CONGRESSIONAL BUDGET OFFICE
U.S. Congress
Washington, DC 20515

Peter R. Orszag, Director

January 15, 2008

Honorable Terry Everett
Ranking Member
Subcommittee on Strategic Forces
Committee on Armed Services
U.S. House of Representatives
Washington, DC 20515

Dear Congressman:

At your request, the Congressional Budget Office (CBO) has analyzed whether a difference exists between the Department of Defense's (DoD's) funding for science and technology (S&T) activities supporting unclassified space programs and its funding for S&T activities supporting other (nonspace) programs. The enclosed report indicates that funding for S&T activities supporting unclassified space programs has been less than S&T funding for other defense programs and that DoD's plans for the future maintain that difference in funding. (Because of a lack of information, CBO's analysis does not address the extent to which classified research might be supporting unclassified space programs.)

If you would like further details, we would be pleased to provide them. CBO's analysis was performed by Matthew Goldberg and Paul Rehmus, who can be reached at 202-226-2900.

Sincerely,

Peter R. Orszag

Enclosure

cc: The Honorable Ellen O. Tauscher
Chairman
Subcommittee on Strategic Forces
House Committee on Armed Services

Honorable Ike Skelton
Chairman
House Committee on Armed Services

Honorable Duncan Hunter
Ranking Member

Honorable John M. Spratt Jr.
Chairman
House Committee on the Budget

Honorable Paul Ryan
Ranking Member

Honorable Carl Levin
Chairman
Senate Committee on Armed Services

Honorable John McCain
Ranking Member

Honorable Kent Conrad
Chairman
Senate Committee on the Budget

Honorable Judd Gregg
Ranking Member

A Comparison of Science and Technology Funding for DoD's Space and Nonspace Programs

January 15, 2008

The Congress of the United States ■ Congressional Budget Office

Contents

Tables

Figures

Introduction and Summary

As is the case with many of its other programs, a number of the Department of Defense's (DoD's) unclassified space programs have experienced growth in their costs and delays in their schedules—compared with what DoD envisioned when the programs entered the development and demonstration phase of their implementation. Some analysts have suggested that those problems may be caused in part by insufficient funding for science and technology (S&T) activities before the programs began.[1] In this analysis, the Congressional Budget Office (CBO) considered whether a difference exists between the funding that the Defense Department provides for unclassified S&T activities that support such space programs and the funding it provides for S&T activities that support other, nonspace programs.

In its comparisons, all of which involve unclassified activities, CBO found that, relative to the programs' total spending on research, development, test, and evaluation (RDT&E) activities, funding for S&T activities in support of space programs has been significantly less over the 1980–2007 period than S&T funding for programs that do not involve space systems; moreover, DoD's plans for the future maintain that difference. CBO's analysis did not, however, establish a causal link between that lower amount of S&T funding and the cost growth and schedule delays that have occurred in some ongoing space programs. Also, CBO's analysis did not consider the extent to which funding for classified space programs might be supporting unclassified space programs.[2]

CBO's analysis is based on funding data from the Future Years Defense Program (FYDP) for fiscal year 2008 (which spans 2008 through 2013) and other government budget documents.[3] (All years referenced in this attachment are fiscal years.) Using those data, CBO compared the ratio of S&T funding to total spending on RDT&E

1. Defense S&T activities include basic research to improve understanding of physical phenomena, applied research to explore and test potential applications of the results of basic research, and advanced technology development of specific ways to implement particular applications in military systems.

2. No data were available to CBO regarding spending for classified S&T activities or space programs. If there are classified research activities that support unclassified space programs, the inclusion of the funding for that classified research, if any, could lessen the difference CBO has noted between funding for S&T activities supporting space and nonspace programs.

3. The FYDP is a database comprising a historical record of defense forces and spending as well as DoD's plans for future spending. The historical portion of the FYDP shows costs, forces, and personnel levels since 1962. The plan portion presents DoD's program budgets (estimates of funding needs for the next five or six years based on the department's current plans for all of its programs). This CBO assessment used the FYDP submitted to the Congress as part of the President's fiscal year 2008 budget request. The set of space programs that CBO used for its analysis is described in Congressional Budget Office, *The Long-Term Implications of Current Plans for Investment in Major Unclassified Military Space Programs* (September 12, 2005). Also, Appendix A describes DoD's budgetary and programmatic classifications of science and technology activities, which CBO used in drawing funding data from the FYDP.

activities (S&T funding is a subset of that broader category). In this report, CBO refers to that measure as "S&T intensity." The study period spanned 1980 to 2007; the analysis considered five mutually exclusive sets of DoD programs: space and nonspace programs run by the Army, space and nonspace programs run by the Air Force, and nonspace programs run by the Navy.[4] Over the 1980–2007 period, funding for all of DoD's S&T activities averaged about $10 billion annually, and funding for all of DoD's RDT&E activities averaged about $50 billion annually. Over that 28-year period, funding for space-related S&T activities averaged about $400 million annually.

CBO found significant differences between the S&T intensities for space and nonspace programs. Its analysis indicates that over the 1980–2007 period, relative to the programs' total spending for RDT&E, the Army and Air Force spent significantly less for S&T activities that support space programs than they spent for such activities supporting their other programs. S&T intensity for the Army's space programs averaged about 10 percent; however, S&T intensity averaged 28 percent for the service's other (nonspace) programs. S&T intensity averaged about 12 percent for the Air Force's space programs but 17 percent for its other programs (see Figure 1). Those differences between S&T intensity for space and nonspace programs are statistically significant, according to CBO's analysis; that is, the differences are unlikely to have occurred by chance.

Will the priorities that the services assign to funding S&T activities for their space and nonspace programs change markedly in the future? CBO used data from the FYDP to compare the historical data discussed above with the S&T funding that the military services plan to allocate to support their unclassified space and nonspace programs:

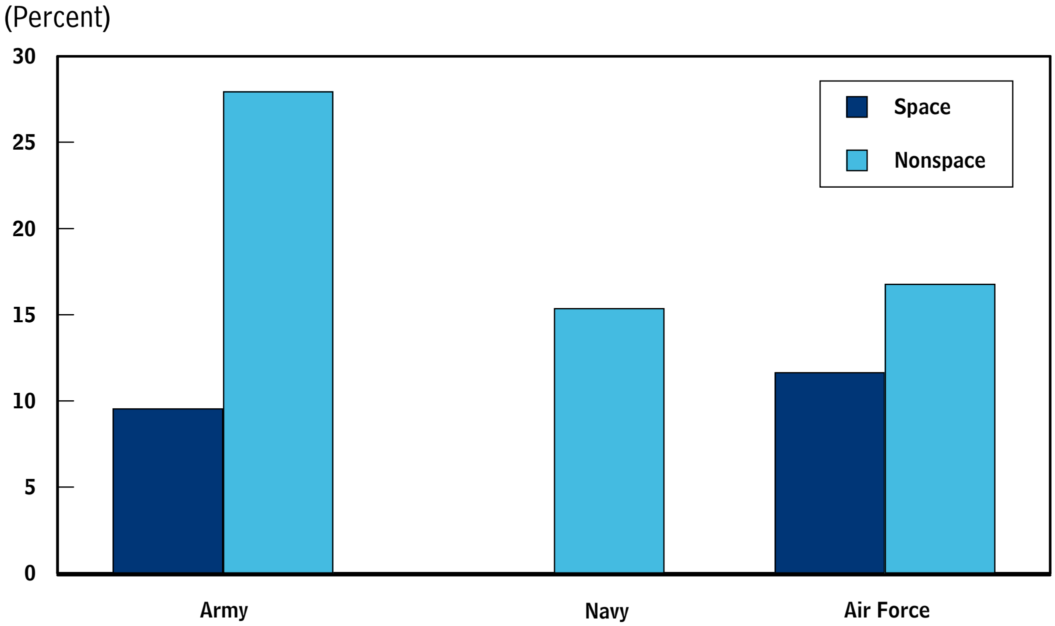
- The 2008 FYDP indicates that S&T intensity for the Army's space programs will fall to about 6 percent or less over the 2008–2013 period—or 40 percent lower than its 28-year average of 10 percent. That prospective 6 percent intensity for those programs falls at the lower end of the range of annual variation over the past 28 years.

- According to the FYDP, S&T intensity for the Air Force's space programs will average about 4 percent during the 2008–2013 period, a figure significantly below the range of annual variation over the past 28 years.

4. The funding for the Navy's space-related S&T activities is less than 1 percent of the service's space-related RDT&E funding—for an S&T intensity close to zero. Similarly, during the period considered in CBO's analysis, the defense agencies (including the Missile Defense Agency) funded only small (often zero) amounts of such activities. In those two cases, space-related S&T activities funded by other DoD components, such as the Air Force, could obviate the need for service- or agency-specific S&T funding. Consequently, CBO excluded Navy and defense agency space programs from its analysis.

Figure 1.

Average Science and Technology Intensity for Space and Nonspace Programs, by Military Service



Source: Congressional Budget Office.

Note: S&T intensity is the ratio of S&T funding to total funding for research, development, test, and evaluation activities. The intensities displayed are averages (means) for the 28-year period spanning 1980 to 2007.

CBO's analysis also indicates that if the plans in the 2008 FYDP are executed, S&T intensity for the Air Force's and Army's space programs will continue to be significantly lower than the S&T intensity for the two services' other programs. In other words, both the Army and the Air Force plan to continue to allocate relatively less funding to S&T activities that support space programs than to such activities that support their other programs. In addition, the Air Force's funding for space-related S&T activities will be significantly lower in the future than it has been in the past.

CBO also conducted case studies of individual space programs. The National Polar-Orbiting Operational Environmental Satellite System and the Space-Based Infrared System in High-Earth Orbit are two ongoing unclassified programs that have experienced substantial schedule delays and cost growth. Historical data from the FYDP indicate that the predecessors of those programs—respectively, the Defense Meteorological Satellite Program and the Defense Support Program—were both allocated a comparable or greater amount of S&T funding for activities uniquely associated with them than has been provided for their successors; moreover, both of the older programs experienced less cost growth and fewer schedule problems than their successors have experienced. CBO's analysis, however, does not indicate whether that better programmatic performance is linked to more funding for S&T activities, nor does it suggest whether historical and current experience with those four programs can be used to draw general conclusions about other DoD space programs.

CBO's Analysis of Funding for Space and Nonspace Programs

Averaging the 28 annual observations that span 1980 to 2007 shows that S&T intensity in the Army's and Air Force's space programs is lower than S&T intensity in those services' nonspace programs. For example, S&T intensity for the Army's space programs averaged about 10 percent, but intensity for its other (nonspace) programs averaged 28 percent. S&T intensity for the Air Force's space programs averaged about 12 percent; for the service's other programs, S&T intensity averaged 17 percent (see Figure 1).[5] In addition, the Army shows higher S&T intensity in its nonspace programs than the other two services exhibit.

In studying funding for the military's unclassified S&T activities, CBO used analysis-of-variance (ANOVA) techniques to test for statistically significant differences in S&T intensity between space and other, nonspace programs, notwithstanding other differences among the services. (Another part of CBO's analysis considered such service-related differences.) A single data point in the ANOVA calculation consisted of the S&T intensity for a particular fiscal year and sector. (In CBO's analysis, a sector represents one of the three military services and either space or nonspace programs; thus, CBO's analysis considered five sectors corresponding to the five sets of programs noted earlier.) CBO performed an unweighted ANOVA on the grounds that the annual S&T intensity for one service is as valid a data point as the annual intensity for either of the other services. The ANOVA confirms that the differences in intensity between the services and between the space and nonspace programs are statistically significant at levels well beyond the conventional 1 percent.[6]

A potential concern is that one of the assumptions underlying a classical ANOVA may be violated if S&T funding for some pairs of sectors have similar time trends and are thereby correlated over time. For example, the large buildup in defense spending during the Reagan years (the early 1980s) and again during the current Bush Administration (starting in 2002) might induce (presumably positive) correlations in S&T funding among the five sectors studied. However, some of the correlation can be removed by considering annual S&T intensities instead of annual funding data—because both

5. For graphic displays of the time-series data for the S&T intensities considered in CBO's analysis, see Appendix B.

6. That is, predictions of annual S&T intensity are significantly improved by knowledge of which service is involved and whether the programs are space or nonspace. The F-statistic for the space effect is 515.3, compared with a 1 percent critical value of 6.79 (1 and 162 degrees of freedom). Similarly, the F-statistic for the service effect is 126.3, compared with a 1 percent critical value of 4.74 (2 and 162 degrees of freedom).

the S&T funding in the numerator of a sector's intensity calculation and the RDT&E funding in its denominator will manifest a similar trend over time to that of the overall defense budget. As a result, the S&T ratio will be less sensitive to time trends than the raw dollar amounts of S&T funding will be.[7]

A remaining question is whether the pairwise differences among sectors are all statistically significant and, in particular, how S&T intensity in the Navy compares with that in the Air Force. Over the 28-year period, S&T intensity in the Navy's nonspace programs averaged 15 percent versus 12 percent in the Air Force's space programs and 17 percent in the Air Force's nonspace programs (see Figure 1). A multiple regression analysis can control for the effect of space versus nonspace programs and measure any remaining difference in intensity between the activities of the two services. According to the analysis that CBO performed, S&T intensity is higher for the Air Force's than for the Navy's nonspace programs (17 percent versus 15 percent)—and higher still for the Army's nonspace programs (28 percent).[8] Those differences are all statistically significant.

CBO compared the S&T funding levels that the military services proposed in the 2008 FYDP with the historical data discussed above to determine whether the services intend to sustain their current S&T intensity, particularly with regard to space programs. The Army has programmed S&T funding for its space sector that falls to 6 percent of the total RDT&E budget—or roughly half the level in 2006 and 2007, which was about 12 percent (see Figure 2). However, that S&T intensity of 6 percent falls within one standard error of the average over the past 28 years (see Figure 2).

By contrast, the S&T intensity of the Air Force's space programs through 2013 is about 4 percent, which is below the one-standard-error historical band for the Air Force's programs. The Air Force's S&T intensity in 2007 (about 6 percent) also fell below the historical band; indeed, the last time that S&T intensity for the Air Force's space programs fell within the band was in 2006 (see Figure 3).

CBO's analysis also indicates that if the plans in the 2008 FYDP are executed, S&T intensity for the Air Force's and Army's space programs will continue to be significantly lower than the intensity for the two services' other programs. Thus, both services plan to continue to allocate relatively less funding to S&T activities that

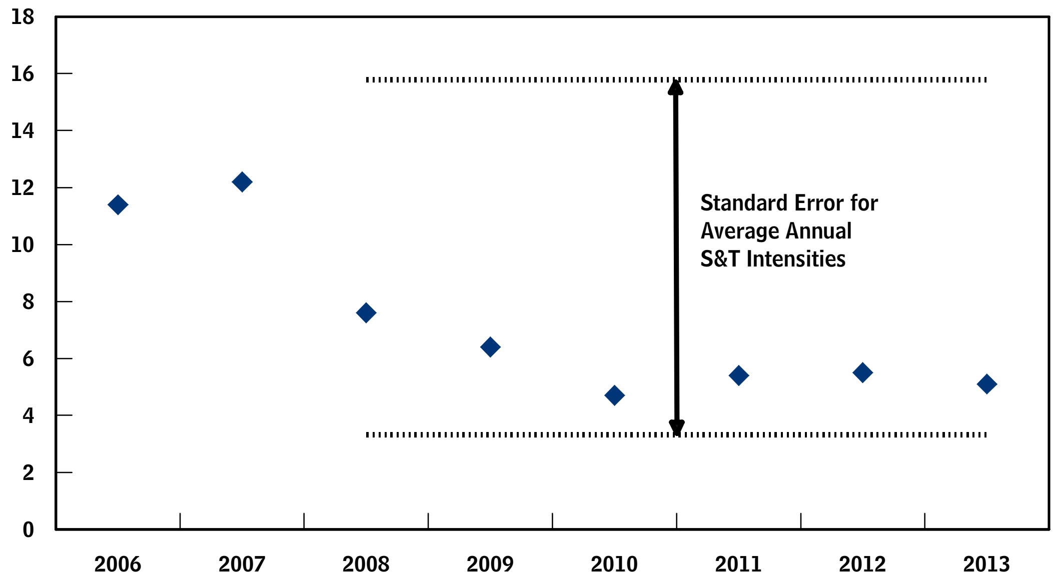
7. Over the five sectors, the average absolute value of the 10 pairwise correlations, measured as raw S&T dollar amounts of funding, was 0.289 during the 1980–2007 period. Thus, correlations resulting from time trends (or other effects) among the sectors are relatively small. As expected, the average absolute correlation in S&T intensity was somewhat lower—0.235 over the same period.

8. The multiple regression yields a coefficient for the space effect (that is, whether S&T intensity differs between space or nonspace programs) of -11.8 (indicating that S&T intensity for space programs is lower than for nonspace programs), with a *t*-statistic of -12.35. The coefficient in the regression for the S&T intensity of the Air Force versus that of the Navy is 4.72, with a *t*-statistic of 3.74. The coefficient in the regression for S&T intensity in the Army versus that of the Air Force is 4.54, with a *t*-statistic of 4.76. The value of R squared in the regression is 0.57.

Figure 2.

Planned Science and Technology Intensity for the Army's Space Programs

(Percent)



Source: Congressional Budget Office.

Note: S&T intensity is the ratio of S&T funding to total funding for research, development, test, and evaluation activities. The range spanned by the double arrow is one standard error in the variation of annual S&T intensities around the mean intensity for the 1980–2007 period.

support space programs than to S&T activities that support their other programs. In addition, the Air Force's funding for space-related S&T activities will be significantly lower in the future than it has been in the past.

Comparing Science and Technology Intensity for Selected Space Programs

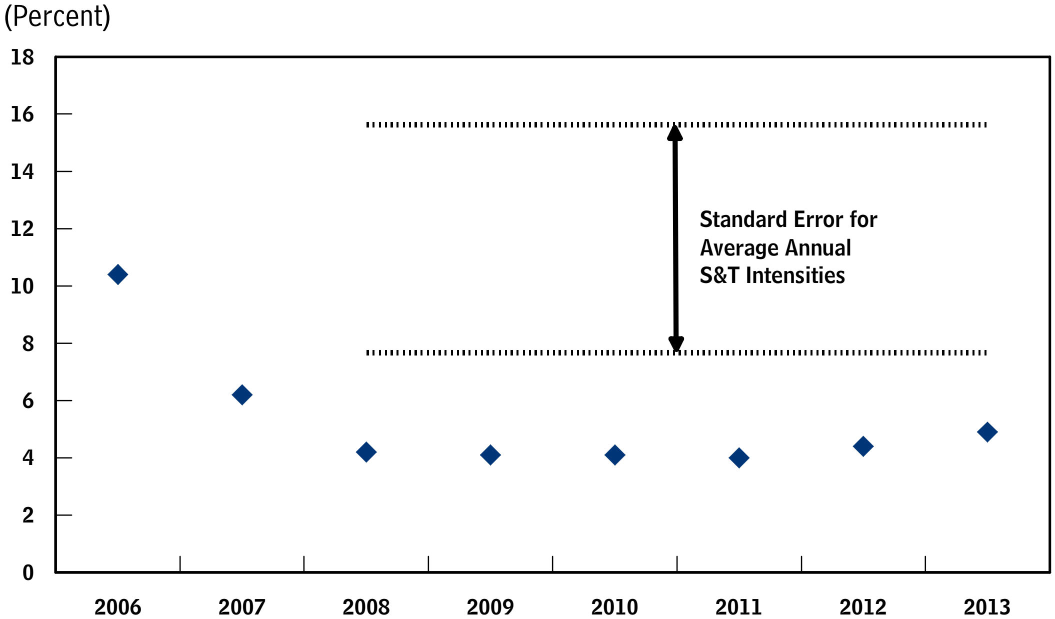
As noted earlier, a number of DoD's unclassified space programs have experienced cost growth and delays in their schedules.[9] CBO assessed the intensity of S&T funding for two of the Air Force's space programs and compared it with the S&T intensity of the programs that preceded them:

- The National Polar-Orbiting Operational Environmental Satellite System (NPOESS) program, which is conducted jointly by DoD, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric

9. For example, see Government Accountability Office, *Defense Acquisitions: Space System Acquisition Risks and Keys to Addressing Them*, GAO-06-776R (June 1, 2006).

Figure 3.

Planned Science and Technology Intensity for the Air Force's Space Programs



Source: Congressional Budget Office.

Note: S&T intensity is the ratio of S&T funding to total funding for research, development, test, and evaluation activities. The range spanned by the double arrow is one standard error in the variation of annual S&T intensities around the mean intensity for the 1980– 2007 period.

Administration, builds satellites that carry environmental and weather sensors that will replace environmental satellites currently in orbit.

- The Defense Meteorological Satellite Program (DMSP) is the predecessor to the NPOESS program. Conducted by DoD alone, DMSP was started in 1982; its last satellite is scheduled to be launched in 2011.

- The Space-Based Infrared System in High-Earth Orbit (SBIRS-H) is a DoD program that builds satellites launched into geosynchronous orbits, or GEOs, 26,200 miles above the earth's surface and payloads placed into highly elliptical orbits (HEOs). The satellites carry sensors that can detect emissions in the infrared portion of the spectrum, which allows them to determine whether a missile has been launched. The satellites also carry other sensors that can detect the flashes of light and radiation emitted when a nuclear detonation occurs.

- The Defense Support Program (DSP) is the predecessor to SBIRS-H. The program was started in 1967, and its last satellite was launched in 2007.

Table 1.

Schedule Delays and Cost Growth for Selected DoD Satellite Programs

Program	Schedule Delays (Years)	RDT&E Cost Growth (Percent)	Procurement Cost Growth per Satellite (Percent)
Ongoing			
National Polar-Orbiting Operational Environmental Satellite System	6.0	97	352
Space-Based Infrared System in High-Earth Orbit	5.0	184	471
Predecessor			
Defense Meteorological Satellite Program (To NPOESS)	1.5	13	39
Defense Support Program (To SBIRS-H)	0	23	7

Source: Congressional Budget Office based on data from the Department of Defense's Selected Acquisition Reports.

Note: RDT&E = research, development, test, and evaluation.

In the two case studies CBO considered (comparing NPOESS with DMSP and comparing SBIRS-H with DSP), the analysis showed that all four of the programs experienced—or are experiencing—cost growth and schedule delays. However, the cost growth that the NPOESS and SBIRS-H programs are experiencing is greater than the growth experienced by their predecessor programs (see Table 1).

The sensors aboard satellites from the NPOESS program and DMSP have many technologies in common. For example, the sensors in both satellites can produce images from the optical and infrared spectra, measure the temperature of the earth's atmosphere and its moisture content by detecting the emission of microwave energy (called microwave sounding), and measure other physical characteristics of the space environment. However, because the NPOESS satellites will be larger and have more power-generation capacity than DMSP satellites, the NPOESS satellites will generally carry sensors that have more capabilities. For example, sensors aboard NPOESS satellites will be able to measure atmospheric temperature more precisely as a function of altitude than the DMSP satellites can. NPOESS satellites will also have better sensors (compared with those on DMSP satellites) for measuring the ozone content of the upper atmosphere.

Similarly, sensors aboard DSP and SBIRS-H satellites have many technologies in common. For example, both carry infrared sensors to detect the exhaust plumes of missiles as well as sensors to detect the light, neutrons, X-rays, and gamma rays emitted during a nuclear detonation.

In its analysis of the technologies used in DoD's programs, CBO uses several terms whose definitions are important in determining S&T intensity for a program and also in determining which technologies are supporting which activities or systems. For example, a "unique technology" is one that is associated with a particular acquisition program and not broadly applicable to other programs. To illustrate, the NPOESS satellites will carry weather sensors that incorporate technologies applicable only to weather satellites, such as those in the NPOESS program. CBO categorizes such technologies as unique to NPOESS.[10]

By comparison, a "supporting technology" is one that is applicable to many programs. For example, the technologies used in the power and propulsion systems on NPOESS satellites support not only that program's satellites but also satellites from many of DoD's other such programs.

Another important definition for this analysis is "direct S&T funding"—funding for S&T activities that involve only the unique technologies supporting a particular program. CBO computed S&T intensities for the four programs considered in this part of its analysis by using only direct S&T funding, because that investment—rather than the funding for supporting technologies applicable to many, if not all, space programs—is most likely, in CBO's judgment, to affect a particular program's cost and schedule performance.[11] Thus, CBO computed S&T intensity for a particular program in the case studies as the ratio of direct S&T funding to total RDT&E funding.

Using the historical portion of the FYDP and other sources, CBO constructed time-series data for investment in the DMSP, NPOESS, DSP, and SBIRS-H programs to calculate S&T intensities for each one; those data included funding for direct S&T activities that preceded the formal beginning of a program (see Appendix D). The time series incorporated the following assumptions:

- The start of direct S&T investment associated with a program occurs 25 years before the program's initial operational capability (IOC).[12] Because DoD has not

10. However, a unique technology is not necessarily associated with a single defense program; it can be associated with several similar programs.

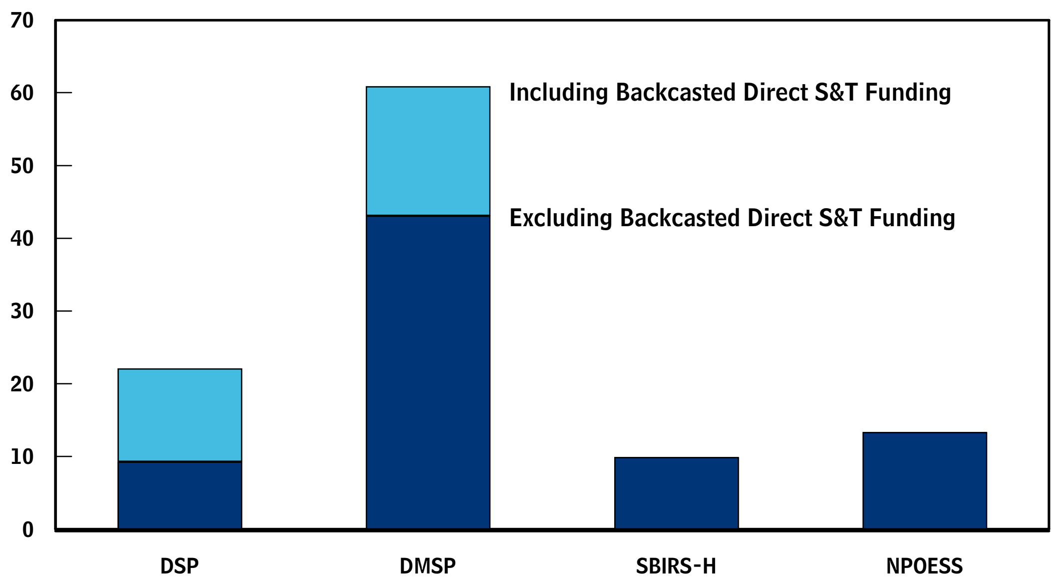
11. Appendix C displays the complete set of projects and subprojects from the FYDP that are associated with the four satellite programs that make up CBO's two case studies.

12. The Air Force fielded systems such as the Airborne Warning and Control System, the Joint Surveillance and Target Attack Radar System, the Low-Altitude Navigation Targeting Infrared for Night system, the Maverick missile, the Advanced Medium-Range Air-to-Air Missile, the F-117 tactical fighter, and the Global Positioning System about 25 years after initiating work on the key technologies associated with those programs. Also, the Air Force manages its S&T program by using a method referred to as Current Mission Area Plans, which each cover a 25-year planning period.

Figure 4.

Science and Technology Intensity Over the Lifetimes of Two Ongoing Space Programs and Their Predecessor Programs

(Percent)



Source: Congressional Budget Office based on data from the Department of Defense.

Notes: S&T intensity is the ratio of direct S&T funding supporting a program to the total funding for that program's research, development, test, and evaluation (RDT&E) activities less funding for satellites built during the RDT&E period. (Direct S&T funding comprises funding for S&T activities that involve only the technologies supporting a particular program.)

Backcasting is the assumption that funding in earlier years for which data are unavailable is equal to the average funding allocated over a period of subsequent years for which data are available.

DSP = Defense Support Program, the predecessor to SBIRS-H; DMSP = Defense Meteorological Satellite Program, the predecessor to NPOESS; SBIRS-H = Space-Based Infrared Systems in High-Earth Orbit; NPOESS = National Polar-Orbiting Environmental Satellite System.

yet specified an IOC for SBIRS-H, CBO used the date set for delivery of the first satellite to DoD.[13]

- Direct S&T investment ends on the date of production of the last satellite.

CBO used linear interpolation to estimate direct S&T investment in years for which data were unavailable—that is, during the 1982–1986 and 1992–1993 periods. (Data

13. According to the Air Force, the timing of the launching of the first SBIRS-H GEO satellite will depend on the rate of failure of the existing DSP satellites and the degradation in the surveillance coverage they provide. SBIRS-H HEO payloads have been delivered to the Air Force, and one is in orbit.

on direct S&T investment were available for the 1978–1981, 1987–1991, and 1994–2013 periods.) CBO also used backcasting—for example, to estimate S&T funding for DMSP prior to 1978.[14]

The streams of funding for each of the four satellite programs follow a similar pattern: Each has an initial period of S&T funding only, followed by a period of funding for other research and development activities and culminating in the procurement phase (the usual pattern of funding for almost all of DoD's programs—see Appendix D). Direct S&T investment and other research and development funding continue throughout the procurement period to support improvements to the sensors used on the satellites.

Comparing the S&T intensities of the four programs indicates that both DSP and DMSP were preceded by a comparable or substantially larger amount of direct S&T investment than is currently planned for the SBIRS-H and NPOESS programs (see Figure 4). CBO's analysis did not, however, determine whether lower levels of S&T funding caused cost overruns and delays in the programs' schedules.

The use of backcasting may have introduced errors in the S&T intensities computed for DMSP and DSP, and CBO thus displays two sets of results for those programs: one that includes the use of backcasted S&T funding and one that excludes it. The S&T intensity for the NPOESS program of 13 percent is within one standard error of the historical average of S&T intensity associated with all of the Air Force's space programs (12 percent); the 10 percent S&T intensity for SBIRS-H also falls within that range. The S&T intensity for DSP ranges from 9 percent to 22 percent (excluding and including backcasted S&T funding, respectively), which is within the range of one standard error of the historical average to more than 2 standard errors above the historical average. The S&T intensity for DMSP ranges from 43 percent to 61 percent (excluding and including backcasted S&T funding), or from about 8 to 12 standard errors above the historical average.

14. Backcasting is the assumption that funding in earlier years for which data are unavailable is equal to the average funding allocated over a period of subsequent years for which data are available.

Appendix A: Budgetary Treatment of Funding for the Department of Defense's RDT&E and Science and Technology Activities

In preparing budgets for its programs, the Department of Defense (DoD) categorizes research, development, test, and evaluation (RDT&E) activities in three ways: by type of budget authority, by major force program, and by technology readiness level. In analyzing DoD's funding of RDT&E for its unclassified space programs, the Congressional Budget Office (CBO) used funding data arrayed by major force program taken from the 2008 Future Years Defense Program. This appendix illustrates how those data are related to the other two ways that DoD treats funding for RDT&E activities.

Categorization by Budget Authority

Budget authority is the authority provided by law to incur financial obligations that will result in immediate or future outlays of federal government funds. The Administration's Office of Management and Budget and DoD both use budget authority to differentiate among the kinds of RDT&E that DoD conducts. DoD divides its RDT&E funding into seven different types of budget authority. The first three are collectively termed "science and technology (S&T) budget authority":

- Budget authority 1 (BA 1) funds basic research, which is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts but without specific applications to processes or products in mind.[1]

- BA 2 funds applied research—systematic study to understand the means to meet a recognized and specific need.

- BA 3 funds advanced technology development, which includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments or tests in a simulated environment.

The other types of RDT&E budget authority are as follows:

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1. Definitions for the above categories of budget authority are taken from the preambles to the complete definitions provided in Department of Defense, *DoD Financial Management Regulation*, vol. 2B (June 2006), Chapter 5, section 0501, p. 5-2.

- BA 4 funds advanced component development and prototypes, including efforts that evaluate integrated technologies, representative modes, or prototype systems in a high-fidelity and realistic operating environment.

- BA 5 funds system development and demonstration programs. Such programs conduct engineering and manufacturing development tasks aimed at meeting validated requirements prior to full-scale production.

- BA 6 funds RDT&E management support.

- BA 7 funds development of operational systems, which covers development efforts to upgrade systems that have been fielded or have received approval for full-scale production.

Categorization by Major Force Program

DoD organizes its budget into 11 so-called major force programs (MFPs). The first 10 of the MFPs were defined in the 1960s; program 11 followed in the 1980s.

- Program 1—Strategic Forces. The funds in this category are organized into program elements that pay for organizations and associated weapon systems whose missions encompass intercontinental or transoceanic intertheater responsibilities.[2]

- Program 2—General-Purpose Forces. These program elements fund organizations and associated weapon systems whose mission responsibilities are, at any given point in time, limited to one theater of operations.

- Program 3—Intelligence and Communications. This category funds assets and resources related primarily to centrally directed mission-support functions that are not specifically identified with another MFP. Examples of program elements include mapping and charting, geodesy activities (basically, mathematical studies related to the Earth and its gravitational field), weather service, oceanography, special activities, nuclear weapons operations, space boosters, and satellite control and aerial targets.

- Program 4—Airlift and Sealift Forces. These program elements fund airlift, sealift, traffic management, and water terminal activities; they include command, logistics, and support elements that are part of the units engaged in those activities.

- Program 5—Guard and Reserve Forces. This category covers funding for guard and reserve training units that support strategic, general-purpose, and other major force programs.

2. Definitions of the programs are taken from the preambles to the complete definitions provided in Defense Finance and Accounting Service–Indianapolis Center, *DFAS-IN Manual 37-0100-07* (August 2006), p. 14-OSDPG-2.

- Program 6—Research, Development, Test, and Evaluation. These program elements fund all research and development activities for weapon systems and forces that have not yet been approved for operational use. The category has six subcategories: 6.1, basic research; 6.2, applied research; 6.3a, advanced technology development; 6.3b, demonstration and validation (DEMVAL) activities;[3] 6.4, engineering and manufacturing development, which completes engineering for and development of products that the services will use (production-quality blueprints are typically an output); 6.5, RDT&E management support; and 6.6, operational systems development.

- Program 7—Central Supply and Maintenance. These program elements fund centrally managed activities related to supply, maintenance, logistics, transportation, overseas port units, industrial preparedness, and commissaries.

- Program 8—Training, Medical, and Other General Personnel Activities. Under this category are mainly centrally managed resources for training and education, personnel procurement services, health care, permanent-change-of-station travel, family housing, and other personnel-associated support activities that are not included in the other MFPs.

- Program 9—Administration and Associated Activities. This category comprises resources for the support of departmental and major administrative headquarters and field commands, as well as associated activities not accounted for elsewhere (such as public affairs, claims, criminal investigations, and construction planning and design).

- Program 10—Support of Other Nations. These resources support international activities and include funds for the Military Assistance Program, foreign military sales, and the North Atlantic Treaty Organization.

- Program 11—Special Operations Forces. These program elements consist of special operations forces (active, guard, and reserve), including the command organizations and support units directly related to those forces.

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3. DEMVAL efforts are evaluations of system-specific integrated technologies in as realistic an operating environment as possible to assess performance and the potential for cost reductions that the integrated technologies may offer.

DoD uses both budget authority and 6.X labels to categorize its research and development activities. The two taxonomies are approximately related as follows:

- BA 1 ≈ 6.1
- BA 2 ≈ 6.2
- BA 3 ≈ 6.3a
- BA 4 ≈ 6.3b
- BA 5 ≈ 6.4
- BA 6 ≈ 6.5
- BA 7 ≈ 6.6

The reason for the approximate association is that over time, exceptions to the use of the original 6.X labels have occurred. In particular, MFPs 2, 3, 4, and 11 now have small amounts of funding in BAs 1, 2, and 3. Cumulatively, the S&T funds that are not found under the 6.1, 6.2, or 6.3 categories average about 2 percent of total S&T funding.

Categorization by Technology Readiness Level

During the 1970s and 1980s, the National Aeronautics and Space Administration developed a system of what it called technology readiness levels (TRLs) to measure progress in R&D activities and programs. The Air Force Research Laboratory adopted the system in the late 1990s. At the urging of the Government Accountability Office, DoD officials have been discussing the idea of tying attainment of program milestones to the achievement of certain TRLs.[4] The TRLs are as follows:

- TRL 1—Basic principles observed and reported;
- TRL 2—Technology concepts or applications (or both) formulated;
- TRL 3—Analytical and experimental critical function or characteristic proof of concept (or both);
- TRL 4—Component or breadboard validation in a laboratory environment;

4. See National Research Council Air Force Science and Technology Board, *Effectiveness of Air Force Science and Technology Program Changes* (Washington, D.C.: National Academies Press, 2003); and Government Accountability Office, *Best Practices: Better Support of Weapon System Program Managers Needed to Improve Outcomes*, GAO-06-110 (Washington, D.C.: November 30, 2005).

- TRL 5—Component or breadboard validation in the relevant environment;
- TRL 6—Demonstration of system or subsystem model or prototype in the relevant environment;
- TRL 7—Demonstration of a system prototype in an operational environment;
- TRL 8—Actual system completed and "flight qualified" through testing and demonstration activities; and
- TRL 9—Actual system "flight proven" through successful mission operations.

An approximate correlation of TRLs with the 6.X funding required to achieve them is as follows:

- TRL 1 and TRL 2 ≈ 6.1
- TRL 3 and TRL 4 ≈ 6.2
- TRL 5 ≈ 6.3a
- TRL 6 and above ≈ 6.3b and above

Completion of TRL 5 corresponds to the completion of activities supported by S&T budget authority (basic and applied research and advanced technology development), which would be approximately associated with activities funded under program elements 6.1 through 6.3a.

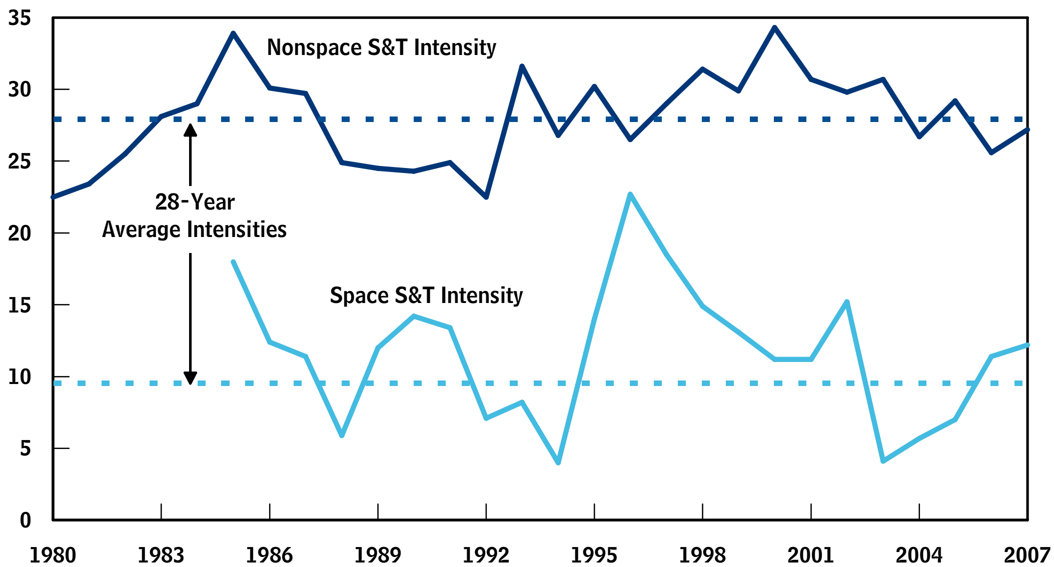
Appendix B: Time-Series Data for Army, Air Force, and Navy Science and Technology Intensities

To perform its analysis of funding for science and technology (S&T) activities supporting major programs in the Department of Defense (DoD), the Congressional Budget Office (CBO) used data drawn from the fiscal year 2008 Future Years Defense Program and other U.S government budget documents. Data from those sources were used to compare S&T funding to total spending on research, development, test, and evaluation (of which S&T is a subset)—a ratio that CBO refers to in this attachment as S&T intensity—for the period spanning 1980 to 2007. CBO constructed time-series data of S&T intensities for the Army's unclassified space and nonspace programs, the Air Force's unclassified space and nonspace programs, and the Navy's unclassified nonspace programs. This appendix provides graphic displays of those time-series data (see Figures B-1, B-2, and B-3).

Figure B-1.

Science and Technology Intensity for the Army's Space and Nonspace Programs

(Percent)

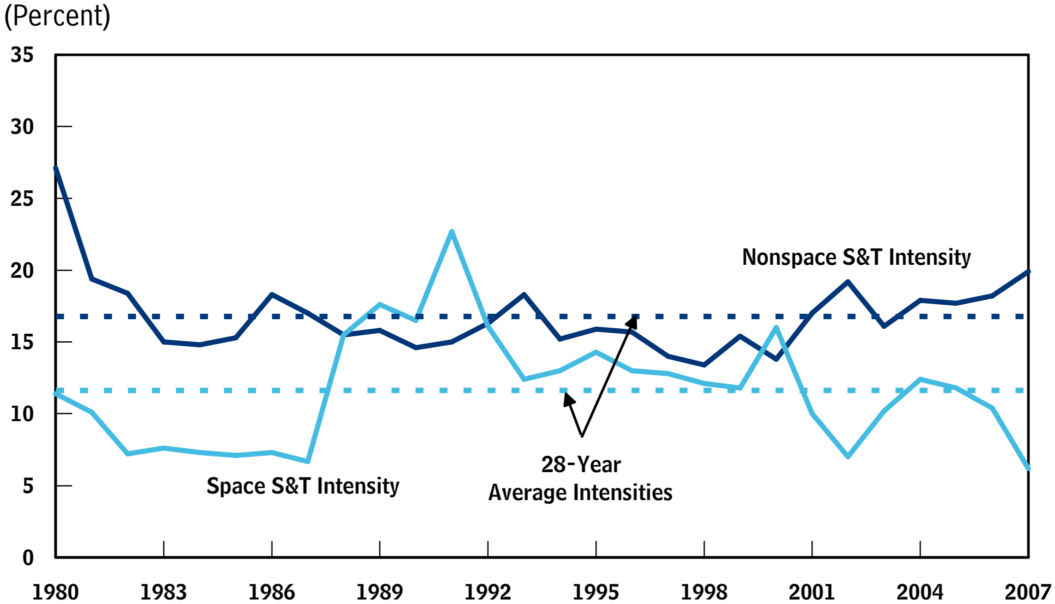


Source: Congressional Budget Office based on data from the Department of Defense.

Note: S&T intensity is the ratio of S&T funding to total funding for research, development, test, and evaluation activities.

Figure B-2.

Science and Technology Intensity for the Air Force's Space and Nonspace Programs

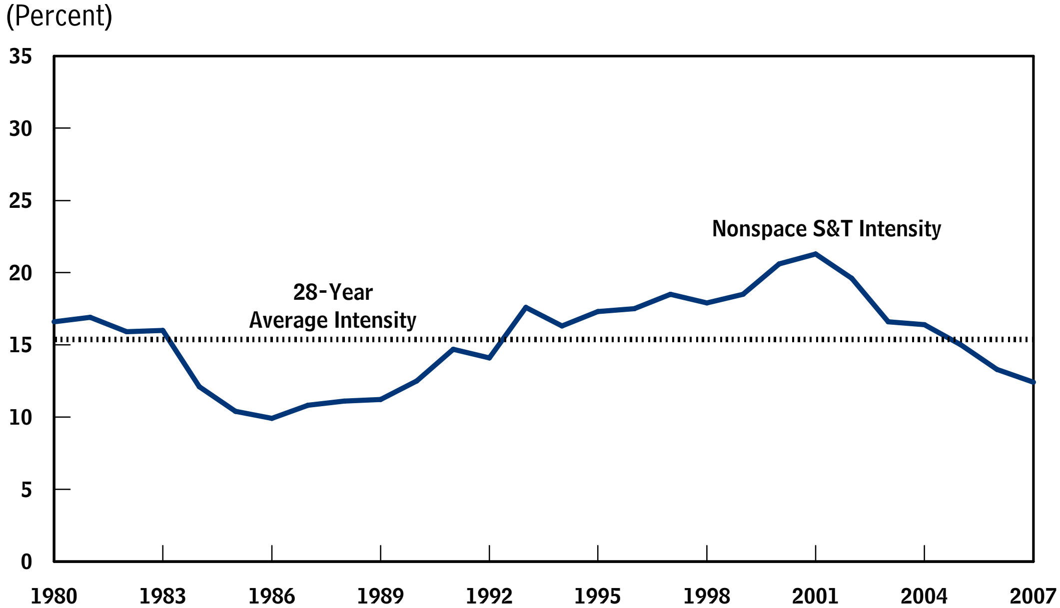


Source: Congressional Budget Office based on data from the Department of Defense.

Note: S&T intensity is the ratio of S&T funding to total funding for research, development, test, and evaluation activities.

Figure B-3.

Science and Technology Intensity for the Navy's Nonspace Programs



Source: Congressional Budget Office based on data from the Department of Defense.

Note: S&T intensity is the ratio of S&T funding to total funding for research, development, test, and evaluation activities.

Appendix C: Projects and Subprojects Associated With Direct Science and Technology Funding Supporting Selected Department of Defense Space Programs

In its budget materials—including the Future Years Defense Program for fiscal year 2008—the Department of Defense (DoD) displays funding data for its major programs and their associated projects and subprojects.[1] The Congressional Budget Office (CBO) used those materials to identify what it refers to as "direct S&T funding"—that is, funding for science and technology (S&T) activities involving the unique technologies that support a particular program. CBO considered the direct S&T funding associated with four specific satellite programs: the National Polar-Orbiting Operational Environmental Satellite System (NPOESS), the Space-Based Infrared System in High-Earth Orbit (SBIRS-H), the Defense Meteorological Satellite Program (DMSP), and the Defense Support Program (DSP) (see Tables C-1 and C-2). For NPOESS and DMSP, direct S&T funding supports activities associated with measuring physical characteristics of the atmosphere and forecasting weather conditions. For SBIRS-H and NPOESS, direct S&T funding supports activities associated with detecting nuclear blasts and objects—in particular, the plumes generated by burning rocket motors—radiating in the high- and midinfrared frequency ranges. The S&T funding for activities associated generally with satellite programs—such as for rocket engine development, satellite survivability, satellite communications, cryogenics, or propellants—does not support work that is specifically tied to the four programs. Consequently, for this analysis, CBO did not judge such funding to be direct S&T.

The data available to CBO document the funding for the Defense Department's S&T projects and associated subprojects, as well as the activities conducted under each subproject. However, not all of the activities listed as being conducted under a subproject constitute direct S&T efforts in support of a particular program (such as DSP or DMSP). Therefore, CBO had to assume how much of a subproject's total funding supports direct S&T activities for each of the four programs considered in this

1. The DoD Comptroller and the Air Force's Office of Financial Management were the sources for most of the data on direct S&T funding. CBO also surveyed the Defense Technical Information Center; the Office of the Secretary of Defense's Program Analysis and Evaluation directorate; the Air Force Operations office; the Deputy Under Secretary of Defense for Science and Technology's Office of Plans and Programs; the Naval Research Laboratory; the Missile Defense Agency; and the Air Force's offices of historical information at Hanscom and Bolling Air Force Bases.

analysis. CBO assumed that the amount was equal to the fraction of the total number of activities listed for a subproject that constituted direct S&T funding in support of each program.[2]

That assumption introduces errors into CBO's analysis. To bound the potential effects of those errors, CBO computed S&T intensities (including backcasted funding) for the four programs using two alternative assumptions about the amount of subproject funding constituting direct S&T (see Table C-3 on page 30).[3] Under all three methods of allocating subproject funding (excluding or including all funding for subprojects with ambiguous allocations, or allocating funding for ambiguous subprojects based on the number of supporting activities), the ratio of the S&T intensity of DMSP to that of the NPOESS program spans a range from 5.2 to 5.5. The ratio of the S&T intensity of DSP to that of the SBIRS-H program spans a range from 2.4 to 3.0. The relatively narrow range of variation in the ratios indicates that CBO's results do not depend strongly on the method chosen for allocating subproject funding.

The available funding data span actual appropriations from 1978 to 2007; CBO used data from the 2008 FYDP for the 2008–2013 period. Because the starting and ending dates for individual programs differ (for instance, the starting dates for DSP and the SBIRS-H program are more than three decades apart), the direct S&T funding attributed to the programs begins and ends at different times. For the four programs considered in this analysis, CBO used the following starting and ending dates for direct S&T funding:

- NPOESS—1991 to 2014;
- DMSP—1966 to 1991;
- SBIRS-H—1983 to 2009; and
- DSP—1948 to 1996.

2. Project names and numbers may change over time. In the tables, CBO notes the period over which data were available for particular projects as named. Gaps in the historical record were filled by using linear interpolation.

3. S&T intensity is the ratio of S&T funding for a program to DoD's total funding for research, development, test, and evaluation activities.

Table C-1.

Projects and Subprojects Associated With Direct S&T Funding for the NPOESS and Defense Meteorological Satellite Programs

Program No.	Program Element	Project No.	Project Name	Subproject Content	Funding[a] (Percent)	Data Period
0602601F	Space Technology	1010	Space Survivability and Surveillance	Environmental conditions that endanger space operations	100	2001-2013
				Artificial intelligence for ionospheric prediction	100	
				HAARP	100	
				Multispectral signature libraries	100	
0602601F	Phillips Laboratory	1010	Space System Protection Technology	Environmental conditions that endanger space operations	100	1999-2000
				Ionospheric prediction	100	
				HAARP	100	
				Weather software for navigation and surveillance	100	
				Atmospheric compensation for space-based hyperspectral sensors	100	
0602601F	Phillips Laboratory	1010	Geophysics and Weather Technology	Hardware and software for solar eruptions	100	1994-1998
				HAARP	100	
0602601F	Space Technology	5018	Spacecraft Protection Technology	Electromagnetic interference for sensors that support weather forecasting	100	2001-2006
0602601F	Phillips Laboratory	3326	Lasers and Imaging Technology	Microwave effects phenomenology	100	1994-1997
0602101F	Geophysics	6670	Meteorological Devices	Subproject details were not available	100	1978-1981
		6687	Stratospheric Environment	Subproject details were not available	100	
		6690	Upper Atmospheric Technology	Subproject details were not available	100	
		7601	Magnetospheric Effects on Space Systems	Subproject details were not available	100	
		7659	Aerospace Probes	Subproject details were not available	100	
0602204F	Aerospace Avionics	2002	Microwave Technology	Nondestructive microwave detection	50	1989
0601102F	Defense Research Science	2301	Physics	Plasma theory in the space environment	100	2008-2013
		2311	Information Technology	Plasma theory in the space environment	100	2006-2007

Continued

Table C-1.

Continued

Program No.	Program Element	Project No.	Project Name	Subproject Content	Funding[a] (Percent)	Data Period
0601102F (Continued)	Defense Research Science (Continued)	2311	Space and Information Technology	Plasma theory in the space environment	100	2000-2005
		2311	Space Science	Solar and interplanetary magnetic fields, solar wind, and the magnetosphere	100	1997-1999
		2311	Astronomy and Astrophysics	Solar and interplanetary magnetic fields, solar wind, and the magnetosphere	83	1988-1991
				Solar and interplanetary magnetic fields, solar wind, and the magnetosphere	100	1978-1981
		2310	Atmospheric Science	Atmospheric irregularities and thermospheric dynamics	100	1996-2002
				Auroral irregularities and prediction of tropical clouds and lightning	100	1997-1991
				Weather forecasting models	100	1978-1981
		2303	Chemistry	Sensor limitations from airglow and infrared emissions	50	1987-1991
0601[b]	Naval Research Laboratory		n.a.	Middle-atmosphere research	100	1987-2006
0603707F	Weather System Technology	2688	Weather Support Technology	Ionospheric/thermospheric forecasting and turbulence models	20	1998
	Weather System Advanced Development		n.a.	Broad-spectrum signal processing	38	1987-1988
0603401F	Advanced Spacecraft Technology	5021	Space System Survivability	Sensor development to forecast space environment	92	2001-2013
				Resolution sensors for radiation, charge, and kinetic anomalies	100	2001-2013
		4400	Space System Protection	Space radiation hazard specification and forecasting	100	1997-2003

Source: Congressional Budget Office based on annual data from Department of Defense, *Descriptive Summaries of the Research, Development, Test, and Evaluation, Exhibit R-2,* annexes supporting DoD's budget estimates from 1978 to 2007.

Notes: Detailed data on subprojects were not available in the R-2 annexes.

n.a. = not applicable.

a. CBO's assumption about the amount of a subproject's total funding that is directly for science and technology (S&T)—that is, funding for S&T activities that involve only the technologies supporting a particular program.

b. Data provided by the Naval Research Laboratory's (NRL's) Legislative Liaison Office covered NRL's funding for a long-term basic research S&T effort involving middle-altitude atmospheric research.

Table C-2.

Projects and Subprojects Associated With Direct S&T Funding for the SBIRS-H and the Defense Support Programs

Program No.	Program Element	Project No.	Project Name	Subproject Content	Funding[a] (Percent)	Data Period
0602601F	Space Technology	1010	Space Survivability and Surveillance	Nuclear detonation monitoring	100	2001-2013
	Phillips Laboratory	1010	Space System Protection Technology	Infrared background clutter rejection	100	1999-2000
		1010	Geophysics and Weather Technology	Infrared background clutter rejection	100	1994-1998
	Space Technology	4846	Spacecraft Payload Technology	Advanced infrared technologies for space applications	100	2001-2013
				Analysis tools for optical/infrared imaging systems	100	2001-2013
	Phillips Laboratory	8809	Spacecraft Vehicle Technology	Analysis tools for optical/infrared imaging systems	100	1998-2000
		8809	Space and Missile Technology	Quantum well, infrared photo-detector focal plane arrays	50	1995-1997
602204F	Aerospace Sensors	2000	Electronic Countermeasures Technology	Infrared clutter rejection techniques	50	1998-2000
		2003	Electro-optical and Infrared Countermeaures Technology	Infrared clutter rejection technologies for space-based platforms	50	2000-2013
		4916	Electromagnetic Technology	Passive polarization techniques to enhance electro-optical/infrared focal plane arrays	50	2002-2013
		2001	Electro-optical Technology	Infrared discrimination in the 8- to 12-micron range	67	1987-1991
		7633	Passive Electronic Countermeasures	False alarm rejection in infrared	33	1987-1991
		6AA	Avionics Laboratory Operations	Infrared component testing	13	1987-1991

Continued

Table C-2.

Continued

Program No.	Program Element	Project No.	Project Name	Subproject Content	Funding[a] (Percent)	Data Period
0602702F	Aerospace Avionics	4600	Electromagnetic Technology	Infrared small target discrimination	50	1996-2003
0601102F	Defense Research Science	2303	Chemistry	Sensor limitations from airglow and infrared emissions	25	1987-1991
				Molecular dynamics of rocket plumes	50	1978-1981
		2311	Astronomy and Astrophysics	Infrared noise rejection	17	1987-1991
0601101F	In-House Research	n.a.	n.a.	Direction of incident infrared	17	1978-1981
0603401F	Advanced Spacecraft Technology	2181	Spacecraft Payloads	Infrared technologies to enable focal plane array tracking	100	2001-2013
		3784	Space Sensors and Satellite Communication Technologies	Focal plane array demonstration	100	2001-2013
				Infrared technologies to enable focal plane array tracking	100	1994-2001
0601 and 602[b]	Missile Defense Agency	n.a.	n.a.	S&T in the high- and midinfrared frequency range	100	1994-2007

Source: Congressional Budget Office based on annual data from Department of Defense, *Descriptive Summaries of the Research, Development, Test, and Evaluation, Exhibit R-2,* annexes supporting DoD's budget estimates from 1978 to 2007.

Note: Detailed data on subprojects were not available in the R-2 annexes.

a. CBO's assumption about the amount of a subproject's total funding that is directly for science and technology (S&T)—that is, funding for S&T activities that involve only the technologies supporting a particular program.

b. The Missile Defense Agency's Legislative Liaison Office provided aggregated data on its funding for basic and applied research under S&T initiatives in the high- and midinfrared frequency ranges.

Table C-3.

S&T Intensity for Selected DoD Space Programs Under Different Assumptions About Allocating Subproject Funding

	Excluding Funding for Subprojects That Have Ambiguous Allocations	Allocating Funding for Ambiguous Subprojects by Number of Supporting Activities	Including Funding for Subprojects That Have Ambiguous Allocations
		S&T Intensity (Percent)	
NPOESS (Ongoing)	9	10	10
DMSP	47	53	55
SBIRS-H (Ongoing)	5	6	12
DSP	12	18	33
		Ratio of S&T Intensities	
DMSP to NPOESS	5.2	5.3	5.5
DSP to SBIRS-H	2.4	3.0	2.8

Source: Congressional Budget Office based on data from the Department of Defense.

Notes: The S&T (science and technology) intensity is the ratio of direct S&T funding to total funding for research, development, test, and evaluation. (Direct S&T funding supports S&T activities that involve only the technologies associated with a particular program.)

NPOESS = National Polar-Orbiting Operational Environmental Satellite System; DMSP = Defense Meteorological Satellite Program (the predecessor to NPOESS); SBIRS-H = Space-Based Infrared System in High-Earth Orbit; DSP = Defense Support Program (the predecessor to SBIRS-H).

Appendix D: Time-Series Funding Data for the DMSP, NPOESS, DSP, and SBIRS-H Programs

The Congressional Budget Office's (CBO's) analysis of funding for science and technology (S&T) activities supporting major defense programs includes two case studies: one comparing the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) program with the Defense Meteorological Satellite Program (DMSP) and the other comparing the Space-Based Infrared System in High-Earth Orbit (SBIRS-H) program with the Defense Support Program (DSP).

NPOESS is a program conducted jointly by the Department of Defense (DoD), the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Administration to build satellites carrying environmental and weather sensors. DMSP is the DoD-only predecessor program to NPOESS.

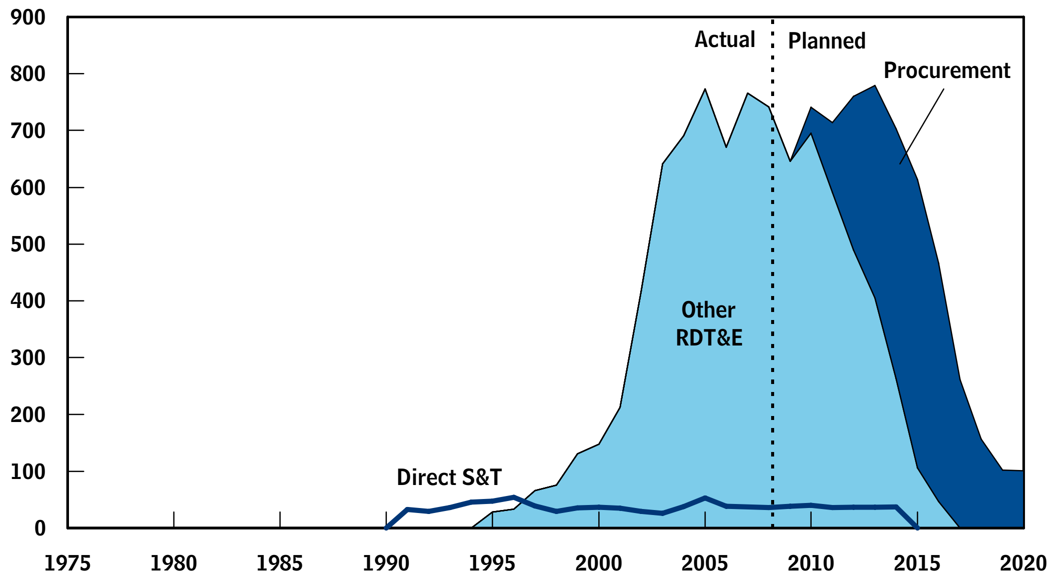
SBIRS-H is a DoD program that builds satellites launched into geosynchronous orbits, or GEOs, 26,200 miles above the earth's surface and payloads placed into highly elliptical orbits (HEOs). SBIRS-H satellites and payloads are composed of sensors that can detect the infrared emissions generated by a rocket motor's hot gas plume, thereby providing warning of the launching of a ballistic missile. SBIRS-H satellites also carry sensors that are used to detect the flashes of light and other radiation emitted when a nuclear detonation occurs. DSP is the predecessor program to SBIRS-H.

This appendix provides graphic displays of the time-series funding data that CBO used in its analysis of those four programs (see Figures D-1, D-2, D-3, and D-4).

Figure D-1.

Actual and Planned Investment in the National Polar-Orbiting Environmental Satellite System

(Millions of 2007 dollars)



Source: Congressional Budget Office based on data from the Department of Defense (DoD), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA).

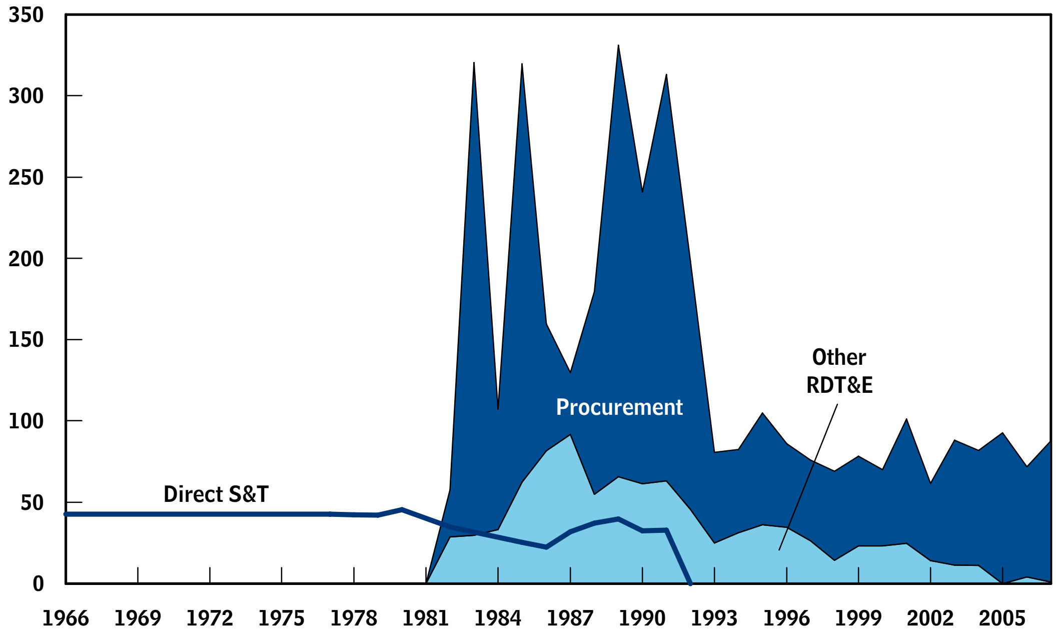
Notes: Other research, development, test, and evaluation funding, which totals $8.6 billion, includes amounts that paid for activities conducted by NASA, DoD, and NOAA. Currently, DoD's Selected Acquisition Reports include two prospective NPOESS satellites paid for with $2.8 billion in procurement funding.

CBO's tally of direct S&T funding associated with NPOESS totals $920 million. (Direct S&T funding comprises funding for S&T activities that involve only the technologies supporting a particular program.)

Figure D-2.

Investment in the Defense Meteorological Satellite Program

(Millions of 2007 dollars)



Source: Congressional Budget Office based on data from the Department of Defense.

Notes: DoD's Selected Acquisition Reports include nine DMSP satellites paid for with $2.7 billion in procurement funding and $900 million in funding for research, development, test, and evaluation activities other than those categorized as science and technology (S&T).

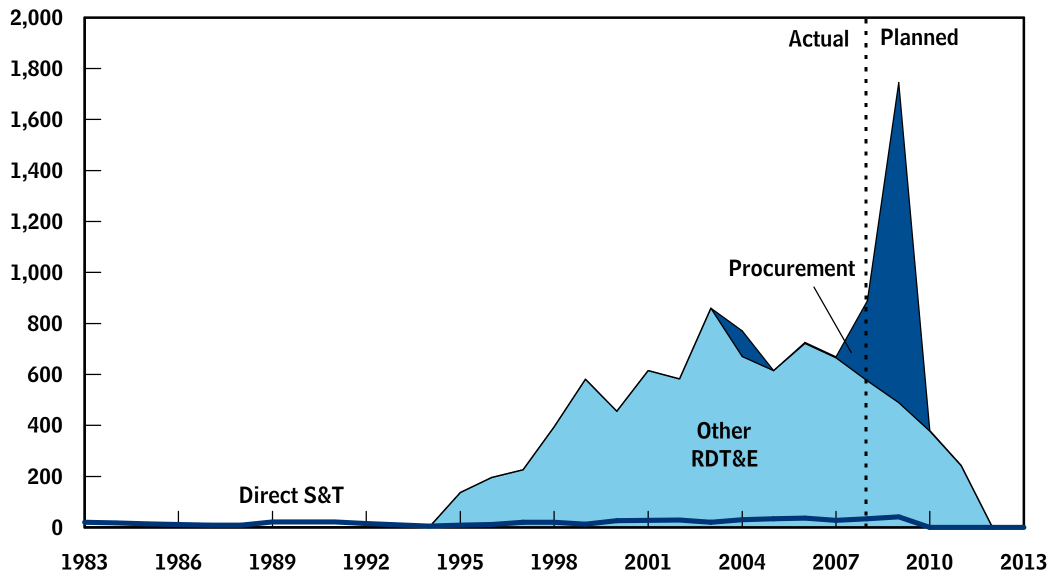
CBO's tally of direct S&T funding associated with DMSP totals $800 million, about 45 percent of which is inferred funding for the years spanning 1966 to 1977. (Direct S&T funding comprises funding for S&T activities that involve only the technologies supporting a particular program.)

The backcasted extrapolation of direct S&T funding before 1978 represents the average of the stream of such funding between 1978 and 2007.

Figure D-3.

Actual and Planned Investment in the Space-Based Infrared System in High-Earth Orbit

(Millions of 2007 dollars)



Source: Congressional Budget Office based on data from the Department of Defense.

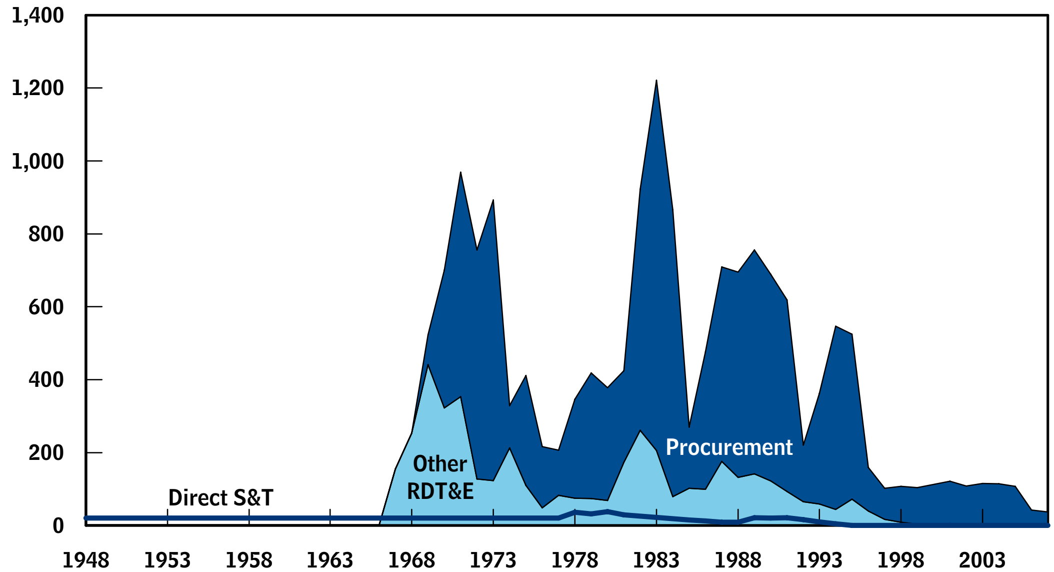
Notes: DoD's Selected Acquisition Reports currently include one SBIRS-H satellite paid for with $1.7 billion in procurement funding (purchases of additional satellites are expected) and $8.4 billion in funding for research, development, test, and evaluation activities other than those categorized as science and technology (S&T).

CBO's tally of direct S&T associated with SBIRS-H totals $560 million for the years spanning 1983 to 2009. (Direct S&T funding comprises funding for S&T activities that involve only the technologies supporting a particular program.)

Figure D-4.

Investment in the Defense Support Program

(Millions of 2007 dollars)



Source: Congressional Budget Office based on data from the Department of Defense.

Notes: DoD's Selected Acquisition Reports include 19 DSP satellites paid for with $12.7 billion in procurement funding (purchases of additional satellites are expected) and $4.4 billion in funding for research, development, test, and evaluation activities other than those categorized as science and technology (S&T).

CBO's tally of direct S&T associated with DSP totals $950 million for the years spanning 1948 to 1994, about 62 percent of which is inferred funding for years prior to 1978. (Direct S&T funding comprises funding for S&T activities that involve only the technologies supporting a particular program.)