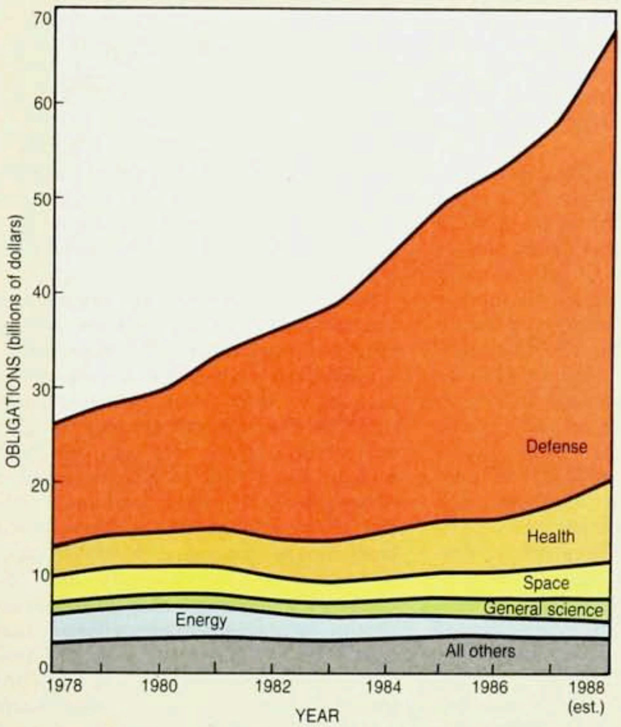
R&D enriched by 1988 budget but science policy impoverished

President Reagan, it has been said, has never heard of a big military or science project he didn't immediately endorse. That certainly was the case for the Strategic Defense Initiative, the space station, the National Aerospace Plane, which he immediately dubbed the "Orient Express," and, most recently, the Superconducting Super Collider. Judging by the budget his Administration sent to Congress on 5 January to cover government spending in fiscal 1988, the President has done it again for R&D—though not all is as it seems on paper.

Despite the scads of money in his full budget request, the first to break the $1 trillion barrier, most of the major R&D themes are boringly familiar: Out of the proposed total obligations of $64.8 billion for R&D, representing an increase of more than $7 billion (or 12% above the current level), the Defense Department once again is the big winner. If the President has his way, R&D for the Pentagon would amount to $44.1 billion, an increase of $6.8 billion (nearly 17% above this year's sum). As usual, DOD funds for R&D would go largely to development programs (up 18% in today's dollars) and applied research (up 6%), while basic research would rise much less (by 3%, which is equivalent to a 1% decline when measured in constant 1986 dollars).



R&D funding for the past decade in actual dollars shows 250% military increase while the rest of the major budget functions remain fairly constant. General science includes basic research at NSF and DOE. Others include obligations for natural resources and environment, transportation and agriculture. (Data from NSF.)

The proposed budget calls for NASA to get about $4.5 billion for R&D, an increase over 1987 of $313 million (up 15%), much of this destined for further development of the space station but also for two new programs, the Civil Space Technology Initative, which is devoted to rebuilding the agency's engineering capabilities, and Global Geospace Science, the US part of the International Solar Terrestrial Physics program. In seeking to gain more understanding of the interaction between the Sun and Earth, ISTP will deploy five US spacecraft, along with two developed by the European Space Agency and one by Japan.

New record. The National Science Foundation's substantial 16.7% increase of $238 million would bring the agency to a record of $1.7 billion for research and educational programs. Much of the additional funding would go to set up five to ten new Science and Technology Centers, modeled after its rapidly proliferating Engineering Research Centers (now numbering 13). These centers are intended to stimulate research funding and enhance collaboration between industry and universities, to become the centerpieces in the agency's strategy for revitalizing the country's economic competitiveness and improving the foreign trade balance. NSF's programs in engineering would increase by 26% and in computer and information science by 23%. By contrast, programs in mathematics and physical science would rise by 11%, with large increases for university instrumentation and research on the physics and chemistry of surfaces and interfaces. Global Geosciences, the rubric for all the agency's activities in atmospheric, Earth and ocean sciences, would receive almost 16% more than in fiscal 1987, to rise to a total of $330 million in 1988. NSF accounts for about two-thirds of all government support for geosciences.

In addition, NSF's new Computer and Information Science and Engineering Directorate, created last year out of programs scattered around the agency, is budgeted for a whopping 23% jump. The biggest outlays are tagged for microelectronic information processing, research in parallel processing concepts, cooperation with DOD to provide chips and systems for university research and teaching, and expansion of NSFNET, the online computer network for academics. The smallest increase for any unit within NSF is earmarked for astronomy, which would rise 8.8% above this year's planned $85 million. The 1988 budget calls for purchasing two antennas for the Very

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Long Baseline Array and starting construction on the Solar Global Oscillations Network at the National Optical Astronomy Observatory.

In presenting the NSF request, the Administration announced its intention to double the agency's budget over the next five years, minding the recommendation of the White House Science Council's Packard–Bromley report (PHYSICS TODAY, March 1986, page 65). So far in this year's budget cycle, Congress appears sympathetic to the promised increase for the agency, though when push comes to shove in meeting the targets of the Balanced Budget and Emergency Deficit Control Act of 1985, better known as the Gramm–Rudman–Hollings law, there are likely to be many who will vote to trim NSF's sails.

Modest rise. The Department of Energy's total R&D request for $5.7 billion represents a modest increase of $215 million (up 2.2%). More than half of DOE's R&D would go to finance military programs, such as work on nuclear warheads, the Strategic Defense Initiative x-ray laser and the SP-100 space-based power reactor. General science and research, which centers mainly on particle and nuclear physics, also stands to gain, rising from $716.8 million in fiscal 1987 to $811.7 million. This would go mainly for the first full year of operation of three newly completed facilities—the Tevatron at Fermilab, the Stanford Linear Collider and Brookhaven's new heavy ion project, which links the Tandem Van de Graaff accelerator with the Alternating Gradient Synchrotron. While all DOE construction is down 27% from this year, the budget calls for building the Continuous Electron Beam Accelerator Facility at Newport News, Virginia, as well as a 3-GeV SPEAR injector at SLAC, the 1–2 GeV synchrotron light source at Lawrence Berkeley's Center for Advanced Materials, and the neutron scattering experimental hall at Los Alamos.

Conspicuously absent from the DOE request is any funding of the Superconducting Super Collider. Shortly after the President approved it at the end of January, the department reprogrammed $35 million from its high-energy budget for additional R&D for the SSC and for its already fiercely contested site selection procedure (PHYSICS TODAY, March, page 47).

Traditional losers. As usual in Reagan Administration budgets, the losers are familiar old standbys: At the National Institutes of Health spending would plummet 9% to $5.5 billion. DOE's energy conservation and renewable energy programs stand to lose $213 million from last year's appropriation, with solar programs taking a beating of 39%. The Department of Commerce's R&D would go down $63 million from 1987, winding up with an estimated $333 million. In doing this, the Administration's intends to eliminate NOAA's Sea Grant and undersea research programs, which Congress has restored to the budget the past six years.

The budget submitted in early January, to comply with the G–R–H budget-balancing act, lacked many of the details. This was made up four weeks later when more numbers and explanations appeared. Accordingly, it turns out that despite the pats on the back the Administration gives itself for upping funds in basic research, those programs are set to rise in 1988 by not quite 4%, from $8.8 billion in 1987 to $9.1 in 1988. The Office of Management and Budget reckons that inflation will be somewhere between 3.3% and 4% this year, basic research is thus likely to get only a smidgen more than inflation.

Who's in charge? Budget requests, as anyone who's ever taken a civics class knows, simply represent the executive branch's wish list and not an accurate account of how much money will be spent by the departments and agencies on specific projects. With the Senate as well as the House of Representatives now controlled by Democrats, and with the White House still mired in the Iran–contra quagmire, it is virtually certain that Congress will call the tunes. The political change in Washington is evident everywhere—most especially in the overrides of the President's veto of the first two bills enacted by the 100th Congress, the Clean Water Act and the Highway and Mass Transit Act.

On Capitol Hill, Republicans and Democrats alike say the Administration is in a severely weakened position to promote its own priorities. They paint a picture of a lethargic and leaderless White House out of step with the consensus in Congress on many key issues, especially the budget. "I'm concerned," said Representative Trent Lott of Mississippi, the Republican whip. "The direction is unclear. Right now we're drifting."

James R. Schlesinger, who has served the Carter and Ford Administrations as, repectively, Secretary of Energy, and CIA director and Secretary of Defense, observes: "We are witnessing a massive shift of power from the President to Congress. While the President is certainly not powerless, he is not going to regain control over the national agenda."

Even using the past two years' performance with G–R–H as a guide, Congress is sure to deny some of the Reagan Administration's spending spree on military R&D, which accounts for some three-quarters of the 1988 R&D budget. Among the first targets for cuts is the President's pet Strategic Defense Initiative, which is listed in next year's DOD budget for $5.3 billion. Already there seems to be widespread reluctance to appropriate any more than last year's $3.2 billion to the "Star Wars" program. Other likely changes include an increase for the energy conservation and renewables programs at DOE and resistance to the Administration's persistent attempts to reduce funds for the National Institutes of Health.

Capitol buzzword. In explaining why R&D increases need to be so big, the Administration rests its case on national security and on economic growth and international competitiveness. "Competitiveness" is this year's watchword in Washington and most big R&D activities are explained by agency officials in terms of meeting the country's economic challenges, whether it is the SSC, Engineering Research Centers or the prospective doubling of NSF's budget by 1992. Most members of Congress are dubious that throwing money at R&D translates into more jobs and better living standards.

The debate over R&D and competitiveness began the day after the budget first appeared when the President's science adviser, William R. Graham, was battered by both Democrats and Republicans on the House Science, Space and Technology Committee. Prepared to cheer for the R&D budget, he waffled in answer to questions about the Administration's apparent lack of interest in increasing NSF's science education funding. Seizing the opportunity to state his position, the committee's new chairman, Robert A. Roe, a New Jersey Democrat, exploded: "That boils my blood." Graham attempted to explain that the Federal role in science education was under continual study. Obviously exasperated, Roe shouted: "How long do you have to study it?"

The subject of NSF's education programs as one of the best ways of increasing productivity and improving standards also came up in late February before a House Appropriations subcommittee at which Republican Representative Bill Green of New York waved that month's PHYSICS TODAY before Erich Bloch, the agency's director. Green asked Bloch to justify the graph showing the disparity between funds for education and research programs. Representative Edward Boland of New York, the subcommittee chairman, interrupted Bloch's reply to say: "If you don't increase the amounts for education in your agency, the Congress will do it for you."

What strategy? Graham and NASA Administrator James C. Fletcher have also been barraged by tough questions about the cost and mission for the proposed space station and the agency's reluctance to order expendable launch vehicles to supplement the shuttle for space science projects. On other occasions, Graham and Alvin W. Trivelpiece, director of DOE's research office, have been criticized for the Administration's persistence in reducing funds for energy conservation programs and alternative energy technologies. At one House session, Chairman Roe scoffed at Graham's assurance that "market forces" were the best device for assuring energy efficiences. The US, he went on, "is sitting on a time bomb, waiting for the energy crisis to erupt again."

Whenever Administration officials and science witnesses appear on Capitol Hill they are likely to feel they are living under a volcano that could erupt at any moment. Members of Congress are not content to speak of budget numbers alone, but ask about priorities and strategies for science and technology programs—for DOD, and for NASA, NSF and DOE as well. The chairman of the House Armed Services Committee, Les Aspin, a Wisconsin Democrat, recently suggested that his colleagues ask fewer questions about high-technology weapons and more about overall defense concepts. "Don't get me wrong," he said on the House floor. "Congress will always get involved in hardware questions. . . . After all, that's what generates jobs and local economic growth. . . . But hardware must not drive our consideration of the defense budget. The defense budget must not be a gigantic pork barrel. . . . Budget numbers are easy to crunch. Strategy is a tough nut to crack."

Speaking to the National Space Club at the University of Alabama on 12 February, Congressman Roe declared that "Annual budgets without enunciated policy goals are like armies without generals; they are fragments and pieces that move independently in many directions but frequntly lose sight of where the forward direction exists." He argued that despite all the money Congress has given NASA, the nation lacked a comprehensive space policy for either NASA or DOD. "We expect our scientists and engineers to be creative," he said. "We should expect no less from our agency administrators."

The already huge disparity between Federal outlays on civilian and military R&D would become even greater under the Reagan budget for fiscal 1988. In 1981 the government obligated $17 billion for defense-related R&D

Department of Energy physics-related research

	FY 86 actual	FY 87 approp (millions of dollars)	FY 88 request
High-energy physics			
Physics research			
Argonne	4.8	4.9	5.2
Brookhaven	7.0	7.0	7.4
Fermilab	9.4	9.4	9.9
Lawrence Berkeley	8.5	8.6	9.1
Stanford Linear Accelerator Center	10.8	10.8	11.5
Other DOE laboratories	1.8	1.7	1.9
Universities (for experiment and theory)	63.5	67.0	74.7
Total research	105.8	109.4	119.7
Facilities operations	173.0	208.4	240.3
Tecnologies, including detectors and SSC work	86.7	80.5	77.2
Capital equipment	70.0	70.1	80.2
Construction	55.0	31.3	49.2
Total high-energy physics	**490.4**	**499.7**	**566.6**
Nuclear physics			
Low energy, including Triangle Universities, North Carolina, Texas A&M and Yale University accelerators	20.9	25.4	26.2
Medium energy, including LAMPF, MIT's Bates Linear accelerator, and R&D for CEBAF in Virginia	73.1	81.0	84.0
Heavy ion, including experiments at CERN and the 88-inch cyclotron at Lawrence Berkeley Lab and R&D for RHIC at Brookhaven	48.8	60.7	65.3
Nuclear theory	9.0	10.0	10.5
Capital equipment	14.0	15.9	17.7
Total construction, including CEBAF (total cost, 255.0)	6.7	24.1	41.5
Total nuclear physics	**172.5**	**217.0**	**245.1**
Basic energy sciences			
Materials sciences, including solid-state physics	132.6	155.0	169.8
Chemical sciences	104.3	115.1	124.1
Engineering and geosciences	25.3	29.4	31.4
Advanced energy projects	11.9	12.8	14.3
Biological energy research	11.8	16.5	18.6
Applied mathematical sciences	37.5	38.8	40.5
Capital equipment	25.7	31.1	31.7
Construction			
3 GeV SPEAR injector (total cost, 13.5)	—	—	3.0
Center for Advanced Materials (total cost, 40.3)	22.1	10.6	7.6
1–2 GeV synchrotron facility (total cost, 98.7)	—	1.5	18.0
Neutron scattering guide hall at Los Alamos (total cost, 17.5)	—	5.0	8.5
General plant projects	—	6.1	7.2
Additional projects, including Congressional "pork barrel"	—	99.7	—
Program direction	3.5	4.1	4.5
Total basic energy sciences	**419.9**	**525.5**	**479.1**
Supporting research activities			
University research support			
University laboratory research	5.7	10.6	9.8
University reactor fuel assistance	3.6	3.9	1.9
Precollege teacher and student programs	0.8	1.3	1.7
Total university support	10.1	15.8	13.4
University research instrumentation	6.2	5.0	5.0
Multiprogram laboratories facilities support	39.9	56.7	56.6
Magnetic fusion			
Toroidal confinement systems	142.4	165.3	162.1
Mirror confinement systems	46.2	21.2	8.9
Applied plasma physics, including National Magnetic Fusion Energy Computer Center at Lawrence Livermore	69.7	73.5	73.1
Development and technology	57.6	50.5	55.9
Planning and projects	0.9	4.7	4.5
Capital equipment	28.3	18.0	19.7
Construction, including Compact Ignition Tokomak (total cost, 357.0)	12.7	8.2	16.9
Total magnetic fusion	**361.5**	**345.3**	**345.6**
Inertial fusion			
Gas laser, including Aurora krypton fluoride test-bed system	29.5	28.6	25.0
Glass laser, including NOVA x-ray experiments	86.5	87.5	66.5
Pulsed power, including PBFA II experiments	21.9	26.6	21.0
Capital equipment	9.5	8.9	6.0
Total inertial fusion	**147.4**	**151.6**	**118.5**
Nuclear directed-energy weapons (for SDI)	**157.5**	**169.6**	**270.7**

National Science Foundation physics-related research

	FY 86 actual	FY 87 request	FY 87 approp	FY 88 request
		(millions of dollars)		
Mathematical and physical sciences				
Physics				
Elementary particles	39.7	45.7	42.1	46.1
Intermediate energy	17.5	18.8	17.7	21.2
Nuclear	20.5	21.2	20.8	22.3
Atomic, molecular and plasma	13.3	13.9	13.4	14.8
Theoretical	14.4	16.0	14.8	16.5
Gravitational	7.7	11.0	8.5	10.4
Total physics	113.2	126.6	117.2	131.3
Materials research				
Solid state physics	11.5	12.4	11.9	12.9
Solid state chemistry	8.3	9.1	8.6	9.6
Low-temperature physics	7.8	8.5	8.1	8.8
Condensed matter theory	8.2	9.5	8.7	10.2
Metallurgy	9.3	10.2	9.6	10.5
Ceramics and electronics materials	6.3	6.9	6.5	7.2
Polymers	6.9	7.5	7.3	8.0
Instrumentation	5.8	6.2	5.0	5.3
Materials Research Laboratories	25.7	27.7	26.5	27.8
National facilities	9.9	10.7	10.5	11.3
Materials Research Groups	4.5	8.8	6.0	8.0
Total materials research	104.3	117.4	108.6	119.6
Mathematical sciences	51.9	59.8	59.8	67.8
Chemistry, including physical chemistry	85.8	101.0	93.5	102.8
Astronomical sciences				
Solar-system astronomy	1.2	1.2	1.2	1.3
Stars and stellar evolution	6.4	7.0	7.0	7.3
Galactic and extragalactic	12.0	14.2	14.2	16.0
Instrumentation and development	5.1	5.1	5.0	4.9
National Astronomy and Ionospheric Center	5.7	6.1	5.9	6.3
National Optical Astronomy Observatories, including Kitt Peak and Cerro Tololo	22.7	24.2	23.1	25.8
National Radio Astronomy Observatory	16.3	17.3	17.0	19.0
VLBA construction	9.0	9.4	11.4	11.9
Total astronomy	80.2	85.1	85.1	92.6
Total mathematical and physical sciences	**435.3**	**486.9**	**463.4**	**514.0**
Geosciences				
Atmospheric sciences	47.6	51.3	48.1	54.8
National Center for Atmospheric Research	41.0	45.2	41.2	47.1
Upper atmospheric facilities	4.0	4.1	4.1	4.8
Earth sciences, including geophysics, lithosphere research and instrumentation	46.8	55.0	49.9	63.4
Ocean-sciences research	56.9	66.4	66.4	72.9
Oceanographic centers and facilities	33.7	37.2	37.2	43.9
Ocean drilling	28.8	30.1	30.1	31.3
Arctic research program	8.0	8.9	8.1	10.5
Total Earth and ocean sciences	**266.9**	**289.2**	**285.1**	**330.0**
Antarctic research program	**110.2**	**117.0**	**117.0**	**143.0**
Computer and information sciences and engineering				
Computer and computation research, including microelectronics	55.9	65.5	63.8	81.5
Advanced scientific computing	36.5	46.6	42.9	48.2
Networking and communications research	8.6	10.9	9.9	13.4
Total computer and communications	**100.9**	**123.0**	**116.4**	**143.0**
Engineering				
Chemical, biochemical and thermal	27.7	30.2	28.4	31.5
Mechanical, structural and materials	22.7	26.3	24.9	28.5
Electrical, communications and systems	19.8	20.7	22.5	28.4
Design, manufacturing and automation	12.8	14.2	14.0	18.0
Emerging research, including biotechnology	10.4	16.3	15.6	19.4
Earthquake and environmental	23.8	26.8	24.6	27.7
Engineering Research Centers	21.9	35.0	30.0	48.0
Industry-University Projects	3.0	0.0	0.0	0.0
Industry-University Research Centers	2.9	3.0	3.0	3.5
Total engineering	**114.9**	**172.5**	**163.0**	**205.0**
Science and engineering education				
Teacher preparation and enhancement	26.3	27.0	30.0	36.0
Learning materials development	24.4	25.0	29.5	26.0
College science instrumentation	5.3	7.5	9.5	9.5
Research career development	26.0	27.3	27.3	36.0
Studies and program assessment	2.8	2.2	2.2	7.5
Total science and engineering education	**84.6**	**89.0**	**99.0**	**115.0**

and $15.3 billion for civilian R&D. In 1988 the Administration proposes to spend $46 billion for military R&D and $18 billion for civilian R&D, of which nearly $8 billion will go to research support at universities. In achieving this and supporting other aspects of the new budget at the same time, argues the Congressional Budget Office, the G–R–H goal of a $108 billion deficit in fiscal 1988 cannot be met.

What worries Congress is that some recent R&D initiatives, particularly the space station and super collider, involve huge sums. Congress is far more economy-minded than at any time in the Reagan Presidency. It knows that if these proposals are approved for 1988, most of the financial impact would be felt after Reagan leaves office.

Finding revenue. The House budget resolution proposes raising about $18 billion more than the expected revenue in 1988. The President refuses to consider more taxes as a way of increasing revenue. Congress is equally obstinate about accepting the President's proposed spending reductions, many of these vintage Reagan. Some of the so-called "revenue enhancements" or nontax receipts involve selling Conrail, Amtrak, the Elk Hills and Teapot Dome oil reserves and various pieces of real estate. Other fund-raising proposals include slashing or eliminating some 40 domestic programs (including school lunches, education grants, public housing and mass transit) that date back to Lyndon B. Johnson's Great Society or even to Franklin D. Roosevelt's New Deal.

In fiscal 1986 the budget deficit reached a record $221 billion, raising the national debt above $2 trillion—double the level in 1981 when Reagan took office. What's more, the Congressional Budget Office estimates that the deficit in 1988 is likely to be about $171 billion, despite the efforts in the past two years to hold down spending. Such a deficit would leave some $63 billion to make up somehow in achieving the G–R–H target.

House Budget Committee Chairman William H. Gray III of Pennsylvania and his Senate counterpart, Lawton Chiles of Florida, insist it is impossible to make such massive cuts. "It's a mess," says Gray. He fears that any attempt to reduce the 1988 budget by another $63 billion would risk a recession. Even if all appropriations were frozen at 1987 levels, and nothing new is introduced, Gray warns that the budget would have an excess deficit of about $46 billion. To reduce the deficit to zero would require almost an 18% cut in this year's funding levels, says Gray, which equals about $28 billion

NASA physics-related projects

	FY 86 actual	FY 87 amended	FY 87 estimate	FY 88 request
		(millions of dollars)		
Physics and astronomy				
Hubble Space Telescope development	125.8	95.9	101.3	98.4
Gamma Ray Observatory development	85.3	51.5	50.5	49.1
Spacelab–Space Station payload development	89.4	84.6	90.1	95.4
Explorer development	48.2	56.7	56.7	60.3
Mission operations and data analysis	111.7	125.7	125.7	128.1
Research and analysis	49.0	51.1	53.4	60.1
Suborbital programs				
Sounding rockets	23.1	27.7	30.9	32.1
Airborne science and applications	25.0	24.1	31.6	30.3
Balloon program	6.1	7.9	7.9	8.2
Spartan payloads for space shuttle	5.7	4.7	4.7	5.1
Total physics and astronomy	**569.3**	**529.9**	**552.8**	**567.1**
Planetary exploration				
Galileo development (to Jupiter)	64.2	77.0	71.2	55.3
Magellan (formerly Venus Radar Mapper)	120.3	69.7	92.6	59.6
Ulysses (formerly International Solar-Polar)	8.8	24.0	10.3	10.8
Mars Observer	33.8	62.9	35.8	29.3
Mission operations and data analysis	67.0	77.2	80.0	77.0
Research and analysis	59.5	63.5	68.5	75.3
Total planetary exploration	**353.6**	**374.3**	**358.4**	**307.3**
Science and applications				
Solid Earth observations				
Shuttle-Spacelab payloads	21.8	21.6	21.6	21.1
Geodynamics, including crustal dynamics	30.0	32.1	32.1	33.1
Research and analysis	19.1	20.4	21.9	22.6
Total solid Earth observations	70.9	74.1	75.6	76.8
Environmental observations				
Upper-atmosphere research and analysis	31.1	33.4	33.4	34.4
Atmospheric-dynamics and radiation research	28.7	30.9	31.9	32.9
Oceanic processes research	17.4	20.8	20.8	21.5
Space physics research	16.8	18.0	21.0	21.5
Shuttle–Spacelab payload development	5.3	12.0	12.0	19.4
Extended missions operations	35.0	33.6	33.6	26.8
Interdisciplinary research	1.0	1.1	1.1	1.1
Tethered satellite payloads	6.4	1.0	1.0	3.1
Scatterometer	14.0	35.9	32.9	22.7
Upper atmosphere research satellite	114.0	121.2	114.2	95.4
Ocean Topography Experiment	—	29.0	19.0	90.0
Global Geospace Science	—	—	—	25.0
Earth radiation budget experiment	1.9	—	—	—
Total environmental observation	271.6	336.9	320.9	393.8
Total science and applications	**342.5**	**411.0**	**396.5**	**470.6**
Materials processing in space				
Microgravity shuttle-station payloads	18.9	26.5	34.0	31.5
Research and analysis	12.1	12.9	13.9	14.4
Total materials processing	**31.0**	**39.4**	**47.9**	**45.9**

taken out of defense and $18 billion from nondefense discretionary programs, including R&D of course. Gray claims Congress will be unable to offset the anticipated deficit without Draconian reductions virtually everywhere. The alternatives therefore are to increase taxes to make up the difference or to abandon the G–R–H goal for 1988—choices the President insists are unacceptable.

Following are some highlights in the 1988 budgets of the R&D agencies that affect physics and physicists:

Defense Department. President Reagan's defense budget would rise by only 3% above OMB's estimated inflation rate—the smallest increase he has proposed since he took office. The Pentagon's total request, including military spending by DOE, comes to $303 billion, with some $45 billion of that earmarked for research, development, testing and evaluation. Out of the R&D funds, $918 million would go to basic research, a 2.4% rise from the current $892 million (which represents a real decline of 0.6% in constant dollars). The University Research Initiative, which is funded by the basic research program or 6.1 category of DOD's budget, would rise to $92.8 million, approaching the $89.7 million level in fiscal 1986 and far above the $34.1 million this year.

URI is a popular program that enables academic scientists to work at any of the 73 DOD laboratories, but the Pentagon funds only a fraction of those who apply. Out of 965 applications last year, DOD wrote only 86 contracts. That's because the program is a catch-all, covering not only research, but instrumentation, fellowships, young investigator awards and scientific exchanges.

The largest increase in military research would go to SDI, which would get nearly $2 billion more in 1988, reaching a total of $5.3 billion. In addition, Star Wars R&D would go up at DOE, from $349 million in fiscal 1987 to $481 million next year. The program is unlikely to receive such largesse: Many members of Congress are distressed by its massive budget and by Defense Secretary Caspar W. Weinberger's unabashed declarations that the project needs to be speeded up, with a "Phase 1" system actually deployed in the early 1990s. Weinberger's plan hinges on the government's adoption of the so-called "broad" interpretation of the 1972 antiballistic missile treaty—a topic of considerable controversy in Washington. The phased introduction of SDI is in keeping with a strategy outlined in a report by the George C. Marshall Institute (PHYSICS TODAY, January, page 47), which envisions a three-layered antimissile defense. It would use some 11 000 kinetic-kill vehicles, such as electromagnetic rail guns hurling projectiles to destroy Soviet ballistic missiles by impact in boost and postboost stages. At the ready on thousands of space satellites, these weapons would be directed by sensor satellites and by ground- and air-based systems using supercomputers to track the missiles and relay data to the battle stations. Another 10 000 Exoatmospheric Reentry-vehicle Interceptors would be launched from the ground against warheads in midcourse. To strike the warheads that make it through the first two layers, 3000 High-Endoatmospheric Defense Interceptors would be launched from the ground.

Early deployment of such a system means demoting for the time being research on directed energy weapons (see page S–1) and concentrating instead on conventional chemical rockets. Early deployment also requires abandoning the restrictive interpretation of the 1972 ABM Treaty within the next year or so in favor of the broad view that allows for testing components of a Star Wars system. SDI's chief, Lieutenant General James A. Abrahamson, told a House Armed Services subcommittee last February that the 1988 budget is still based on a narrow reading of the ABM treaty, but that unimpeded testing and development would save money and increase confidence for Phase 1.

Congress is also concerned about Weinberger's supplemental request for another $500 million to be spent on Star Wars this fiscal year. Half of this extra money would go to develop heavy

Department of Defense basic research funding (6.1 budget category)

	FY 86 actual	FY 87 approp (millions of dollars)	FY 88 request
Army			
Physics, astronomy, radiation sciences	36.4	25.7	25.2
Mechanics, aeronautics, energy conversion	22.8	18.8	18.9
Materials	18.8	16.4	15.7
Electronics	25.9	22.9	21.4
Mathematics and computer sciences	15.8	14.4	13.1
Earth sciences, including geophysics	7.9	7.8	6.5
Atmospheric sciences	8.4	7.7	7.0
Chemistry	18.1	14.8	15.0
Biology and medical sciences	55.4	46.3	45.8
Behavioral sciences	7.6	6.9	6.3
University research instrumentation	9.6	9.1	—
University Research Initiative	5.7	8.3	24.1
Army laboratories independent research	23.8	16.7	—
Total Army	**250.3**	**215.6**	**199.0**
Navy			
Physics, astronomy, radiation sciences	44.2	41.4	44.4
Mechanics, aeronautics, energy conversion	31.8	27.7	29.6
Materials	27.9	30.7	31.3
Electronics	29.9	30.2	30.3
Mathematics and computer sciences	28.8	30.7	31.1
Oceanography	73.0	78.8	84.6
Atmospheric sciences	11.4	13.3	15.2
Chemistry	23.8	25.5	23.1
Biological and medical sciences	19.3	22.1	25.6
Behavioral sciences	12.5	12.0	10.2
University research instrumentation	10.0	10.0	—
Special studies	—	—	8.2
University Research Initiative	5.9	8.5	24.6
Navy laboratories independent research	24.8	23.3	22.6
Total Navy	**343.3**	**354.2**	**380.8**
Air Force			
Physics, astronomy, radiation sciences	27.4	27.6	28.0
Mechanics, aeronautics, energy conversion	39.0	39.2	37.9
Materials	22.9	23.3	26.2
Electronics	21.0	22.0	21.2
Mathematics and computer sciences	20.5	21.4	20.9
Earth sciences, including geophysics	2.8	2.1	2.0
Atmospheric sciences	12.9	12.4	11.4
Chemistry	20.8	22.8	25.0
Biological and medical sciences	9.5	9.9	10.6
Behavioral sciences	7.7	8.5	8.6
University research instrumentation	10.0	10.0	—
University Research Initiative	5.9	8.8	19.5
Air Force laboratories independent research	15.1	15.9	15.7
Total Air Force	**215.5**	**224.2**	**227.0**
Defense Advanced Research Projects Agency			
Materials	16.8	22.2	22.2
Electronics	15.7	24.0	21.3
Mathematics and computer sciences	27.1	24.1	30.0
Earth sciences, including geophysics	2.0	1.7	2.0
Biology and medical sciences	4.6	6.3	4.5
Behavioral sciences	11.8	7.3	4.2
University Research Initiative	5.4	8.8	24.6
Total DARPA	**82.4**	**94.4**	**108.8**
Total Department of Defense basic research	**891.5**	**888.4**	**915.6**

launch vehicles to place SDI hardware in space and the remainder is required to keep the program on track, according to Weinberger. Prospects for getting much of these increases are generally deemed slim on Capitol Hill.

Indeed, it is not considered likely that DOD will get much more than a 1% real increase in 1988—though actual defense outlays will increase for the next few years because of payments required to meet budget authorizations of previous years.

NSF. No startling new initiatives are on paper for 1988, though Bloch has appointed an internal group to come up with a strategem for spending the vast new sums the Reagan Administration promises after it leaves office on 20 January 1989. In the meantime, the agency expects to increase the amounts for centers and other research groups from the current $449 million to $529 million in 1988. The new budget also calls for substantial rises in several education programs, including $68 million for precollege activities, $70 million for undergraduate education and 200 new fellowships, bringing the total to 1700. In addition, NSF would sponsor 14 000 graduate assistantships and 3700 postdocs, with the intention of funding one graduate student for each investigator.

NASA. At first glance, NASA's budget looks remarkably healthy. If the $2.1 billion NASA got in fiscal 1987 for a new orbiter to replace Challenger is removed from the calculation, the space agency's budget would increase by almost $1.1 billion in 1988, to reach $9.5 billion. Space science and applications would not be so fortunate, however. The budget for those activities would decline slightly and spending for planetary science would be especially hard hit.

There are some bright spots, though. Included in the budget is $25 million for a Global Geospace Science Mission. This is the first installment for a $400 million program over five years to develop a series of spacecraft for examining in the 1990s how incoming solar energy is distributed, stored and released. NASA's funding of global geosciences would climb 80% to $60 million. A new addition to the program in fiscal 1988 would be initial studies of upper-atmosphere physics.

The space station continues to perplex NASA and Congress. It is in the budget for $767 million, up from $420 million in fiscal 1987. But during a series of hearings in Congress it became obvious that even NASA's staunchest supporters are warning Fletcher and his deputy, Dale Myers, they must come up with answers, fast, about the station's uncertain mission and soaring costs. Members of the key House space subcommittee showed frustration when NASA officials were unable to answer several questions about the station because, they said, the matter was under White House review.

Subcommittee Chairman Bill Nelson of Florida, who flew in the shuttle just before the Challenger disaster, pointed out that Congress had "gone to the wall" to ensure that station funding was included in the last budget, based on repeated assurances that it would cost $8 billion and that NASA would be "bending metal" sometime this year. "This committee is not going forward under the illusions under which we operated last year," Nelson told Andrew Stofan, NASA's top space station administrator. "If you don't have this committee fighting for you, there's deep trouble."

Nelson and Representative Robert S. Walker, a Pennsylvania Republican, quoted from a confidential memo to the President from James C. Miller III, director of the Office of Management and Budget, indicating that the station's construction costs have risen to at least $14.5 billion or possibly $15.5

billion in 1984 dollars, depending on what was included in the estimate—or to more than $21 billion, adjusted year by year for inflation. At a previous hearing of the full House science committee, Fletcher waffled on costs when Walker tried to pin him down to figures of $13 billion and then $15 billion. "It's in that ballpark, Mr. Walker," said Fletcher. "What about $18 billion?" asked Walker. "It's in that ballpark too," replied Fletcher.

Before a House Appropriations subcommittee, Graham, the President's science adviser, admitted the space station was the most troubling project in his office. The White House had placed him in charge of an interagency task force that included NASA, the State and Defense departments and National Security Agency, to resolve several problems. Only one dealt with cost. The most sensitive involved negotiations with the European Space Community, Canada and Japan, which signed up to collaborate on the station as a peaceful project. After insisting it had no interest in a permanent orbiting laboratory with people aboard, the Pentagon now wants assurance from NASA that it can use the station to perform experiments on DOD or SDI components if it wants to. Such a request has upset the foreign partners, who are designing research modules and an external robotic arm for the station. Though a memorandum of understanding was signed after 17 days of meetings between NASA and the State and Defense departments, forbidding any weapons of mass destruction to be carried or tested on the station, it does not preclude testing lasers or other Star Wars hardware, according to Fletcher's testimony before Congress. "DOD was concerned that its options be preserved," said Fletcher.

On 4 April the White House approved a NASA plan to cut the rapidly rising costs for the space station and reduce the even more rapidly rising political opposition in Congress. Under the new plan the station would be developed and deployed in two stages, thus delaying the first assembly by a year and permanent habitation even longer. In doing this, the total cost would be kept at $14.5 billion.

Even more disturbing than escalating costs to many members of Congress and to officials of participating governments is a classified National Security Decision Directive signed by Reagan last December. The directive, designated NSDD 254, deals with the entire US space launch strategy and calls for DOD to participate in the station.

Department of Energy. The Administration argues that such programs as solar energy, conservation and fossil fuels should be axed from the budget because commercial firms should be funding this kind of R&D. One important new energy project has been approved, however. DOE wants to spend $8 million to begin construction of a compact ignition tokamak, a device long sought by fusion researchers. The project, to be built at Princeton University, is expected to cost a total of $357 million.

The 1987 budget for basic energy sciences contains a $99.7 million anomaly—caused largely by Congress, which dipped into the "pork barrel" for several science projects at universities and hospitals (PHYSICS TODAY, December, page 47. DOE wants Congress to rescind these, but that is unlikely.

While some of DOE's applied research programs are being reduced, the budget for general sciences would increase by 13%, from $719 million to $815 million. This will enable construction work to proceed on CEBAF, though the department trimmed the original request from $60 million to $33 million before submitting its budget. The budget also calls for larger operating funds for the SLC and Tevatron. Notwithstanding the original request, the decision to go ahead with the SSC has put a crimp in the amounts available for high-energy physics at the national labs. In a talk to DOE's High Energy Physics Advisory Panel on 10 February, Fermilab Director Leon Lederman complained about the "SSC tax" that is being imposed on his lab, saying it could mean layoffs of scientific and technical people.

—Irwin Goodwin

Strategic Defense Initiative (6.2 and 6.3 budget categories)

	FY 86 actual	FY 87 approp	FY 88 request
		(millions of dollars)	
Directed-energy weapons			
Technology base development, including chemical lasers, free-electron lasers and particle beams	435.5	339.7	340.5
Technology integration experiments	329.4	402.1	587.9
Concept formulation	18.7	26.8	32.3
Support programs	19.7	62.4	115.0
Innovative Science & Technology program	19.7	12.7	28.0
Total directed-energy weapons	**823.0**	**843.6**	**1103.7**
Kinetic-energy weapons			
Space-based kinetic-kill vehicles	134.4	126.8	303.5
Exoatmospheric kinetic-kill vehicles	61.6	107.6	220.6
Endoatmospheric kinetic-kill vehicles	76.7	111.3	237.6
Mini projectiles, including laser guided	56.0	74.5	102.9
Test and evaluation	185.9	252.1	109.3
Allied and theater defense	69.9	44.3	72.9
Innovative Science & Technology program	61.4	13.0	28.0
Total kinetic-energy weapons	**595.8**	**729.6**	**1074.7**
Surveillance, acquisition, tracking and kill assessment	**847.0**	**911.0**	**1492.7**
Systems analysis and battle management			
SDI strategic architecture	63.5	58.4	91.0
SDI systems engineering	12.1	20.2	39.0
Theater architecture	1.7	39.8	38.4
Command control and communications technology	70.9	88.5	121.8
Command control and communications experimental systems	23.4	80.7	172.9
National test bed (at Falcon Air Force Base in Colorado)	12.0	60.6	119.2
Countermeasures	6.1	5.0	—
Innovative Science & Technology program	13.4	18.1	28.0
Civil applications	—	2.0	2.0
Medical free-electron laser development	9.2	13.5	15.0
Total systems analysis and battle management	**212.3**	**386.9**	**627.3**
Survivability, lethality and key technology			
Systems survivability	59.4	60.0	94.2
Lethality and target hardening	78.3	78.0	102.5
Power and power conditioning	12.5	85.7	158.0
Space propulsion, propellants and support	20.7	36.4	433.8
Materials and structures	—	14.2	22.5
Countermeasures	8.7	26.7	42.8
Innovative Science & Technology program	21.5	18.2	28.0
High-energy laser test facility (at White Sands, New Mexico)	—	18.8	18.5
Total survivability, lethality and key technology	**201.1**	**338.0**	**900.4**
Military construction	3.0	10.0	125.0
Headquarters management	13.1	19.9	27.0
Total Defense Department SDI program	**2679.2**	**3239.0**	**5345.8**
Department of Energy SDI program	285.0	514.0	569.0
Total SDI program	**2964.2**	**3753.0**	**5914.8**