Report of the
Defense Science Board
Task Force on

Basic Research

January 2012

Office of the Under Secretary of Defense
for Acquisition, Technology and Logistics
Washington, D.C. 20301-3140

This report is a product of the Defense Science Board (DSB).

The DSB is a Federal Advisory Committee established to provide independent advice to the Secretary of Defense. Statements, opinions, conclusions, and recommendations in this report do not necessarily represent the official position of the Department of Defense (DOD). The DSB Task Force on Basic Research completed its information gathering in April 2011. The report was cleared for open publication by the DOD Office of Security Review on December 7, 2011.

This report is unclassified and cleared for public release.

Part I

The Current DOD Basic Research Program

Chapter 1. Overview of Defense Basic Research

The Department of Defense funds long-term basic research in a wide variety of scientific and engineering fields with a goal of exploiting new knowledge to enhance—and, where possible, transform—future capabilities. DOD funded research is known for high-risk endeavors that have led to paradigm shifts in the nation's technical capabilities. In many cases, DOD was the first to seed new research performed by many of the world's leading scientists and engineers at universities and federal laboratories, as well as in private industry.

Historically, the United States, through both government and industry support, has maintained a world-dominating lead in basic research. Beginning with efforts supporting World War II, the United States built a commanding scientific infrastructure second to none, and reaped considerable economic and military benefits as a result. DOD also can dominate the world's military organizations in being able to use basic research results to create new and enhanced military capabilities, by dint of financial resources, infrastructure, and national culture—if DOD can overcome the immense burden of its acquisition system, and if DOD pays sufficient attention to worldwide basic research. In principle, worldwide basic research could benefit DOD disproportionally among global armed forces.

Today, the U.S. government's investment in basic research has increased roughly at the rate of inflation while private industry's investment has shrunk dramatically. The United States remains a pioneer and leader in many areas, but it is increasingly the case that in today's scientifically competitive world, the United States is only one *among* the world leaders.

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Rationale for DOD Investment in Basic Research

Basic research provides the Department of Defense with a deep and broad awareness in relevant areas of research. It is defined by the DOD[1] as:

> *The 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.*

The rationale for DOD to invest strongly in basic research is four-fold:

- Basic research probes the limits of today's technologies and discovers new phenomena and know-how that ultimately lead to future technologies.
- Basic research funding attracts some of the most creative minds to fields of critical DOD interest.
- Basic research funding creates a knowledgeable workforce by training students in fields of critical DOD interest.
- Basic research provides a broad perspective to prevent capability surprise by fostering a community of U.S. experts who are accessible to DOD, and who follow global progress in both relevant areas, as well as those that may not seem relevant—until they are.

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1. Department of Defense, Financial Management Regulation, DoD 7000.14-R, Vol. 2B, Ch. 5, Para 050201, Part B, December 2010. Available at http://goo.gl/vKJjC (accessed November 2011). Note the entire section, with definitions of all sectors of defense science, technology, research, and engineering, is included for reference in Appendix A.

Currently, much more emphasis is placed on the first reason than on the last three reasons, and the task force's recommendations that follow address that imbalance.

Exploration and discovery provide the means for disruptive advances that can improve or radically change military strategy and operations. It is, many times, the only way to solve hard problems, and provides the unique means to enable and prevent capability surprise. Some examples of these are provided in the box on page 10.

Defense basic research establishes and maintains the ready national availability to DOD of experts and expert teams that understand the fundamentals behind today's military technologies, and who can be readily brought in to address time-critical military technology problems. Examples where such expert teams have been critical include the Manhattan Project, radar, stealth technology, satellite reconnaissance, and cyber security.

The DOD basic research program has supported a large fraction of revolutionary research in the physical sciences, as attested, for instance, by the American Academy of Arts and Sciences in its 2008 *ARISE* report.[2] Basic research funding sustains scientific and engineering communities in areas that form the critical technical underpinning of DOD capabilities. (See Figure 1.) These include, for example, mechanical engineering and electrical engineering, where DOD provides 86 and 71 percent of basic research funding, respectively. (See Figure 2.) Other areas that depend on defense funding include ocean acoustics, naval architecture, aerodynamics, and computer science. 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.

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2. American Academy of Arts and Sciences, 2008. *Advancing Research In Science and Engineering: Investing in Early-Career Scientists and High-Risk, High-Reward Research.* Available at http://goo.gl/4zMmD (accessed November 2011).

Five examples of how DOD-sponsored basic research has led to broad and powerful game-changing applications in the military and economics arena:

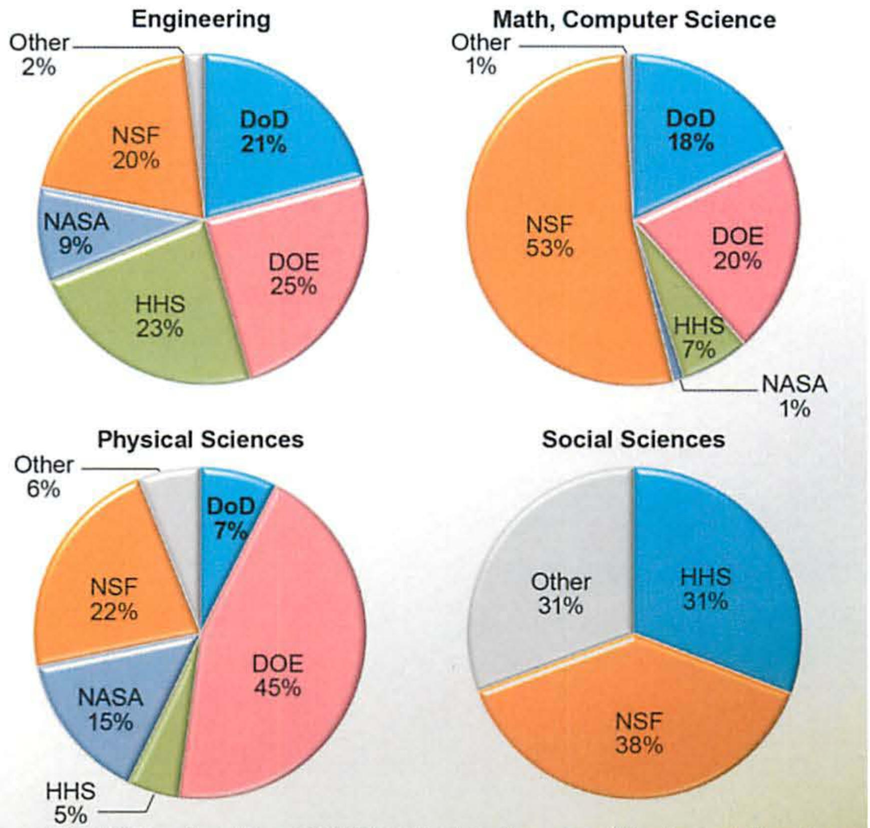
Global Positioning Satellite (GPS) System. The basic science that made this remarkable system possible was started with the magnetic resonance studies of nuclei starting with the work of I.I. Rabi in the 1940s, who realized that nuclear transitions could be the basis for an atomic clock. This was followed by the pioneering work of many others, including his students N. Ramsey, J. Zacharias, C. Townes, and others. Much of the early work was funded by the Navy and was developed and fielded by the Naval Research Laboratory (NRL). The Transit Satellite and the Timation system, which demonstrated the first satellite fix in 1964, eventually evolved into the GPS system, which has become a key military and commercial asset.

Gallium Arsenide (GaAs) Microwave Electronics. In the 1950s, the Navy and the Air Force began funding research on the basic properties of GaAs, which produced the first indication that this compound could improve the performance of high-frequency electronics as compared to silicon by virtue of its very high mobility, and tunable and large band gap. In 1966, Carver Mead demonstrated the first GaAs Field Effect Transistor, and over the next decade the potential of this semiconductor for microwave circuits was evident. By the late 1970s, the Defense Advanced Research Projects Agency (DARPA) began to invest considerable sums into developing the processes for medium- and then large-scale integration of these devices, primarily at Rockwell. In the early 1980s, two companies, Gigabit Logic and Vitesse Semiconductor, were spawned and they pushed GaAs into many defense and commercial applications, spurred on by the DARPA Monolithic Microwave Integrated Circuit (MMIC) project. For example, GaAs chips are in nearly every defense radar system and in many commercial products, such as cell phones.

Magnetic Random Access Memory (MRAM). The fundamental work of R. Meservey and P.M. Tedrow in the early 1970s, supported by the Air Force, proved that ferromagnetic metals had spin-polarized carriers, and for the first time measured the degree of spin polarization using a very novel tunneling technique. However it wasn't until the late 1980s that this spin-polarized transport provided a very novel effect, called Giant Magnetoresistance (GMR), which was demonstrated in a multilayer structure of alternating magnetic and non-magnetic films. The resistance was very different if the magnetic layers had their moment aligned (low resistance) or anti-aligned (high resistance). This work was carried out in Europe independently by two groups, one in France, and one in Germany. By the late 1990s, IBM had incorporated a related structure (spin valve) into a magnetic sensor that became ubiquitous as the read head sensor for magnetic hard drives. In the meantime Moodera, supported by the Navy and working at the Massachusetts Institute of Technology Magnet Laboratory, demonstrated that this GMR-type effect could be significantly enhanced if the normal metal was replaced by a very thin insulating tunnel barrier. This effect, now called Spin Dependent Tunneling, became the basis for a new type of random access, non-volatile memory called MRAM. DARPA started the Spintronics Program to develop this memory in 1996, and this project culminated in 2005 in the introduction of a commercial memory now produced and marketed by Everspin, and a radiation-hard part produced for the DOD by Honeywell, using the Everspin process, in 2010.

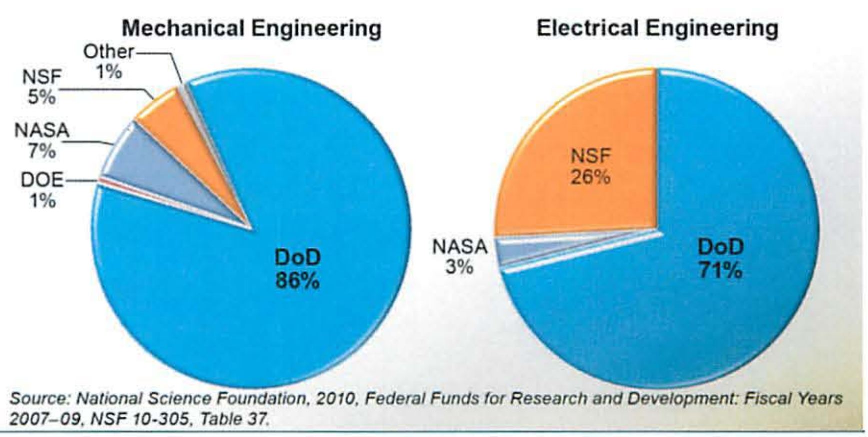
Stealth Technology. While tracking the history of stealth technology is difficult owing to issues of secrecy, there was considerable research beginning in the 1950s on what would now be called metamaterials. These consisted of mixtures of metallic materials, insulating materials, and magnetic materials that had interesting properties at high frequencies. These early experiments were funded by the Navy and the Air Force. The problem of the scattering of electromagnetic waves off arbitrary surfaces was addressed in a fundamental manner in the late 1960s and early 1970s through Air Force funding. These and other basic science efforts were pulled together into several projects to develop the stealth technology as it is known today.

Kalman Filter. A Kalman filter is a set of equations used to minimize the mean square error of measurements in a space and time system that is exposed to random noise and other sources of inaccuracies. The basis for this filter was a paper by R.E. Kalman, published in 1960, supported by the Air Force. The original equations, developed for linear systems, were extended to deal with non-linear systems. Although these equations were not immediately embraced by the mathematics and engineering communities, the extended Kalman filter is now used in many military and commercial systems ranging from image processing to weather forecasting.



Source: National Science Foundation, 2010, Federal Funds for Research and Development: Fiscal Years 2007–09 , NSF 10-305, Table 31.

Figure 1. DOD percentage of federal funding for basic research in selected disciplines, Fiscal Year 2007



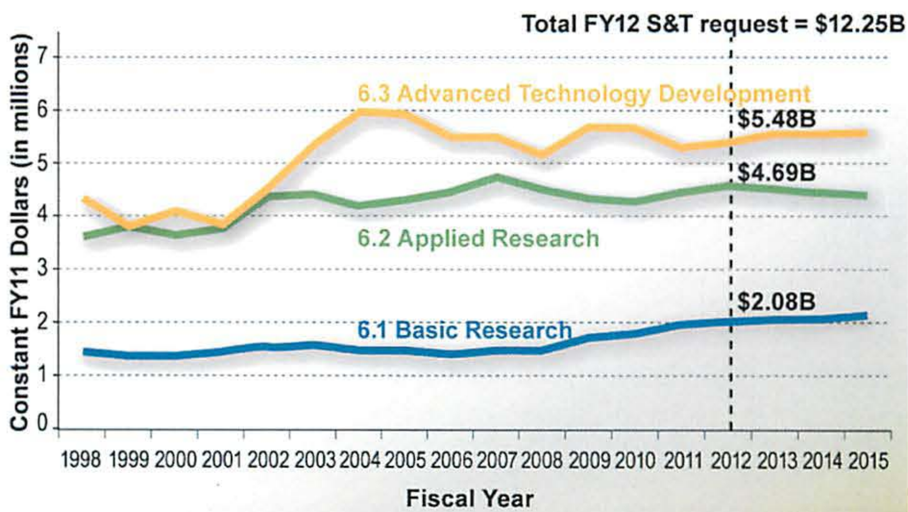
Source: National Science Foundation, 2010, Federal Funds for Research and Development: Fiscal Years 2007–09, NSF 10-305, Table 37.

Figure 2. In certain fields, DOD funds a much larger share of federal basic research, Fiscal Year 2007

Defense Basic Research Funding and Trends

As shown in Figure 3, and broken down in detail in Table 1, the defense basic research budget was approximately $2 billion in Fiscal Year (FY) 2011. While DOD research and development (R&D) investments dominate federal R&D spending, largely because of the substantial DOD investment in development of large military systems, the DOD basic research budget overall is modest compared to other federal agencies, such as medical research in the Department of Health and Human Services and energy and environmental research in the Department of Energy.[3]

Funding for DOD science and technology (S&T) has been relatively flat over the past few years. (See Figure 3.)[4] The DOD basic research budget increased in FY 2011 with a further increase requested in FY 2012. This movement is an indicator of the importance of exploration and discovery to the U.S. defense enterprise.[5]



Source: Z Lemnios, 2011, Shaping the Department's S&T Strategy, presentation at the National Defense Industry Association Meeting, June 21, 2011.

Figure 3. DOD S&T funding by budget activity

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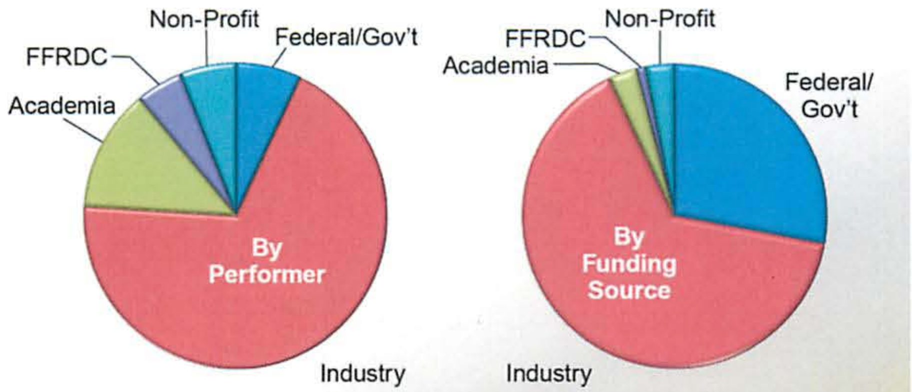
3. National Science Board, 2010. *Science and Engineering Indicators 2010*. National Science Foundation, (NSB 10-01), Figure 4-8.
4. Defense S&T generally includes funding labeled 6.1, 6.2, and 6.3; Defense R&D generally also includes funding labeled 6.4. More extensive definitions are provided in Appendix A.
5. Joanne Padrón Carney, Chapter 5, Department of Defense, in *AAAS Report XXXVI, Research and Development FY 2012*. Available at http://goo.gl/f1OPg (accessed November 2011).

Table 1. Research in the FY 2012 budget (in millions of dollars)

	FY 2010 Actual	FY 2011 Budget	FY 2012 Request
Defense S&T - all	$6,799		$6,875
Defense—Basic Research	*1,815*	*$1,999*	*2,078*
Army	*420*	*449*	*437*
Navy	*544*	*626*	*577*
Air Force	*474*	*514*	*519*
DARPA	*194*	*328*	*329*
Defense Threat Reduction Agency (DTRA)	*40*	*47*	*48*
DTRA Chem-Bio	*64*	*49*	*53*
Health and Human Services – all	31,259		32,173
National Institutes of Health	*30,047*		*31,041*
National Aeronautics and Space Administration	1,488		4,573
Energy – all	7,378		9,030
Energy – Office of Science	*3,908*		*4,142*
National Science Foundation	4,963		5,877
Agriculture	2,235		2,114
Commerce – all	937		1,232
National Oceanic and Atmospheric Admin	*467*		*506*
National Institute of Standards and Tech	*448*		*649*
Interior – all	692		658
U.S. Geological Survey	*587*		*548*
Transportation	727		846
Environmental Protection Agency	502		493
Veterans' Administration	1,082		938
Education	218		242
Homeland Security	361		382
Smithsonian	167		171
All Other	388		483
Total	**$59,196**		**$66,087**

Source: President's 2012 Budget Request

All R&D expenditures in the United States in 2011 totaled approximately $405 billion. As shown in Figure 4, industry substantially leads both in funding and performing R&D, albeit much more development than research.



Note: R&D is primarily funded and performed by industry; DoD basic research (~$2 billion) is less than 0.5% of U.S. R&D funding.

Source: National Science Board. 2010. Science and Engineering Indicators 2010. *National Science Foundation, (NSB 10-01), appendix table 4-3.*

Figure 4. Each circle represents total U.S. R&D expenditures in FY 2007

Finally, the global investment in R&D rose to nearly $1.1 trillion (total) in 2007 in the three major regions where R&D is funded. (See Figure 5.) Since the beginning of the 21st century, global spending on R&D has nearly doubled, publications have grown by a third, and the number of researchers worldwide continues to rise. The rate of growth of these indicators in China, India, and Brazil is much faster than the United States. Funding for R&D in China, for example, has grown by 20 percent per year since 1999, with a goal to spend 2.5 percent of their gross domestic product (GDP) on R&D in 2010.[6] India, Brazil, and South Korea have similar targets; over the same period, U.S. spending is flat or declining.

6. The Royal Society, 2011. *Knowledge, Networks, and Nations: Global scientific collaboration in the 21st century*. RS Policy Document 03/11, pp. 19.

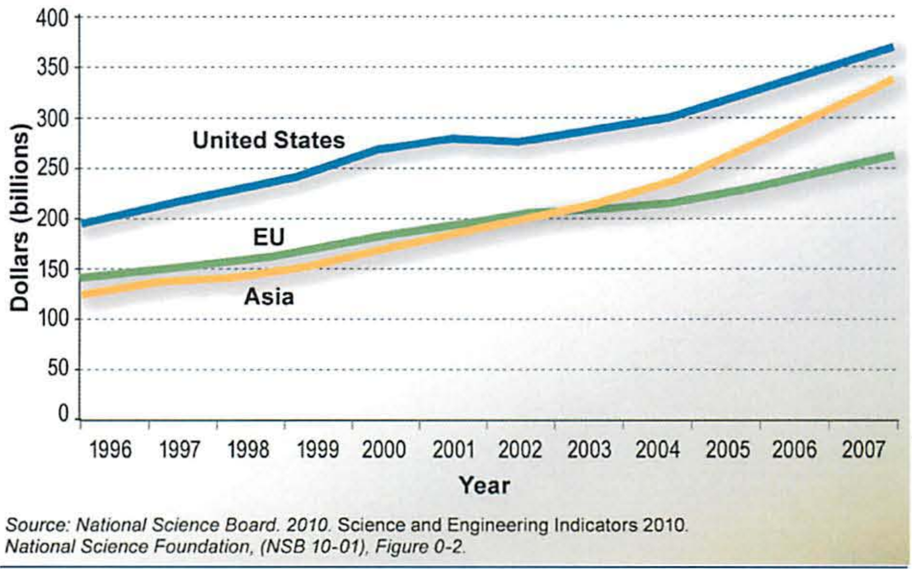


Figure 5. R&D expenditures for the United States, the European Union (EU), and Asia, 1996–2007

Basic Research Organizations

Within the DOD, a number of organizations fund, oversee, and perform basic research. Coordination among the DOD organizations and the external organizations that perform basic research is a constant challenge.

The simplest organizational structure for basic research in DOD is in the Air Force. All Air Force basic research funding is budgeted through the Air Force Office of Scientific Research (AFOSR), and all basic research program management resides in this organization. Intramural research is carried out primarily at the Air Force Research Laboratory (AFRL).

In the Navy, all DOD basic research funding is budgeted through the Office of Naval Research (ONR), and all basic research program management resides in this organization. However, ONR also oversees and manages applied research and advanced development S&T funding for the Navy. Intramural basic research is carried out primarily at the Naval Research Laboratory (NRL).

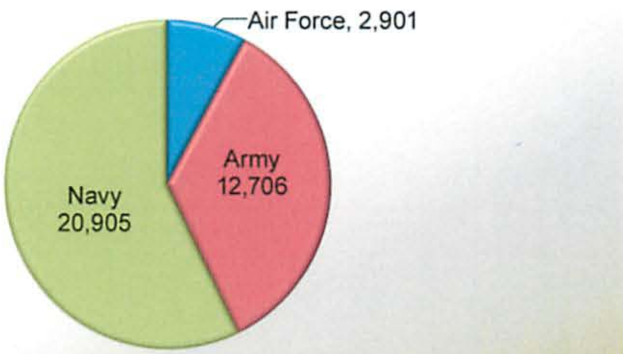
The Army presents perhaps the greatest organizational complexity. All Army basic research funding is budgeted through the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology, and policy guidance is provided by the Deputy Assistant Secretary for Research and Technology. However, much of the program management is carried out at other organizations, as follows:

- The Army's research organizations within the Research, Development, and Engineering Command (RDECOM) execute approximately 85 percent of the Army's basic research funding, with about 27 percent intramural (primarily at the Army Research Laboratory, ARL) and about 73 percent extramural (primarily through the Army Research Office, ARO).
- The Medical Research and Materiel Command (MRMC), under the Office of the Surgeon General, is responsible for about 9 percent of the Army's basic research funding, split between intramural and extramural efforts, and including a substantial number of congressional special interest projects.
- The Engineer Research and Development Center (ERDC), under the Army Corps of Engineers, executes an additional 4 percent of the Army's basic research budget, focused on engineering and environmental sciences.
- The Army Research Institute (ARI) for the Behavioral and Social Sciences, within the Army Human Resources Command, executes about 2 percent of the Army's basic research budget, primarily extramurally.
- The Army Space and Missile Defense Technical Center executes less than 1 percent of the Army basic research budget.

At the level of the Office of the Secretary of Defense (OSD), basic research is carried out at DARPA and the Defense Threat Reduction Agency (DTRA). DARPA and DTRA are organized similarly to ONR, overseeing basic and applied research, and advanced development programs. Neither DARPA nor DTRA have a direct relationship with an intramural research laboratory, and their programs fund both extramural researchers and Service laboratories.

The DOD Service Laboratories

Among DOD Service laboratories there are 67 separate facilities.[7] These Service laboratories perform a special role relative to basic research. Basic researchers at the Service laboratories are typically more knowledgeable about military needs, and this knowledge and co-location can facilitate technology transfer to applied research and advanced development. On a broader level, Service laboratories have important missions that involve all levels of research and development, and working in such an environment can provide a unique perspective that enhances basic research. The relative numbers of scientists and engineers at each Service's laboratories are compared in Figure 6.



Source: Diligent Innovations, Department of Defense Laboratory Civilian Science and Engineering Workforce—2011, *May 2011.*

Figure 6. Scientists and engineers employed at Service laboratories

The demographics of the laboratory scientists and engineers may impact their ability to contribute to the DOD mission. The largest population of scientists and engineers within the laboratories is between the ages of 45 and 54, making up 37 percent of the total population of approximately 35,000 individuals. Since 2008, however, the DOD laboratories have seen an increase in the total percentage of scientists and engineers 34 years and under. This group now makes up approximately one-third of the total DOD laboratory population. Scientists and engineers with baccalaureates dominate the current DOD civilian laboratory workforce, with 63 percent holding a bachelor's degree. Individuals with master's level degrees make up 26 percent, and 9 percent hold PhD

7. The Defense Laboratory Enterprise Directory is available at http://goo.gl/eOwU5 (accessed November 2011).

degrees.[8] This demographic profile reflects the fact that the Service laboratories engage in a full gamut of activities, of which basic research is only a part.

While some of these individuals work solely in basic research, many combine basic research with related applied research. In some disciplines, basic and applied research are tightly linked, and the proximity available in a large laboratory environment can facilitate advances. Opportunities for collaboration and an integrated approach can make the Service laboratory a more attractive place for all researchers. Laboratories can also provide access to specialized equipment or information that is difficult for an extramural researcher to purchase or support. However, some basic science techniques are used almost exclusively for military applications, and extramural researchers may not be interested in pursuing them.

University Affiliated Research Centers

A university affiliated research center (UARC) is a strategic DOD research center associated with a university. UARCs were established to ensure that essential engineering and technology capabilities of particular importance to the DOD are maintained. Although UARCs receive sole-source funding under the authority of 10 U.S.C. Section 2304(c)(3)(B), they may also compete for science and technology work unless precluded from doing so by their DOD UARC contracts.

These not-for-profit organizations maintain essential research, development, and engineering core capabilities; maintain long-term strategic relationships with their DOD sponsors; and operate in the public interest. Collaboration with the educational and research resources available at their universities enhances each UARC's ability to meet the needs of their sponsors. A list of DOD sponsored UARCs is provided in Table 2.

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8. Diligent Innovations, 2011. *Department of Defense Laboratory Civilian Science and Engineering Workforce—2011*, May 2011.

Table 2. University affiliated research centers

	Manager	FY10 budget (millions)
University of California at Santa Barbara: *Institute for Collaborative Biotechnologies*	Army	$11.9
University of Southern California: *Institute for Creative Technologies*	Army	$31.3
Georgia Institute of Technology: *Georgia Tech Research Institute*	Army	$13.2
Massachusetts Institute of Technology: *Institute for Soldier Nanotechnologies*	Army	$12.0
University of Texas at Austin: *Institute for Advanced Technology*	Army	$6.1
Utah State University: *Space Dynamics Laboratory*	Missile Defense Agency	$30.5
Johns Hopkins University: *Applied Physics Laboratory*	Navy	$684.3
Pennsylvania State University: *Applied Research Laboratory*	Navy	$97.7
University of Texas at Austin: *Applied Research Laboratories*	Navy	$81.2
University of Washington: *Applied Physics Laboratory*	Navy	$14.0
University of Hawaii at Manoa: *Applied Research Laboratory*	Navy	$2.5
University of Maryland, College Park: *Center for Advanced Study of Language*	National Security Agency (NSA)	$18.7
Stevens Institute of Technology: *Systems Engineering Research Center*	ASD(R&E) and NSA	$7.2

DOD Federally Funded Research and Development Centers

The federally funded research and development centers (FFRDCs) listed in Table 3 were established to perform the mission of providing the Department with unique capabilities in the many areas where the government cannot attract and retain personnel in sufficient depth and numbers. FFRDCs operate in the public interest, free from organizational conflicts of interest, and can therefore assist DOD in ways that industry, non-profit contractors that work for industry, and for-profit contractors cannot. DOD's FFRDCs maintain long-term capability in core competencies in domains that continue to be of great importance to the Department, such as analysis, engineering, acquisition support, and research and development. The three R&D laboratories listed in Table 3 carry out varying amounts of basic research.

Table 3. DOD federally funded research and development centers

	Sponsor
Study and Analysis Centers	
Center for Naval Analyses (CNA)	Navy
Institute for Defense Analyses (IDA)	USD(AT&L)
RAND Arroyo Center	Army
RAND National Defense Research Institute	USD(AT&L)
RAND Project AIR FORCE	Air Force
System Engineering and Integration Centers	
Aerospace Corporation	Air Force
MITRE National Security Engineering Center (NSEC)	USD(AT&L)
Research and Development Laboratories	
IDA Center for Communications and Computing	NSA
MIT Lincoln Laboratory	USD(AT&L)
Software Engineering Institute	USD(AT&L)

FFRDCs that are sponsored by agencies other than DOD also perform substantial and important basic research for DOD. The Department of Energy Lawrence Livermore National Laboratory, the Los Alamos National Laboratory, and the Sandia National Laboratories are examples.

Previous Assessments of Defense Basic Research

A number of previous studies have been conducted to assess basic research in the Department of Defense.

National Academies

In 2005, the National Academies published a report assessing basic research in the DOD.[9] This study was requested by Congress, which noted that in order to maintain the nation's competitive technology base, the DOD continues to fund basic research. However, between 2002 and 2008, it came to the attention of the congressional committees on armed services that basic research funded by the DOD may have changed direction or emphasis. Several organizations, including university research departments and defense laboratories, described areas of concern that included the following:

9. National Research Council, 2005. *Assessment of Department of Defense Basic Research*. National Academies Press.

- Some research conducted using funds designated specifically for basic research might not, under the DOD's definition, be considered basic research.
- Reporting requirements on DOD grants and contracts had become cumbersome and constraining to basic researchers.
- Basic research funds were handled differently among the Services, which made the funds, in some cases, difficult to track and monitor.

These concerns prompted the armed services committees to request that the National Academies perform a study regarding the nature of basic research being funded by the Department of Defense.

The overall conclusion of the study was that no significant quantities of 6.1 funds had been directed toward projects that were typical of research funded under categories 6.2 or 6.3. (See Appendix A.) However, the study members questioned the standard definition of basic research, generally stated as efforts that explore the fundamental nature of science with a goal to discover new phenomena. Such efforts may occur long before a specific use is identified, but, the study noted, it is important to consider the continuing and interconnected need for discovery from basic research through applied research, development, and operations stages.

The study report also expressed concern over trends within DOD for reduced attention to unfettered exploration owed to pressure to meet near-term needs of a nation at war. Finally, the study identified the key to effective management of basic research as experienced, empowered managers. Empowerment factors included flexibility to modify goals and approaches, freedom to pursue unexpected paths and high-risk research questions, minimum requirements for detailed reporting, open communications, freedom to publish, unrestricted involvement of students and postdoctoral fellows, no restrictions on nationality of researchers, and stable funding.

Detailed findings and recommendations from this report are included in Appendix B.

JASON Group

In 2009, the JASON group reported on their 2008 Summer Study on S&T for National Security.[10] This study was chartered by the ASD(R&E) to consider how basic research should be structured within the DOD to best meet the challenges ahead.[11] The study began by recognizing that the context for DOD basic research was changing rapidly owing to changing global circumstances, changing national security missions, the accelerating pace of technology advances, the globalization of technology, the rise and spread of commercial technology that dilutes DOD's influence, and improvements in the global technical talent pool.

The study noted that current and projected future budget requests allocated more money to basic research, but cautioned that such increases alone would not address the aforementioned issues. Rather, systemic and institutionalized changes in process, organization, and personnel would be required.

The JASON group found that a vital DOD basic research program is important to advancing a number of defense-unique fields, to attracting and retaining a high-quality science and engineering workforce, and to maintaining an awareness of (and readiness to exploit) fundamental advances in an increasingly global research enterprise. The common belief that long-term research investments yield low returns and that results can be generated as needed were deemed not correct.

According to the JASON report, the organization of basic research in the Department could be characterized as program management and execution by the Services, with certification, representation, and relatively weak review and coordination provided by the ASD(R&E). While this allowed the Services to "own" their individual programs, it made coordination and synergies less likely, and rendered the basic research program susceptible to a "drift" away from long-term imperatives to short-term needs. Indeed, the extraordinarily productive DOD tradition of knowledgeable and empowered program managers (PMs) supporting the very best researchers working on the most

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10. The MITRE Corporation, *S&T for National Security*. JASON JSR-08-146, May, 2009.
11. When this report was published in 2009, the office was termed Director, Defense Research and Engineering (DDR&E). The office of the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) was created in 2011.

fundamental problems seemed to have morphed during the past decade into a more tightly managed effort with a shorter term and more applied character. Evolutionary advances seemed to be the norm, and revolutions were less likely to be fostered.

The study's most fundamental recommendation was to protect basic research funding at the OSD level by strengthening and expanding the role of the ASD(R&E), with a greater visibility in the Department and greater capability to understand and shape the Services' basic research activities.

To address some of the endemic personnel issues in the DOD, the study recommended that a Research Corps be established. A related recommendation was made to the DOD laboratories. While these personnel focus principally on applied R&D activities, the laboratories should also house some researchers engaged in basic research who are well-coupled to the broader research communities.

The study concluded with recommendations to increase DOD participation in the development and maintenance of the S&T educational pipeline. Mechanisms included enhancing existing mechanisms of graduate student and postdoctoral support, exploring training grants and vertically integrated models, and expanding and improving the National Security Science and Engineering Faculty Fellowship (NSSEFF) Program.

Detailed recommendations from this report are included in Appendix B.

Office of Management and Budget Assessment

In 2002, a formal assessment was conducted by the Office of Management and Budget, which published the main conclusion that the DOD basic research program had clear purposes. It helped develop technologies that provide options for new weapons, helped prevent technological surprise by adversaries, and developed new scientists who could contribute to the DOD mission in the future.

Additional conclusions found the program was reviewed regularly by technically capable outside experts, who recommended improvements they believed should be implemented. The expert reviewers indicated that the work is of overall high quality. Finally, research earmarks were found to have increased dramatically in the past 15–20 years. Such projects contribute less than typical projects to meeting the Department's mission, as they don't have to be screened for relevance or quality, and cost more to administer.[12]

12. ExpectMore.com, *Program assessment of Defense Basic Research*. Available at http://goo.gl/9DWjd (accessed November 2011).