

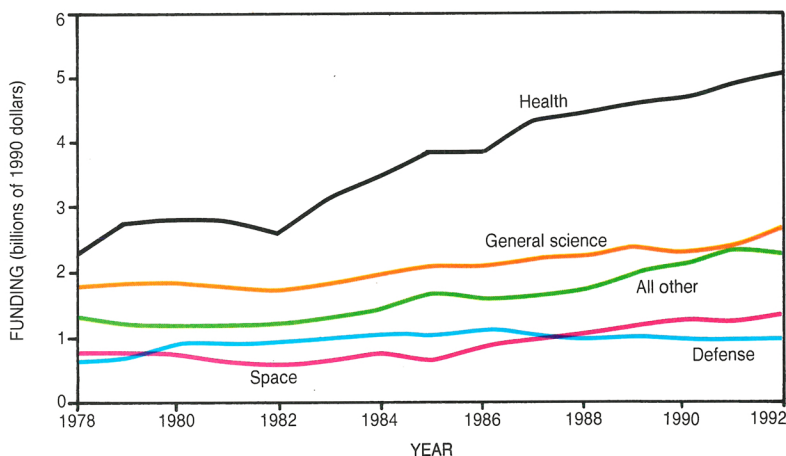
BUSH, HIS FAITH IN R&D, RAISES HOPE FOR HIGHER 1992 BUDGET IN HARD TIMES

Not since American astronauts first set foot on the Moon in 1969 has the nation experienced such an unalloyed sense of success. For many, the stunning 100-day triumph in the Persian Gulf War has swept away dark memories of a succession of military fiascos and technological debacles. Opinion polls indicate that President Bush's popularity is so high that few in Congress are inclined to oppose him publicly. The polls also suggest that the war has renewed the nation's faith in the need for more government support of science, technology and education.

This combination of sentiments is likely to bode well for R&D and education programs in Bush's budget for fiscal 1992, which begins on 1 October. It is not accidental that those two themes are dominant in the 2026-page budget document the President sent to Capitol Hill on 4 February. One of the longest chapters bears the heading "Enhancing Research and Expanding the Human Frontier" and another is titled "Investing in Human Capital and Reforming American Education." The President voiced his enthusiasm for science and education programs in his budget address to Congress and in two speeches since: one, on Valentine's Day, to the American Association for the Advancement of Science, and the other at the annual banquet for the Westinghouse Talent Search. In both he made it clear that he believes the nation's security, in the broadest sense of the term, is directly related to the country's scientific enterprise.

At a time when the Federal government is awash in red ink, the economy struggles in recession and the Administration proposes to pare some politically popular programs, the Bush budget would spend \$75.6 billion for R&D programs, an increase of \$8.4 billion over the amount for the current fiscal year. This represents a 13% rise—well above the expected inflation rate of 4.5% to 5%.

Despite the end of the cold war,



Basic research would be expanded under the fiscal 1992 budget at the National Science Foundation, National Institutes of Health, NASA and Departments of Energy and Agriculture. (Source: OMB.)

however, military considerations rank above scientific knowledge and industrial competitiveness on the R&D agenda of the Bush Administration. Civilian R&D would climb from \$26.3 billion to \$28.8 billion, a boost of 10%. But defense R&D, virtually all of it for weapons development, would rise even faster, by 15%—from \$37.8 billion to \$43.2 billion, the biggest increase in terms of both percentage and dollars in the entire R&D budget. While the Pentagon's R&D share has declined from a Reagan era high of nearly 75%, Bush would still give it 60% of such expenditures in 1992. In the past decade, civilian R&D has barely kept pace with inflation, experiencing a 3% real growth. It is notable that the Strategic Defense Initiative continues to be the largest single R&D line item in the proposed budget, as it has been the past few years, with a request of \$4.6 billion, 59% more than Congress gave the program this year.

The Bush budget makers have awarded academic basic research a relatively generous raise. It would increase by \$1 billion, or 8.1%, from

\$12.3 billion this year to \$13.3 billion in 1992. The National Science Foundation would receive nearly \$2.8 billion, an injection of \$406 million, or 17.5% more than the current operating budget. The foundation's research and related activities are slated to go up by \$284 million to \$2.1 billion, a 16% improvement. NSF's Education and Human Resources directorate would do even better, going up to \$390 million—a 23% increase. Unlike in previous years, when NSF failed to propose large increases for its education programs, in 1992 the budget takes advantage of the efforts on Capitol Hill over the past seven years to restore the funding for activities that were chopped to the bone in Reagan's early years. In doing so, it anticipates what Congress is almost certain to do anyway.

With NSF's request for 1992, the Administration again attempts to put the agency on track to double its appropriations. This is in keeping with the pledge made by President Reagan in 1987 and repeated by Bush since he entered the White House. Even so, the date for meeting the

Department of Energy physics-related programs

	FY 90 actual	FY 91 request (millions of dollars)	FY 91 current	FY 92 request
High-energy physics				
Physics research	131.1	140.3	137.0	150.4
Technology research, including detectors	68.7	75.2	69.4	73.8
Facilities operations				
Fermilab	129.8	139.4	129.5	136.9
SLAC	85.3	91.4	85.4	90.3
Brookhaven, with Alternating Gradient Synchrotron	36.8	39.2	38.5	42.2
Other operations, including Lawrence Berkeley and ESNET	5.5	8.8	6.9	6.2
Capital equipment	84.1	88.2	83.0	87.7
Construction				
Accelerator improvements, mainly Tevatron and SLC	13.8	14.5	14.5	15.8
General plant (safety and environmental projects)	11.7	12.3	12.3	13.4
Fermilab linac upgrade	4.6	12.0	12.0	6.2
Fermilab main injector	0	0	0	43.5
Brookhaven AGS accumulator-booster	4.9	0	0	0
Total high-energy physics	576.3	621.2	588.6	666.4
Superconducting Super Collider				
Operations and R&D	69.6	116.0	116.0	103.6
Capital equipment for accelerator and detector R&D	20.7	33.0	33.0	56.3
Construction of technical components and facilities	126.6	168.9	93.9	373.8
Total SSC	216.9	317.9	242.9	533.7
Nuclear physics				
Low-energy research				
Universities, mainly Texas A&M, Duke and U. of Washington	2.8	3.1	3.0	3.2
National laboratories	3.6	3.3	3.2	3.3
Reactors, including Tristan and NIST	1.1	1.1	1.1	0.9
Other research, including SAGE and GALLEX	3.5	5.6	5.4	5.9
Accelerator operations	3.2	3.3	3.2	3.4
Data measurements and evaluations	10.9	11.7	11.4	11.8
Medium energy, including LAMPF, Bates and CEBAF				
Research	37.0	38.8	38.1	40.0
Facilities operations	54.7	62.2	60.1	68.1
Heavy ion, including Yale, Texas A&M, U. of Washington, Brookhaven, Lawrence Berkeley and Oak Ridge				
Research	32.2	36.7	35.0	37.2
Facilities operations	34.9	36.2	36.0	37.5
Nuclear theory	12.2	13.5	13.1	14.0
Capital equipment, including research instrumentation	19.7	26.7	24.1	28.0
Construction				
Continuous Electron Beam Accelerator Facility (CEBAF)	62.6	65.0	58.5	31.8
Brookhaven Relativistic Heavy Ion Collider (RHIC)	0	15.0	13.5	49.4
Accelerator improvements and modifications	4.5	4.3	3.8	4.1
General plant projects	4.3	4.2	3.9	3.9
Total nuclear physics	287.2	330.7	313.3	342.4
Basic energy sciences				
Materials sciences, including solid-state physics				
Research	140.3	141.5	150.5	156.7
Facilities operations (safety and environmental projects)	55.9	80.4	77.6	100.4
Congressionally directed projects, including Ames Lab	0	0	46.8	0
Chemical sciences	138.5	150.5	157.6	158.3
Applied mathematical sciences, including DOE's contribution to the President's High Performance Computing Initiative	43.2	48.0	52.7	75.5
Engineering and geosciences	32.8	32.5	34.3	35.8
Advanced energy projects	14.4	24.0	24.9	10.8*
Energy biosciences, performed mainly at universities	20.4	20.2	22.1	24.7
Program direction	5.4	6.5	6.1	7.5
Capital equipment and instrumentation	36.5	37.0	36.8	37.0
Construction and modifications				
Accelerator and reactor improvements	4.5	7.0	6.9	6.6
General plant projects	2.8	3.1	3.1	4.5
1-2-GeV Synchrotron Radiation Source, Lawrence Berkeley	25.6	23.0	22.9	6.5
6-7-GeV Synchrotron Radiation Source, Argonne	39.4	75.0	69.6	90.4
Total basic energy sciences	564.1	648.7	711.8	714.7

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doubling goal has slipped from 1992 to 1994.

In describing the basic research budget in testimony before Congress and in talks before scientific groups, D. Allan Bromley, President Bush's science adviser, often refers to a study by Edward Mansfield, an economist at the University of Pennsylvania, who claims that the US derives a 28% return on its investment in basic research. Mansfield has examined the payoffs of research in new products and processes in fields such as pharmaceuticals, semiconductors, scientific instruments and medical technologies. Though the budget document urges caution in accepting the finding without qualifications, it declares that "the contribution of academic research to industrial innovation in several important sectors appears to be considerable, even apart from its more traditional benefits to the education of students and to the acquisition of knowledge for its own sake."

Still, an examination of the 1992 budget reveals that growth in basic research is uneven from agency to agency. The new budget calls for basic research in the Departments of Energy and Defense to rise by a paltry 2%, while NASA and the National Institutes of Health would get increases in basic research spending of 18% and 7%, respectively.

Though the general themes in the R&D budget may have a familiar ring, the document sent to Congress does contain some significant departures from previous years. In particular, three Presidential initiatives on key issues are more heavily funded and more tightly coordinated among several agencies. These "grand challenges," as Bromley refers to them, have been developed by the inter-agency Federal Coordinating Council on Science, Engineering and Technology, familiarly known as FCCSET.

The first of the initiatives is in high-performance computing. Under this program, a total of \$638 million—an increase of \$149 million, or 30% more than the current budget—would be spent on an interagency effort designed to make the US preeminent in supercomputers and electronic communications. One of the specific goals is to increase the performance of the most advanced computers by three orders of magnitude. The program's centerpiece is a National Research and Education Network that would hook up government labs with universities, lower schools and commercial firms. In time the network would provide access to libraries, museums and small businesses. Budget in-

creases for the program are proposed for the Defense Advanced Research Projects Agency (by \$49 million), NSF (\$44 million), DOE (\$28 million) and NASA (\$18 million).

The second initiative enlarges the global change program that was started last year. It is directed toward better understanding of world climate, ozone depletion, the carbon cycle and ecological systems. The effort is budgeted for \$1.2 billion next year—an increase of \$232 million, or 24% more than the current program, and double the amount spent in fiscal 1990. The 1992 increase would support a wide range of research involving nine different agencies. Most prominent is NASA's "Mission to Planet Earth," which would get \$336 million to begin developing a flotilla of high-technology satellites called the Earth Observing System, along with its associated data system. While EOS satellites would be the most expensive single component of the program, the budget increase would also support ground-based research, such as the World Ocean Circulation Experiment, as well as major new projects to model the world's climate and to examine the economic consequences of global warming, deforestation and desertification.

The third of the grand challenges is central to President Bush's goal of getting American schoolchildren to rank at the top of international achievement tests in science and mathematics by the turn of the century. When the budget was issued in February, Bromley released a report entitled "By the Year 2000: First in the World." It calls for increasing the number of fully trained and highly motivated teachers in science and math, improving teaching materials, developing new educational technologies and raising student interest and performance, especially among young women and such underrepresented minorities as blacks, Hispanics and Puerto Ricans. The education initiative was drawn up by a committee formed by Bromley's Office of Science and Technology Policy. Under the chairmanship of Energy Secretary James D. Watkins, the group took an inventory of all Federal efforts on the problem and found that the government would be spending \$1.7 billion this year on everything from pre-college curriculums to graduate fellowships. At the committee's prompting, the Administration proposes that funding be increased to nearly \$2 billion in 1992, some 13% more than this year.

Considerably smaller but still significant sums are allocated to some

Department of Energy physics-related programs, continued

	FY 90 actual	FY 91 request (millions of dollars)	FY 91 current	FY 92 request
University and science education				
Laboratory cooperative science centers	11.6	18.2	24.0	27.6
University programs, including museums and EPSCOR	6.8	1.9	11.9	7.8
University reactor fuel assistance	4.0	7.2	3.2	3.7
University research instrumentation	4.9	4.9	4.9	5.0
R&D laboratory technology transfer	2.2	2.4	2.6	4.9
Magnetic fusion				
Confinement systems, including Burning Plasma Experiment	160.2	163.1	150.9	183.3
Applied plasma physics, including theory and computing	71.6	70.9	62.9	61.8
Development and technology, including ITER	46.3	48.1	46.6	56.7
Planning, projects and program direction	5.6	9.9	9.6	11.8
Inertial fusion energy**	1.2	1.5	1.6	8.2
Capital equipment and instrumentation	13.3	14.3	10.4	11.0
Construction				
General plant projects	7.7	8.0	2.1	2.0
Confinement Physics Research Facility, Los Alamos	10.9	11.1	5.5	0
Safety improvements, Princeton	0	0	0	2.6
Total magnetic fusion	316.7	325.3	289.6	337.1
Inertial fusion (weapons R&D program)				
Gas laser, including AURORA and NIKE	35.8	36.7	28.7	28.9
Glass laser, including NOVA and OMEGA	96.5	90.1	98.1	103.0
Pulsed power, including PBFA II and Hermes III	27.4	29.3	29.3	31.5
Supporting activities	0.9	1.8	1.8	1.9
Capital equipment	8.6	8.9	17.1	17.2
Total inertial fusion	169.2	166.8	175.0	182.5
Nuclear directed-energy weapons (for SDI program)	98.7	103.5	0†	0
Weapons activities				
Research, development and testing	1772.1	1884.6	1737.1	1764.0
Production and surveillance	2468.9	2757.0	2509.4	2548.5
Program direction	98.7	106.4	106.4	164.0
Total weapons activities	4339.7	4748.0	4352.9	4476.4
Verification and control technology	165.8	174.0	196.4	235.0
Nuclear materials production and enrichment	2081.6	2413.0	2341.9	1876.9
Nuclear warhead complex cleanup and modification	1984.6	2791.4	3129.9††	3705.0

*Heavy Ion Fusion Accelerator Research (HIFAR) will be transferred to the Office of Fusion Energy in 1992.

**A new component of the Office of Fusion Energy and coordinated with inertial confinement fusion in Defense Programs.

†This program has been included in the weapons technology base and in the basic equipment program.

††Includes supplemental appropriation of \$340 million.

brand new programs. At NSF, for instance, \$84 million would go into science and engineering research relating to materials synthesis and processing, solid-state physics and biomaterials. This program will initially emphasize novel electronic and photonic materials and biomolecular materials. The initiative will enable NSF to increase its support of "small science," which has been hit badly by budget cuts and funding reallocations at the agency in recent years. The budget also proposes that NSF, DOE, NASA, DARPA and the National Institute of Standards and Technology (the new name for the venerable National Bureau of Standards) devote \$93 million to all aspects of superconductivity, with special emphasis on investigator-initiated studies. In recent years, the field has received annual funding of \$55 million to \$65 million.

One of the most contentious issues in US science is the disparity between the number of individual scientists

applying for grants and the capacity of government agencies to fund them. The budget document assails those who have expressed dismay over inadequate funding of academic researchers. "The historical trend in Federal support for basic research shows that during the 1980s such support increased overall by 50% in real terms," it states. At the same time, the duration of grants for individual investigators has been increased. This was done in response to pressure from scientists who argued that the complexity of academic research demands more funding for state-of-the-art equipment, requires greater stability of graduate student support and allows less time and effort for writing proposals. In consequence, fewer than 25% of ongoing projects are renewed in any single year by NIH or NSF, the agencies that fund most university scientists. Success rates of new proposals at those agencies have dropped from 40% to 30% or even

lower. What's more, by stretching out the periods of grants, the agencies have created "out-year mortgages," says Bromley, resulting in reductions in the amount of dollars per grant.

Bromley admits that the problem is acute. He fought some rearguard actions with the White House Office of Management and Budget over the 1992 budget. To satisfy the demand for improving laboratory infrastructure, Bromley got \$50 million placed into NSF's budget to fund a new program enabling university scientists to obtain new instruments costing more than \$200 000 but less than \$4 million. The rules require that Federal funding for this initiative, to be conducted competitively through the peer-review process, be matched dollar for dollar by non-Federal sources such as foundations, universities and states. In gaining this popular new program, NSF gave up its Academic Research Facilities Modernization program, which Congress had authorized in 1988 and funded with \$20 million in each of fiscal 1990 and 1991.

Proving Einstein right

NSF is requesting \$23.5 million to begin the five-year construction of two identical but widely separated detectors for the Laser Interferometer Gravitational Wave Observatory. LIGO was in the foundation's fiscal 1991 budget but was killed by Congress. The cost of the observatory has more than doubled, to about \$211 million, since NSF began supporting a feasibility study in 1979. LIGO was designed by teams at Caltech and MIT to verify the existence of gravitational waves and black holes. Along with similar instruments being planned by observers in Britain and Germany, the detectors are expected to test Einstein's prediction as part of his general theory of relativity in 1916 that gravitational waves exist, that they travel at the same speed as light and that the graviton has a rest mass of 0. In advancing LIGO, Caltech has already received proposals for sites in 17 states.

The foundation also seeks \$16 million in fiscal 1992 to build the first of two unique 8-m infrared-optimized telescopes. This project, which includes Britain and Canada as partners, is expected to take eight years to complete, at a total cost of \$176 million, with the US putting up half.

These projects are dwarfed, relatively speaking, by the Superconducting Super Collider. DOE's budget asks for \$534 million for the SSC, a 120% increase over the current year's \$243 million. Of course, everything

about the SSC is whopping—its estimated total cost of \$8.24 billion (a figure at the low end of the four cost calculations the department received last summer), its 54-mile oval ring for proton-proton collisions, and the 10 000 superconducting dipole and quadrupole magnets that will bend the beams. The budget request anticipates that Texas will chip in \$1 billion and foreign governments at least \$1.6 billion to help finance the megaproject. When Bromley was asked whether he agreed with the estimate at a budget hearing before the House science committee, he admitted that he was troubled: "I can't tell you what the actual cost will be. I don't think anyone can." Then when he was asked how much would be too much for the giant machine, he replied that Congress would have to decide that.

The SSC is at once one of the most celebrated and most controversial items in the R&D budget. It evokes criticism that DOE cannot fund other programs adequately while paying for it. In fact, funding for the rest of high-energy physics and all nuclear physics at DOE would increase by 12% in the 1992 budget—from \$906 million to somewhat more than \$1 billion. While this appears to be a significant boost in support, much of the additional money is for ramping up construction projects, including a major upgrade of the main injector ring at Fermilab (see the news story on page 86) and increased-second year funding of the Relativistic Heavy Ion Collider at Brookhaven.

Such claims on DOE's funds in 1992 lead some to speculate about the causes of the reduction by \$20 million of the budget request for the Continuous Energy Beam Accelerator Facility, being built at Newport News, Virginia, and the elimination of a combined total of \$20 million from capital equipment and operations accounts at SLAC, Brookhaven, Lawrence Berkeley and Argonne. "We're all taking part in a zero-sum game," complains a Brookhaven physicist who prefers that his name not be used.

Facing rough passage

Nobody now doubts that the proposed increases for R&D will face rough passage through Capitol Hill this year—for technical reasons, not scientific ones. The problem is the still untested budget plan negotiated between Congress and the White House last October after a half-year of wrangling. The budget agreement is a true zero-sum game.

The accord, which is meant as a

five-year deal, created tight caps on the growth of discretionary spending, the part of the Federal budget subject to annual appropriations. Nondiscretionary programs, such as Social Security and Medicare, have payments mandated by law. The agreement also separated discretionary spending into three categories—domestic, defense and foreign assistance programs—and it forbade shifting money from one category to another. This means that cuts in defense, for instance, cannot be used to fund domestic programs. The immediate effect is to force choices: If Congress agrees to increase spending on science, it must also agree to reduce other programs to stay within the overall spending limits. That's the draconian prospect facing members of Congress as they come to grips with the Administration's budget increases for R&D.

But while the agreement essentially removes the deficit as an issue, simply ignoring the deficit doesn't mean the US is without a serious fiscal problem. The rationale behind the agreement was that for once, the White House and Congress wouldn't have the deficit to kick around for a few years, so that, surely, a budget resolution, 13 appropriations bills and other implementing legislation could be enacted without the stress and pain of recent years. The negotiators were too clever by half, for the deal leaves little flexibility, and in the end it may have to be fudged to adjust to some special events—notably the Persian Gulf war, the savings-and-loan bailout and the economic recession that is raising the numbers of jobless and causing more business bankruptcies.

The bottom line for the whole budget in 1992 is \$1.45 trillion, give or take a couple of billion. Of the proposed budget, 14% will go to pay the interest on the national debt—which is something like \$200 billion on a debt of \$3 trillion. If that doesn't boggle the mind, consider that 51% will go toward entitlement programs such as Social Security and Medicare. Another 20%, or about \$290 billion, will be spent on defense—and little of that will be used to pay for the Gulf war. What's left is 15%, or some \$212 billion, to cover all the domestic discretionary programs—from Head Start classes for poor kids to public housing and veterans' benefits, from highway and harbor repairs to space exploration and science research. That amount represents an increase over this year's spending by about 5%, more or less equal to inflation. In other words, there will be no real growth in discretionary spending be-

cause the totals are fixed.

The recession will add about \$50 billion to the Federal budget deficit for the current fiscal year, bringing the gap between tax revenue and government spending to between \$300 billion and \$325 billion, according to the latest calculations by the Bush Administration.

That certainly would be the biggest deficit in US history, overwhelming the politically painful measures Congress and the Administration adopted in last year's contentious battle to reduce the deficit. What's more, the anticipated reduction in tax receipts has made the situation more depressing. Both personal and corporate income are certain to be lower in 1991 as a result of the recession that began just around the time last October that Congress and the White House were putting the finishing touches on the five-year, \$494 billion deficit reduction plan.

The fact is, certain spending programs are running higher than expected. Some, such as Aid to Families with Dependent Children, food stamps and Medicaid, cost more when the economy turns down.

The budget process in itself doesn't favor science. Funds for nondefense science need to go through 4 of the 13 appropriations subcommittees in each house of Congress. In one committee, appropriations for the National Science Foundation, NASA and the R&D programs of the Environmental Protection Agency are pitted against the Veterans Administration and the Department of Housing and Urban Development, two agencies that get more demands on them during recessions. Elsewhere, energy research is considered alongside energy supplies and water and public works projects—funding categories from which much of the pork is ladled to the states. Appropriations for NIST and for the National Oceanic and Atmospheric Administration go up against the Justice Department, FBI and State Department. NIH contends with the Department of Labor, Department of Education and the rest of the Department of Health and Human Resources. Funding inevitably involves a great deal of horse-trading in Congress, and if the totals for, say, domestic discretionary programs exceed the spending limits set for that category, programs within it will be trimmed to bring the bottom line into compliance. To have any effect on such an arrangement requires a strong commitment and forceful leadership.

The Bush budget offers \$18 billion worth of cuts to compensate for its

National Science Foundation physics-related programs

	FY 90 actual	FY 91 request	FY 91 current	FY 92 request
(millions of dollars)				
Mathematical and physical sciences				
Physics research				
Elementary particles	39.9	41.3	42.3	47.2
Nuclear sciences	41.9	43.5	43.0	47.2
Atomic, molecular and optical	14.2	15.4	15.0	16.5
Theoretical	17.5	18.7	18.2	20.0
Gravitational	10.2	11.3	10.6	11.2
Total physics	123.8	130.2	129.0	142.0
Materials research				
Solid-state physics	12.1	12.6	12.6	14.5
Solid-state chemistry	9.1	9.5	9.5	10.7
Low-temperature physics	8.7	8.9	9.0	10.0
Materials theory*	10.9	11.6	11.7	13.0
Metallurgy	8.9	9.2	9.2	10.2
Ceramics and electronic materials	8.6	9.0	9.2	12.4
Polymers	8.0	8.4	8.5	9.5
Materials Research Laboratories	26.4	28.2	27.1	28.6
Materials Research Groups	8.2	8.8	8.8	9.3
National facilities	12.3	13.1	12.8	13.5
Instrumentation	3.9	4.3	4.4	5.1
Total materials research	117.0	123.5	122.6	136.6
Chemistry, including physical chemistry	97.9	103.4	102.1	112.0
Mathematical sciences	69.3	73.7	72.0	79.5
Astronomical sciences				
Solar system, stellar evolution and galactic studies	30.7	31.9	31.7	35.6
National Astronomy and Ionosphere Center	6.2	11.3	8.2	10.4
National Optical Astronomy Observatories, including Kitt Peak and Cerro Tololo	24.4	25.8	25.9	28.0
National Radio Astronomy Observatory, including VLBA construction	30.2	31.8	31.5	33.4
Total astronomical sciences	91.5	100.7	97.3	107.4
Math and physical sciences science and technology centers	14.6	27.0	18.7	21.0
Major research facilities	4.4	63.0	16.5	51.5
Total mathematical and physical sciences	518.5	621.5	558.3	650.1
Geosciences				
Atmospheric sciences research, including global climate studies	53.1	63.4	59.6	69.6
National Center for Atmospheric Research	45.5	49.9	48.5	56.2
Upper atmospheric facilities, including Millstone Hill and National Astronomy and Ionosphere Center	5.6	6.8	6.4	7.1
Earth sciences, including geophysics, lithospheric studies and instrumentation	60.1	71.5	68.3	74.7
Ocean sciences research, including global change	72.9	88.6	82.1	97.7
Oceanographic centers and facilities	42.5	47.4	47.7	54.5
Ocean drilling program	32.0	35.0	35.0	36.4
Arctic research program	12.5	16.7	15.0	17.7
Geosciences science and technology centers	1.0	4.4	5.1	5.9
Total geosciences	325.0	383.7	367.7	419.5
Antarctic research program	151.5	175.0	175.0	193.0
Computer and information science and engineering				
Computer and computation research	22.0	24.3	24.2	30.8
Information, robotics and intelligent systems	20.0	22.9	22.8	28.6
Microelectronic information processing systems	16.6	18.9	18.5	23.5
Advanced scientific computing, mainly at NSF's four supercomputing research centers	62.8	62.6	62.1	70.4
Networking (NSFNET) and communications research	22.3	31.3	29.8	42.2
Cross-disciplinary activities	19.6	24.0	20.0	24.5
Computing science and technology centers	6.6	9.3	8.8	9.4
Total computer and information science and engineering	169.8	193.3	186.1	229.5
Academic research instrumentation	0	0	0	50.0
Research facilities modernization	0.4	20.0	20.5	0
Science and engineering education				
Teacher preparation and enhancement	81.0	89.6	118.6	139.0
Learning materials development, informal education	48.2	61.5	66.0	82.0
Undergraduate science, engineering and math	22.7	35.0	41.0	47.0
Research career development	36.8	44.9	47.9	61.0
Human resource development	27.6	37.4	39.9	50.0
Studies and program assessment	4.3	5.0	9.0	11.0
Total science and engineering education	220.6	273.4	322.4	390.0
EPSCOR	9.8	9.8	11.0	15.0

*The Condensed Matter Theory Program was expanded in scope in FY 1990 by the transfer of grants (\$600 K from the Metallurgy Program and \$300 K from the Polymers Program) and renamed the Materials Theory Program.

NASA physics-related programs

	FY 90 actual	FY 91 request (millions of dollars)	FY 91 current	FY 92 request
Physics and astronomy				
Hubble Space Telescope development	81.8	0	0	0
Gamma Ray Observatory development	41.2	0	22.0	0
Global geospace science: Solar-terrestrial program	57.6	98.5	96.6	65.3
Advanced X-Ray Astrophysics Facility development	44.0	113.0	101.2	211.0
Payload and instrument development	93.0	97.2	94.6	115.9
Shuttle-Spacelab payload support, including ATLAS	75.1	89.1	88.8	88.0
Space station planning and payloads	5.0	15.0	3.0	0
Explorer development, including COBE and ROSAT	88.4	100.8	99.8	107.9
Mission operations and data analysis				
Hubble Space Telescope operations and servicing	139.1	159.7	186.0	209.2
Hubble Space Telescope data	13.3	32.2	35.9	36.0
Astrophysics mission operations and data	42.3	81.1	70.5	98.3
Space physics mission operations and data	21.1	20.9	20.9	44.9
Research and analysis, including SOFIA and SIRTf	104.9	122.5	100.8	103.1
Suborbital programs				
Sounding rockets	30.1	31.3	31.3	34.3
Airborne science, including Kuiper Observatory	10.7	11.5	11.5	12.0
Balloon experiments	11.9	12.2	12.2	14.7
Total physics and astronomy	859.4	985.0	975.1	1140.6
Planetary exploration				
Galileo development	17.1	0	0	0
Ulysses	14.3	3.3	3.0	0
Mars Observer	98.9	68.9	78.5	54.4
Mars balloon relay for 1994 Soviet mission	4.4	2.0	1.5	1.2
Comet Rendezvous Asteroid Flyby/Cassini	29.5	148.0	145.0	328.0
Mission operations and data analysis	156.0	173.5	161.2	150.5
Research and analysis, including supporting equipment	70.7	89.5	67.9	93.2
Total planetary exploration	390.9	485.2	457.1	627.3
Earth science and applications				
Earth Observing System for "Mission to Planet Earth"	(74.0)*	199.0	155.0	253.0
Earth Observing System data information system	0	36.0	36.0	82.6
Earth probes, including Scatterometer and Ozone Mapper	13.6	28.7	54.7	68.2
Remotely piloted aircraft for Earth sensing	0	0	0	5.0
Upper Atmosphere Research Satellite mission	55.2	66.0	64.0	18.2
Ocean Topography Experiment	84.8	68.0	76.0	51.9
Payload and instrument development	76.1	49.7	49.7	48.6
Mission operations and data analysis	23.8	30.4	39.4	56.3
Interdisciplinary research	8.6	2.4	12.4	2.5
Climate and geophysics modeling and data analysis	38.5	41.3	44.3	45.0
Radiation and ecosystem dynamics, atmospheric chemistry and solid Earth science	106.2	111.1	107.5	114.3
Laser research facilities for crystal deformation studies	8.0	8.7	8.7	9.0
Airborne science and applications	19.4	20.2	20.2	20.6
Total Earth science and applications	434.2	661.5	667.9	775.6
Materials processing in space				
Research and analysis	12.6	13.7	13.7	16.6
Materials experiment operations	84.3	79.9	84.9	85.5
Space station utilization	(5.0)*	(15.0)*	(3.0)*	21.3
Commercial microgravity R&D enhancements	5.0	3.7	3.7	2.4
Total materials processing in space	101.9	97.3	102.3	125.8
Academic programs				
Graduate student researchers	6.5	6.9	6.9	7.0
Summer faculty fellowships at NASA centers	3.6	3.8	3.8	4.0
Innovative research at universities and colleges	2.4	2.7	2.7	2.9
Space application studies at universities	4.0	2.8	2.8	2.8
Aerospace education services	(2.6)**	3.9	6.0	6.1
Innovative pre-college education	(1.4)**	3.2	3.6	4.8
Minority university research	14.2	16.8	17.2	22.0
Space grant college and graduate fellowships	6.8	10.0	12.1	15.0
Total academic programs	37.5	50.1	55.1	64.6
Space Station Freedom program	1749.6	2451.0	1900.0	2028.9

*Development funding included in budget of Space Station Freedom.

**FY 1990 funding included in NASA research and program management account.

ty have a major task ahead to support this investment in the future," Bromley asserted. He is likely to have a particularly hard time defending such "big science" items as NASA's space station, the SSC and NIH's Human Genome Project. Congress targeted all three projects for significant cuts last year, along with the Pentagon's Strategic Defense Initiative, and they could well be vulnerable again this year.

Here are some highlights of the fiscal 1992 budget:

Department of Energy. The \$6.4 billion R&D budget is up only 4% from the current spending plan and, accordingly, is not enough to offset inflation. Some scientists who rely on DOE funds may be less than enthusiastic about the share for basic research: Though its budget would increase from \$2.31 billion to \$2.67 billion, the growth proposed for the SSC and other high-energy and nuclear physics projects accounts for much of this. Funding for basic energy sciences would remain virtually steady in 1992.

Still, there has been some good news. Congress agreed to Watkins's request to restore \$25 million to his agency's fiscal 1991 budget for magnetic fusion energy programs. Watkins told reporters at his budget briefing that he had been angered by Congress's decision last October to cut \$50 million from the President's \$325 million request for magnetic fusion in 1991. He charged that much of the \$50 million had gone toward pork-barrel university projects in the districts of influential lawmakers. About \$8 million of the \$25 million that Congress agreed to restore will go to the Princeton Plasma Physics Laboratory, while fusion programs at MIT will get an additional \$1.7 million and those at Lawrence Livermore will get an extra \$1 million.

For 1992, DOE's magnetic fusion program would be boosted by 24% above this year's budget, to \$337 million. Funding is included to prepare Princeton's Tokamak Fusion Test Reactor for deuterium-tritium experiments and to do R&D and design work at the Princeton lab for the Burning Plasma Experiment, once known as the Compact Ignition Tokamak. During 1992 DOE will seek international partners for BPX before making a firm commitment to building the machine. The department also asks for \$41 million to begin an engineering design for the International Thermonuclear Experimental Reactor, which is to be a six-year collaboration among four equal partners—Japan, the European Commu-

proposed increases in such areas as R&D. But the sacrificial lambs include programs favored by powerful constituencies on Capitol Hill: public housing, student loans, urban mass transit and low-income energy grants, to name a few. Though Congress has

generally been supportive of science and technology programs, it has not been forced in the past to make such painful choices quite so explicitly.

Bromley said as much at his budget briefing on 4 February. "The Administration and the scientific communi-

nity, the Soviet Union and the US. The US is pushing to be the host for ITER, proposing a site near San Diego. Japan and the European Community have offered rival sites.

DOE has approved Gammasphere, the major initiative of the nuclear structure community. Proposed to the department in 1988, Gammasphere, a national user facility to detect 1-MeV gamma rays, would be built at Lawrence Berkeley's 88-inch cyclotron. After two years the machine, which will cost \$17.4 million, will be transferred to Oak Ridge.

National Science Foundation. Despite the goals of two Presidents to double the NSF budget in five years, nearly half the programs in four directorates—41 of 84 programs in all—remain at the same spending level, after inflation, as in fiscal 1988, according to a study by Jack Crowley of the Association of American Universities. These programs account for more than 70% of the foundation's total research funding. Across the five divisions of the Mathematical and Physical Sciences directorate, which make up one-third of all NSF research funding, some two-thirds of the programs—or 18 out of 27—were cut to below their fiscal 1988 levels. Only 7 programs in the MPS directorate have grown by more than 4% in real terms since fiscal 1988. It has been almost as bad in Engineering, once considered the darling of the former NSF director, Erich Bloch. Across its five divisions, two-thirds of the programs—or 13 out of 20—remain below the 1988 appropriation. So it's not surprising that research programs at NSF have lost strength and stability in the past few years.

If Congress fully funds NSF with a 17.5% rise in 1992, asks Crowley, how much will it affect the research program? For many, a good deal; for others, much less. Though the NSF budget states that every directorate would get a percentage increase in the double digits, Crowley's analysis shows that real increases above 1988 will be small: mathematics up 5.7%, astronomy up 6%, physics up 2.3%, chemistry up 1.2% and materials research up 4.8%. If significant reductions are made in the fiscal 1992 request, many—perhaps most—of these disciplines would experience pain again.

NSF is a major participant in the grand challenges of high-performance computing, global climate change, and science and math education. The agency's share of the computing initiative amounts to \$213 million. It would receive \$118.5 million for its part in the global change research

Department of Defense basic research funding (6.1 budget category)

	FY 90 actual	FY 91 request (millions of dollars)	FY 91 current	FY 92 request
Army				
Research sciences, including physics and materials	171.1	179.5	173.3	179.4
Electromechanics and hypervelocity physics	0	0	0	3.0
Army laboratories, discretionary research	8.8	9.4	8.8	14.8
Navy				
Research sciences, including physics and materials	338.6	374.4	369.3	395.8
Navy laboratories, discretionary research	24.3	26.8	24.1	25.9
Air Force				
Research sciences, including physics and materials	186.1	193.2	196.2	203.2
Geophysics	37.5	36.5	35.8	40.4
Air Force laboratories, discretionary research	7.5	8.3	7.2	10.0
Defense Advanced Research Projects Agency				
Research sciences, including physics and materials	84.8	85.2	88.3	88.3
Materials and electronics technology	60.2	61.0	155.4	62.0
Manufacturing technology, including SEMATECH	100.0	100.0	100.0	206.2
Office of Secretary of Defense				
Research sciences, including physics and materials	84.8	NA	88.3	88.3
Laboratory research, mainly Bethesda Naval Hospital	2.2	NA	2.5	2.2
Universities research initiatives	94.8	98.7	230.7*	87.4
Research projects	8.0**	NA	19.9**	0
Critical Technology Center	0	0	5.0†	0
High Frequency Active Auroral Research Program	9.9	0	0	0

NA, not available.

*Includes \$62 million in Congressional set-aside programs, also known as "pork barrel" items, as well as \$20 million for fellowships, \$50 million for science and engineering traineeships at universities and \$7 million for Experimental Program to Stimulate Competitive Research.

**Congressional set-aside projects.

†Mandated by Congress for a center to be established by the Office of Science and Technology Policy in fiscal 1991.

program. Support for the Education and Human Resources directorate would total \$390 million, an increase of 23% above 1991. Out of this sum, pre-college science and math education is up 19%, to \$253 million, and undergraduate programs are slated for \$133 million.

NASA. The \$15.8 billion bottom line for the space agency—a 13% increase over 1991—provides \$2.1 billion for the space science program. This represents about 21% of NASA's total request, bettering the 20% recommendation of the Augustine committee. (See the news story on page 87.) Funding in 1992 would include the Mars Observer, the Gamma Ray Observer and the Advanced X-Ray Astrophysics Facility. The space science program is essentially a continuation of what was proposed and approved for 1991.

Exploration of the solar system would receive \$256 million, a boost of 65%, but NASA's most controversial project, space station Freedom, fares poorly in the 1992 budget, with only an 8% increase, to \$2.2 billion. After all the skepticism about the scientific and technical merits of the space station, Congress is almost certain to cut the budget for Freedom and to demand that the agency revisit its purpose and design.

Defense Department. After being clobbered by Congress the past two

years, R&D would get a hefty increase of more than \$5 billion, or 16%, over 1991. Research activities in the 6.1 category of DOD's budget would grow by a feeble 2%, from \$992 million this year to about \$1 billion. Basic research in 6.1 supports a wide range of disciplines, including physics, materials research, mathematics, oceanography and biochemistry. The small increase suggests that individual investigators would get little or no funding boost in 1992.

Applied research would go up by only 4% next year, from \$2.8 billion to \$2.9 billion. DARPA will continue to fund research on parallel processors, structural materials, acoustic detection and other military-related technologies. It also will help support Sematech, the semiconductor industry consortium that Congress helped create to improve manufacturing processes for advanced integrated circuits.

The largest single item in the R&D budget is funding for the Strategic Defense Initiative. Cut back significantly by Congress last year, to \$2.9 billion, SDI would get \$4.6 billion in Bush's budget for fiscal 1992. Congress also had a hand in drastically refocusing SDI so that it is now aimed at protecting the US and its allies against accidental or unauthorized attacks by ballistic missiles.

—IRWIN GOODWIN