in form, fit, and function within a realistic environment. (TRL 7)	Practice implemented	2	31	4	7	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Complete system functional review and system requirements review before system development start	Practice implemented	17	14	0	13	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Complete preliminary design review before system development start	Practice not implemented	21	20	0	3	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Constrain system development phase to 6 years or less	N/A	19	14	1	10	Declining Trend (decrease of more than 5 percent of programs as compared to 2016)

Source: GAO analysis of DOD data | GAO-18-360SP

Notes: Three of eight key knowledge-based acquisition practices correspond with system development start. We have identified these three key practices in bold font within the table. To accommodate shipbuilding programs in this analysis, we correlated detail design contract award and lead ship fabrication start with development start and critical design review, respectively. We assessed knowledge-based acquisition practices as not applicable in situations when programs submitted responses to our questionnaire that identified events or circumstances that made completion of the practice impractical. For example, we assessed the two technology demonstration practices as not applicable in instances where a program did not have any critical technologies.

2. Of the 12 future programs scheduled to begin system development in the next few years, only one plans to fully implement all applicable knowledge-based acquisition practices.

The knowledge-based acquisition practices that programs should demonstrate before beginning system development are (1) demonstrate all critical technologies in a realistic environment, (2) complete all systems engineering reviews, and (3) constrain development to less than 6 years before starting system development.

- Only the Army's Long Range Precision Fires program plans to fully implement all applicable knowledge-based acquisition practices prior to starting development.

- Only 1 of the 12 future programs scheduled to enter system development within the next few years, the Air Force's Weather System Follow-on Microwave program, projects that it will demonstrate all its critical technologies in a realistic environment before starting development. None of the other three future programs that have identified critical technologies to date projected that they would do the same.

Table 8 shows the projected implementation of knowledge-based acquisition practices for the 12 programs we assessed that plan to start development in the next few years.

Table 8: Projected Implementation of Knowledge-Based Practices at Development Start for Future Programs

	Development Start	Projected to Demonstrate all critical technologies in a realistic environment	Projected to complete all systems engineering reviews	Plan to constrain system development to 6 years or less
Advanced Pilot Training	Spring/Summer 2018	N/A	Practice not planned to be implemented	Practice planned to be implemented
Amphibious Ship Replacement	TBD	N/A	Data not available	N/A
B-2 Extremely High Frequency Satellite Communications	TBD	N/A	Data not available	Data not available
Ground Based Strategic Deterrent	9/3/2020	Practice not planned to be implemented	Practice planned to be implemented	Data not available
Improved Turbine Engine Program	TBD	Practice not planned to be implemented	Practice planned to be implemented	Data not available
Joint Surveillance Target Attack Radar System Recapitalization	3/31/2018	Practice not planned to be implemented	Practice planned to be implemented	Practice planned to be implemented
Long Range Precision Fires	1/15/2021	N/A	Practice planned to be implemented	Practice planned to be implemented
MQ-25 Unmanned Aircraft System	7/30/2018	N/A	Practice not planned to be implemented	Practice planned to be implemented
Navy Frigate	9/25/2020	N/A	Practice not planned to be implemented	N/A
UH-1N Utility Helicopter Replacement	N/A	N/A	Practice not planned to be implemented	Practice not planned to be implemented
VC-25B Presidential Aircraft Replacement	6/29/2018	N/A	Practice not planned to be implemented	Practice not planned to be implemented
Weather System Follow-on Microwave	3/25/2019	Practice planned to be implemented	Practice not planned to be implemented	Practice not planned to be implemented

Source: GAO analysis of DOD data | GAO-18-360SP

Notes: To accommodate shipbuilding programs in this analysis, we correlated detail design contract award with development start. We assessed knowledge-based acquisition practices as not applicable in situations when programs submitted responses to our questionnaire that identified events or

circumstances that made completion of a practice impractical. For example, we assessed the technology demonstration practice as not applicable in instances where a program did not have any critical technologies.

Most Programs Did Not Fully Demonstrate System Design Stability Prior to Conducting Critical Design Reviews

3. **Of the four programs that held critical design reviews during our assessment period, none met all of the eight associated knowledge-based acquisition practices. In addition, most of the 35 programs that previously held their critical design reviews did not meet all acquisition practices.**

   The eight knowledge-based acquisition practices that our prior work found programs should demonstrate prior to conducting their critical design reviews include (1) demonstration of all critical technologies in a realistic environment, (2) release of at least 90 percent of drawings to manufacturing, (3) testing of a system-level integrated prototype, (4) establishment of a reliability growth curve, (5) identification of key product characteristics, (6) identification of critical manufacturing processes, (7) completion of producibility assessments to identify manufacturing risks for key technologies, and (8) completion of failure modes and effects analysis (analysis conducted to identify failure points to improve reliability before starting hardware fabrication).

- None of the four programs—the Air Force's Combat Rescue Helicopter and F-15 Eagle Passive Active Warning Survivability System, the Army's Indirect Fire Protective Capability Increment 2-Intercept Block 1, and the Navy's Next Generation Jammer Increment 1—tested an early, integrated, system-level prototype.
- One program, the F-15 Eagle Passive Active Warning Survivability System, did not ensure at least 90 percent of its design drawings were releasable, which is inconsistent with best practices.
- Of the three programs that identified critical technologies—the Combat Rescue Helicopter, F-15 Eagle Passive Active Warning Survivability System, and Next Generation Jammer Increment 1—none ensured their critical technologies were in form, fit, and function within a realistic environment. Programs that carry technology immaturity into design and demonstration phases cannot, with certainty, validate their designs as stable until those technologies fully mature.

Table 9 shows the extent to which current DOD programs have implemented knowledge-based acquisition best practices for knowledge point 2—critical design review or, for shipbuilding programs, lead ship fabrication start. The figure highlights the aforementioned four programs that recently completed critical design reviews as well as the 35 programs that previously held their critical design reviews.

Table 9: Implementation of Knowledge-Based Practices for Selected Programs at Critical Design Review

Knowledge-based practices at critical design review	CRH	F-15 EPAWSS	IFPC Inc 2-I Blk 1	NGJ Inc 1	Other 35 Programs Practice implemented	Other 35 Programs Practice not implemented	Other 35 Programs Data not available	N/A	Trend from 2016 to 2017
Demonstrate all critical technologies in form, fit, and function within a realistic environment	Practice not implemented	Practice not implemented	N/A	Practice not implemented	9	17	5	4	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Release at least 90 percent of design drawings to manufacturing	Practice implemented	Practice not implemented	Practice implemented	Practice implemented	10	17	7	1	Declining Trend (decrease of more than 5 percent of programs as compared to 2016)
Test a system-level integrated prototype	Practice not implemented	Practice not implemented	Practice not implemented	Practice not implemented	6	21	0	8	Negligible Change (change of less than 5 percent of programs as compared to 2016)

Knowledge-based practices at critical design review	CRH	F-15 EPAWSS	IFPC Inc 2-I Blk 1	NGJ Inc 1	Other 35 Programs Practice implemented	Other 35 Programs Practice not implemented	Other 35 Programs Data not available	N/A	Trend from 2016 to 2017
Establish a reliability growth curve	Practice implemented	Practice implemented	Practice implemented	Practice implemented	23	6	1	5	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Identify key product characteristics	Practice implemented	Practice implemented	Practice implemented	Practice implemented	31	0	1	3	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Identify critical manufacturing processes	Practice implemented	Practice implemented	Practice implemented	Practice implemented	28	1	1	5	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Conduct producibility assessments to identify manufacturing risks for key technologies	Practice implemented	Practice implemented	Practice implemented	Practice implemented	27	2	1	5	Negligible Change (change of less than 5 percent of programs as compared to 2016)

Knowledge-based practices at critical design review	CRH	F-15 EPAWSS	IFPC Inc 2-I Blk 1	NGJ Inc 1	Other 35 Programs Practice implemented	Other 35 Programs Practice not implemented	Other 35 Programs Data not available	N/A	Trend from 2016 to 2017
Complete failure modes and effects analysis	Practice implemented	Practice implemented	Practice implemented	Practice implemented	29	1	1	4	Negligible Change (change of less than 5 percent of programs as compared to 2016)

● Practice implemented

○ Practice not implemented

-- Data not available

N/A Practice not applicable

↑ Improving Trend (increase of more than 5 percent of programs as compared to 2016)

↓ Declining Trend (decrease of more than 5 percent of programs as compared to 2016)

↔ Negligible Change (change of less than 5 percent of programs as compared to 2016)

CRH = Combat Rescue Helicopter

F-15 EPAWSS = F-15 Eagle Passive Active Warning Survivability System

IFPC Inc 2-I Blk 1 = Indirect Fire Protective Capability Increment 2-Intercept Block 1

NGJ Inc 1 = Next Generation Jammer Increment 1

Source: GAO analysis of DOD data | GAO-18-360SP

Notes: Two of eight key knowledge-based acquisition practices correspond with critical design review. We have identified these two key practices in bold font within the table. To accommodate shipbuilding programs in this analysis, we correlated detail design contract award and lead ship fabrication start with development start and critical design review, respectively. We assessed knowledge-based acquisition practices as not applicable in situations when programs submitted responses to our questionnaire that identified events or circumstances that made completion of the practice impractical. For example, we assessed the technology demonstration practice as not applicable in instances where a program did not have any critical technologies.

None of the Programs Fully Demonstrated Manufacturing Processes Were in Statistical Control Prior to Starting Production

4. Of the three programs that held a production decision during our assessment period, only one met all applicable knowledge-based acquisition practices. In addition, none of the 18 non-shipbuilding programs that previously began production met all acquisition practices.

The five knowledge-based acquisition practices that our prior work found programs should demonstrate prior to starting production are

(1) demonstration of all critical technologies in a realistic environment, (2) release of at least 90 percent of drawings to manufacturing, (3) demonstration that critical manufacturing processes are in statistical control, (4) demonstration of critical processes on a pilot production line, and (5) testing of a production-representative prototype in its intended environment. The third knowledge-based acquisition practice listed above is to ensure that all critical manufacturing processes are in statistical control—that is, they are repeatable, sustainable, and capable of consistently producing parts within quality tolerances and standards—at the start of production.

- One program, the Navy's MQ-8 Fire Scout, demonstrated all knowledge-based acquisition practices for all applicable practices. Based on the program's responses that it has no critical technologies and uses metrics other than manufacturing readiness levels or statistical measures to track manufacturing readiness, we assessed the program as not applicable for those two practices. We also assessed the Navy's Air and Missile Defense Radar program as not applicable for demonstrating critical processes on a pilot production line based on its response.
- Two of the three programs, the Navy's CH-53K Heavy Lift Replacement Helicopter and Air and Missile Defense Radar, did not demonstrate their critical manufacturing processes were in statistical control prior to starting production.
- Two out of the three programs—the Navy's CH-53K Heavy Lift Replacement Helicopter and MQ-8 Fire Scout—demonstrated critical processes on a pilot production line. These programs also tested production representative prototypes in their intended environments.

Table 10 shows the extent to which DOD implemented knowledge-based acquisition practices for knowledge point 3, or production start, for the three aforementioned programs that recently held production reviews, as well as the other 18 non-shipbuilding programs we assessed that entered production prior to 2017. We do not assess shipbuilding programs for this knowledge point due to difference in the production processes used to construct ships.

Table 10: Implementation of Knowledge-Based Practices for Selected Programs at Production Decision

				For the 18 Non-shipbuilding programs that have reached this juncture				
Knowledge Based Practices at Production Decision	**AMDR**	**CH-53K**	**MQ-8 Fire Scout**	**Practice implemented**	**Practice not implemented**	**Data not available**	**N/A**	**Trend from 2016 to 2017**
Demonstrate all critical technologies in form, fit, and function within a realistic environment	Practice not implemented	Practice implemented	**N/A**	**12**	**4**	**2**	**0**	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Release at least 90 percent of design drawings to manufacturing	Practice implemented	Practice implemented	Practice implemented	**8**	**5**	**2**	**3**	Negligible Change (change of less than 5 percent of programs as compared to 2016)
Demonstrate Manufacturing Readiness Level of at least a 9 or critical processes are in statistical control	Practice not implemented	Practice not implemented	**N/A**	**0**	**15**	**0**	**3**	Declining Trend (decrease of more than 5 percent of programs as compared to 2016)
Demonstrate critical processes on a pilot production line	**N/A**	Practice implemented	Practice implemented	**9**	**5**	**0**	**4**	Negligible Change (change of less than 5 percent of programs as compared to 2016)

				For the 18 Non-shipbuilding programs that have reached this juncture				
Knowledge Based Practices at Production Decision	**AMDR**	**CH-53K**	**MQ-8 Fire Scout**	**Practice implemented**	**Practice not implemented**	**Data not available**	**N/A**	**Trend from 2016 to 2017**
Test a production-representative prototype in its intended environment	Practice not implemented	Practice implemented	Practice implemented	**6**	**9**	**0**	**3**	Negligible Change (change of less than 5 percent of programs as compared to 2016)

Source: GAO analysis of DOD data | GAO-18-360SP

Notes: Three of eight key knowledge-based acquisition practices correspond with production decision. We have identified these three key practices in bold font within the table. We assessed knowledge-based acquisition practices as not applicable in situations when programs submitted responses to our questionnaire that identified events or circumstances that made completion of the practice impractical. For example, we assessed the technology demonstration practice as not applicable in instances where a program did not have any critical technologies.

Exploratory Analysis Suggests that Certain Knowledge-Based Acquisition Practices Correspond with Better Acquisition Outcomes

5. We found that, on average, MDAPs that completed some or all of the following three actions had lower cost increases than other programs:

- **demonstrated all critical technologies were very close to final form, fit, and function, within a relevant environment, before starting development;**[22]
- **held a preliminary design review prior to starting development; and**
- **released at least 90 percent of their design drawings by critical design review.**

Additionally, we found that MDAPs that held a preliminary design review prior to starting development had less schedule growth than other programs.

We analyzed 15 programs that already completed system development, held a critical design review, and started production (i.e., completed knowledge points 1 through 3). These programs, 2 of which we included in our first annual assessment in 2003, were ones that we had previously assessed at the time they completed each knowledge point for their implementation of the correspondent knowledge-based acquisition practices.

- Our analysis revealed that, on average, programs that completed one or more of the aforementioned three knowledge-based acquisition practices had lower cost increases than programs that did not complete these knowledge-based practices by the time they reached each knowledge point.[23] These differences, which ranged from approximately 56 to 63 percentage points lower on average for cost increases, were statistically significant.

[22]GAO's best practices work has shown that a Technology Readiness Level (TRL) 7—which corresponds to demonstrating all critical technologies in form, fit, and function within a realistic environment—is the level of technology maturity that constitutes a low risk for starting development. DOD's policy, however, permits development to start at a lower technology maturity level—TRL 6, which corresponds to demonstrating technology in a relevant environment. DOD's policy is based on a statute that generally prohibits a major defense acquisition program from receiving approval for development start until the milestone decision authority certifies—based on an independent review and technical risk assessment—that the technology in the program has been demonstrated in a relevant environment. 10 U.S.C. § 2366b(a)(2). Although GAO included both TRL 6 and 7 in the knowledge-based acquisition practices exploratory statistical analysis, only one program in the sample achieved TRL 7 before starting development, which was not enough to assess whether this practice corresponded with lower cost and schedule growth.

[23]We conducted a means test comparing averages across systems that did and did not complete knowledge-based acquisition practices using a 95 percent confidence level. See Appendix II for additional details.

- Additionally, programs that held a preliminary design review prior to starting development had 47 percent less schedule growth than programs that did not.
- These results support our work and offer initial validation that MDAPs that follow these particular knowledge-based practices may have lower cost increases and less schedule growth than those programs that do not.
- Because inferences from our analysis were limited by the small sample size and the unique characteristics of the 15 MDAPs in the data set, we plan to update this analysis in our future annual assessments. As more programs we previously assessed at development start and at critical design review enter production, this larger sample may enable more precise analysis of differences between MDAPs that completed or did not complete specific knowledge-based practices.

Our prior work demonstrates that completion of all of the knowledge-based practices by the time programs reach their knowledge points underpins a sound business case that positions programs to better meet their cost and schedule goals.

Programs Often Enter Production with Incomplete Knowledge, Which Contributes to Cost and Schedule Growth

6. **Of the 45 current programs we reviewed, 23 reported schedules that included overlap, or concurrency, between developmental tests and production. We observed that this concurrency was accompanied by higher acquisition cost growth, not attributable to quantity changes, as compared to 8 other programs.**

   We observed that cost growth over the last year averaged $513 million not attributable to quantity changes for the 23 programs with concurrent schedules and $154 million for each of the 8 programs reporting non-concurrent schedules.

- We also observed total acquisition cost growth since first full estimate not attributable to quantity changes averaged $6.05 billion from the first full estimates of the 23 programs with concurrent schedules and $689 million from the first full estimates of the 8 programs reporting non-concurrent schedules.

We excluded 14 current programs from this analysis. These programs constituted development-only programs without a production phase, were

shipbuilding programs with uniquely structured developmental test schedules, or, in a few cases, did not identify specific dates for production start or developmental tests, which precluded us from assessing them for concurrency.

7. Of the 45 current programs we assessed, 18 completed, or plan to complete, software development activities after production start, which increases the risk of cost growth, schedule delays, and capability limitations.

In our previous best practices work, we found that leading commercial companies that develop products attain key knowledge about software before production begins.[24]

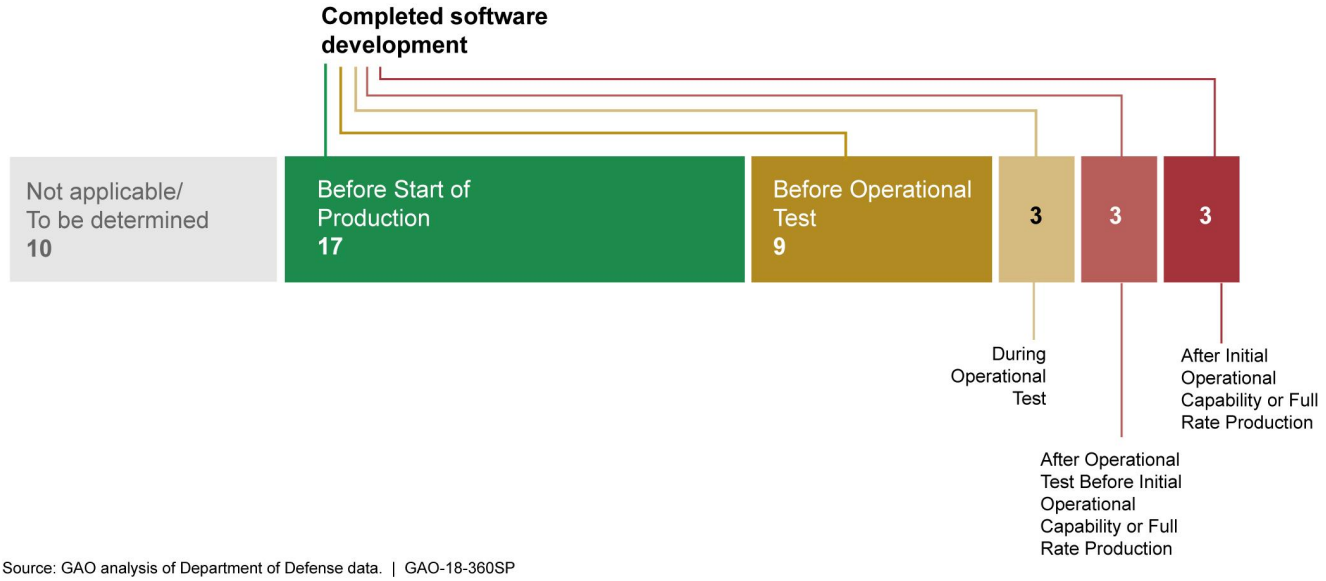
- We have also identified DOD programs that incurred cost and schedule growth when software development activities extended into the production phase.
  - One prominent example of this is the DOD-wide F-35 Lightning II Joint Strike Fighter program, which began low rate initial production in 2007, but—a decade later—has yet to complete its software development activities.[25]
  - Other programs we assessed this year that are currently in production and have reported problems with software development are the Air Force's Small Diameter Bomb Increment II as well as the Navy's Ground/Air Task-Oriented Radar.
- Programs that defer completion of software development activities to post-production phases—such as after initial operational capability or initial operational test and evaluation—risk delivering systems to the warfighter that do not meet their minimum performance requirements.

Figure 14 shows when in development or production the 45 current programs we assessed completed, or plan to complete, software development.

[24]GAO, *Defense Acquisitions: Stronger Management Practices Are Needed to Improve DOD's Software-Intensive Weapon Acquisitions,* GAO-04-393 (Washington, D.C.: Mar. 1, 2014).

[25]GAO, *Joint Strike Fighter: DOD Actions Needed to Further Enhance Restructuring and Address Affordability Risks,* GAO-12-437 (Washington, D.C.: June 14, 2012).

Figure 14: Eighteen Current Programs Completed, or Plan to Complete, Software Development after Production Start



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

Knowledge from Operational Testing Is Often Not Prerequisite to DOD Declaring a Weapon System Capable to Conduct Operations

8. **Over one-third of the 45 current programs we assessed declared, or intend to declare, initial operational capability on the basis of limited or, in a few cases, no initial operational test and evaluation.**

   Initial operational capability occurs when a unit or organization has been equipped and trained and is determined to be capable of conducting operations with a newly fielded system.

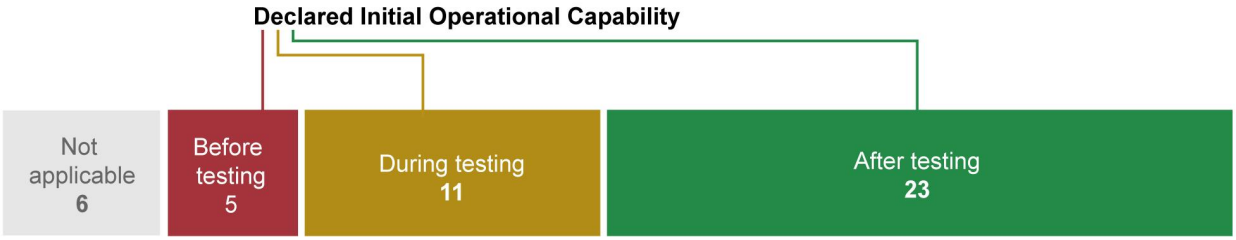
- Initial operational test and evaluation is a separate event that is intended to evaluate a system's effectiveness and suitability under realistic operational conditions before a program makes a full-rate production decision.
- Consequently, programs can declare initial operational capability on the basis of full, partial, or no initial operational test and evaluation.
- We observed that 5 programs declared, or plan to declare, initial operational capability before initial operational test and evaluation begins. Another 11 programs declared, or plan to declare, this capability before the testing completes.

- Programs that declare initial capability before completing initial operational test and evaluation risk fielding systems to warfighters that are not operationally effective or suitable for the missions they will be tasked to perform.

- These totals represent a significant change over last year's assessment, which we attribute in part to additional visibility we gained into programs' operational test schedules, which improved our analysis.

Figure 15 details our analysis of the relationship between initial operational capability and initial operational test and evaluation in 45 current selected DOD programs.

Figure 15: Sixteen Programs Declared or Plan to Declare Initial Operational Capability before Completing Initial Operational Test and Evaluation



Source: GAO analysis of Department of Defense data. | GAO-18-360SP

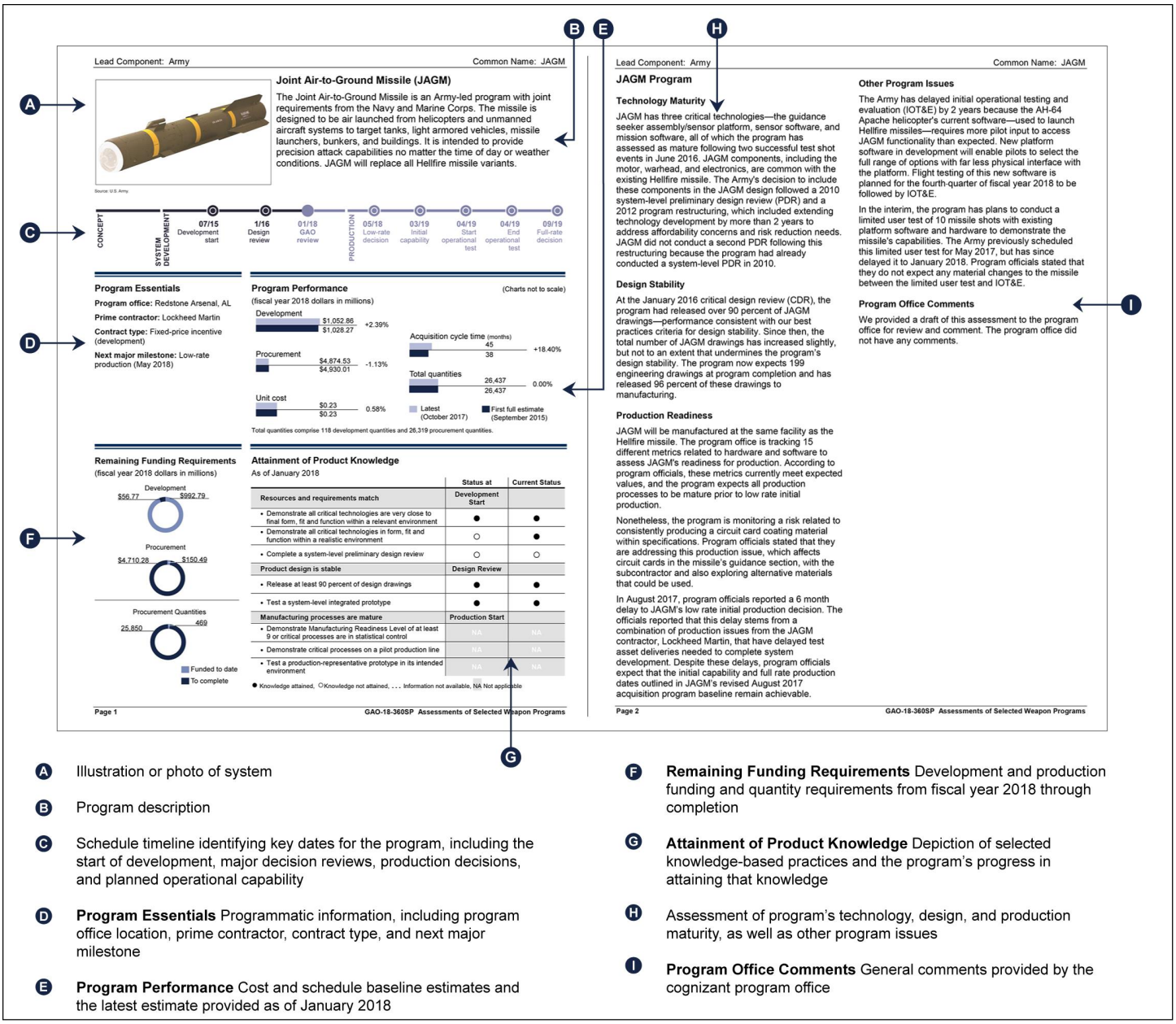
Assessments of Individual Programs

This section contains assessments of individual weapon programs grouped by lead service—Army, Navy and Marine Corps, Air Force, and DOD-wide—and includes a lead service separator page at the start of each grouping. Each assessment presents data on the extent to which programs are following a knowledge-based acquisition approach to product development. Each lead service separator page summarizes information about the acquisition phase, current estimated funding needs, cost and schedule growth, and product knowledge attained. In total, we present information on 57 programs.

For 42 programs, we produced two-page assessments discussing the technology, design, and manufacturing knowledge obtained, as well as other program issues. Each two-page assessment contains a comparison of total acquisition cost from the first full estimate for the program to the current estimate. The first full estimate is generally the cost estimate

established at development start; however, for a few programs that did not have such an estimate, we used the estimate at production start. For shipbuilding programs, we used their planning estimates if those estimates were available. For programs that began as non–major defense acquisition programs, we used the first full estimate available. Of these 42 two-page assessments, most are in development or early production. See figure 16 for an illustration of the layout of each two-page assessment.

Figure 16: Illustration of Program Two-Page Assessment

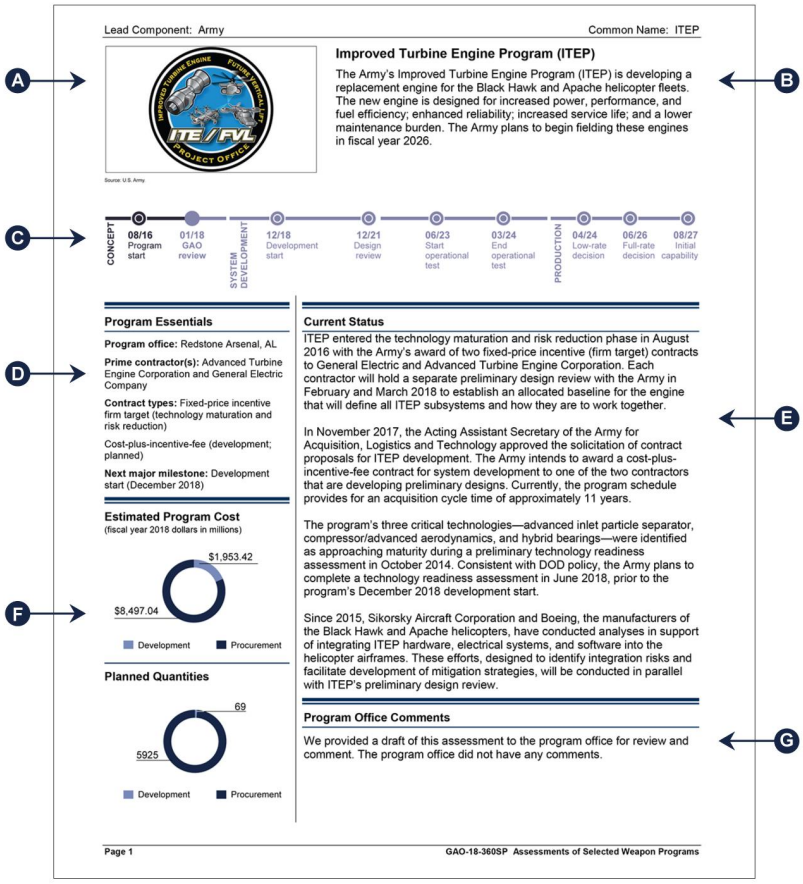


Source: GAO analysis. | GAO-18-360SP

In addition, we produced one-page assessments on the current status of 15 programs, which include 12 future major defense acquisition programs and 3 major defense acquisition programs that are well into production, but are developing new increments of capability as part of their existing

programs. See figure 17 for an illustration of the layout of each one-page assessment.

Figure 17: Illustration of Program One-Page Assessment



- **A** Illustration or photo of system
- **B** Program description
- **C** Schedule timeline identifying key dates for the program, including the start of development, major decision reviews, production decisions, and planned operational capability
- **D** **Program Essentials** Programmatic information, including program office location, prime contractor, contract type, and next major milestone
- **E** **Current Status** Updated status of program
- **F** **Estimated Program Cost** Current estimated funding needs and quantity requirements
- **G** **Program Office Comments** General comments provided by the cognizant program office

Source: GAO analysis. | GAO-18-360SP

For our two-page assessments, we use a scorecard to depict the extent of knowledge gained. These scorecards display key knowledge-based acquisition practices that should be implemented by certain points in the acquisition process. The more knowledge the program has attained by each of these key points, the more likely the weapon system will be delivered within its estimated cost and schedule. A knowledge deficit means the program is proceeding without sufficient knowledge about its technologies, design, or manufacturing processes, and faces unresolved risks that could lead to cost increases and schedule delays.

For each program, we identified a knowledge-based practice that had been implemented with a closed circle. We identified a knowledge-based practice that had yet to be implemented with an open circle. If the program did not provide us with enough information to make a determination, we showed this with a dashed line. A knowledge-based practice that is not applicable to the program is grayed out. A knowledge-based practice may not be applicable to a particular program if the point in the acquisition cycle when the practice should be implemented has yet to be reached, or if the particular practice is not relevant to the program. For programs that have yet to enter system development, we show a projection of knowledge attained for the first three practices. For programs that have entered system development but have yet to hold a critical design review, we assessed actual knowledge attained for these three practices. For programs that have held a critical design review but have yet to enter production, we assessed knowledge attained for the first five practices. For programs that have entered production, we assessed knowledge attained for all eight practices.

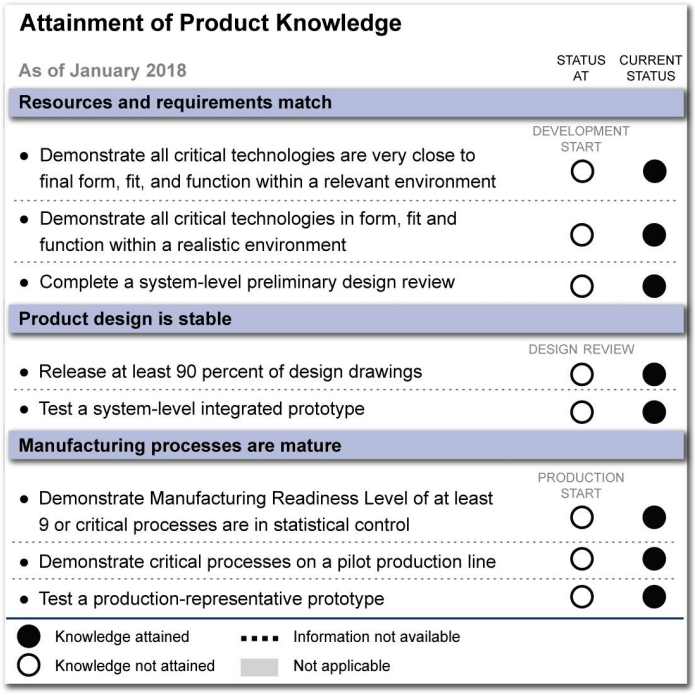
For shipbuilding programs, we assessed different key points in the acquisition cycle and applicable knowledge-based practices, which were informed by our prior work.[26] For shipbuilding programs that have yet to award a detail design contract, we showed a projection of knowledge attained for the first three practices. For shipbuilding programs that have awarded this contract but have yet to start construction, we assessed actual knowledge attained for these three practices. For shipbuilding programs that have started construction, we assessed the knowledge attained for the first four practices. We did not assess the remaining four practices that correspond with knowledge point 3 for shipbuilding programs as our prior work has found that these are not applicable to

[26]GAO-09-322.

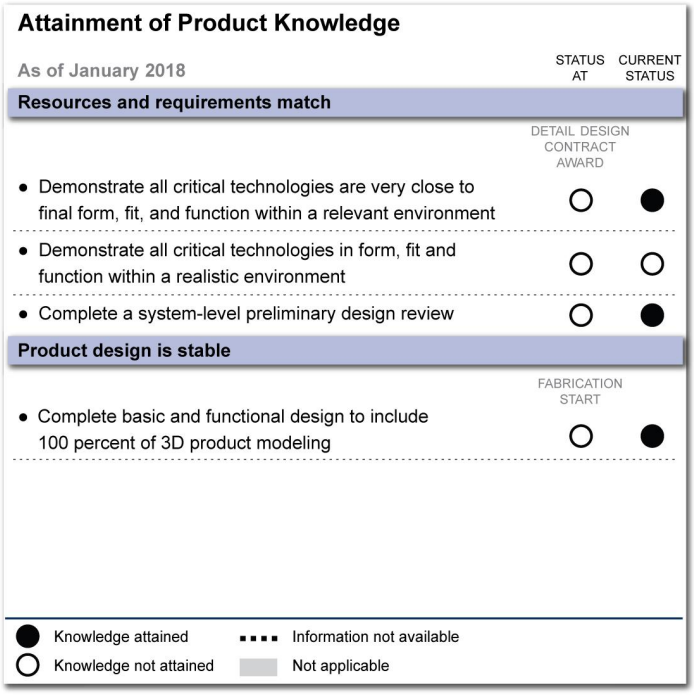
these programs. See figure 18 for examples of the knowledge scorecards we use to assess these different types of programs.

Figure 18: Examples of Knowledge Scorecards

Program in production



Shipbuilding program



Source: GAO. | GAO-18-360SP

Agency Comments

We provided a draft of this report to DOD for comment. In its comments, reproduced in appendix VII, DOD generally concurred with our observations. DOD also provided us with technical comments, which we incorporated as appropriate.

In its comments, DOD stated that our report shows that the acquisition reform initiatives started in 2010 have resulted in measurable improvements. Specifically, DOD stated that it was encouraged by our observations that it has improved the cost performance of recent programs while also expanding its total acquisition portfolio size and cost. DOD further noted that it remains committed to reducing the costs and time required to deliver weapon systems to warfighters.

DOD also identified plans to increase investments aimed at maintaining technology superiority over adversaries. Further, DOD stated that the separation of the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics into the Offices of the Under Secretary of Defense for Acquisition and Sustainment and Under Secretary of Defense for Research and Engineering represents a major shift in how DOD develops and procures weapon systems.

We are sending copies of this report to the appropriate congressional committees and offices; the Secretary of Defense; the Secretaries of the Army, Navy, and Air Force; and the Director of the Office of Management and Budget. In addition, the report will be made available at no charge on the GAO website at http://www.gao.gov.

If you are your staff have any questions concerning this report, please contact me at (202) 512-4841. Contact points for our offices of Congressional Relations and Public Affairs may be found on the last page of this report. Staff members making key contributions to this report are listed in appendix VIII.

Shelby S. Oakley
Director, Contracting and National Security Acquisitions

List of Committees

The Honorable John McCain
Chairman
The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Richard Shelby
Chairman
The Honorable Richard J. Durbin
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Mac Thornberry
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Kay Granger
Chairwoman
The Honorable Peter Visclosky
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Major Defense Acquisition Programs' Individual Subcontracting Reports in the Electronic Subcontracting Reporting

Table 11 shows the number of prime contractors for the programs we assessed where an individual subcontracting report is reported as accepted during 2017 in the Electronic Subcontracting Reporting System (eSRS). We reviewed this information for 86 major defense acquisition programs included in our assessment that reported prime contract information in their December 2016 Selected Acquisition Report (SAR) submissions. The government uses individual subcontracting reports from eSRS as one method of monitoring small business participation, as this tool includes information on contractors' performance against small business subcontracting goals. There are multiple reasons why a prime contractor may not have an accepted subcontracting report in eSRS. For example, some contractors may have pending or rejected reports within the system as all reports are reviewed prior to acceptance. Not all prime contractors for major defense acquisition programs are required to submit individual subcontracting reports. Instead, some contractors report small business participation at a corporate level as opposed to the program level and this data is not captured in the individual subcontracting reports. In addition, although a prime contractor may be required to submit a report, it may not yet have done so for the period we reviewed.

Table 11: Major Defense Acquisition Programs' Individual Subcontracting Reports in the Electronic Subcontracting Reporting System (eSRS)

Program name	Number of contracts listed in the December 2016 Selected Acquisition Report	Contracts with an accepted individual subcontracting report (as of July 2017)
Advanced Arresting Gear (AAG)	4	3
Amphibious Combat Vehicle Phase 1 Increment 1 (ACV 1.1)	2	2
Advanced Extremely High Frequency (AEHF) Satellite	2	2
AGM-88E Advanced Anti-Radiation Guided Missile (AGM-88E AARGM)	3	3
AH-64E Apache New Build (AH-64E New Build)	2	2
AH-64E Apache Remanufacture (AH-64E Remanufacture)	6	5
AIM-9X Block II Sidewinder (AIM-9X Blk II)	5	4

Program name	Number of contracts listed in the December 2016 Selected Acquisition Report	Contracts with an accepted individual subcontracting report (as of July 2017)
Air and Missile Defense Radar (AMDR)	1	1
Airborne and Maritime/Fixed Station (AMF)	0	0
Armored Multi-Purpose Vehicle (AMPV)	1	1
AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM)	4	2
Airborne Warning and Control System Block 40/45 Upgrade (AWACS Blk 40/45 Upgrade)	1	1
B-2 Defensive Management System Modernization (B-2 DMS-M)	1	1
B61 Mod 12 Life Extension Program Tailkit Assembly (B61 Mod 12 LEP TKA)	2	1
C-130J Hercules Transport Aircraft (C-130J)	4	4
C-5 Reliability Enhancement and Re-engining Program (C-5 RERP)	1	1
Cooperative Engagement Capability (CEC)	5	1
CH-47F Improved Cargo Helicopter (CH-47F)	1	1
CH-53K Heavy Lift Replacement Helicopter (CH-53K)	2	1
Chemical Demilitarization-Assembled Chemical Weapons Alternatives (Chem Demil-ACWA)	2	2
Common Infrared Countermeasure (CIRCM)	1	1
Combat Rescue Helicopter (CRH)	1	1
Gerald R. Ford Class Nuclear Aircraft Carrier (CVN 78)	6	4
DDG 1000 Zumwalt Class Destroyer (DDG 1000)	2	2
DDG 51 Arleigh Burke Class Guided Missile Destroyer (DDG 51)	5	5
E-2D Advanced Hawkeye Aircraft (E-2D AHE)	5	5
EA-18G Growler Aircraft (EA-18G)	6	6
Evolved Expendable Launch Vehicle (EELV)	8	2
Enhanced Polar System (EPS)	1	1
F-15 Eagle Passive Active Warning Survivability System (F-15 EPAWSS)	1	0
F-22 Increment 3.2B Modernization (F-22 Inc 3.2B Mod)	1	1
F-35 Lightning II Program (F-35)	6	5
Family of Advanced Beyond Line-of-Sight Terminals (FAB-T)	2	1
Ground/Air Task Oriented Radar (G/ATOR)	3	3
Global Broadcast Service (GBS)	1	1
Guided Multiple Launch Rocket System/Guided Multiple Launch Rocket Sys Alt Warhead (GMLRS/GMLRS AW)	5	5
Global Positioning System III (GPS III)	2	2
H-1 Upgrades (4BW/4BN) (H-1 Upgrades)	6	3
HC/MC-130 Recapitalization Aircraft (HC/MC-130 Recap)	1	1

Program name	Number of contracts listed in the December 2016 Selected Acquisition Report	Contracts with an accepted individual subcontracting report (as of July 2017)
Integrated Air and Missile Defense (IAMD)	0	0
Intercontinental Ballistic Missile Fuze Modernization (ICBM Fuze Mod)	1	0
Integrated Defensive Electronic Countermeasures (IDECM) Block 4	2	1
Infrared Search and Track (IRST)	2	1
Joint Air-to-Ground Missile (JAGM)	1	0
Joint Air-to-Surface Standoff Missile (JASSM)	3	2
Joint Direct Attack Munition (JDAM)	2	1
Joint Light Tactical Vehicle (JLTV)	1	1
Joint Precision Approach and Landing System Increment 1A (JPALS Inc 1A)	1	0
Joint Tactical Radio System Handheld, Manpack, and Small Form Fit Radios (JTRS HMS)	7	5
KC-130J Transport Aircraft (KC-130J)	4	3
KC-46 Tanker Modernization Program (KC-46A)	4	3
Littoral Combat Ship (LCS)	2	2
Littoral Combat Ship - Mission Modules (LCS Packages)	3	1
LHA 6 America Class Amphibious Assault Ship (LHA 6)	2	2
LPD 17 San Antonio Class Amphibious Transport Dock (LPD 17)	1	1
M88A2 Heavy Equipment Recovery Combat Utility Lift Evacuation System (M88A2 HERCULES)	1	1
Military Global Positioning System (GPS) User Equipment Increment 1 (MGUE Inc 1)	3	2
MH-60R Multi-Mission Helicopter (MH-60R)	3	2
Multifunctional Information Distribution System (MIDS)	4	4
MQ-1C Gray Eagle Unmanned Aircraft System (MQ-1C Gray Eagle)	3	3
MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)	2	2
MQ-8 Fire Scout	1	0
MQ-9 Reaper Unmanned Aircraft System (MQ-9 Reaper)	3	1
Mobile User Objective System (MUOS)	0	0
Next Generation Jammer Increment 1 (NGJ Inc 1)	2	1
Navy Multiband Terminal (NMT)	2	2
OASuW Inc 1 (LRASM)	2	2
Next Generation Operational Control System (GPS OCX)	1	1
P-8A Poseidon Multi-Mission Maritime Aircraft (P-8A)	3	2
Patriot Advanced Capability-3 Missile Segment Enhancement (PAC-3 MSE)	3	2
M109A7 Family of Vehicles (M109A7 FOV)	2	2

Program name	Number of contracts listed in the December 2016 Selected Acquisition Report	Contracts with an accepted individual subcontracting report (as of July 2017)
Space Based Infrared System High (SBIRS High)	1	1
Small Diameter Bomb Increment II (SDB II)	3	2
Standard Missile-6 (SM-6)	2	2
Space Fence Ground-Based Radar System Increment 1	1	1
SSBN 826 Columbia Class Submarine(SSBN 826)	1	1
Ship to Shore Connector Amphibious Craft (SSC)	1	1
SSN 774 Virginia Class Submarine (SSN 774)	2	2
Tactical Tomahawk RGM-109E/UGM 109E Missile (TACTOM)	2	1
Trident II (D-5) Sea-Launched Ballistic Missile UGM 133A (Trident II Missile)	10	6
UH-60M Black Hawk Helicopter (UH-60M Black Hawk)	1	1
V-22 Osprey Joint Services Advanced Vertical Lift Aircraft (V-22)	4	3
VH-92A Presidential Helicopter Replacement Program	1	1
Wideband Global SATCOM (WGS)	1	1
Warfighter Information Network-Tactical Increment 2 (WIN-T Inc 2)	1	1
Warfighter Information Network-Tactical Increment 3 (WIN-T Inc 3)	1	0
Totals	**215**	**161**

Source: GAO analysis of Department of Defense (DOD) and eSRS data. | GAO-18-360SP

Appendix II: Objectives, Scope, and Methodology

This report includes observations on (1) the cost and schedule performance of the Department of Defense's (DOD) 2017 portfolio of 86 major weapon programs, (2) implementation of key acquisition reform initiatives within 57 current and future programs, and (3) the knowledge that 57 current and future programs attained at key decision points in the acquisition process.

Analysis of Portfolio Cost and Schedule Performance

To develop our 10 observations on the cost and schedule of DOD's 2017 portfolio of current major defense acquisition programs, we obtained and analyzed cost, quantity, and schedule data from Selected Acquisition Reports (SAR) and other information in the Defense Acquisition Management Information Retrieval system, referred to as DAMIR. We entered this data into a database and verified that the data was entered correctly. We converted all cost information to fiscal year 2018 dollars using conversion factors from the DOD Comptroller's National Defense Budget Estimates for Fiscal Year 2018 (table 5-9).

To assess the reliability of the SAR data, we reviewed our previous assessment and DOD officials' responses regarding any changes to DAMIR's data quality control procedures. We determined that the SAR data and the information retrieved from DAMIR were sufficiently reliable for the purposes of this report. Our assessment includes comparisons of cost and schedule changes over the past year, 5 years, and from baseline estimates which utilize SAR data from December 2016, December 2015, December 2011, and from the programs' initial SAR submissions.

We also analyzed the data to determine the number of programs in each portfolio year. In general, we refer to the 86 major defense acquisition programs with SARs dated December 2016 as DOD's 2017 or current portfolio and use a similar convention for prior year portfolios. We retrieved data on research, development, test, and evaluation; procurement; military construction; acquisition operation and maintenance; total acquisition cost; and schedule estimates for the 86 programs in the 2017 portfolio.

The Missile Defense Agency's Ballistic Missile Defense System and its elements are excluded from all analyses as they do not have an integrated long-term baseline, which prevents us from assessing the program's cost progress or comparing it to other major defense acquisition programs.

For our first observation, we compared the 2017 portfolio with the programs that issued SARs in December 2015 (2016 portfolio) to identify the programs that exited and entered the current portfolio, the total cost and number of programs in the current portfolio compared to previous years, and the total cost and schedule change in the current portfolio over the past year.

We then divided the programs into percent cost change categories based on the percent change in total acquisition cost they experienced over the past year. We then totaled the number of programs in each category and the total cost change of the programs in each category.

For our second observation, in order to determine whether programs experienced an increase or decrease in buying power over the past year, we used data on the programs' number of procurement units, procurement cost changes, and average procurement unit costs.

We calculated cost change "due" to quantity changes as the change in quantity over the last year multiplied by the average procurement unit cost for the program a year ago. We calculated cost change "not due" to quantity changes as the current acquisition quantity times the change in average per unit costs. In practice, changes in quantity will often affect per unit cost—as discussed in this appendix—so this is more precisely described as "Cost change due to change in quantity assuming no change in average procurement unit cost" and "Cost change due to change in average procurement unit cost." If changes in quantity affect per unit cost, those changes will appear in the cost change "not due" to quantity changes. We first calculated the amount of procurement cost growth attributable to quantity changes. To do this, we multiplied any change in quantity by the average procurement unit cost for the program a year ago. The resulting dollar amount is considered a change due solely to shifts in the number of units procured and may overestimate the amount of change expected when quantities increase. Additionally, it could also underestimate the expected change when quantities decrease as it does not account for other effects of quantity changes on procurement such as gain or loss of learning in production that could result in changes to unit cost over time or the use or absence of economic

orders of material. However, these changes are accounted for as part of the change in cost not due to quantities.

For the third observation, we aggregated funding stream data for the total planned investment of each portfolio from DAMIR for each year since 2007 to determine any trends. We determined the yearly totals for research and development, procurement, and total acquisition cost. To distinguish the funding already invested from the funding remaining that is needed to complete the programs in each portfolio since 2007, we used funding stream data obtained from DAMIR for each December SAR submission for the years 2006 (2007 portfolio) through 2016 (2017 portfolio). We define funding invested as all funding that has been provided to the programs in the fiscal year of the annual SAR submission (this includes fiscal year 2017 for the December 2016 submission) and earlier, while funding remaining is all the amounts that will be provided in the fiscal years after the annual SAR submission (fiscal year 2018 and later for the December 2016 submission).

For our fourth observation, we evaluated program performance against high-risk criteria discussed by DOD, the Office of Management and Budget, and GAO. We calculated how many programs had less than a 2 percent increase in total acquisition cost over the past year, less than a 10 percent increase over the past 5 years, and less than a 15 percent increase from baseline estimates using data from SARs. We calculated the percentage of programs meeting each of these high-risk criteria for the 2012 through 2017 timeframe to identify any changes. For programs with multiple sub-programs presented in the SARs, we calculated the net effect of the sub-programs to reach an aggregate program result.

For our fifth observation, we determined the total acquisition-related cost growth on defense acquisition programs in the current portfolio from all previous SAR estimates. To do this, we collected data from programs' annual SARs. In addition, we analyzed programs' cost growth between three intervals based on the program's knowledge points: development start to critical design review, critical design review to production start, and after the production decision. We then calculated the total cost growth for the entire portfolio within these intervals.

For our sixth observation, we determined which programs were initiated after December 4, 2009, the date on which DOD implemented selected requirements of the Weapon Systems Acquisition Reform Act of 2009 (WSARA), and what percentage of the portfolio's total acquisition cost

was allocated to these programs as well as the remainder of the portfolio and the F-35 program.

For our seventh observation, we determined which programs were initiated after December 4, 2009, the date on which DOD implemented selected requirements of WSARA. We then examined these programs' cost and schedule changes over the past year as a group and compared them with the group of programs initiated after December 4, 2009, in the remainder of the 2017 portfolio.

For the eighth observation, we identified the development, procurement, and other acquisition funding (military construction and acquisition operations and maintenance) and the change in these over the past year. We identified the specific programs with the largest total acquisition cost increases in terms of cost and percentage. Additionally, we used the same identification factors to assess the 25 post-WSARA programs—programs which were initiated in or after 2010—and 61 pre-WSARA programs—those initiated prior to 2010—separately in terms of cost and schedule changes. We divided these programs into percent cost change categories based on the percent change in total acquisition cost, both due to quantity changes and not due to quantity change, they experienced over the past year. We then totaled the number of programs in each category—pre-2010 and since 2010 groups—and the total cost change of the programs in each category.

For our ninth observation, we performed a buying power analysis repeating the same steps as detailed in the second observation above, but separated our analysis into the post-2010 group of programs and pre-2010 group of programs. We did this so we could compare the buying power difference between the two groups of programs.

For our 10th observation, we took our total acquisition-related cost growth between the knowledge points analysis, which we detailed in observation five above, and separated the analysis into the subgroup of programs initiated since 2010 and the subgroup of program initiated prior to 2010. We did this so we could compare the difference in acquisition cost growth between the knowledge point intervals for both groups of programs.

Analysis of Acquisition Initiatives

To develop observations on how DOD is implementing acquisition reforms, we reviewed the DOD Instruction 5000.02, the Weapon Systems

Acquisition Reform Act of 2009 (WSARA), and the September 19, 2014, Under Secretary of Defense for Acquisition, Technology, and Logistics "Better Buying Power 3.0 Interim Release" as well as earlier related memorandums. We analyzed questionnaire data received from the 45 current and 12 future major defense acquisition programs in our assessment to determine the extent to which acquisition reforms have been implemented. Based on the questionnaire responses, we determined which programs have established affordability constraints, whether they were meeting those constraints, and, for current programs, examined the average total cost growth of programs with these constraints compared to those without. We tallied programs that conducted "should-cost" analyses the amount of savings identified, savings to date and future expected savings. We also identified the most common practices these programs used to realize their savings. We also analyzed whether programs are planning for competition, both prior to and after development as well as throughout the acquisition life cycle. Further, for all 57 programs, we identified the programs that competitively awarded development, test, or production contracts and those that awarded non-competitive contracts and determined the cost changes not due to quantity changes experienced by the programs on average in each group.

Analysis of Selected DOD Programs Using Knowledge-Based Criteria and Analysis of Concurrency in Those Programs' Developmental Test and Production Schedules

To collect data from current and future major defense acquisition programs—including cost and schedule estimates, technology maturity, and planned implementation of acquisition reforms—we distributed two electronic questionnaires—one questionnaire for the 45 current programs and a slightly different questionnaire for the 12 future programs. Both of the questionnaires were web-based so that respondents could respond and submit their answers online. We received responses from all of the programs we assessed from October 2017 to January 2018. To ensure the reliability of the data collected through the data collection instrument and our questionnaires, we took a number of steps to reduce measurement error and non-response error.

These steps included conducting three pretests of the future major defense acquisition program questionnaire and three pretests for the current major defense acquisition program questionnaire prior to distribution to ensure that our questions were clear, unbiased, and

consistently interpreted. Our pretests covered each branch of the military to better ensure that the questionnaires could be understood by officials within each branch. We determined that the data from the SARs and DAMIR were sufficiently reliable for the purposes of this report.

Our analysis of how well programs are adhering to a knowledge-based acquisition approach focuses on 45 major defense acquisition programs that are mostly in development or the early stages of production. To assess the knowledge attained by key decision points (system development start or detailed design contract award for shipbuilding programs, critical design review or lead ship fabrication start for shipbuilding programs, and production start), we collected data from program offices about their knowledge at each point.

We also provide information on how much knowledge was obtained at key decision points by programs that accomplished these previously. We also included observations on the knowledge that the 12 future programs expect to obtain before starting development. We did not validate the data provided by the program offices, but reviewed the data and performed various checks to determine that they were reliable for our purposes. Where we discovered discrepancies, we clarified the data accordingly. In addition, we determined the percentage of programs which previously met each knowledge-based acquisition practice for the 2017 portfolio of programs as well as for the 2016 portfolio and determined whether the trend from year to year was improving (percentage change was increasing greater than 5 percentage), was declining (percentage change was decreasing greater than 5 percent) or was negligible (percentage change was between 0 to 5 percent).

For programs that have passed a key decision point and have since been restructured, we will continue to assess them against their original cost and schedule estimates at that milestone or decision point, such as development start. We will not reassess a program at milestones that have already been reached if a program is repeating a key decision point or milestone such as milestone B. We will keep our original assessment of the program's knowledge attained at the original milestone. However, we will change a future milestone date if that milestone had not yet been reached and assess the program for its implementation of our best practices at that point in time.

We performed an exploratory statistical analysis that examined our identified knowledge-based acquisition practices and select programs' cost and schedule changes. We focused the analysis on the 15 non-

shipbuilding major defense acquisition programs (MDAP) that prior to this assessment completed each of the three knowledge points within the acquisition process (i.e., completed development, held a critical design review, and started production). Our statistical analysis compared average cost and schedule changes for those programs that had implemented eight key knowledge-based acquisition practices by the time they reached knowledge points 1 through 3, compared to those programs that did not complete the best practices at each knowledge point. To ensure a minimally reliable estimate of the average in each group, we limited our analysis to those knowledge-based acquisition practices for which at least three programs had engaged in the practice, and at least three programs had not engaged in the practice. Although we sought to assess the statistical significance of demonstrating technologies to form, fit, and function within a realistic environment, we observed that only one program in the sample demonstrated this level of technology maturity before it started development. This one program provided an insufficient basis to determine whether this best practice corresponded with lower cost and schedule growth. We assessed the statistical significance of the observed differences between the groups at the 95 percent confidence level.[1] With such a small sample of MDAPs, our estimates are fairly imprecise and do not meet normality assumptions. In addition, we observed three knowledge-based acquisition practices that potentially had higher cost and schedule outcomes, but did not attain statistical significance at the 95 percent confidence level.

To assess programs' developmental testing and production concurrency, we identified the programs—among those we included in our assessment—with production start dates. We used the questionnaire responses from those programs to identify the dates for the start and end of developmental testing, compared those dates to the timing of each program's production decision, and determined the number of months of concurrency, if any, of developmental testing done after production start. We then divided the programs with concurrency into one group and the programs without any identified concurrency into another and determined the average amount of cost change not due to quantity changes for each group.

[1]Statistical significance at the 95 percent confidence level indicates that the chances of observing a statistical difference as large or larger as observed by chance, if no difference existed, is less than 5 percent.

To examine programs' software development efforts, we identified the dates reported by programs for their software and hardware integration and compared those dates to each program's production start date to assess each program's degree of software development and production concurrency.

To examine when programs' were declaring initial operational capability compared to finishing their operational testing, we identified programs initial operational capability and start and end dates of their operational testing. We determined whether the initial operational capability date was before, during or after its testing dates. Based on our determination, we summed and analyzed what percent of programs were in each category. For some programs, either one or both of these dates were not available

The 57 current and future programs included in our assessment were in various stages of the acquisition cycle, and not all of the programs provided information on knowledge obtained at each point. Programs were not included in our assessments at key decision points if relevant data were not available. Our analysis of knowledge attained at each key point includes factors that we have previously identified as underpinning a knowledge-based acquisition approach, including holding early systems engineering reviews, testing an integrated prototype prior to the design review, using a reliability growth curve, planning for manufacturing, and testing a production-representative prototype prior to making a production decision. Additional information on how we collect these data is found in the product knowledge assessment section of this appendix. See also appendix III for a list of the practices that are associated with a knowledge-based acquisition approach.

Individual Assessments of Weapon Programs

This report presents individual assessments of 57 current and future weapon programs. A table listing these assessments is found in appendix VIII. Of our 57 total assessments, 42 are captured in a two-page format discussing technology, design, and manufacturing knowledge obtained and other program issues. These two-page assessments are of current major defense acquisition programs, most of which are in development or early production. The remaining 15 assessments are described in a one-page format that describes their current status. Those one-page assessments include (1) 12 future major defense acquisition programs and (2) three major defense acquisition programs that are well into production, but planning to introduce new increments of capability—

specifically, the Navy's DDG 51 Arleigh Burke Class Destroyer, Flight III; P-8A Poseidon Multi-Mission Maritime Aircraft Increment 3; and SSN 774 Virginia Class Submarine, Block V.

For presentation purposes we grouped the individual assessments by lead service—Army, Navy and Marine Corps, Air Force, and DOD-wide—and inserted a lead service separator page at the start of each grouping. These four separator pages summarize information about the acquisition phase, current estimated funding needs, cost and schedule growth, and product knowledge attained that is provided in the one- and two-page assessments. We report cost and schedule growth in the separator pages in a manner that is consistent with how it is reported and described elsewhere in the report. Estimates of "funding needed to complete" in the separator pages are based on all amounts that will be provided in fiscal year 2018 and later. For some future major defense acquisition programs, the estimates of funding needed represents only those amounts provided through fiscal year 2022 and are not the full amount needed to complete the acquisition.

Over the past several years, DOD has revised policies governing weapon system acquisitions and changed the terminology used for major acquisition events. To make DOD's acquisition terminology more consistent across our individual program assessments, we standardized the terminology for key program events. For most individual programs in our assessment, "development start" refers to the initiation of an acquisition program as well as the start of either engineering and manufacturing development or system development. This generally coincides with DOD's milestone B. A few programs in our assessment have a separate "program start" date, which begins a pre–system development phase for program definition and risk-reduction activities. This "program start" date generally coincides with DOD's former terminology for milestone I or DOD's current milestone A, which denotes the start of technology maturation and risk reduction. The "production decision" generally refers to the decision to enter the production and deployment phase, typically with low-rate initial production. The "initial capability" refers to the initial operational capability—sometimes called first unit equipped or required asset availability. For shipbuilding programs, the schedule of key program events in relation to acquisition milestones varies for each program. Our work on shipbuilding best practices has identified the detailed design contract award and the start of lead ship fabrication as the points in the acquisition process roughly equivalent to development start and design review for other programs.

We obtained the information presented in the Program Essentials section of the individual assessments from program office responses to a questionnaire and program office documents. As a result, DOD is the source of the information regarding the identity of the contractors and the contract types. We did not review individual contracts for each system.

For each program we assessed in a two-page format, we present cost, schedule, and quantity data at the program's first full estimate as well as an estimate from either the latest SAR or the program office reflecting 2017 data where they were available. The first full estimate is generally the cost estimate established at milestone B—development start; however, for a few programs that did not have such an estimate, we used the estimate at milestone C—production start—instead. For shipbuilding programs, we used their planning estimates if those estimates were available. For systems for which a first full estimate was not available, we only present the latest available estimate of cost and quantities. For the other programs assessed in a one-page format, we present the latest available estimate of cost and quantity from the program office.

For each program we assessed, all cost information is presented in fiscal year 2018 dollars. We converted cost information to fiscal year 2018 dollars using conversion factors from the DOD Comptroller's National Defense Budget Estimates for Fiscal Year 2018 (table 5-9). We have depicted only the program's main elements of acquisition cost—research and development and procurement. However, the total program cost also includes military construction and acquisition-related operation and maintenance costs. Because of rounding and these additional costs, in some situations, total cost may not match the exact sum of the research and development and procurement costs. The program unit costs are calculated by dividing the total program cost by the total quantities planned. These costs are often referred to as program acquisition unit costs. In some instances, the data were not applicable, and we annotate this by using the term "not applicable (NA)." The quantities listed refer to total quantities, including both procurement and development quantities.

The schedule assessment for each program is based on acquisition cycle time, defined as the number of months between program start and the achievement of initial operational capability or an equivalent fielding date. In some instances the data were not yet available, and we annotate this by using the term "to be determined (TBD)" or "NA."

The information presented in "Remaining Funding Requirements" is from fiscal year 2018 through completion and draws on information from SARs

or on data from the program office. The quantities listed refer only to procurement quantities. Satellite programs, in particular, produce a large percentage of their total operational units as development quantities, which are not included in the quantity figure.

The intent of these comparisons is to provide an aggregate, or overall, picture of a program's history. These assessments represent the sum of the federal government's actions on a program, not just those of the program manager and the contractor. DOD does a number of detailed analyses of changes that attempt to link specific changes with triggering events or causes. Our analysis does not attempt to make such detailed distinctions.

In this year's assessment we also reviewed whether individual subcontracting reports from a program's prime contractor or contractors were accepted on the Electronic Subcontracting Reporting System (eSRS). We reviewed this information for 86 of the major defense acquisition programs included in our assessment using the contract information reported in their December 2016 Selected Acquisition Reports. See appendix IV for a list of the programs we reviewed.

Product Knowledge Data on Individual Two-Page Assessments

In our past work examining weapon acquisition issues and knowledge-based acquisition practices for product development, we have found that leading commercial firms pursue an acquisition approach that is anchored in knowledge, whereby high levels of product knowledge are demonstrated by critical points in the acquisition process. On the basis of this work, we have identified three key knowledge points during the acquisition cycle—system development start, critical design review, and production start—at which programs need to demonstrate critical levels of knowledge to proceed. To assess the product development knowledge of each program at these key points, we reviewed questionnaires submitted by programs; however, not every program had responses to each element of the questionnaire. We also reviewed pertinent program documentation and discussed the information presented on the questionnaire with program officials as necessary.

For our attainment of product knowledge tables, we assessed the programs' current status in implementing the knowledge-based acquisition practices criteria, as well as the programs' progress in meeting

the criteria at the time they reached the three key knowledge points during the acquisition cycle—system development start, critical design review, and production start. For programs that have passed a key decision point and have since been restructured, we continue to assess them against their original cost and schedule estimates at that milestone or decision point, such as development start. We have not reassessed a program at milestones that have already been reached if a program is repeating a key decision point or milestone, such as milestone B. We have kept our original assessment of the program's knowledge attained at the original milestone. However, we have changed future milestone dates in instances when the program had not yet reached the affected milestone. In these instances, we assessed the program for its implementation of our knowledge-based acquisition practices criteria at that point in time. To assess a program's readiness to enter system development, we collected data through the questionnaire on critical technologies and early design reviews. To assess technology maturity, we asked program officials to apply a tool, referred to as technology readiness levels (TRL), for our analysis. The National Aeronautics and Space Administration originally developed TRLs, and the Army and Air Force science and technology research organizations use them to determine when technologies are ready to be handed off from science and technology managers to product developers. TRLs are measured on a scale from 1 to 9, beginning with paper studies of a technology's feasibility and culminating with a technology fully integrated into a completed product. See appendix VI for TRL definitions. Our knowledge-based acquisition practices work has shown that a TRL 7—demonstration of a technology in its form, fit, and function within a realistic environment—is the level of technology maturity that constitutes a low risk for starting a product development program.[2] For shipbuilding programs, we have recommended that this level of maturity be achieved by the contract award for detailed design.[3] In our assessment, the technologies that have reached TRL 7, a prototype demonstrated in a realistic environment, are referred to as mature or fully mature. Those technologies that have reached TRL 6, a prototype very close to final form, fit, and function demonstrated within a relevant environment, are

[2]GAO, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999); GAO, *Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes*, GAO-01-288 (Washington, D.C.: Mar. 8, 2001).

[3]GAO, *Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding*, GAO-09-322 (Washington, D.C.: May 13, 2009).

referred to as approaching or nearing maturity. Satellite technologies that have achieved TRL 6 are assessed as fully mature due to the difficulty of demonstrating maturity in a realistic environment—space. In addition, we asked program officials to provide the date of the system-level preliminary design review. We compared this date to the system development start date.

In most cases, we did not validate the program offices' selection of critical technologies or the determination of the demonstrated level of maturity. We sought to clarify the TRLs in those cases where information existed that raised questions. If we were to conduct a detailed review, we may or may not adjust the critical technologies assessed, their readiness levels demonstrated, or both. It was not always possible to reconstruct the technological maturity of a weapon system at key decision points after the passage of many years. Where practicable, we compared technology assessments provided by the program office to assessments by officials from the Office of the Assistant Secretary of Defense for Research and Engineering.

To assess design stability, we asked program officials to provide the percentage of design drawings completed or projected for completion by the design review, the production decision, and as of our current assessment in the data-collection instrument. In most cases, we did not verify or validate the percentage of engineering drawings provided by the program office. We clarified the percentage of drawings completed in those cases where information that raised questions existed. Completed drawings were defined as the number of drawings released or deemed releasable to manufacturing that can be considered the "build to" drawings. For shipbuilding programs, we asked program officials to provide the percentage of the three-dimensional product model that had been completed by the start of lead ship fabrication, and as of our current assessment. To gain greater insights into design stability, we also asked program officials to provide the date they planned to first integrate and test all key subsystems and components into a system-level integrated prototype. We compared this date to the date of the design review. We did not assess whether shipbuilding programs had completed integrated prototypes.

To assess production maturity, we asked program officials for their Manufacturing Readiness Level (MRL) for process capability and control or to identify the number of critical manufacturing processes and, where available, to quantify the extent of statistical control achieved for those processes as a part of our questionnaire. In most cases, we did not verify

or validate the information provided by the program office. We clarified the number of critical manufacturing processes and the percentage of statistical process control where information existed that raised questions. We used a standard called the Process Capability Index, a process-performance measurement that quantifies how closely a process is running to its specification limits. The index can be translated into an expected product defect rate, and we have found it to be a best practice. We also used data provided by the program offices on their MRL for process capability and control, a sub-thread tracked as part of the manufacturing readiness assessment process recommended by DOD, to determine production maturity. We assessed programs as having mature manufacturing processes if they reported an MRL 9 for that sub-thread—meaning that manufacturing processes are stable, adequately controlled, and capable. To gain further insights into production maturity, we asked program officials whether the program planned to demonstrate critical manufacturing processes on a pilot production line before beginning low-rate production. We also asked programs on what date they planned to begin system-level developmental testing of a fully configured, production-representative prototype in its intended environment. We compared this date to the production start date. We did not assess production maturity for shipbuilding programs.

Although the knowledge points provide indicators of potential risks, by themselves they do not cover all elements of risk that a program encounters during development, such as funding instability.

We conducted this performance audit from May 2017 to April 2018, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix III: Knowledge-Based Acquisition Practices

Our prior work on best product development practices found that successful programs take steps to gather knowledge that confirm that their technologies are mature, their designs stable, and their production processes are in control. Successful product developers ensure a high level of knowledge is achieved at key junctures in development. We characterize these junctures as knowledge points. The related GAO Products section of this report includes references to the body of work that helped us identify these practices and apply them as criteria in weapon system reviews. Table 12 summarizes these knowledge points and associated practices.

Table 12: Best Practices for Knowledge-based Acquisitions

Knowledge Point 1: Technologies, time, funding, and other resources match customer needs. Decision to invest in product development.

- Demonstrate technologies to a high readiness level—Technology Readiness Level 7—to ensure technologies are fit, form, function, and work within a realistic environment[a]
- Ensure that requirements for product increment are informed by system-level preliminary design review using system engineering process (such as prototyping of preliminary design)
- Establish cost and schedule estimates for product on the basis of knowledge from system-level preliminary design using system engineering tools (such as prototyping of preliminary design)
- Constrain development phase (5 to 6 years or less) for incremental development
- Ensure development phase fully funded (programmed in anticipation of milestone)
- Align program manager tenure to complete development phase
- Contract strategy that separates system integration and system demonstration activities
- Conduct independent cost estimate

- Conduct independent program assessment
- Conduct major milestone decision review for development start

Knowledge Point 2: Design is stable and performs as expected. Decision to start building and testing production-representative prototypes.

- Complete system critical design review
- Complete 90 percent of engineering design drawing packages
- Complete subsystem and system design reviews
- Demonstrate with system-level integrated prototype that design meets requirements
- Complete failure modes and effects analysis
- Identify key system characteristics
- Identify critical manufacturing processes
- Establish reliability targets and growth plan on the basis of demonstrated reliability rates of components and subsystems
- Conduct independent cost estimate
- Conduct independent program assessment
- Conduct major milestone decision review to enter system demonstration

Knowledge Point 3: Production meets cost, schedule, and quality targets. Decision to produce first units for customer.

- Demonstrate manufacturing processes on a pilot production line
- Build and test and production-representative prototype to demonstrate product in intended environment
- Test production-representative prototypes to achieve reliability goal
- Collect statistical process control data
- Demonstrate that critical processes are capable and in statistical control
- Conduct independent cost estimate
- Conduct independent program assessment
- Conduct major milestone decision review to begin production

Source: GAO | GAO-18-360SP

[a]DOD policy permits development to start at a technology maturity level commensurate with TRL 6—demonstration of program technology in a relevant environment. Therefore we have assessed programs against this measure as well.

Appendix IV: Comparison of December 2016 and First Full Estimates of Total Acquisition Cost for Programs in the Department of Defense

Table 13 outlines the December 2016 and first full estimates of total acquisition cost (in fiscal year 2018 dollars) for each program in the Department of Defense's (DOD) 2017 portfolio of major weapon programs. For each program, we show the percentage change in total acquisition cost from the first full estimate, as well as over the previous year and 5 years.

Table 13: December 2016 Cost Estimates and First Full Estimates for DOD's 2017 Portfolio of Major Defense Acquisition Programs (Fiscal year 2018 dollars in millions)

Program Name	December 2016 estimated total acquisition cost	First full estimate of total acquisition cost	Percentage change in total acquisition cost from first full estimate	Percentage change in total acquisition cost since December 2015	Percentage change in total acquisition cost since December 2011
Advanced Arresting Gear (AAG)	2,090.64	2,070.50	1.0	1.0	1.0
Advanced Extremely High Frequency (AEHF) Satellite	15,276.77	7,048.33	116.7	-0.5	-1.1
AGM-88E Advanced Anti-Radiation Guided Missile (AGM-88E AARGM)	2,784.14	1,771.05	57.2	-0.1	27.9
AH-64E Apache New Build (AH-64E New Build)	1,942.38	2,621.89	-25.9	-15.9	-10.3
AH-64E Apache Remanufacture (AH-64E Remanufacture)	14,093.65	8,012.96	75.9	-2.0	21.0
AIM-9X Block II Sidewinder (AIM-9X Blk II)	3,452.03	4,420.39	-21.9	-11.4	-19.5
Air and Missile Defense Radar (AMDR)	5,707.89	6,184.71	-7.7	3.1	-7.7
Airborne and Maritime/Fixed Station (AMF)	3,321.05	9,021.63	-63.2	-1.8	-23.3
Armored Multi-Purpose Vehicle (AMPV)	11,352.88	11,270.28	0.7	0.5	0.7
AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM)	25,176.44	12,094.04	108.2	0.0	-1.5
Airborne Warning and Control System Block 40/45 Upgrade (AWACS Blk 40/45 Upgrade)	2,968.37	3,088.98	-3.9	2.1	-3.9
Amphibious Combat Vehicle (ACV)	1,838.95	1,940.83	-5.2	-5.2	-5.2

Program Name	December 2016 estimated total acquisition cost	First full estimate of total acquisition cost	Percentage change in total acquisition cost from first full estimate	Percentage change in total acquisition cost since December 2015	Percentage change in total acquisition cost since December 2011
B-2 Defensive Management System Modernization (B-2 DMS-M)	2,634.72	2,654.14	-0.7	-0.7	-0.7
B61 Mod 12 Life Extension Program Tailkit Assembly (B61 Mod 12 LEP TKA)	1,247.24	1,446.43	-13.8	-4.6	-13.8
C-130J Hercules Transport Aircraft (C-130J)	17,496.05	1,050.01	1,566.3	-0.9	-0.9
C-5 Reliability Enhancement and Re-engining Program (C-5 RERP)	7,658.26	12,065.28	-36.5	-1.7	-6.0
CH-47F Improved Cargo Helicopter (CH-47F)	16,191.50	3.562.39	354.5	-1.3	3.0
CH-53K Heavy Lift Replacement Helicopter (CH-53K)	28,318.75	18,318.54	54.6	5.8	13.7
Chemical Demilitarization-Assembled Chemical Weapons Alternatives (Chem Demil-ACWA)	13,547.63	2,923.24	363.4	18.3	21.8
Columbia Class Ballistic Missile Submarine (SSBN 826)	101,277.54	102,225.52	-0.9	-0.9	-0.9
Combat Rescue Helicopter (CRH)	8,746.84	8,595.45	1.8	0.5	1.8
Common Infrared Countermeasure (CIRCM)	2,690.94	2,666.14	0.9	0.9	0.9
Cooperative Engagement Capability (CEC)	6,455.94	3,256.49	98.2	2.1	10.1
DDG 1000 Zumwalt Class Destroyer (DDG 1000)	24,492.81	38,505.53	-36.4	1.5	6.1
DDG 51 Arleigh Burke Class Guided Missile Destroyer (DDG 51)	128,236.10	16,803.68	663.1	2.5	15.6
E-2D Advanced Hawkeye Aircraft (E-2D AHE)	22,466.61	16,321.76	37.6	0.4	4.8
EA-18G Growler Aircraft (EA-18G)	16,779.94	9,930.79	69.0	-1.8	35.4
Evolved Expendable Launch Vehicle (EELV)	57,889.90	19,224.09	201.1	-4.8	53.6
Enhanced Polar System (EPS)	1,462.66	1,475.73	-0.9	-0.3	-0.9
F-15 Eagle Passive Active Warning Survivability System (F-15 EPAWSS)	2,690.30	4,414.39	-39.3	-39.3	-39.3
F-22 Increment 3.2B Modernization (F-22 Inc 3.2B Mod)	1,530.58	1,657.97	-7.7	-5.5	-7.7
F-35 Lightning II Program (F-35)	355,281.38	236,448.60	50.3	3.6	-1.8
Family of Advanced Beyond Line-of-Sight Terminals (FAB-T)	4,660.68	3,527.77	32.1	1.1	-5.4
MQ-8 (Fire Scout)	2,961.34	2,893.62	2.3	-1.1	3.2
Gerald R. Ford Class Nuclear Aircraft Carrier (CVN 78)	39,661.55	39,359.85	0.8	3.6	3.9
Ground/Air Task Oriented Radar (G/ATOR)	2,916.27	1,621.80	79.8	1.5	79.8
Global Broadcast Service (GBS)	1,366.74	637.21	114.5	-0.1	4.7
Guided Multiple Launch Rocket System/Guided Multiple Launch Rocket Sys Alt Warhead (GMLRS/GMLRS AW)	7,734.43	1,956.41	295.3	10.8	16.0
Global Positioning System III (GPS III)	5,772.47	4,360.81	32.4	-2.0	26.7

Program Name	December 2016 estimated total acquisition cost	First full estimate of total acquisition cost	Percentage change in total acquisition cost from first full estimate	Percentage change in total acquisition cost since December 2015	Percentage change in total acquisition cost since December 2011
Next Generation Operational Control System (OCX)	5,569.33	3,663.35	52.0	25.4	52.0
H-1 Upgrades (4BW/4BN) (H-1 Upgrades)	13,160.23	4,012.79	228.0	-2.6	-5.1
HC/MC-130 Recapitalization Aircraft (HC/MC-130 Recap)	14.419.29	9.254.32	55.8	-1.4	2.3
Handheld, Manpack, and Small Form Fit Radios (HMS)	9,640.89	11,105.50	-13.2	-1.2	4.7
Infrared Search and Track (IRST)	2,213.84	2,226.28	-0.6	-0.6	-0.6
Integrated Air and Missile Defense (IAMD)	7,144	5,563.75	28.4	7.7	12.1
Intercontinental Ballistic Missile Fuze Modernization (ICBM Fuze Mod)	1,926.48	1,927.97	-0.1	-1.0	-0.1
Integrated Defensive Electronic Countermeasures (IDECM) Blocks 2/3/4	3,073.14	2,408.84	27.6	-0.6	16.4
Joint Air-to-Ground Missile (JAGM)	5,951.13	5,958.28	-0.1	-0.3	-0.1
Joint Air-to-Surface Standoff Missile Extended Range (JASSM-ER)	4,361.40	2,494.60	74.8	3.7	20.8
Joint Direct Attack Munition (JDAM)	11,330.94	3,782.65	199.6	11.1	48.8
Joint Light Tactical Vehicle (JLTV)	21,369.69	24,931.82	-14.3	2.4	-14.3
Joint Precision Approach and Landing System (JPALS)	1,896.58	1,120.00	69.3	-5.4	73.8
KC-130J Transport Aircraft (KC-130J)	9,826.34	10,494.26	-6.4	-0.4	-7.2
KC-46 Tanker Modernization Program (KC-46A)	41,171.84	48,488.25	-15.1	-7.5	-14.5
Littoral Combat Ship (LCS)	20,814.18	2,482.76	738.3	-23.4	-40.3
Littoral Combat Ship - Mission Modules (LCS Packages)	7,291.28	7,250.26	0.6	0.7	0.6
LHA 6 America Class Amphibious Assault Ship (LHA 6)	10,362.44	3,518.46	194.5	1.7	-5.2
LPD 17 San Antonio Class Amphibious Transport Dock (LPD 17)	23,371.75	12,958.90	80.4	6.6	14.0
M109A7 Family of Vehicles (M109A7 FOV)	7,494.61	7,399.44	1.3	-0.8	1.5
M88A2 Heavy Equipment Recovery Combat Utility Lift Evacuation System (M88A2 Hercules)	3,280.91	3,330.18	-1.5	-1.5	-1.5
MH-60R Multi-Mission Helicopter (MH-60R)	14,845.07	6,125.08	142.4	-0.8	-7.2
Military GPS User Equipment (MGUE) Increment 1	1,178.80	1,535.80	-23.2	-23.2	-23.2
MQ-1C Gray Eagle Unmanned Aircraft System (MQ-1C Gray Eagle)	6,064.89	1,123.25	439.9	10.6	18.9
MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)	15,509.92	14,214.53	9.1	15.9	8.9
MQ-9 Reaper Unmanned Aircraft System (MQ-9 Reaper)	13,042.91	2,917.49	347.1	6.4	-2.8
Multifunctional Information Distribution System (MIDS)	5,205.16	1,442.90	260.7	1.7	40.6
Mobile User Objective System (MUOS)	6,982.89	7,436.50	-6.1	-7.5	-10.2

Program Name	December 2016 estimated total acquisition cost	First full estimate of total acquisition cost	Percentage change in total acquisition cost from first full estimate	Percentage change in total acquisition cost since December 2015	Percentage change in total acquisition cost since December 2011
Navy Multiband Terminal (NMT)	2,439.52	2,567.96	-5.0	3.4	19.1
Next Generation Jammer Increment 1 (NGJ Inc 1)	7,762.64	7,749.66	0.2	0.2	0.2
Offensive Anti-Surface Warfare Increment 1 (OASuW Inc 1)	1,632.85	1,558.80	4.8	4.8	4.8
P-8A Poseidon Multi-Mission Maritime Aircraft (P-8A)	35,044.89	34,336.44	2.1	2.6	-3.1
Patriot Advanced Capability-3 Missile Segment Enhancement (PAC-3 MSE)	6,882.40	8,062.34	-14.6	3.2	-22.7
Space Based Infrared System High (SBIRS High)	3,464.31	3,930.24	-11.9	3.5	-11.9
Small Diameter Bomb Increment II (SDB II)	4,390.29	5,202.30	-15.6	0.2	5.7
Standard Missile-6 (SM-6)	9,674.83	6,306.77	53.4	3.2	45.9
Space Fence Ground-Based Radar System Increment 1	1,570.17	1,664.72	-5.7	-0.9	-5.7
Ship to Shore Connector Amphibious Craft (SSC)	4,622.51	4,373.93	5.7	13.3	5.7
SSN 774 Virginia Class Submarine (SSN 774)	137,099.81	66,881.28	105.0	40.6	50.4
Tactical Tomahawk RGM-109E/UGM 109E Missile (TACTOM)	7,518.01	2,341.40	221.1	5.5	-5.5
Trident II (D-5) Sea-Launched Ballistic Missile UGM 133A (Trident II Missile)	59,636.42	52,233.71	14.2	-0.1	1.6
UH-60M Black Hawk Helicopter (UH-60M Black Hawk)	28,012.86	14,351.28	95.2	3.7	-2.8
V-22 Osprey Joint Services Advanced Vertical Lift Aircraft (V-22)	65,076.53	44,371.15	46.7	0.4	3.3
VH-92A Presidential Helicopter Replacement Program	4,859.34	4,939.13	-1.6	-1.1	-1.6
Wideband Global SATCOM (WGS)	4,177.63	1,320.83	216.3	-4.1	-5.6
Warfighter Information Network-Tactical Increment 2 (WIN-T Inc 2)	11,203.43	4,102.63	173.1	2.8	66.9
Warfighter Information Network-Tactical Increment 3 (WIN-T Inc 3)	2,077.79	18,109.63	-88.5	-0.1	-84.9

Source: GAO analysis of DOD data. | GAO-18-360SP

Note: We obtained data for this table from DOD's Selected Acquisition Reports.

Appendix V: Cost and Schedule Changes over 5 Years and since First Full Estimates for the 86 Programs in DOD's 2017 Portfolio

Table 14 shows the 2017 portfolio's aggregate changes in research and development, procurement, and total acquisition costs, as well as average delays in delivering operational capability, over the last 5 years and since programs' first full estimates.

Table 14: Cost and Schedule Changes for Programs in DOD's 2017 Portfolio (Fiscal year 2018 dollars)

	5-year comparison (December 2011 to December 2016)	Since first full estimate (baseline to December 2016)
Change in total research and development cost	$19.8 billion	$103.1 billion
	6.7 percent	48.9 percent
Change in total procurement cost	52.7 billion	430.8 billion
	4.1 percent	47.9 percent
Change in total other acquisition costs[a]	-0.9 billion	2.9 billion
	-6.1 percent	26 percent
Change in total acquisition cost	73.0 billion	536.8 billion
	4.6 percent	47.9 percent
Average delay in delivering initial capabilities	10.9 months	27.4 months
	13.7 percent	37.7 percent

Source: GAO analysis of DOD data | GAO-18-360SP

Note: We obtained table data from DOD's Selected Acquisition Reports. Some numbers may not sum due to rounding.

[a]Other total acquisition costs include acquisition-related operation and maintenance and system-specific military construction costs.

Appendix VI: Technology Readiness Levels

Table 15: Technology Readiness Levels and Descriptions

Technology readiness level	Description	Hardware/software	Demonstration environment
1. Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.	None (paper studies and analysis)	None
2. Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (paper studies and analysis)	None
3. Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Analytical studies and demonstration of non-scale individual components (pieces of subsystem)	Lab
4. Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.	Low-fidelity breadboard. Integration of nonscale components to show pieces will work together. Not fully functional or form or fit but representative of technically feasible approach suitable for flight articles.	Lab
5. Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.	High-fidelity breadboard. Functionally equivalent but not necessarily form and/or fit (size weight, materials, etc). Should be approaching appropriate scale. May include integration of several components with reasonably realistic support elements/subsystems to demonstrate functionality.	Lab demonstrating functionality but not form and fit. May include flight demonstrating breadboard in surrogate aircraft. Technology ready for detailed design studies.

Technology readiness level	Description	Hardware/software	Demonstration environment
6. System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated realistic environment.	Prototype. Should be very close to form, fit and function. Probably includes the integration of many new components and realistic supporting elements/subsystems if needed to demonstrate full functionality of the subsystem.	High-fidelity lab demonstration or limited/restricted flight demonstration for a relevant environment. Integration of technology is well defined.
7. System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in a realistic environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Prototype. Should be form, fit and function integrated with other key supporting elements/subsystems to demonstrate full functionality of subsystem.	Flight demonstration in representative realistic environment such as flying test bed or demonstrator aircraft. Technology is well substantiated with test data.
8. Actual system completed and "flight qualified" through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Flight-qualified hardware	Developmental Test and Evaluation in the actual system application.
9. Actual system "flight proven" through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.	Actual system in final form	Operational Test and Evaluation in operational mission conditions.

Source: GAO and its analysis of National Aeronautics and Space Administration data. | GAO-18-360SP

Appendix VII: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION
AND SUSTAINMENT

Ms. Shelby S. Oakley
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G St NW
Washington, DC 20548

APR 09 2018

Dear Ms. Oakley,

This is the Department of Defense (DoD) response to the Government Accountability Office (GAO) Draft Report, GAO-18-360SP, "Defense Weapon Systems: Programs Initiated after Acquisition Reforms Show Improved Performance, but Knowledge Shortfalls Persist" dated April 3, 2018 (GAO Code 102042).

The Department is pleased GAO findings show measurable improvements to the DoD Acquisition System as a result of major reform initiatives started in 2010 and continuing in the current Administration. The Department remains committed to driving down the costs of our weapon systems and reducing the time it takes to deliver them to our Warfighters. The separation of the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics into the Office of the Under Secretary of Defense for Acquisition and Sustainment and the Office of the Under Secretary of Defense for Research and Engineering presents the next major shift in how the Department develops and procures weapon systems.

This report documents that the Department continues to show improved cost performance while expanding the total acquisition portfolio size and cost. That is an encouraging finding as the Department makes a strategic turn to increase investment in our technology edge over our adversaries.

The Department appreciates the opportunity to comment on the Draft Report. My point of contact for this effort is LCDR Jake Ferrari at 703-697-8020.

Sincerely,

Nancy L. Spruill

Nancy L. Spruill
Director
Acquisition Resources and Analysis

Appendix VIII: GAO Contact and Staff Acknowledgments

GAO Contact

Shelby S. Oakley, (202) 512-4841 or oakleys@gao.gov

Staff Acknowledgments

Principal contributors to this report were Christopher R. Durbin, Assistant Director; Marcus Ferguson, Program Assessments Analyst-in-Charge; J. Andrew Walker, Portfolio Analysis Analyst-in-Charge; Adrienne Austin; Jenna Blair; Emily Bond; Tana M. Davis; Wendy P. Smythe; and Robin M. Wilson. Other key contributors included Matthew Ambrose, Cheryl K. Andrew, Andrew H. Berglund, David B. Best, Matthew Crosby, Mary C. Diop, Jeffrey L. Hartnett, Leigh Ann Haydon, Rich Horiuchi, Wendell K. Hudson, Justin M. Jaynes, J. Kristopher Keener, Jill N. Lacey, Katherine Lenane, Travis J. Masters, LaTonya D. Miller, Diana Moldafsky, Anh Nguyen, Anna Maria Ortiz, Scott M. Purdy, Beth Reed Fritts, Carrie Rogers, Ronald E. Schwenn, Charlie Shivers III, Jay Tallon, Brian A. Tittle, Bruce H. Thomas, Nathan A. Tranquilli, Nathaniel Vaught, Abby C. Volk, Alyssa B. Weir, Khristi A. Wilkins, and Tonya Woodbury.

Table 16 lists the staff responsible for individual program assessments.

Table 16: GAO Staff Responsible for Individual Program Assessments

	Program name	Primary staff
Army programs	Airborne & Maritime/Fixed Station (AMF)	Tana M. Davis, Jenna Blair
	Armored Multi-Purpose Vehicle (AMPV)	Charlie Shivers III, Eli DeVan
	Common Infrared Countermeasure (CIRCM)	Jacqueline W. Wade, Carol Mebane
	Handheld, Manpack, and Small Form Fit Radios (HMS)	Scott M. Purdy, Jessica E. Karnis
	Improved Turbine Engine Program (ITEP)	Wendy P. Smythe, Jenna Blair
	Indirect Fire Protection Capability Increment 2 – Intercept, Block 1 (IFPC Inc 2-I Block 1)	Brian T. Smith, Zachary Sivo
	Integrated Air and Missile Defense (IAMD)	Julie C. Hadley, Erin L. Stockdale
	Joint Air-to-Ground Missile (JAGM)	Jessica M. Berkholtz, Jenny Shinn
	Long Range Precision Fires (LRPF)	Cale Jones, Billy Allbritton

	Program name	Primary staff
	M109A7 Family of Vehicles (M109A7 FOV)	Billy Allbritton, Cale Jones
	Patriot Advanced Capability-3 Missile Segment Enhancement (PAC-3 MSE)	Zachary Sivo, Tana M. Davis
Navy and Marine Corps programs	Air and Missile Defense Radar (AMDR)	Nathan Foster, Sean D. Merrill
	Amphibious Combat Vehicle (ACV 1.1)	Matthew M. Shaffer, Alexandra Jeszeck
	Amphibious Ship Replacement (LX(R))	Samuel Woo, Holly Williams
	CH-53K Heavy Lift Replacement Helicopter (CH-53K)	Victoria C. Klepacz, Lauren Wright
	CVN 78 Gerald R. Ford Class Nuclear Aircraft Carrier (CVN 78)	Burns C. Eckert, Lindsey Cross
	DDG 51 Arleigh Burke Class Destroyer, Flight III (DDG 51 Flight III)	Jillian C. Schofield, Laura M. Jezewski
	DDG 1000 Zumwalt Class Destroyer (DDG 1000)	Ramzi N. Nemo, Angie Nichols-Friedman , Luqman M. Abdullah
	Guided Missile Frigate FFG(X) (Guided Missile Frigate)	Sean D. Merrill, Jeff Hartnett
	Ground/Air Task Oriented Radar (G/ATOR)	Joe E. Hunter, Claire Li
	John Lewis Class Fleet Replenishment Oiler (T-AO 205)	Matthew Ambrose, Jocelyn C. Yin, Daniel M. Kuhn
	Joint Precision Approach and Landing System (JPALS)	Stephen V. Marchesani, Jennifer A. Dougherty
	LHA 6 America Class Amphibious Assault Ship (LHA 6)	Jeffrey L. Hartnett, Dennis A. Antonio
	Littoral Combat Ship (LCS)	Elisha T. Matvay, Jacob L. Beier, Brendan K. Orino
	Littoral Combat Ship - Mission Modules (LCS Packages)	Laurier R. Fish, Tonya Woodbury, Ruben G. Gzirian
	MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)	Erin L. Stockdale, Tonya Woodbury
	MQ-8 Fire Scout (MQ-8 Fire Scout)	James Kim, Raffaele Roffo
	MQ-25 Unmanned Aircraft System (MQ-25 Stingray)	Jillena Roberts, Robert Bullock
	Next Generation Jammer Mid-Band (NGJ Mid-Band)	Carmen Yeung, Laura T. Holliday
	Offensive Anti-Surface Warfare Increment 1 (OASuW Inc 1)	Thomas P. Twambly, Leslie C. Ashton, Sean T. Sannwaldt
	P8-A Poseidon Multi-Mission Maritime Aircraft Increment 3 (P-8A Inc. 3)	Heather B. Miller, Jocelyn C. Yin
	Ship to Shore Connector Amphibious Craft (SSC)	Teague A. Lyons, Gina M. Flacco
	SSBN 826 Columbia Class Ballistic Missile Submarine (SSBN 826)	Lindsey Cross, James Madar
	SSN 774 Virginia Class Submarine Block V (SSN 774 Block V)	Jenny Shinn, James Madar
	VH-92A Presidential Helicopter Replacement Program (VH-92A)	Bonita J. P. Oden, Ramzi N. Nemo
Air Force programs	Advanced Pilot Training (APT)	Marvin Bonner, Meghan Perez
	B-2 Defensive Management System Modernization (B-2 DMS-M)	Matthew B. Lea, Megan Setser
	B-2 Extremely High Frequency Satellite Communications (B-2 EHF SATCOM)	Matthew Metz, Mary C. Diop

	Program name	Primary staff
	Combat Rescue Helicopter (CRH)	Sean C. Seales, Matthew T. Drerup
	Evolved Expendable Launch Vehicle (EELV)	Erin R. Cohen, Laura D. Hook
	F-15 Eagle Passive Active Warning Survivability System (F-15 EPAWSS)	Matthew T. Drerup, LeAnna M. Parkey
	F-22 Increment 3.2B Modernization (F-22 Inc 3.2B Mod)	Nathaniel Vaught, Sean C. Seales
	Family of Advanced Beyond Line-of-Sight Terminals Command Post Terminals (FAB-T CPT)	Alexandra Dew Silva, Andrew H. Berglund
	Global Positioning System III (GPS III)	Jonathan Mulcare, Erin R. Cohen, William V. Lamping
	Global Positioning Satellite Next Generation Operational Control System (GPS OCX)	Patrick Breiding, Claire Buck, Alexandra D. Gebhard
	Ground Based Strategic Deterrence (GBSD)	Maricela Cherveny, Meredith Allen Kimmett
	KC-46A Tanker Modernization Program (KC-46A)	Katheryn S. Hubbell, Nathaniel Vaught, Adrienne Austin
	Joint Surveillance Target Attack Radar System Recapitalization (JSTARS Recap)	Sameena Ismailjee, J. Andrew Walker
	Military Global Positioning Satellite User Equipment Increment 1 (MGUE Increment 1)	Erin E. Carson, Claire Buck
	Small Diameter Bomb Increment II (SDB II)	Suzanne Sterling, John W. Crawford
	Space Fence Ground Based Radar System Increment 1 (Space Fence Inc 1)	Laura D. Hook, Mary C. Diop
	Three-Dimensional Expeditionary Long-Range Radar (3DELRR)	Claire Li, Joe E. Hunter, Colleen Taylor
	Utility Helicopter Replacement (UH-1N) Replacement	Jonathan Munetz, Cody Knudsen
	VC-25B Presidential Aircraft Recapitalization (VC-25B PAR)	LeAnna M. Parkey, Katherine M. Pfeiffer
	Weather System Follow-on - Microwave (WSF-M)	Brenna Derritt, Maricela Cherveny
Joint Department of Defense programs	F-35 Lightning II Joint Strike Fighter Program (F-35)	Desiree E. Cunningham, Jennifer K. Leone
	Joint Light Tactical Vehicle (JLTV)	Marcus C. Ferguson, Andrea C. Evans

Source: GAO. | GAO-18-360SP

Appendix IX: Accessible Data

Data Tables

Data for Figure 2: DOD's Major Defense Acquisition Program Portfolio's Gains and Losses between 2016 and 2017

Programs exiting the portfolio

- B-2 Extremely High Frequency SATCOM and Computer Increment 1 (B-2 EHF Inc 1)
- Excalibur Precision 155mm Projectiles (Excalibur)
- Remote Minehunting System (RMS)

Programs entering the portfolio

- Advanced Arresting Gear (AAG)
- Amphibious Combat Vehicle Phase 1 Increment 1 (ACV)
- B-2 Defensive Management System-Modernization (B-2 DMS-M)
- Common Infrared Countermeasure (CIRCM)
- F-15 Eagle Passive Active Warning Survivability System (F-15 EPAWSS)
- F/A-18E/F Infrared Search and Track (IRST)
- M88A2 Heavy Equipment Combat Utility Lift Evacuation System (M88A2 Hercules)
- Military Global Positioning System User Equipment Increment 1 (MGUE Inc 1)
- Next Generation Jammer Increment 1(NGJ)
- Offensive Anti-Surface Warfare Increment 1 (OASuW Inc 1)
- SSBN 826 Columbia Class Submarine (SSBN 826)

Data for Figure 3: DOD's Portfolio Cost and Size Have Increased Since 2016, but Remain within Historic Ranges

Fiscal year	Total acquisition cost (FY2018 dollars in billions)	Number of programs
2004	1571	80
2005	1606	90
2006	1698	88
2007	1736	94
2008	1718	95
2010	1752	97
2011	1746	95
2012	1579	85
2013	1594	80
2014	1500	78
2015	1485	79
2016	1494	78
2017	1658	86

Data for Figure 4: Between 2016 and 2017, 23 DOD Programs Experienced Total Acquisition Cost Increases or Decreases of Greater than 5 Percent

Percentage cost change interval (X-axis)	Number of programs in each percentage cost change interval	Amount of cost change in each percentage interval over the past year
<-25%	1	-$1.73
-25-20%	2	-$6.73
-20-15%	1	-$0.37
-15-10%	1	-$0.45
-10-5%	5	-$4.20
-5-0%	33	-$6.69
0-5%	30	$22.19
5-10%	5	$4.67
10-15%	4	$3.01
15-20%	2	$4.22
20-25%	0	$0.00
>25%	2	$40.73

Data for Figure 5: When Controlling for Quantity Changes, 16 DOD Programs Experienced Total Acquisition Cost Increases or Decreases of Greater than 5 Percent between 2016 and 2017

Percentage cost change interval (X-axis)	Number of programs in each percentage cost change interval	Amount of cost change in each percentage interval over the past year
<-25%	0	$0.00
-25-20%	1	-$0.36
-20-15%	0	$0.00
-15-10%	2	-$0.73
-10-5%	7	-$11.45
-5-0%	37	-$6.05
0-5%	33	$17.36
5-10%	1	$1.54
10-15%	2	$1.30
15-20%	2	$4.22
20-25%	0	$0.00
>25%	1	$1.13

Data for Figure 6: DOD's 2017 Portfolio Shows Changes in Funding Requirements and Sunk Costs that Indicate Programs Are Further Along in the Acquisition Process

Year	Procurement funding needed to complete the portfolio	Development funding needed to complete the portfolio	Total development and procurement funding invested in the portfolio
2007	846.7	98.3	-752.1
2008	755.6	79.3	-843
2010	689	52.8	-972.9
2011	712.8	58.3	-937.8
2012	656	45.2	-836.8
2013	671.1	38.3	-870.3
2014	629.8	33.8	-823.1
2015	589.2	33	-848.7
2016	556.8	28.1	-895.6
2017	654.9	38.4	-950.5

Data for Figure 7: DOD's 2017 Portfolio Reflects a Decline in Performance against 1- and 5-Year Cost Growth Metrics, but Demonstrates Improvement in Meeting the Metric for Cost Growth since First Full Estimate

	Year	Percentage of programs that meet the cost growth metric	Percentage of programs that do not meet the cost growth metric
1-year comparison (<2% growth)	2012	85	15
	2013	76	24
	2014	69	31
	2015	76	24
	2016	72	28
	2017	66	34
5-year comparison (<10% growth)	2012	56	44
	2013	55	45
	2014	0	0
	2015	72	28
	2016	78	22
	2017	72	28
First full estimate comparison (<15% growth)	2012	48	52
	2013	44	56
	2014	44	56
	2015	47	53
	2016	46	54
	2017	52	48

Data for Figure 8: Programs in DOD's 2017 Portfolio Incurred Most of Their Cost Growth after Production Start

Phase	Fiscal year 2018 dollars (in billions)
Production start to end of production	272.06
Critical design review to production start	124.90
Development start to critical design review	74.03

Data for Figure 9: Over 85 Percent of the 2017 Portfolio's Estimated Total Acquisition Cost Is for 61 Programs That DOD Initiated Prior to 2010

- $247 billion, 14.9% of the total acquisition cost is for 25 Post-2010 programs
- $355 billion, 21.4% of the total acquisition cost is for the F-35 program
- $1056 billion, 63.7% of the total acquisition cost is for 60 Pre-2010 programs

Data for Figure 10: Programs Initiated since 2010 Show Fewer Significant Year-to-Year Cost Changes as Compared to the Programs Initiated Prior to 2010

Percentage cost change interval (X-axis)	Number of Post-WSARA programs in each percentage cost change interval	Number of Pre-WSARA programs in each percentage cost change interval	Amount of cost change for Post-WSARA programs in each percentage interval over the past year	Amount of cost change for Pre-WSARA programs in each percentage interval over the past year
<-25%	1	0	(1.73)	--
-25-20%	1	1	(0.36)	(6.37)
-20-15%	1	0	(0.37)	--
-15-10%	1	0	(0.45)	--
-10-5%	3	2	(3.52)	(0.68)
-5-0%	8	25	(1.35)	(5.34)
0-5%	8	22	0.51	$21.68
5-10%	1	4	0.51	4.16
10-15%	0	4	--	3.01
15-20%	0	2	--	4.22
20-25%	0	0	--	--
>25%	1	1	1.13	39.60

Data for Figure 11: When Controlling for Quantity Changes, the Programs Initiated since 2010 Incurred an Overall Cost Decrease while Programs Initiated Prior to 2010 Experienced an Overall Cost Increase

Percentage cost change interval (X-axis)	Number of Post-2010 programs in each percentage cost change interval	Number of Pre-2010 programs in each percentage cost change interval	Amount of cost change for Post-2010 programs in each percentage interval over the past year	Amount of cost change for Pre-2010 programs in each percentage interval over the past year
<-25%	0	0	--	--
-25-20%	1	0	(0.36)	--
-20-15%	0	0	--	--
-15-10%	1	1	(0.45)	(0.28)
-10-5%	4	3	(3.74)	(7.70)
-5-0%	9	28	(1.53)	(4.52)
0-5%	9	24	0.71	16.65
5-10%	0	1	--	1.54
10-15%	0	2	--	1.30
15-20%	0	2	--	4.22
20-25%	0	0	--	--
>25%	1	0	1.13	--

Data for Figure 12: Programs in DOD's 2017 Portfolio Initiated since 2010 Incurred Their Cost Growth before Critical Design Review, while Programs Initiated Prior to 2010 Incurred Most of Their Cost Growth after Production

	Post-2010 Programs(25), Fiscal year 2018 dollars (in billions)	Pre-2010 Programs (61), Fiscal year 2018 dollars (in billions)
Production start to end of production	-2389	274.45
Critical design review to production start	-3464	128.36
Development start to critical design review	268	73.76

Data for Figure 13: Actions Programs Reported They Have Taken to Achieve "Should-Cost" Savings

Program Actions Resulting in Should Cost Savings	Percent
Eliminating Unproductive or Non-Value Added Processes	1.4
More Efficient Developmental and Operational Test Planning	1.5
Better Management of the Supply Chain Vendors	4.5
Design Tradeoffs to Balance Cost and Capability	19.2
Other Program Office Actions	24.4
Better Contract Negotiations with Contractors	24.5
Savings from Multi-Year or Block Buys vs. Annual Procurements	24.5

Data for Figure 14: Eighteen Current Programs Completed, or Plan to Complete, Software Development after Production Start

Not applicable/To be determined	10
Before start of production	17
Before operational test	9
During operational test	3
After operational test before initial operational capability or full rate production	3
After initial operational capability or full rate production	3

Data for Figure 15: Sixteen Programs Declared or Plan to Declare Initial Operational Capability before Completing Initial Operational Test and Evaluation

Initial Operational Capability Declared	Count
Not applicable	6
Before Testing	5
During Testing	11
After Testing	23

Agency Comments

Appendix VII: Comments from the Department of Defense

Ms. Shelby S. Oakley

Director, Acquisition and Sourcing Management

U.S. Government Accountability Office 441 G St NW

Washington, DC 20548 Dear Ms. Oakley,

April 9, 2018

This is the Department of Defense (DoD) response to the Government Accountability Office (GAO) Draft Report, GAO-18-360SP, "Defense Weapon Systems: Programs Initiated after Acquisition Reforms Show Imp roved Performance, but Knowledge Shortfalls Persist" dated April 3, 2018 (GAO Code 102042).

The Department is pleased GAO findings show measurable improvement s to the DoD Acquisition System as a result of major reform initiatives stai1ed in 2010 and continuing in the current Administration. The Department remains committed to driving down the costs of our weapon systems and reducing the time it takes to deliver them to our Warfighters. The separation of the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics into the Office of the Under Secretary of Defense for Acquisition and Sustainment and the Office of the Under Secretary of Defense for Research and Engineering presents the next major shift in how the Department develops and procures weapon systems.

This report documents that the Department continues to show improved cost performance while expanding the total acquisition portfolio size and cost. That is an encouraging finding as the Department makes a strategic turn to increase investment in our technology edge over our adversaries.

The Depa11ment appreciates the opportunity to comment on the Draft Report. My point of contact for this effort is LCDR Jake Ferrari at 703-697-8020.

Sincerely,

Nancy L. Spruill Director

Acquisition Resources and Analysis

Related GAO Products

Columbia Class Submarine: Immature Technologies Present Risks to Achieving Cost, Schedule, and Performance Goals. GAO-18-158. Washington D.C.: December 21, 2017

Global Positioning System: Better Planning and Coordination Needed to Improve Prospects for Fielding Modernized Capability. GAO-18-74. Washington D.C.: December 12, 2017

Weapon Systems: Prototyping Has Benefited Acquisition Programs, but More Can Be Done to Support Innovation Initiatives. GAO-17-309. Washington D.C.: June 27, 2017

Ford-Class Aircraft Carrier: Follow-On Ships Need More Frequent and Accurate Cost Estimates to Avoid Pitfalls of Lead Ship. GAO-17-575. Washington D.C.: June 13, 2017

F-35 Joint Strike Fighter: DOD Needs to Complete Developmental Testing Before Making Significant New Investments. GAO-17-351. Washington, D.C.: April 24, 2017

Defense Acquisitions: Assessments of Selected Weapon Programs. GAO-17-333SP. Washington, D.C.: March 30, 2017.

KC-46 Tanker Modernization: Delivery of First Fully Capable Aircraft Has Been Delayed over One Year and Additional Delays Are Possible. GAO-17-370. Washington D.C.: March 24, 2017

High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others. GAO-17-317. Washington, D.C.: February 15, 2017.

Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects. GAO-16-410G. Washington D.C. August, 2016.

Littoral Combat Ship and Frigate: Slowing Planned Frigate Acquisition Would Enable Better-Informed Decisions. GAO-17-279T. Washington, D.C.: December 8, 2016.

Weapon System Requirements: Detailed Systems Engineering Prior to Product Development Positions Programs for Success. GAO-17-77. Washington, D.C.: November 17, 2016.

Federal Subcontracting: Linking Small Business Subcontractors to Prime Contracts Is Not Feasible Using Current Systems. GAO-15-116. Washington, D.C.: December 11, 2014.

National Defense: Department of Defense's Waiver of Competitive Prototyping Requirement for the Navy's Fleet Replenishment Oiler Program. GAO-15-57R. Washington, D.C.: October 8, 2014.

Best Practices: DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed. GAO-10-439. Washington, D.C.: April 22, 2010.

Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding. GAO-09-322. Washington, D.C.: May 13, 2009.

Defense Acquisitions: A Knowledge-Based Funding Approach Could Improve Major Weapon System Program Outcomes. GAO-08-619. Washington, D.C.: July 2, 2008.

Defense Acquisitions: Stronger Management Practices are Needed to Improve DOD's Software-Intensive Weapon Acquisitions. GAO-04-393. Washington, D.C.: March 1, 2004.

Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes. GAO-02-701. Washington, D.C.: July 15, 2002.

Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes. GAO-01-288. Washington, D.C.: March 8, 2001.

Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes. GAO/NSIAD-99-162. Washington, D.C.: July 30, 1999.

GAO's Mission

The Government Accountability Office, the audit, evaluation, and investigative arm of Congress, exists to support Congress in meeting its constitutional responsibilities and to help improve the performance and accountability of the federal government for the American people. GAO examines the use of public funds; evaluates federal programs and policies; and provides analyses, recommendations, and other assistance to help Congress make informed oversight, policy, and funding decisions. GAO's commitment to good government is reflected in its core values of accountability, integrity, and reliability.

Obtaining Copies of GAO Reports and Testimony

The fastest and easiest way to obtain copies of GAO documents at no cost is through GAO's website (https://www.gao.gov). Each weekday afternoon, GAO posts on its website newly released reports, testimony, and correspondence. To have GAO e-mail you a list of newly posted products, go to https://www.gao.gov and select "E-mail Updates."

Order by Phone

The price of each GAO publication reflects GAO's actual cost of production and distribution and depends on the number of pages in the publication and whether the publication is printed in color or black and white. Pricing and ordering information is posted on GAO's website, https://www.gao.gov/ordering.htm.

Place orders by calling (202) 512-6000, toll free (866) 801-7077, or TDD (202) 512-2537.

Orders may be paid for using American Express, Discover Card, MasterCard, Visa, check, or money order. Call for additional information.

Connect with GAO

Connect with GAO on Facebook, Flickr, Twitter, and YouTube. Subscribe to our RSS Feeds or E-mail Updates. Listen to our Podcasts. Visit GAO on the web at https://www.gao.gov.

To Report Fraud, Waste, and Abuse in Federal Programs

Contact:

Website: https://www.gao.gov/fraudnet/fraudnet.htm

Automated answering system: (800) 424-5454 or (202) 512-7470

Congressional Relations

Orice Williams Brown, Managing Director, WilliamsO@gao.gov, (202) 512-4400,
U.S. Government Accountability Office, 441 G Street NW, Room 7125,
Washington, DC 20548

Public Affairs

Chuck Young, Managing Director, youngc1@gao.gov, (202) 512-4800
U.S. Government Accountability Office, 441 G Street NW, Room 7149
Washington, DC 20548

Strategic Planning and External Liaison

James-Christian Blockwood, Managing Director, spel@gao.gov, (202) 512-4707
U.S. Government Accountability Office, 441 G Street NW, Room 7814,
Washington, DC 20548