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Defense Science and Technology Funding

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Summary

Defense science and technology (Defense S&T) is a term that describes a subset of Department of Defense (DOD) research, development, testing, and evaluation (RDT&E) activities. The Defense S&T budget is the aggregate of funding provided for the three earliest stages of DOD RDT&E: basic research, applied research, and advanced technology development. Defense S&T is of particular interest to Congress due to its perceived value in supporting technological advantage and its importance to key private sector and academic stakeholders.

Advocates of strong and sustained Defense S&T funding assert that Defense S&T funding plays important and unique roles in the DOD innovation system, supporting medium-term, evolutionary technologies and incremental innovation that help improve existing products and systems, as well as longer-term, revolutionary technologies providing U.S. technological dominance, deterring conflict, and, when necessary, defeating adversaries. Both evolutionary and revolutionary technologies are viewed by most warfighters and policymakers as central to U.S. national security as well as to the lives of those serving in uniform.

In FY2017, Defense S&T was $13.4 billion, nearly six times the FY1978 level of $2.3 billion. Most growth occurred from FY1978 to FY2006, at a compound annual growth rate (CAGR) of 6.4%. From FY2006 to FY2017, growth was slower (0.1% CAGR). Most of the growth and volatility was in advanced technology development. In FY2017 constant dollars, Defense S&T funding peaked at $16.2 billion in FY2005 and declined by $2.8 billion through FY2017.

In FY2016, basic research accounted for $2.2 billion of the Defense S&T total. The Navy accounted for the largest share of DOD basic research (29.2%), followed by the Defense-Wide agencies (27.6%), Air Force (23.0%), and Army (20.3%). Universities and colleges performed nearly half ($1.1 billion, 48.8%) of DOD basic research in FY2016; DOD and other intramural federal laboratories performed 22.9%; industry, 18.2%; other nonprofits, 7.5%; federally funded research and development centers (FFRDCs), 0.7%; and others, 2.0%.

A number of recommendations have been put forth by various organizations regarding the appropriate level of funding for Defense S&T and DOD basic research, as well as the level of funding for investments in research supporting potentially revolutionary advancements.

A 1998 Defense Science Board (DSB) report recommended setting Defense S&T at 3.4% of total DOD funding. In 2001, the Quadrennial Defense Review recommended that 3.0% of total DOD funding be directed toward Defense S&T. In FY1996, Defense S&T was at the 3.0% level. It subsequently fell to 1.7% in FY2011 and has since risen to 2.2%. An alternative approach recommended by the DSB in 1998 was to set Defense S&T at a percentage of DOD RDT&E, similar to the industry ratio of research funding to total R&D funding (which it calculated for the pharmaceutical industry as 24%). In 2015, the Coalition for National Security Research (CNSR), a coalition of industry, universities, and associations, recommended a target of 20%. At the time of the DSB report, S&T's share of DOD RDT&E was approximately 21%. After rising to 21.5% in FY2000, Defense S&T's share fell to 15.2% in FY2011, and then rose to 17.9% in FY2016.

With respect to DOD basic research, the Council on Competitiveness (2004) and the CNSR (2015) recommended a target of at least 20% of Defense S&T. As a share of Defense S&T, basic research declined from 14.6% in FY1996 to 11.0% in FY2006, then began a steady rise to 18.4% in FY2015. In FY2016, basic research's share of Defense S&T was 17.4%. In its 1998 report, the DSB recommended that one-third of Defense S&T be devoted to research targeted toward revolutionary technological advancements. The Defense Advanced Research Projects Agency (DARPA) has been the lead DOD agency focused on revolutionary R&D. In FY2017, DARPA accounted for 21.6% of Defense S&T.

Contents

Figures

Tables

Contacts

This report provides an overview of the portion of Department of Defense (DOD) research, development, testing, and evaluation (RDT&E) funding referred to as Defense Science and Technology (Defense S&T). It provides perspectives on the role of Defense S&T in supporting U.S. defense capabilities, historical funding levels, recent funding trends, and approaches to determining how much the federal government should invest in Defense S&T, particularly in basic research.[1]

What Is Defense Science and Technology?

Congress provides appropriations to DOD for RDT&E activities conducted in support of its mission requirements. DOD's *Financial Management Regulation* (DOD 7000.14-R) provides a taxonomy for requesting, tracking, and accounting for federal investments in RDT&E based on the character of work performed. DOD budget justifications and congressional appropriations reports and explanatory statements typically employ this taxonomy, which consists of seven budget activity codes (6.1 through 6.7) and a description (as shown in **Table 1**).[2]

Table 1. DOD RDT&E Budget Activity Codes and Descriptions

Budget Activity Code	Description
6.1	Basic Research
6.2	Applied Research
6.3	Advanced Technology Development
6.4	Advanced Component Development and Prototypes
6.5	System Development and Demonstration
6.6	RDT&E Management Support
6.7	Operational Systems Development

Source: Department of Defense, *Financial Management Regulation (DOD 7000.14-R),* Volume 2B, March 2016, http://comptroller.defense.gov/fmr.aspx.

Defense Science and Technology is a subset of DOD RDT&E appropriations that includes funding for basic research (6.1), applied research (6.2), and advanced technology development (6.3)—the earliest stages of the RDT&E process.

[1] Issues related to overall DOD RDT&E are addressed in CRS Report R44711, *Department of Defense Research, Development, Test, and Evaluation (RDT&E): Appropriations Structure*, by (name redacted) , CRS In Focus IF10553, *Defense Primer: RDT&E,* by (name redacted) , and CRS Report R45088, *Defense Advanced Research Projects Agency: Overview and Issues for Congress*, by (name redacted) This report addresses issues specifically related to Defense S&T and basic research.

[2] DOD RDT&E appropriations acts typically do not include this taxonomy, instead making appropriations to the Defense-Wide, Army. Navy, Air Force, and other accounts; these appropriations support specific program elements associated with the budget activity codes. For example, funding for Army RDT&E is provided in Title IV (Research, Development, Test, and Evaluation), Research, Development, Test, and Evaluation, Army. Appropriations Committee, and conference reports, as well as explanatory statements, generally provide more detailed guidance for the use of these funds. For example, within the Army RDT&E appropriation of $8.3 billion, the 2017 explanatory statement identifies specific program elements and Congress' intended funding levels (e.g., In-House Laboratory Independent Research (program element 0601101A, a part of Army basic research, budget activity code 1), $12.4 million).

DOD defines these budget activities in the following manner:

> Basic research [Budget Activity Code 6.1] is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind. It includes all scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs. It is farsighted high payoff research that provides the basis for technological progress. Basic research may lead to: (a) subsequent applied research and advanced technology developments in Defense-related technologies, and (b) new and improved military functional capabilities in areas such as communications, detection, tracking, surveillance, propulsion, mobility, guidance and control, navigation, energy conversion, materials and structures, and personnel support.
>
> Applied research [Budget Activity Code 6.2] is systematic study to understand the means to meet a recognized and specific need. It is a systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods. It may be oriented, ultimately, toward the design, development, and improvement of prototypes and new processes to meet general mission area requirements. Applied research may translate promising basic research into solutions for broadly defined military needs, short of system development. This type of effort may vary from systematic mission-directed research beyond that in Budget Activity 1 [basic research] to sophisticated breadboard hardware, study, programming and planning efforts that establish the initial feasibility and practicality of proposed solutions to technological challenges. It includes studies, investigations, and non-system specific technology efforts. The dominant characteristic is that applied research is directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters. Applied research precedes system specific technology investigations or development.
>
> Advanced Technology Development, [Budget Activity Code 6.3] includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment. Budget Activity 3 includes concept and technology demonstrations of components and subsystems or system models. The models may be form, fit, and function prototypes or scaled models that serve the same demonstration purpose. The results of this type of effort are proof of technological feasibility and assessment of subsystem and component operability and producibility rather than the development of hardware for service use. Projects in this category have a direct relevance to identified military needs. Advanced Technology Development demonstrates the general military utility or cost reduction potential of technology when applied to different types of military equipment or techniques….Projects in this category do not necessarily lead to subsequent development or procurement phases, but should have the goal of moving out of Science and Technology (S&T) and into the acquisition process within the Future Years Defense Program (FYDP). Upon successful completion of projects that have military utility, the technology should be available for transition.[3]

Perspectives on the Roles and Value of Defense S&T

Defense S&T is of particular interest and importance to Congress due to its perceived value in supporting military competitive advantage. Defense S&T is also of interest to key stakeholders in the private sector and academia. For example, advocates of strong and sustained Defense S&T

[3] Department of Defense, *Financial Management Regulation (DoD 7000.14-R)*, Volume 2B, March 2016.

funding assert that this funding plays important and unique roles in the DOD innovation system. The scientific and technological insights that emerge from Defense S&T funding—often referred to as the nation's "seed corn"—are seen by many as the critical body of knowledge available to DOD and the industrial base for future defense technology development.[4] Defense S&T supports both

- **medium-term, evolutionary technologies and incremental innovations** to help improve existing products and systems; and
- **longer-term, revolutionary technologies** to support U.S. technological dominance, deter conflict, and defeat adversaries.

These technologies—both evolutionary and revolutionary—are seen by most warfighters and policymakers as central to U.S. national security as well as to the lives of those serving in uniform in the medium and long term.

In contrast, most of the balance of DOD RDT&E is focused on near-term applications. Budget activity 6.4, Advanced Component Development and Prototypes, efforts are directed toward the evaluation of integrated technologies and prototype systems in realistic operating environments, not just in controlled laboratory environments. Funding in this budget activity seeks to expedite technology transition from the laboratory to operational use. Budget activity 6.5, System Development and Demonstration, is engineering and manufacturing development tasks aimed at meeting validated requirements prior to full-rate production. At this stage, prototype performance is near or at planned operational system levels. Budget activity 6.7, Operational Systems Development, is focused on development efforts to upgrade systems that have been fielded or have received approval for full rate production and anticipate production funding in the current or subsequent fiscal year. Budget activity 6.6, RDT&E Management Support, includes management support for RDT&E efforts and funds to sustain and/or modernize the installations required for general research. Accordingly, BA 6.6 funding supports RDT&E activities in each of the other budget activities.[5]

From FY2007 to FY2017, Defense S&T averaged 17.1%, approximately one-sixth, of total Defense RDT&E (ranging from 15% to 19% during these years). Historical funding levels and recent trends are discussed in more detail in the following section of this report.

According to the National Academies' 2007 report *Rising Above the Gathering Storm*:

> Keeping a technological edge over adversaries of the United States has long been a key component of our national security strategy. US preeminence in science and technology is considered essential to achieving that goal.[6]

The report further emphasizes the importance of DOD basic research, asserting that

> The importance of DOD basic research is illustrated by its products—in defense areas these include night vision; stealth technology; near-real-time delivery of battlefield

[4] Seed corn refers to the high-quality kernels of corn (and other crops) used as seeds for growing future crops. Thus, seed corn has been essential to maintaining agricultural output. The term is used metaphorically to refer to an asset or investment that is expected to provide future returns.

[5] Department of Defense, *Financial Management Regulation (DoD 7000.14-R)*, Volume 2B, March 2016.

[6] National Academies, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, 2007, p. 483.

> information; navigation, communication, and weather satellites; and precision munitions.[7]

DOD investments in basic research are also considered vital to maintaining university research, the education of scientists and engineers, and the preservation of teaching capacity in key scientific and engineering fields. Proponents of these investments assert that it is essential to ensure steady funding to these fields to ensure stability for professors, researchers, and academic programs. Uneven funding patterns, some assert, can create uncertainty (in positions, salary, equipment, and programs, for example) that may drive out some of the best scientists and engineers and discourage the most capable students from pursuing degrees and research in these disciplines, resulting in adverse impacts on future innovation in fields key to national security.

Some analysts express concern that, in times of tightly constrained budgets, Defense S&T may be an easy target for budget cuts. Cuts to Defense S&T might produce few short-term consequences to national defense, as the benefits of these investments tend to be realized in the medium to long term. However, the neglect of these earlier-stage research and development activities could have serious medium- and long-term consequences, depriving the U.S. defense sector of the critical underpinnings necessary for maintaining technological superiority and global dominance in the future.[8]

Former Under Secretary of Defense for Acquisition, Technology and Logistics Frank Kendall noted the following:

> R&D is not a variable cost. R&D drives our rate of modernization. It has nothing to do with the size of the force structure. So, when you cut R&D, you are cutting your ability to modernize on a certain time scale, period—no matter how big your force structure is ... [T]he investments we're making now in technology are going to give us the forces that we're going to have in the future. The forces we have now came out of investments that were made, to some extent, in the 80s and 90s…if you give up the time it takes for lead time to get…a capability, you are not going to get that back.[9]

Alan R. Shaffer, Principal Deputy, Assistant Secretary of Defense for Defense Research and Engineering, underscored this point, stating the following:

> If we don't do the research and development for a new system then the number of systems of that type we will have is zero. It is not variable.[10]

Such cuts may also result in lasting damage to important segments of the U.S. R&D infrastructure—researchers, professors, academic programs, student interest, equipment, infrastructure, etc.—in defense-critical fields, even if funding were to be later restored. Such effects could not only diminish U.S. innovative capacity, but result in the transfer of knowledge

[7] Ibid, p. 140. The report also asserts the importance of Defense basic research for its contribution to nondefense applications, stating "The Internet, communications and weather satellites, global positioning technology, the standards that became JPEG, and even the search technologies used by Google all had origins in DOD basic research" and asserts that these investments are "the primary reason that the United States leads the world today in information technology."

[8] See, for example, Aviation Week and Space Technology, "Budget Cuts to Future Weapons Could Have Long-Term Impact," April 3, 2015, http://aviationweek.com/technology/budget-cuts-future-weapons-could-have-long-term-impact.

[9] Honorable Frank Kendall, Under Secretary of Defense for Acquisition, Technology and Logistics, presentation to McAleese/Credit Suisse FY 2015 Defense Programs Conference, February 25, 2014, as cited in testimony of Alan R. Shaffer, Principal Deputy, Assistant Secretary of Defense for Defense Research and Engineering, before the Senate Armed Services Committee, Subcommittee on Emerging Threats and Capabilities, April 8, 2014.

[10] Testimony of Alan R. Shaffer, Principal Deputy, Assistant Secretary of Defense for Defense Research and Engineering, before the Senate Armed Services Committee, Subcommittee on Emerging Threats and Capabilities, April 8, 2014.

and loss of people, capabilities, and leadership to other nations. According to a 2012 Defense Science Board report on DOD basic research

> The DOD basic research program has supported a large fraction of revolutionary research in the physical sciences. Without DOD support, these U.S.-based research communities would find it more difficult to expand knowledge, collaborate, publish, and meet. Without adequate U.S. support, these centers of knowledge will drift to other countries.[11]

While there is little direct opposition to Defense S&T spending in its own right, there is intense competition for available dollars in the appropriations process. This competition has been made more acute under congressionally enacted budget control provisions.[12] Congressional acts establish and provide enforcement mechanisms for separate spending caps for defense and nondefense spending. These independent budget caps essentially fence off certain funds from being used for defense purposes by those who would prioritize such defense spending over certain nondefense activities. Increases in the defense and nondefense budget caps for FY2018 and FY2019 included in the Bipartisan Budget Act of 2018 (P.L. 115-123) may ease the resource competition in these fiscal years, but not eliminate it. With the spending caps has come greater competition for available dollars within the defense portion of the budget (for example, between RDT&E and procurement), and among the various RDT&E budget activities and program elements (for example, between Defense S&T and the rest of the defense RDT&E budget activities). With members of the U.S. Armed Forces currently engaged in combat and others facing potentially imminent threats in other locations around the world, some may believe it is appropriate to prioritize defense spending to support immediate operational needs and contingency preparations of the military over activities whose payoff is likely to be realized only in the longer term.

In addition, some have questioned the effectiveness of defense investments in R&D. For example, a 2012 article published by the Center for American Progress (CAP), a public policy research and advocacy organization, notes that the technological superiority of the United States did not initially provide an effective defense for U.S. troops against low-tech improvised explosive devices (IEDs) in Iraq and Afghanistan. The article also asserts that many high-priced major weapons systems—such as President Reagan's missile defense program—have failed to deliver on their promised capabilities due to scientific and engineering shortcomings. Further, the article notes that commercial technology development is now outstripping defense technology due to the "strength of capitalism"—including large markets, consumer demand, and competitive challenges—suggesting the potential benefits of pursuing a technology acquisition strategy based more heavily on off-the-shelf technologies or the repurposing of those technologies to meet defense needs. The article treats basic research less harshly than other Defense RDT&E activities, which CAP describes as "the kind of boondoggle R&D spending the Pentagon engages in at the applied and developmental level."[13]

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[11] Department of Defense, Defense Science Board, *Report of the Defense Science Board Report on Basic Research,* January 2012, p. 9, https://www.acq.osd.mil/dsb/reports/2010s/BasicResearch.pdf.

[12] See, for example, the Budget Control Act of 2011 (BCA, P.L. 112-25), American Taxpayer Relief Act of 2012 (P.L. 112-240), and the Bipartisan Budget Act of 2013 (P.L. 113-67), Bipartisan Budget Act of 2015 (P.L. 114-74). For more information on the BCA and the federal budget, see CRS Report R42506, *The Budget Control Act of 2011 as Amended: Budgetary Effects*, by (name redacted) an d (name redacted)

[13] Eric Altman, Senior Fellow, *Is Defense R&D Spending Effective?*, Center for American Progress, January 13, 2012, https://www.americanprogress.org/issues/general/news/2012/01/13/11001/think-again-is-defense-rd-spending-effective.

Historical Defense S&T Funding and Recent Trends

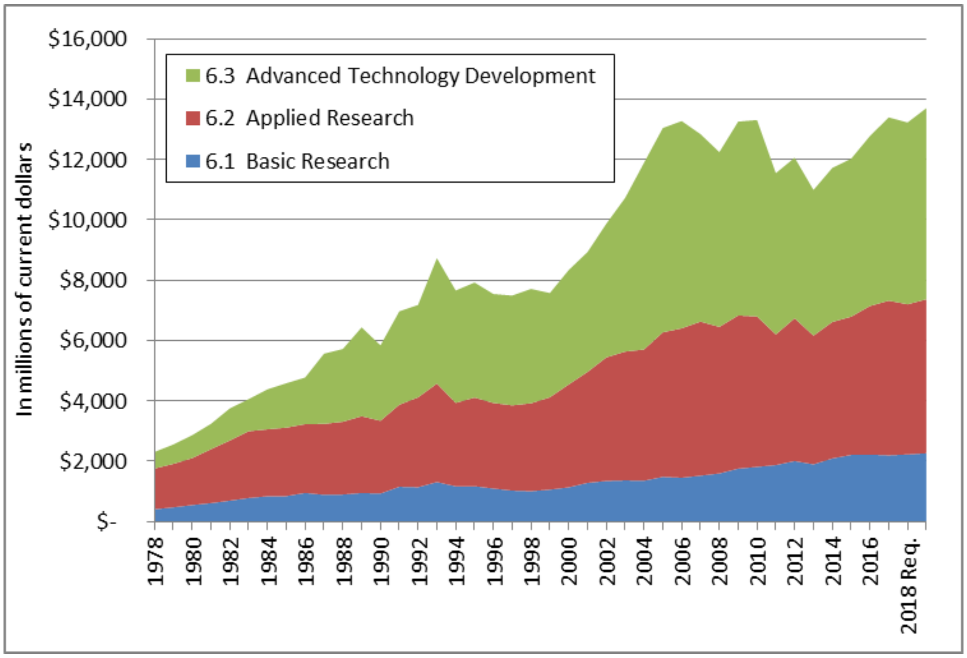
Defense S&T has grown substantially in current dollars (unadjusted for changes in buying power) over the past four decades, from $2.3 billion in FY1978 to $13.4 billion in FY2017.[14] This growth is illustrated in **Figure 1**, which shows this growth by its component budget activities. During the FY1978-FY2017 period, Defense S&T grew at a compound annual growth rate (CAGR) of 4.6%. Most of this growth occurred between FY1978 and FY2006 (6.4% CAGR); from FY2006 to FY2017 Defense S&T grew at a pace of 0.1% CAGR, though the period was punctuated by periods of growth and contraction. The funding trends for each of the component budget activities (6.1-6.3) during the FY1978-FY2017 period were different.

- **Basic research** (6.1) funding grew at 4.4% CAGR from FY1978 to FY2017, approximately the same pace as overall Defense S&T funding (4.7% CAGR), but the growth was steadier, with fewer periods of substantial decrease.
- **Applied research** (6.2) funding grew steadily from FY1978 to FY2017, in general, but at a slightly slower rate (3.5% CAGR) than overall Defense S&T and basic research funding. Similar to overall Defense S&T, most of the growth in applied research occurred between FY1978 and FY2006 (4.8% CAGR); from FY2006 to FY2017 applied research grew at a slower pace of 0.3% CAGR.
- **Advanced technology development** (6.3) funding experienced periods of growth and decline from FY1978 to FY2017. From FY1978 to FY1993, advanced technology development grew at a rate of 14.4% CAGR. From FY1993 to FY1999, funding declined at a rate of 3.0% CAGR. Funding grew at a rate of 10.3% CAGR from FY1999 to FY2006, and then fell again from FY2006 to FY2013 at a rate of 4.9% CAGR. Most recently, funding for advanced technology development has grown at a rate of 5.9% CAGR from FY2013 to FY2017.

[14] FY2018 and FY2019 request levels are included in several of the charts in this section for reader reference, but are not discussed in the analyses.

Figure 1. Defense S&T Funding, by Budget Activity, FY1978-FY2019

In millions of current dollars



Source: CRS analysis of data from Department of Defense, *Research, Development, Test, and Evaluation Programs (R-1)* for FY1978-2019. CRS used funding levels from two years before the request year. For example, the FY2017 funding levels are from the FY2019 R-1. FY2018 and FY2019 data are request levels from the FY2018 R-1 and FY2019 R-1, respectively.

Notes: FY1978-FY2017 (actual), FY2018 (request), FY2019 (request). Req.=Request

Figure 2 illustrates Defense S&T by budget activity in constant FY2017 dollars.[15] This figure provides an illustration of Defense S&T funding levels from FY1978 to FY2017 in terms of the purchasing power of these funds.[16]

Defense S&T grew by nearly 90% in constant dollars between FY1978 and FY2017. Despite the increase, there were periods of decline. Between FY1993 and FY1999, funding decreased at a rate of 4.0% CAGR. Funding rebounded between FY1999 and FY2005 (when Defense S&T funding reached its peak in constant dollars for the FY1978-FY2017 period), growing by 7.1% CAGR. This growth period was followed by another period of decline through FY2013 (4.0% CAGR). From FY2013 to FY2017, Defense S&T grew at a rate of 3.5% CAGR.

- **Basic research** funding grew, with some ups and downs, at a rate of 1.4% CAGR, during the FY1978-FY2017 period. From FY1993 to FY1998, funding fell by nearly 30%, then recovered, surpassing its FY1993 level in FY2012. Funding then rose an additional 1.4% between FY2012 and FY2017.
- **Applied research** funding was essentially flat through FY1998, then grew steadily through FY2005 (5.1% CAGR) and remained flat again through

[15] As calculated using the GDP (Chained) Price Index from Table 10.1 of the Historical Tables in the President's Budget for Fiscal Year 2019, to adjust for inflation; this index is used by the Office of Management and Budget to convert federal research and development outlays from current dollars to constant dollars. https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/hist10z1.xls.

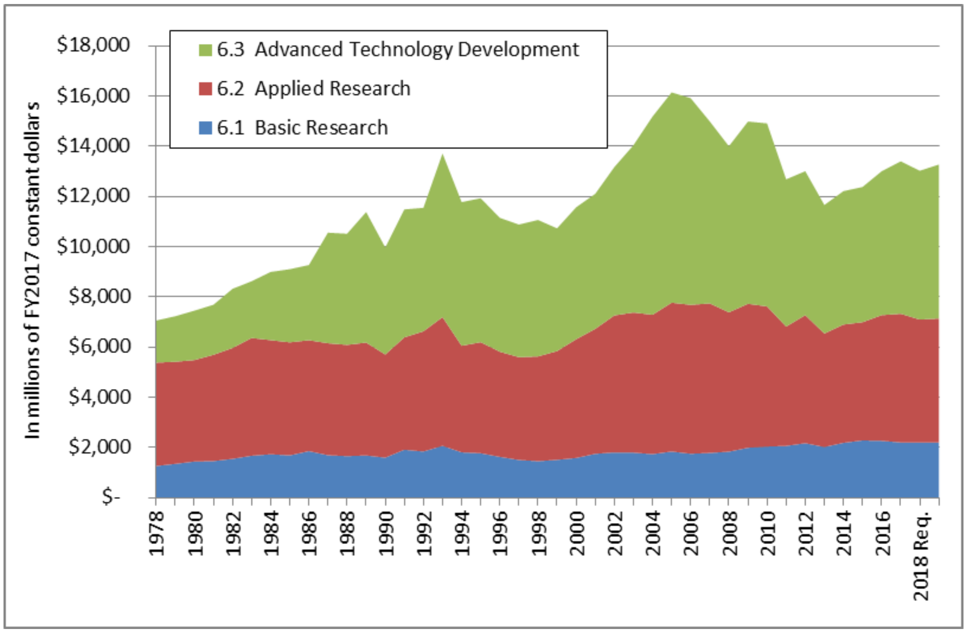
[16] The President's FY2018 and FY2019 request levels are also included in this figure for reference.

FY2007. Funding fell by 24% from FY2007 to FY2013, declining at a rate of 4.5% CAGR. Funding recovered between FY2013 and FY2017, rising by 13.4%, at a rate of 3.2% CAGR.

- The largest swings in Defense S&T resulted from changes in the **advanced technology development** funding component. Advanced technology development funding nearly quadrupled in constant dollars from FY1978 to FY1993. From FY1993 through FY1999, it fell by 25%, before rising again to its constant dollar peak in FY2005. Between FY2005 and FY2013, advanced technology development fell by 39%, and then recovered somewhat between FY2013 and FY2017 (up 19%).

Figure 2. Defense S&T Funding, by Budget Activity, FY1978-FY2019

In millions of constant FY2017 dollars



Source: CRS analysis of data from Department of Defense, *Research, Development, Test, and Evaluation Programs (R-1)* for FY1978-2019. CRS used funding levels from two years before the request year. For example, the FY2017 funding levels are from the FY2019 R-1. FY2018 and FY2019 data are request levels from the FY2018 R-1 and FY2019 R-1, respectively.

Notes: FY1978-FY2017 (actual), FY2018 (request), FY2019 (request). For purposes of this chart, CRS used the GDP (Chained) Price Index from Table 10.1 of the Historical Tables in the President's Budget for Fiscal Year 2019, to adjust for inflation; this index is used by the Office of Management and Budget to convert federal research and development outlays from current dollars to constant dollars. https://www.whitehouse.gov/wp-content/uploads/2018/02/hist10z1-fy2019.xlsx.
Req.=Request

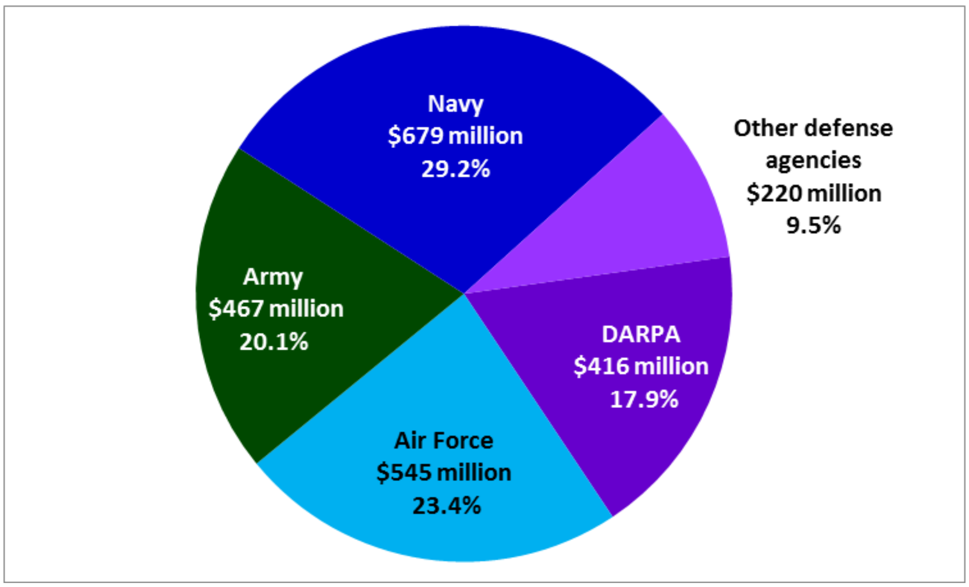
DOD Basic Research Funding

In FY2016, DOD spent an estimated $2.3 billion on basic research. The following sections describe the composition of DOD basic research funding by organizational component and the composition of performers of the research by organizational component.[17]

DOD Basic Research Funding by Organizational Component

The Department of Defense funds basic research activities through the Army, Navy, Air Force, and Defense-Wide (D-W) agencies.[18] **Figure 3** illustrates the composition of that funding based on FY2016 obligations. Funding was broadly distributed, with each of the services and Defense-Wide agencies accounting for 20%-30% of total DOD basic research funding. The Navy accounted for the largest share (29.2%) of DOD basic research, followed by the Defense-Wide agencies (27.3%), the Air Force (23.4%), and the Army (20.1%). The Defense Advanced Research Projects Agency (DARPA) is the largest funder of basic research among the D-W agencies, accounting for 17.9% of total DOD RDT&E.

Figure 3. Basic Research Funding of DOD Services and Agencies, FY2016



Source: CRS analysis of data from National Science Foundation, National Center for Science and Engineering Statistics, *Survey of Federal Funds for Research and Development, FYs 2015–17*, Table 31.

Notes: According to NSF, FY2016 data are estimates of congressional appropriations actions and apportionment and reprogramming decisions. Percentages rounded and therefore may not add to 100%.

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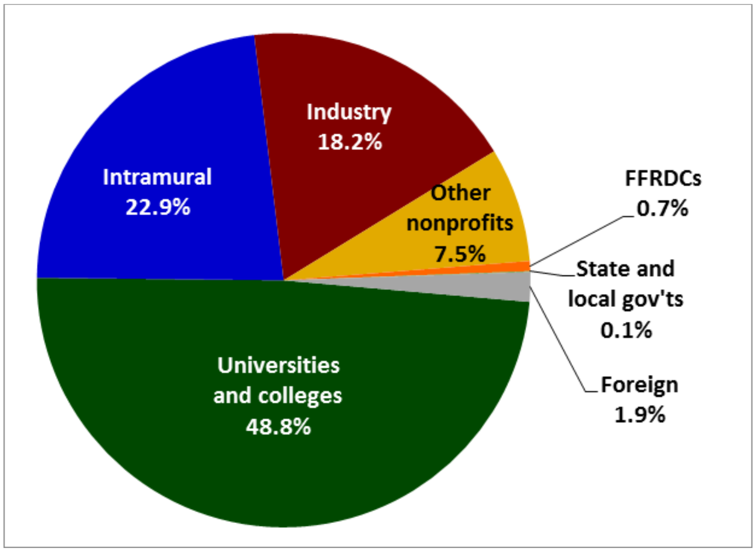
[17] FY2016 is the latest available data for analysis of DOD basic research by performing sector.

[18] Defense-Wide agencies engaged in DOD RDT&E include, but are not limited to, the Defense Advanced Research Projects Agency (DARPA), Office of the Secretary of Defense (OSD), Missile Defense Agency (MDA), Chemical and Biological Defense Program (CBDP), Defense Contract Management Agency (DCMA), Defense Human Resources Activity (DHRA), Defense Information Systems Agency (DISA), Defense Logistics Agency (DLA), Defense Security Cooperation Agency (DSCA), Defense Security Service (DSS), Defense Technical Information Center (DTIC), Defense Threat Reduction Agency (DTRA), Operational Test and Evaluation, the Joint Staff (TJS), U.S. Special Operations Command (SOCOM), and Washington Headquarters Service (WHS).

Basic Research of DOD Components by Performing Sector

Figure 4 illustrates the share of total DOD basic research by performing sector.[19] Universities and colleges performed nearly half ($1.1 billion, 48.8%) of DOD basic research in FY2016. Nearly another quarter of DOD basic research was performed by intramural performers ($533 million, 22.9%). Industry performed 18.2% ($423 million) of DOD basic research; other nonprofits 7.5% ($174 million); and all other performers 1.7% ($61 million).

Figure 4. DOD Basic Research Obligations by Performing Sector, FY2016



Source: CRS analysis of data from National Science Foundation, National Center for Science and Engineering Statistics, *Survey of Federal Funds for Research and Development, FYs 2015–17*, Table 31.

Notes: According to NSF, FY2016 data are estimates of congressional appropriations actions and apportionment and reprogramming decisions. FFRDC=federally funded research and development center.

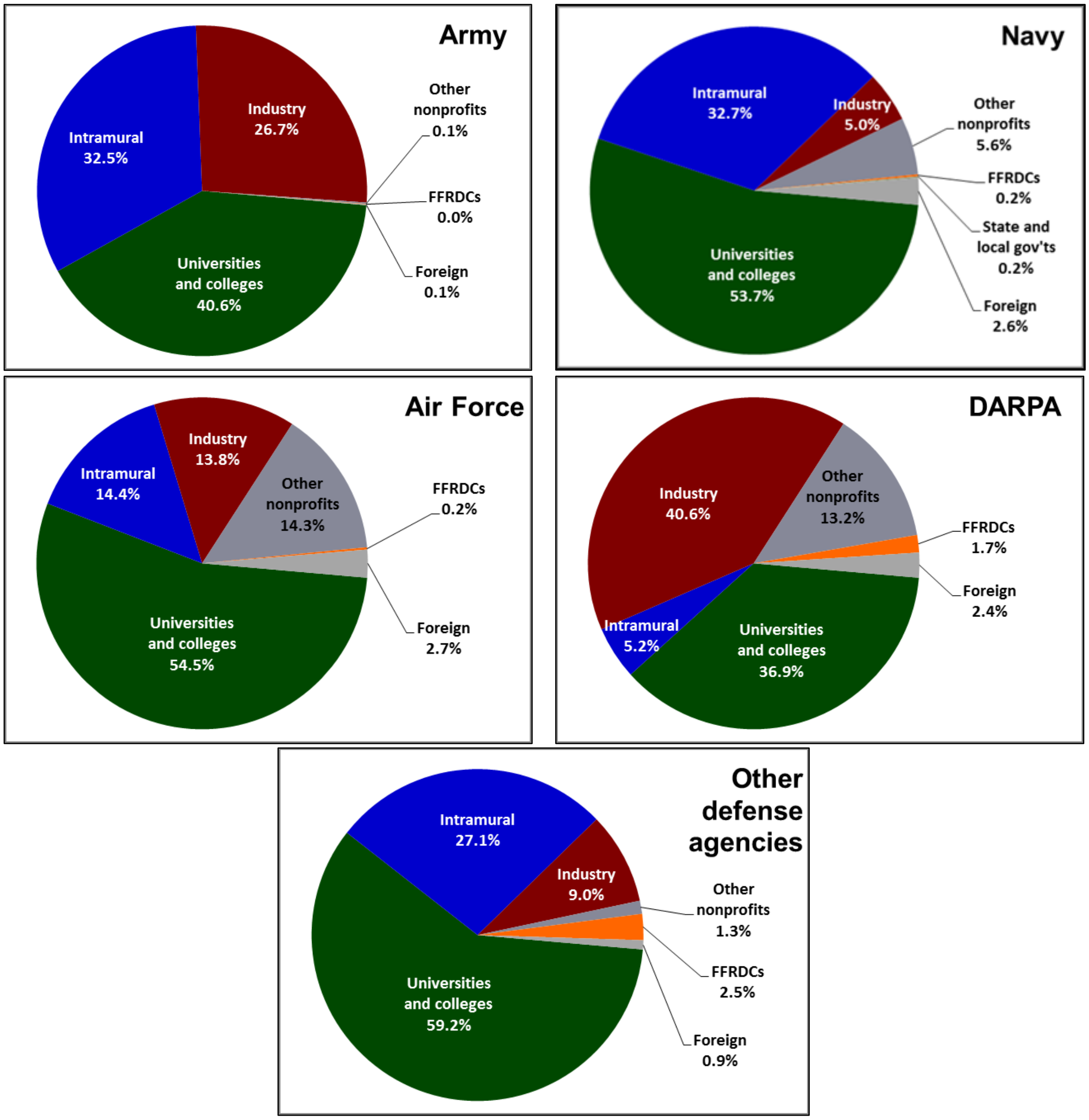
Figure 5 illustrates the composition of DOD components' basic research by performing sector.[20] As the charts show, the components' degree of reliance on performing sectors varies. In FY2016

- All components relied heavily on universities and colleges, especially the other defense agencies (59.2%).
- Reliance on industry varied widely, from 40.6% (DARPA) to 5.0% (Navy).
- The components' reliance on intramural performers also varied, from 5.2% (DARPA) to 32.7% (Navy).
- Other nonprofits are significant performers for the Air Force (14.3%) and DARPA (13.2%), but barely used by the Army (0.1%) and other defense agencies (1.3%).

[19] Data collected by the National Science Foundation through the *Survey of Federal Funds for Research and Development* assigns obligations to nine performing sectors: intramural; universities and colleges; industry; federally funded research and development centers (by type of administrator: industry, university, and nonprofit); state and local governments; other nonprofits; and foreign. Intramural research is that performed by federal employees using federally owned and operated facilities. Research performed by all other performers is characterized as extramural research. For more information see the technical notes to the *Survey of Federal Funds for Research and Development Fiscal Years 2015–17*, which can be accessed at https://ncsesdata.nsf.gov/fedfunds/2015/fedfunds_2015_tech_notes.pdf.

[20] DARPA and the other defense agencies comprise the D-W agencies.

Figure 5. Share of DOD Components' Basic Research Obligations Performing Sector, FY2016



Source: CRS analysis of data from National Science Foundation, National Center for Science and Engineering Statistics, *Survey of Federal Funds for Research and Development, FYs 2015–17*, Table 31.

Notes: According to NSF, FY2016 data are estimates of congressional appropriations actions and apportionment and reprogramming decisions. FFRDC=Federally funded research and development center.

Program Elements in DOD Basic Research

According to DOD,

> The program element is the primary data element in the Future Years Defense Program (FYDP) and normally the smallest aggregation of resources used by the Office of the Secretary of Defense [OSD] for analysis. It generally represents a collection of functional or organizational entities and their related resources. PEs are designed and quantified to be comprehensive and mutually exclusive. As the building blocks of the programming

> and budgeting system, PEs are continually reviewed to maintain proper visibility into the multitude of defense programs.[21]

DOD RDT&E is generally requested and funded under specified program elements (PEs). Each program element is associated with a seven character number and an alphanumeric suffix which, in part, indicate the budget activity code and the DOD department or agency receiving the funds. **Table 2** identifies each of the basic research PEs for the services and Defense-Wide agencies, their FY2017 enacted funding levels, and their share of each component's basic research funding.

Table 2. Basic Research Program Elements, Services and D-W Agencies, FY2017

Dollars in millions

	Army		Navy		Air Force		Defense-Wide		
Program Element	**Dollars**	**Share of Army 6.1**	**Dollars**	**Share of Navy 6.1**	**Dollars**	**Share of Air Force 6.1**	**Dollars**	**Share of D-W 6.1**	**Total**
Defense Research Sciences	$286.1	60.5%	$413.8	75.3%	$370.6	71.1%	$432.3	62.0%	1,502.9
University Research Initiatives	66.5	14.1%	117.3	21.4%	137.8	26.4%			321.6
In-House Laboratory Indep. Research	11.9	2.5%	18.2	3.3%					30.2
Univ. and Industry Research Centers	108.7	23.0%							108.7
High Energy Laser Research Initiatives					13.2	2.5%			13.2
National Defense Education Program							74.3	10.7%	74.3
Basic Research Initiatives							40.6	5.8%	40.6
Basic Operational Medical Research Science							43.1	6.2%	43.1
Chemical and Biological Defense Program							43.9	6.3%	43.9
Defense Threat Reduction Agency Univ. Strategic Partnership Basic Res.							37.2	5.3%	37.2
Historically Black Colleges and Universities							25.9	3.7%	25.9
Total	**$473.2**	**100.0%**	**$549.4**	**100.0%**	**$521.6**	**100.0%**	**$697.3**	**100.0%**	**2,241.5**

Source: Department of Defense, *Research, Development, Test, and Evaluation Programs (R-1), FY2019,* February 2018.

Note: Column elements may not add to totals due to rounding.

DOD basic research has some program elements that are continuing efforts (that is, they continue across multiple fiscal years). In addition, some of the PEs are common to one or more of the services or Defense-Wide agencies.

The following section provides descriptions of these PEs, as well as the other basic research PEs. The descriptions are drawn largely from the FY2018 budget justifications of the services and Defense-Wide agencies.

[21] Defense Acquisition University, Department of Defense, website, "Future Years Defense Program (FYDP)," https://www.dau.mil/acquipedia/Pages/ArticleDetails.aspx?aid=a2cc2ade-6336-433e-a088-42f497cdf7ef.

Defense Research Sciences

The Defense Research Sciences programs conducted by the Army, Navy, Air Force, and DARPA comprise the largest component and the core of the DOD basic research program.

Army. The Army Defense Research Sciences PE supports the development of fundamental scientific knowledge intended to contribute to the sustainment of Army scientific and technological superiority in land warfighting capability and to solving military problems related to long-term national security needs, supports investigation of new concepts and technologies for the Army's future force, and seeks to provide the means to exploit scientific breakthroughs and avoid technological surprises. This PE fosters innovation in Army niche areas (e.g., lightweight armor, energetic materials, and night vision capability) and areas where there is no commercial investment due to limited markets (e.g., vaccines for tropical diseases). It also focuses university single investigator research on areas of high interest to the Army (e.g., high-density compact power and novel sensors). The in-house portion of the program relies on the Army's scientific talent and specialized facilities to transition knowledge and technology into appropriate developmental activities. The extramural program leverages the research efforts of other government agencies, academia, and industry.[22]

Navy. The Navy Defense Research Sciences PE supports development of new technological concepts for the maintenance of naval power and national security, and to prevent scientific surprise. The program seeks to exploit scientific breakthroughs and to provide options for new future naval capabilities and innovative naval prototypes. The basic research efforts include scientific study and experimentation directed toward increasing knowledge and understanding in national security-related aspects of physical, engineering, environmental, and life sciences. The program's investments include National Naval Responsibilities (NNRs)[23] and the Basic Research Challenge Program.[24]

Air Force. The Air Force Defense Research Sciences PE funds extramural research activities in academia and industry along with in-house investigations performed in the Air Force Research Laboratory (AFRL). Funding supports fundamental broad-based scientific and engineering research in areas critical to Air Force weapon, sensor, and support systems.[25]

DARPA. The DARPA Defense Research Sciences PE seeks to provide the technical foundation for long-term national security enhancement through the discovery of new phenomena and the exploration of the potential of such phenomena for defense applications. It supports scientific study and experimentation that serves as the basis for more advanced knowledge and understanding in information, electronic, mathematical, computer, biological, and materials sciences.

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[22] Department of Defense, *Department of Defense Fiscal Year (FY) 2018 Budget Estimates, Army Justification Book of Research, Development, Test & Evaluation, Army RDT&E, Volume I, Budget Activity 1*, May 2017.

[23] NNRs are areas that are uniquely important to the Navy and Marine Corps that are not addressed by research investments from other DOD services, other federal R&D funding agencies (such as the National Science Foundation, the National Institutes of Health), or private industry.

[24] The Basic Research Challenge Program competitively funds promising research programs in areas not addressed by the current basic research program, placing a focus on high-risk basic research projects in multidisciplinary and collaborative departmental efforts. Department of Defense, *Department of Defense Fiscal Year (FY) 2018 Budget Estimates, Navy, Justification Book Volume 1 of 5, Research, Development, Test & Evaluation, Navy Budget Activities 1,2, and 3*, May 2017.

[25] Department of Defense, *Department of Defense Fiscal Year (FY) 2018 Budget Estimates, Air Force Justification Book Volume 1 of 3, Research, Development, Test & Evaluation, Vol-1*, May 2017.

University Research Initiatives

Army. The Army's University Research Initiatives (URI) PE supports several activities, including the Multidisciplinary University Research Initiative (MURI), the Defense University Research Instrumentation Program (DURIP), the Presidential Early Career Awards for Scientists and Engineers (PECASE) program, and the Army's contribution to the Minerva Research Initiative (MRI). The MURI program supports university-based basic research across a wide range of scientific and engineering disciplines pertinent to maintaining land combat technology superiority. Army MURI efforts involve teams of researchers investigating high-priority, transformational topics that intersect more than one traditional technical discipline. The MURI multidisciplinary approach seeks to accelerate research progress and to expedite the transition of research results into application. The DURIP program provides funds to acquire major research equipment to augment current research capabilities, or to devise new research capabilities, in support of Army transformational research. The PECASE program funds single-investigator research efforts performed by academic scientists and engineers early in their research careers. The Minerva Research Initiative is a university-based social science research program that seeks to improve DOD's basic understanding of the social, cultural, behavioral, and political forces that shape regions of the world of strategic importance to the United States. The program has three primary components: (1) a university-based social science basic research grant program; (2) the Research for Defense Education Faculty program for the professional military education institutions; and (3) a collaboration with the U.S. Institute of Peace to award research support to advanced graduate students and early career scholars working on security and peace.[26] According to DOD

> The Minerva Research Initiative has a unique relationship between research and policy within DOD. As such, leadership across the department collaborate to identify and support basic social science research issues in need of attention and to integrate those research insights into the policy-making environment. In doing this, the leadership team closely works with the program managers within the Military Service Branches.[27]

Navy. The Navy's URI PE includes support for multidisciplinary basic research in a wide range of scientific and engineering disciplines to enable the U.S. Navy to maintain technological superiority, and for the acquisition of research instrumentation needed to maintain and improve the quality of university research important to the Navy. Navy MURI efforts are focused on high-priority topics and opportunities that intersect more than one traditional technical discipline. This program is intended to stimulate innovation, accelerate research progress, and expedite transition of research results into naval applications. The Navy DURIP program supports university research infrastructure deemed essential to high-quality, Navy-relevant research. The program complements other Navy research programs by supporting the purchase of high-cost research instrumentation that is necessary for the conduct of cutting-edge research. Navy URI funding also supports PECASE efforts focused on providing the knowledge base, scientific concepts, and technological advances needed for the maintenance of naval power and national security.[28]

Air Force. The Air Force's URI PE supports defense-related basic research across a wide range of scientific and engineering disciplines deemed relevant to maintaining U.S. military

[26] Department of Defense, *Department of Defense Fiscal Year (FY) 2018 Budget Estimates, Army Justification Book of Research, Development, Test & Evaluation, Army RDT&E, Volume I, Budget Activity 1*, May 2017.

[27] Department of Defense, website, "The Minerva Research Initiative: Supporting Social Science for a Safer World," http://minerva.defense.gov/Minerva.

[28] Department of Defense, *Department of Defense Fiscal Year (FY) 2018 Budget Estimates, Navy, Justification Book Volume 1 of 5, Research, Development, Test and Evaluation, Navy Budget Activities 1,2, and 3*, May 2017.

technological superiority. Research topics include transformational and high-priority technologies such as nanotechnology, sensor networks, intelligence information fusion, smart materials and structures, efficient energy and power conversion, and high-energy materials for propulsion and control. The program also seeks to enhance and promote the education of U.S. scientists and engineers in disciplines critical to maintaining, advancing, and enabling future U.S. defense technologies. The program also assists universities in acquiring the instrumentation capabilities needed to improve the quality of defense-related research and education. The Air Force asserts that a fundamental component of this program is recognition that future technologies and technology exploitations require highly coordinated and concerted multi- and interdisciplinary efforts.[29]

In-House Laboratory Independent Research

The In-House Laboratory Independent Research (ILIR) PEs support basic research at Army and Navy laboratories, including

- six Army Materiel Command Research, Development, and Engineering Centers; six U.S. Army Medical Research and Materiel Command Laboratories; seven Corps of Engineers U.S. Army Engineer Research and Development Centers; the U.S. Space and Missile Defense Command Technical Center; and
- participating Naval Warfare Centers and Laboratories.

Army. Army ILIR efforts seek to catalyze major technology breakthroughs by providing laboratory directors flexibility in implementing novel research ideas, by nurturing promising young scientists and engineers, and by attracting and retaining top scientists and engineers. The ILIR program also provides a source of competitive funds for peer reviewed efforts at Army laboratories to stimulate high-quality, innovative research with significant opportunity for payoff to Army warfighting capability.[30]

Navy. Navy ILIR efforts are selected by Naval Warfare Centers/Laboratories' commanding officers and technical directors near the start of each fiscal year through internal competition. Efforts typically last three years, and are generally designed to assess the promise of new lines of research. Successful efforts typically attract external, competitively awarded funding.[31]

University and Industry Research Centers

The Army University and Industry Research Centers PE seeks to foster university- and industry-based research to provide a scientific foundation for enabling technologies for future force capabilities. The work falls broadly into three categories:

Collaborative Technology Alliances/Collaborative Research Alliances (CTAs/CRAs). CTAs seek to leverage large investments by the commercial sector in basic research areas that are of interest to the Army. CTAs are industry-led partnerships between industry, academia, and the Army Research Laboratory (ARL) that seek "to incorporate the practicality of industry, the expansion of the boundaries of knowledge from universities, and Army scientists to shape,

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[29] Department of Defense, *Department of Defense Fiscal Year (FY) 2018 Budget Estimates, Air Force Justification Book Volume 1 of 3, Research, Development, Test and Evaluation, Vol-1*, May 2017.

[30] Department of Defense, *Department of Defense Fiscal Year (FY) 2018 Budget Estimates, Army Justification Book of Research, Development, Test and Evaluation, Army RDT&E, Volume I, Budget Activity 1*, May 2017.

[31] Department of Defense, *Department of Defense Fiscal Year (FY) 2018 Budget Estimates, Navy, Justification Book Volume 1 of 5, Research, Development, Test and Evaluation, Navy Budget Activities 1,2, and 3*, May 2017.

mature, and transition technology relevant to the Army mission."[32] CRAs are academia-led partnerships, which seek to leverage cutting-edge academic research.

University Centers of Excellence (COEs). University COEs seek to expand the frontiers of knowledge in research areas where the Army has enduring needs. COEs couple state-of-the-art research programs at academic institutions with broad-based graduate education programs to help increase the supply of scientists and engineers in automotive and rotary wing technology.

The Army University and Industry Research Centers program element also supports the Historically Black Colleges and Universities and Minority Institution (HBCU/MI) Centers of Excellence.

University Affiliated Research Centers (UARCs). UARCs were established to advance new capabilities through sustained multidisciplinary efforts. The Institute for Soldier Nanotechnologies focuses on soldier protection by emphasizing revolutionary materials research for advanced soldier protection and survivability. The Institute for Collaborative Biotechnologies focuses on enabling network-centric technologies, and broadening the Army's use of biotechnology for the development of bio-inspired materials, sensors, and information processing. The Institute for Creative Technologies is a partnership with academia and the entertainment and gaming industries to leverage innovative research and concepts for training and simulation, in areas such as realistic immersion in synthetic environments, networked simulation, standards for interoperability, and tools for creating simulated environments.

Other DOD Basic Research PEs

In addition to the program elements discussed above, there are seven other DOD basic research program elements (sponsoring agency noted after program name/abbreviation):

- **High Energy Laser (HEL) Research Initiatives (Air Force):** This PE supports basic research aimed at developing fundamental scientific knowledge to support future DOD HEL systems. This program funds multidisciplinary research institutes to conduct research on laser and beam control technologies. In addition, this program supports educational grants to stimulate student interest in HELs.
- **National Defense Education Program (NDEP, Defense-Wide: Office of the Secretary of Defense):** The NDEP supports a number of specific workforce development programs, including the Science, Mathematics, and Research for Transformation program, and the Military Child Pilot Program, that seek to improve the DOD workforce by increasing STEM proficiency in the nation's talent pool; shaping DOD as a STEM workplace of choice for scientists and engineers through public communications and outreach; leading the DOD STEM strategic efforts and coordinating STEM efforts in alignment with DOD workforce and mission requirements; and identifying approaches for innovative solutions in support of U.S. current and future defense challenges.[33]
- **Basic Research Initiatives (D-W: OSD):** The Basic Research Initiatives PE supports defense basic research through several activities. Strategic Support for Basic Research (SSBR) initiatives drive the direction of DOD basic research investments; coordinate and conduct oversight of DOD basic research programs;

[32] Department of Defense, *Department of Defense Fiscal Year (FY) 2018 Budget Estimates, Air Force Justification Book Volume 1 of 3, Research, Development, Test and Evaluation, Vol-1,* May 2017.

[33] STEM is an acronym for science, technology, engineering, and mathematics.

improve science and engineering workforce and public outreach; enhance university-industry collaboration; and engage with academic research community and international partners. The PE also supports the Minerva Research Initiative (discussed above) and the Vannevar Bush Faculty Fellowship Program, which supports research across a broad set of emerging scientific areas with transformative potential.

- **Basic Operational Medical Research Science (D-W: DARPA):** This PE supports basic research in medical-related information and technology leading to fundamental discoveries, tools, and applications critical to solving defense-related challenges. Efforts focus on identified medical gaps in warfighter care related to health monitoring and preventing the spread of infectious disease. The program uses information, computational modeling, and physical sciences to discover properties of biological systems that cross multiple scales of biological architecture and function, from the molecular and genetic level through cellular, tissue, organ, and whole organism levels. To enable in-theater, continuous analysis and treatment of warfighters, this project seeks to explore diagnostic and therapeutic approaches, including the use of bacterial predators as therapeutics against infections caused by antibiotic-resistant pathogens; developing techniques to enable rapid transient immunity for emerging pathogens; and identifying fundamental biological mechanisms that enable certain species to survive in harsh environments.
- **Chemical and Biological Defense Program (D-W: Nuclear, Chemical, and Biological Defense Program):** The Chemical and Biological Defense Program (CBDP) includes PEs in all seven RDT&E budget activities. The basic research-focused Chemical and Biological Defense Program PE supports theoretical and experimental research in life sciences—focused on understanding living systems' response to biological or chemical agents, to support detection, diagnostics, protection, and medical treatment—and physical sciences—focused on investigation of physical and chemical properties and interactions to improve detection, diagnostics, protection, and decontamination.
- **Defense Threat Reduction Agency (DTRA) University Strategic Partnership Basic Research (D-W: DTRA):** The DTRA Basic Research PE funds research across physical, material, engineering, computational, and life sciences directed toward greater knowledge and understanding of the fundamental aspects of observable phenomena associated with weapons of mass destruction. This PE provides support for the discovery and development of basic knowledge by researchers in academia and research institutions in government and industry.
- **Historically Black Colleges and Universities and Minority-Serving Institutions (HBCU/MI, D-W: OSD):** The HBCU/MI PE provides support for Historically Black Colleges and Universities and Minority-Serving Institutions (HBCU/MI) programs in the fields of science and engineering deemed important to national defense. This PE provides support through grants, cooperative agreements, or contracts for research, education assistance, and instrumentation.

Issues in Defense S&T

Through the authorization and appropriations processes, Congress grapples with a wide variety of issues related to the magnitude, allocation, and strategic direction of DOD RDT&E, Defense S&T

(a subset of RDT&E), and basic research (a subset of Defense S&T). These decisions play an important role in U.S. national security and economic strength, in the near term and longer term.

In practice, appropriations decisions are generally made about specific programs within the context of the available funding. The levels of RDT&E, S&T, and basic research funding are the result of many decisions made during DOD budget formulation and congressional appropriations, and in the end, are calculated on a post-facto basis. Nevertheless, an analysis of the kind that follows may be useful in assessing the big picture and in seeing funding trends in the context of a historical arc that may provide strategic insight and guidance.

Among the ongoing questions lawmakers and policy analysts grapple with are the following:

- What is the appropriate funding level for Defense S&T?
- What is the appropriate funding level for DOD basic research?

Several approaches to addressing these questions are identified below, each with related data and analysis.[34]

What Is the Appropriate Funding Level for Defense S&T?

Congress and others have expressed concerns about the adequacy of funding for Defense S&T. As discussed earlier, the scientific and technological insights that emerge from this funding are seen by many as the pool of knowledge available to DOD and the industrial base for future defense technology development. For this reason, Defense S&T funding has sometimes been singled out for attention by Congress.

Approach: Defense S&T as a Share of Total DOD Funding

A 1998 Defense Science Board (DSB) report suggested two conceptual frameworks for Defense S&T funding. The first approach, using industrial practice as a guide, proposed setting Defense S&T funding at 3.4% of total DOD funding:

> The DOD S&T budget corresponds most closely to the research component of industrial R&D. Using 3.4% of revenue (typical of high-tech industries shown [elsewhere in the report]), the DOD S&T funding should be about $8.4 billion, which is a billion dollars greater than the FY98 S&T funding.[35]

Other organizations have proposed using the same metric, with 3% of total DOD funding as the level for S&T funding. A 2001 report based on the Quadrennial Defense Review (QDR), a legislatively mandated review by DOD of its strategies and priorities, called for "a significant increase in funding for S&T programs to a level of three percent of DOD spending per year."[36] In 2004, the Council on Competitiveness, a leadership organization of corporate chief executive

[34] A question related to Defense S&T funding, is "What is the appropriate funding level for DOD research targeting revolutionary technological advancements?" However, DOD does not request, receive, or report funding using a taxonomy that includes "revolutionary research." In the absence of such an accounting, funding for the Defense Advanced Projects Research Agency (DARPA) has served as a surrogate measure of such DOD research. For a more detailed analysis of DARPA and its appropriations, see CRS Report R45088, *Defense Advanced Research Projects Agency: Overview and Issues for Congress*, by (name redacted)

[35] Defense Science Board, *Report of the Defense Science Board Task Force on Defense Science and Technology Base for the 21st Century*, June 1998.

[36] Department of Defense, *Quadrennial Defense Review Report*, September 30, 2001, p. 41, http://archive.defense.gov/pubs/qdr2001.pdf.

officers, university presidents, labor leaders, and national laboratory directors, reiterated the 3% recommendation of the QDR.[37]

Over the years, Congress has sought to address this perceived shortcoming in funding. The FY1999 defense authorization bill (P.L. 105-261) expressed the sense of Congress that Defense S&T funding should be increased by 2% or more above the inflation rate each year from FY2000 to FY2008.[38] Subsequently, the FY2000 defense authorization bill expressed the sense of Congress that

> the Secretary of Defense has failed to comply with the funding objective for the Defense Science and Technology Program, especially the Air Force Science and Technology Program, as stated [P.L. 105-261], thus jeopardizing the stability of the defense technology base and increasing the risk of failure to maintain technological superiority in future weapon systems.[39]

The act further expressed the sense of Congress that the Secretary of Defense should increase Defense S&T, including the 6.1-6.3 programs within each military department, by 2% or more above the inflation rate each year from FY2001 to FY2009.

In 2002, Congress embraced the DSB's recommendation and underlying rationale in the conference report accompanying the National Defense Authorization Act for Fiscal Year 2003:

> The conferees commend the Department of Defense commitment to a goal of three percent of the budget request for the defense science and technology program and progress toward this goal. The conferees also note the finding in the Defense Science Board report that successful high technology industries invest about 3.5 percent of sales in research (equivalent to the DOD S&T program) and the recommendation that S&T funding should be increased to ensure the continued long-term technical superiority of U.S. military forces in the 21st Century. The conferees believe that the Department must continue to provide the necessary investments in research and technologies that ensure a strong, stable, and robust science and technology program for our Armed Forces.[40]

In 2009, the Senate-passed version of the National Defense Authorization Act for Fiscal Year 2010 (S. 1390) included a provision (§217) stating it was the sense of Congress that the Secretary of Defense should increase Defense S&T by a percentage at least equal to inflation.

Data and Analysis

Following a period of strong growth in the early 2000s, Defense S&T funding reached $13.3 billion in FY2006, then declined to $11.0 billion in FY2013 before climbing to a peak of $14.0 billion in FY2017. (See **Figure 6**.) Growth in the amount of S&T funding that was sought in P.L. 105-261 (red line, **Figure 6**) was largely achieved, though appropriations fell somewhat short in FY2007 and FY2008. Viewed as a share of DOD total obligational authority (TOA), S&T declined from about 3.0% in the late 1990s to about 1.7% in 2011, then rebounded to about 2.3% in FY2017. (See **Figure 7**.)

[37] Council on Competitiveness, *Innovate America*, 2004, p. 58, http://www.compete.org/storage/images/uploads/File/PDF%20Files/NII_Innovate_America.pdf.

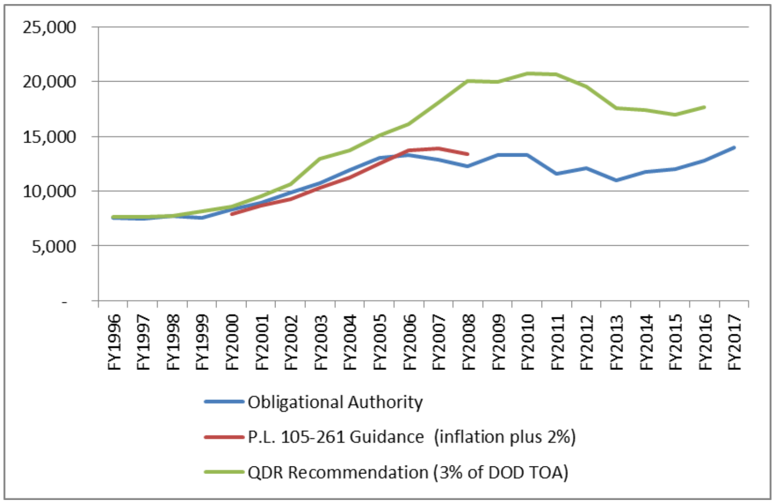
[38] P.L. 105-261, §214.

[39] P.L. 106-65.

[40] H.Rept. 107-772, p. 460, http://lis.gov/cgi-lis/t2gpo/https:/www.gpo.gov/fdsys/pkg/CRPT-107hrpt772/pdf/CRPT-107hrpt772.pdf.

Figure 6. Defense S&T Funding, P.L. 105-261 Guidance, and QDR Recommendation

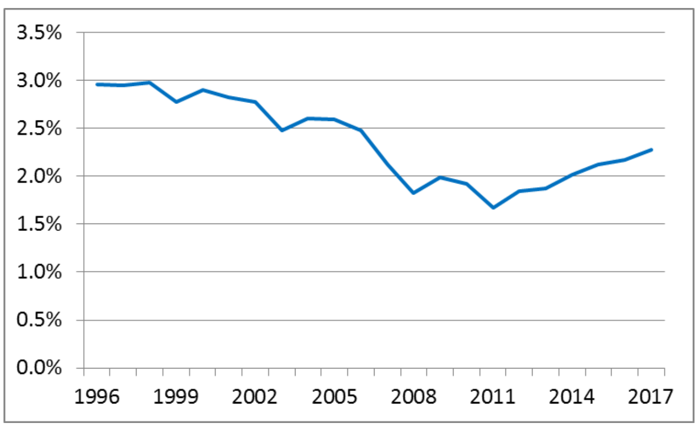
in millions of current dollars



Source: CRS analysis of data from Department of Defense, *Research, Development, Test, and Evaluation Programs (R-1)* for FY1998-2019.

Note: For purposes of this chart, CRS used the GDP (Chained) Price Index from Table 10.1 of the Historical Tables in the *President's Budget for Fiscal Year 2018* to adjust for inflation. This is the index used by the Office of Management and Budget to convert federal research and development outlays from current dollars to constant dollars. https://www.whitehouse.gov/sites/default/files/omb/budget/fy2017/assets/hist10z1.xls.

Figure 7. Defense S&T Funding as a Share of DOD TOA



Source: CRS analysis of data from Department of Defense, *Research, Development, Test, and Evaluation Programs (R-1)* for FY1998-2019; DOD, *National Defense Budget Estimates for FY2018* (*Green Book*), FY2017.

Note: TOA=Total Obligational Authority

Approach: DOD Science and Technology as a Share of DOD RDT&E

The DSB's second proposed framework, also based on industrial practice, was to use the metric of Defense S&T as a share of DOD RDT&E:

> Another approach to this question is to note that the ratio of research funding to total R&D funding in high-technology industries, such as pharmaceuticals, is about 24%.

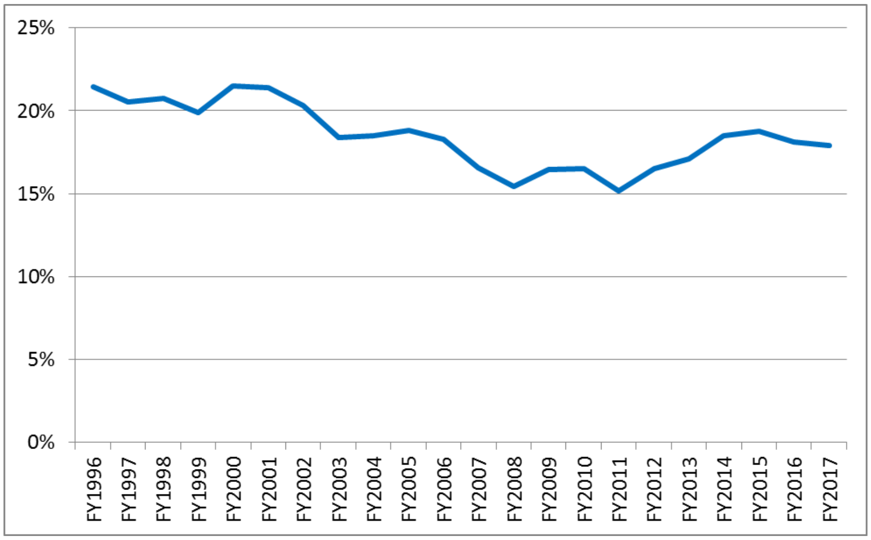
> When this percentage ratio is applied to the FY98 R&D funding of about $36 billion, the result is about $8.6 billion, well above the actual S&T funding.[41]

In 2015, the Coalition for National Security Research, a coalition of industry, universities, and associations, asserted that Defense S&T funding should be 20% of DOD RDT&E.[42]

Data and Analysis

Figure 8 illustrates Defense S&T's share of DOD RDT&E for FY1996-FY2016. At the time of the DSB report (1998), S&T's share of DOD RDT&E was approximately 20.7%. After rising to 21.5% in FY2000, the share fell to 15.2% in FY2011, and then recovered to 17.9% in FY2017.

Figure 8. Defense S&T Funding as a Share of DOD Title IV RDT&E



Source: CRS analysis of data from Department of Defense, *Research, Development, Test, and Evaluation Programs (R-1)* for FY1978-2019. CRS used funding levels from two years before the request year. For example, the FY2017 funding levels are from the FY2019 R-1.

Note: Congress appropriates some RDT&E funding in other appropriations titles. In 2016, for example, Congress appropriated $2.121 billion for the Defense Health Program, $579 million for Chemical Agents and Munitions Destruction, $26 million for the National Defense Sealift Fund, and $2.1 million for the Inspector General for R&D and RDT&E-related purposes. In total, these funds accounted for 3.7% of all RDT&E funds.

What Is the Appropriate Funding Level for DOD Basic Research?

Within the Defense S&T program, basic research is often singled out for additional attention, due in part to its perceived value in advancing breakthrough technologies and in part to the substantial role it plays in supporting university-based research in certain physical sciences and engineering disciplines. DOD describes basic research as "farsighted high payoff research that provides the

[41] Defense Science Board, *Report of the Defense Science Board Task Force on Defense Science and Technology Base for the 21st Century*, June 1998. Some analysts may disagree with DSB's implicit assumption about the applicability of a ratio drawn from the R&D investment behavior of private firms competing in a commercial market to DOD S&T spending.

[42] Richard M. Jones, "Coalition Recommends Higher Level of Defense S&T Funding than Administration Request," *FYI: Science Policy News from AIP*, April 13, 2015, https://www.aip.org/fyi/2015/coalition-recommends-higher-level-defense-st-funding-administration-request.

basis for technological progress."[43] Basic research funding is seen by some as particularly vulnerable to budget cuts or reallocation to other priorities because of the generally long time it takes for basic research investments to result in tangible products and other outcomes (i.e., reductions in funding can be made with minimal short-term consequences) and to the uncertainty of the benefits that will be derived from the results of basic research.

Approach: DOD Basic Research as a Share of Defense S&T

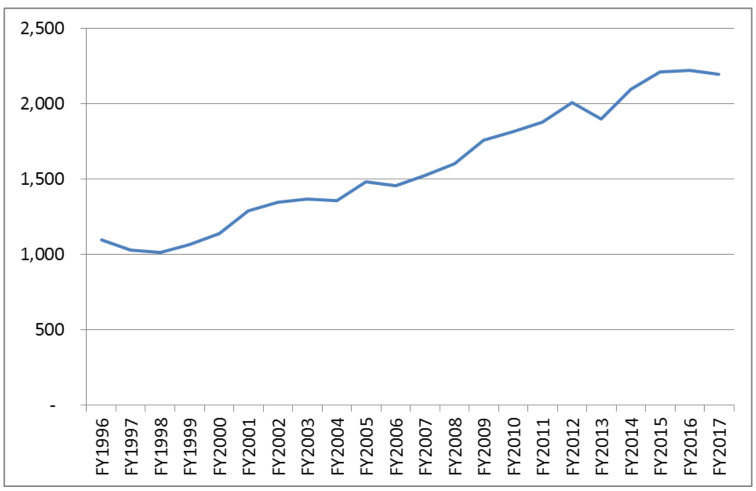
In 2004, the Council on Competitiveness asserted that DOD basic research should be at least 20% of Defense S&T.[44] In 2015, the Coalition for National Security Research also recommended basic research account for 20% of Defense S&T.[45]

Data and Analysis

DOD basic research funding grew steadily from FY1998 through FY2017, more than doubling in current dollars. (See **Figure 9**.) As a share of Defense S&T, basic research declined from 14.6% in FY1996 to 11.0% in FY2006, then began a steady rise to 18.4% in FY2015, its highest level in two decades. Basic research's share of Defense S&T fell in 2016 to 17.4% and in 2017 to 16.2%. (See **Figure 10**.)

Figure 9. DOD Basic Research Funding

In millions of current dollars



Source: CRS analysis of data from Department of Defense, *Research, Development, Test, and Evaluation Programs (R-1)* for FY1998-2019.

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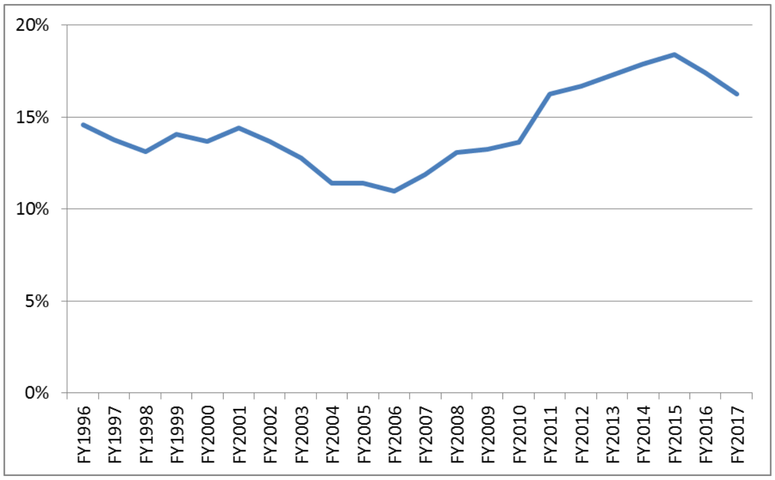
[43] Department of Defense, *Financial Management Regulation (DoD 7000.14-R)*, Volume 2B, March 2016.

[44] Council on Competitiveness, *Innovate America*, 2004, p. 58.

[45] Richard M. Jones, "Coalition Recommends Higher Level of Defense S&T Funding than Administration Request," *FYI: Science Policy News from AIP*, April 13, 2015.

Figure 10. DOD Basic Research as a Share of Defense S&T



Source: CRS analysis of data from Department of Defense, *Research, Development, Test, and Evaluation Programs (R-1)* for FY1998-2019.

Concluding Observations

Defense S&T investments are highly complex and can be parsed in many ways. Some of these are highlighted in this report. Other ways of parsing RDT&E funding—such as allocation by size of industrial performers—may also be important for assessing the balance in allocation of DOD RDT&E resources to meet DOD objectives.

Among the many other factors that may affect the effectiveness of the performance of Defense S&T are organizational structures and relationships; management; workforce recruitment, training, and retention; and policies related to cooperative research and technology transfer. Defense S&T stakeholders have also asserted the importance of stability in funding streams.

As Congress undertakes defense annual authorization and appropriations, it may wish to consider the issues raised in this report related to the magnitude and composition of funding for Defense S&T in the overall context of DOD RDT&E, as well as the other issues such as those identified above.

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