Science Gains Slightly in 1981 Budget

Both R & D and basic research get a cost-of-living increase

Science has fared well in President Carter's 1981 budget, relative to the austerity of the overall proposal. Top budget official James McIntyre notes that "after taking account of inflation, there is virtually no growth" expected in federal outlays for the various agencies.* Research and development rises slightly above this average, with an expected increase of 10 percent, or 1 percent above inflation, amounting to $3.2 billion more funds than in 1980. The total of $33.7 billion is said by science adviser Frank Press to be an all-time high in constant federal dollars. Basic research performs even better than R & D, with an expected increase of 12 percent, or $495 million.

As in previous years, the largest R & D boost will occur in the Department of Defense, which accounts for 45 percent of overall R & D spending. Defense is also the beneficiary of a 22 percent increase in expected outlays for basic research. The energy department and the National Science Foundation also receive funding boosts in basic research that are in excess of the inflation rate.

Proportionately more R & D money will also be spent on college and university campuses. Although the budget release suggests that such spending will rise by 11 percent, or $418 million, Frank Press reports that the amount may actually be 15 percent, because of a late decision by Defense Research Director William J. Perry to spend more of his department's research money in academia.

The budget contains several new projects in science that cross agency lines. One is a new cooperative venture with the automobile industry to research new automotive technologies over a 10-year period. The federal government will contribute $17 million in 1981, and $800 million over 10 years, to be financed by the windfall profits tax presently stalled in Congress. Also, the defense department and the National Science Foundation will embark on a new program of support for experimental computer science at academic institutions and, together with the National Bureau of Standards, on a new program of support for microelectronics. The National Aeronautics and Space Administration will gain a new satellite system, and has won the right to draw upon the budgets of other agencies in the future for programs of mutual benefit.

The Administration is seeking once again to throttle its largest science demonstration project, the Clinch River Breeder reactor. After two budget tries already, the project is becoming an embarassment to Carter's science establishment, which has been unable to persuade Congress it is a white elephant.

Energy

Few surprises are offered in the 1981 budget for the Department of Energy (DOE), which is itself slightly surprising. The budget proposal is the first to be prepared under the guidance of Charles Duncan, the defense department management whiz who succeeded the less orderly James Schlesinger last October. Duncan's imprimatur is apparently in technique and not theory, as the 1981 budget exhibits few diversions from the old policies. In presenting the proposal, Duncan emphasized the long-term, not the immediate, aspects of the "transition to energy diversification," which he pegged at 20 years.

The Administration proposes a $1 billion increase overall, which amounts to a real increase of 3 percent above inflation (estimated at 9 percent). Congress will also be asked for an immediate $517 million in supplemental funds for the current fiscal year, $49 million of which is targeted for research, development, and applications. Authority for overall R & D spending in 1981 is slated to rise by 9 percent, or $362 million.

It should be noted that these projections omit all programs and funds currently pending in Congress, presenting an incomplete picture at best. The President's major new initiatives, announced at the same time Duncan was installed, are at present tied up in House-Senate conference committees, although ultimate approval in some form is assured. Included are revenues for conservation and research from the windfall profits tax, and about $20 billion from the Energy Security Corporation for development of coal, oil shale, biomass, and unconventional gas.

Overlooking these uncertainties, then, the 1981 budget proposal maintains funding for most items at a constant, or inflation-proof, rate. High-energy physics, for example, will gain by only 1 percent above inflation, with increased funding for the intersecting storage accelerator at the Brookhaven national lab and for the colliding beam project at Fermilab. Funding for life sciences applied research will increase by 14 percent—largely for new looks at chromosomes and CAT-scanning techniques. But nuclear physics gains by only 5 percent, with most of this going to construction of the Argonne Tandem Accelerator System. The net gain for general sciences after inflation is zero. Similarly, the net gain for basic research is a point below the inflation level, despite new emphasis on engineering and biology.

Almost half of DOE's real increase in funding goes instead to its nuclear defense program, which already accounts for 30 percent of the overall budget. Included in the defense projects' overall gain of 13 percent (or $403 million) is a big boost in the inertial confinement fusion program, which aims laser light and particles at pellets of heavy isotopes in order to produce fusion, at least in theory. Although construction of the NOVA laser facility at Lawrence Livermore has been deferred, the Administration intends to pour a 23 percent funding increase into development of increasingly powerful lasers. Also receiving healthy increases in the energy department's defense sector are weapons research and production (12 percent) and naval reactors (15 percent). However, the pilot project to isolate and dispose of the defense program's nuclear wastes at Carls-

*These numbers, as well as those in the energy and EPA briefings, refer to budget outlays, the money the government actually spends in 1981; all others refer to budget authority, which may be spent over several years.

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bad, N.M., has now been abandoned, following an initial expense of $84 million. Energy Undersecretary John Deutch says that alternative sites and commercial operations will be explored instead.

The Administration has also proposed a large increase in conservation funding (41 percent) with most of it going to state and local grants for programs in schools, hospitals, and old housing, as well as local energy forecasting. Additional amounts will be used for small-scale localized energy projects, in the patriotic mold of the Pacific Trust Territories. Last year, the territories turned 10,000 gallons a day of tuna sludge into methane gas, feedstock, and fertilizer.

Increases in these areas clearly come at the expense of R & D related to the energy supply, such as solar, wind, and geothermal. Although the amount allotted to solar applications is up by 15 percent, for example, research into solar technologies will increase only 3 percent; the cutback is felt particularly in photovoltaics work. The geothermal allotment increases only 6 percent, although that for hydropower increases by 46 percent (8 million), largely to support the use of small power units on abandoned or little-used dams, a perennial political favorite on Capitol Hill.

Also suffering is research into fossil fuels, which will receive an increase of only 1 percent; funding for research will actually decline in mining, surface coal recovery, combustion and heat recovery, and magnetohydrodynamics, as will that for special university-sponsored programs. Forty percent of the overall funds will support continued construction of the solvent refined coal plants at Morgantown, W. Va., and Newman, Ky., and a high-Btu synthetic pipeline gas plant in Illinois. Funding for commercial nuclear waste will rise 36 percent, largely to renovate hazardous milltailing dumps. The amount for magnetic fusion rises 23 percent, primarily for continued work on the Tokamak at Princeton. But the Administration has proposed once again to end funding for the Clinch River fast breeder reactor, and to reduce research funding for water- and gas-cooled and light water reactors. Clinch River lives on despite two previous attempts to stop it.

Finally, hedging against the chance that research and conservation will somehow fail to alleviate the energy crisis, DOE has proposed to spend $29 million more for an advertising campaign telling us that a crisis exists, and that we ought to use energy more conservatively —an increase over 1980 funding of 725 percent.—R. JEFFREY SMITH

Defense

The defense plan for fiscal 1981, even though it represents pre-Afghanistan thinking, allows for a large increase in spending on military hardware and operations, and a relatively larger emphasis on research. The Carter Administration has reversed the trend of the 1970's. For the first time since the Vietnam war, defense expenditures as a share of the Gross National Product are on the rise. Last year they amounted to 4.6 percent of the GNP; this budget may push the figure up to 5.2 percent.

The total budget authority for the Department of Defense (DOD) increases by about $19.5 billion to a level of $158.7 billion. Once inflation is discounted, this provides a real growth of about 5.4 percent over last year. Research and development grows by about 11 percent in real terms, well ahead of the average rate of growth for R & D in other agencies of 4 percent.

Thus DOD is the biggest buyer of research and development in the government (funding 45 percent of the total), and the fastest growing supporter of basic research this year. DOD plans to increase basic research funding by 12 percent in real dollars, more than the increase proposed by the National Science Foundation (8 percent) or the Energy Department (4 percent). According to Frank Press, the President's science adviser, actual payments for basic research done at universities will grow by an impressive 25 percent this year. This continues the Administration's plan to "recement" the bonds between the campuses and the defense establishment.

DOD Secretary Harold Brown said last week that the budget was essentially finished in December before the Soviets invaded Afghanistan. Next year's budget will reflect some of the adjustments now being made as a result of the Soviets' aggression. In the meantime, he said, the government will express its intentions through military deployments and new military agreements with friendly nations. These will cost money. Cost figures in this budget will probably be forced up as well by unanticipated inflation in fuel expenses and salaries.

One of the Department's major projects this year will be to improve the "rapid deployment force" (RDF) created specifically to deal with crises in Europe and the Middle East. In order to improve military readiness, Brown said, the Administration devoted more funds than usual to operation and maintenance (making an increment of $5.8 billion). In addition, DOD will seek an extra $210 million to acquire a couple of supply ships for the RDF and $80 million worth of research to develop a long-range transport plane. It is being called the CX.

Although the amount sought for Navy shipbuilding declines, the shift is more apparent than real, Brown said. He pointed out that last year's budget included a $2.3 billion aircraft carrier, which has now been completed. Other programs are going ahead as planned, and the Navy intends to meet its ambitious goal of building 97 new ships by the end of 1985.

Brown was asked whether the United States is "militarily able to implement the Carter Doctrine," the assertion that America has a vital interest—to be defended with military force—in the free shipment of oil from the Persian Gulf. Brown said that the two-carrier task force recently moved to the area as "a massive sea and air capability" to respond to an emergency "within a few days." Mounting an amphibious troop landing would take much longer, perhaps "a couple of weeks." This is enough to deter adventurism, he said, although "it is not comparable with the 170 divisions of the Soviet Union, I know." He declined to discuss the circumstances under which the United States might threaten to use nuclear forces.

Nothing dramatically new is planned in the area of strategic weapons. The budget calls for funding the MX mobile intercontinental missile as originally scheduled, at a rate of $1.6 billion this year. This is going ahead unchanged, despite the fact that the present scheme for deployment may not make sense if the SALT II treaty is scuttled. "I have by no means abandoned SALT II," Brown said, explaining that U.S. weapons programs will follow the treaty's guidelines as long as the Soviets' do the same.

The air-launched cruise missile, a computer-guided drone that will serve to replace and enhance manned strategic bombers, will continue to receive strong support. Flight testing is almost finished, and production will begin soon. Funding for air-launched cruises increases from $474 to $746 million; funding for ground-launched cruises goes from $69 to $188 million. Development of a new cruise-carrying aircraft, which some people think may turn out to be similar to the B1 bomber that President Carter canceled, moves along at the same pace as last year with $30 million. A modest increase is given to the Army's antiballistic missile research program, increasing it from $121 to $133 million.

In the area of basic research, DOD will

be increasing its support of the physical sciences. Some areas of special interest, according to the White House, will be the physics and chemistry of the upper atmosphere, the generation of charged particle beams, high energy lasers, and very high speed integrated circuits.

—ELIOT MARSHALL

Science

The National Science Foundation's (NSF) fiscal year 1981 budget continues the emphasis of past years on real growth in the funding of basic research. The President's budget for NSF, 83 percent of which goes toward basic research, is $1.15 billion, an increase of 15.5 percent over 1980. The new twist this year is particularly large increases in the physical, mathematical, and engineering sciences, as well as the computer sciences. The most prominent new undertaking at NSF would be a follow-on to its eminently successful deep-sea drilling program using the *Glomar Challenger*. The new ocean margin drilling program is expected to use the *Glomar Explorer*.

The special attention given the physical sciences and engineering in this year's budget grew out of a concern about the beating they have taken in the last 12 years at the hands of the life sciences. Government-wide, real growth in research in the life sciences was 19 percent since 1967, due in part to the war on cancer. Support for research in the environmental sciences soared about 34 percent in the same period, but support of the physical sciences actually shrank 13.5 percent in constant dollars.

The $38 million (a 17 percent increase) for the physical and mathematical sciences, including a 28 percent increase for computer research, will not appear in any prominent new initiatives but rather will go toward increasing the average size of grants, encouraging young researchers, and supporting such facilities as the Cornell electron storage ring, the National Magnet Laboratory, and the Stanford synchrotron light source. The 22.5 percent increase for engineering and applied science includes a hefty 28 percent increase for electrical, computer, and systems engineering, with an emphasis on the hot subjects of large-scale integrated circuits, automation, and robotics.

Further highlighting the physical side of its activities, NSF will be asking for $10 million in fiscal 1981 as the first step in its new ocean margin drilling program. If taken up in earnest after new cost estimates are in, the conversion of the *Glomar Explorer* into the most powerful drilling ship in the world and its probings of the deep waters beyond the edge of the continental shelf will cost $700 million over the next 10 years. Half of that sum would be supplied by the oil industry, wherein lies a major problem for NSF. The unanticipated necessity of industry funding has tended to distort the original drilling plans of the scientific community, leaving uncertain at the moment exactly what industry might be paying for and what science may receive. Such details are expected to be worked out by June (see accompanying Research News story).

Universities can expect to benefit particularly from two other features of NSF's budget. One is a $20-million program designed to upgrade on a cost-shared basis the research facilities of the nation. This is the first such program since the 1960's. The other feature is the large increase (19 percent) in research and development funds that would be directed to universities.

On the international scene, Richard Atkinson, director of NSF, announced that $2 million of the 1981 budget will go toward cooperative scientific programs with the People's Republic of China. The larger funding for similar programs with Soviet scientists has not been altered since the Soviet troops moved into Afghanistan, but Atkinson stated that a new U.S. position will emerge shortly.

—RICHARD A. KERR

Space

At the head of the National Aeronautics and Space Administration's (NASA) $5.7 billion fiscal year 1981 budget request, as expected, is $1.9 billion for the space shuttle, the schedule for which has been much delayed. Waiting in line behind the shuttle are increased uses of satellites for communication and remote sensing, improvements in aircraft performance and efficiency, and observations of the distant universe. New explorations of the solar system, embodied in missions to Venus and to Halley's Comet and Comet Temple II, were so far back in line that they went unfunded this year.

In addition to running almost 3 years behind its original schedule, the shuttle is costing more (*Science*, 23 November 1979, p. 910). In the past year alone, the estimated cost for fiscal 1981 soared from $1.1 billion to the present $1.9 billion. NASA is also now officially requesting $300 million in supplemental funds to make ends meet in the shuttle program in fiscal 1980. Although engine problems have plagued officials in the last year, Robert Frosch, administrator of NASA, finds problems with the heat-resistant tiles covering the shuttle to be the most worrisome problem at the moment. Still, he believes that there is "a reasonably good chance" of having the first manned orbital launch by the end of calendar 1980. Even so, Frosch confirmed that the shuttle delays have forced many scheduled users of the shuttle to look to expendable rocket launchers for payloads instead. Two users have even shown a serious interest in the new European rocket Ariane.

In spite of the shuttle's big bite, two new space missions are included in NASA's budget request. The National Ocean Survey System (NOSS) would use the techniques proved out by the ill-fated Seasat satellite, which failed after 3 months in orbit in 1978. Through a unique funding arrangement among the Department of Defense (50 percent of costs), the National Oceanic and Atmospheric Administration (25 percent), and the Department of Commerce (25 percent), the two-satellite NOSS would supply observations of the sea surface and of ocean weather to both military and civilian users in order to further improve weather forecasts and predictions of shipping conditions.

Unlike NOSS, an applied science mission which promptly follows the proof of its utility, the other new start in space, the gamma-ray observatory, has waited 7 years since it was bumped from the high-energy observatory series because of weight limitations. The gamma-ray observatory would provide more sensitive measurements and precise locations of the objects thought to be generating huge amounts of energy, such as neutron stars and black holes.

The solar-electric propulsion system (SEPS), or ion drive, lost out for the second year in a row. That eliminates the chance of a dual comet mission including a Halley's Comet flyby and a year-long rendezvous with Comet Temple II. A simple Halley's flyby may still be worthwhile, but the future of SEPS concerns NASA officials in particular because it is considered essential to what one official terms "a thriving planetary program." Such a propulsion system appears to be the only practical way to deliver heavier probes to the outer planets, to orbit Mercury, or to visit comets and asteroids.

With money for both SEPS and the Venus Orbital Imaging Radar (VOIR) missing from the budget, planetary scientists may be facing a fifth year with no

new spacecraft data from the solar system (*Science*, 14 December 1979, p. 1288) and a potentially lean decade. Officials are "kind of nervous" about the lack of new starts, but they are hopeful that this year's $180 million will mark the low point in funding for planetary exploration.—RICHARD A. KERR

Health

The biomedical sciences received a slight boost in the President's proposed budget for fiscal 1981—a marked reversal from last year's no-growth budget. Carter has called for an overall budget authority of $3.6 billion for the National Institutes of Health (NIH), an increase of $139 million or 4 percent over last year. The basic research portion of the NIH pie will fare better, going from $1.6 to $1.7 billion, or an increase of 6 percent. This is, of course, a decline in terms of "real" or inflation-adjusted dollars.

Though paper gains were made in many areas, there were exceptions—most notably in training grants and fellowships. Total funds for training researchers dropped from $176 million to $164 million, a decrease of 7 percent. Hardest hit were awards for individuals rather than institutions, which fell 30 percent to a new low of $22 million.

Funds to support new and renewal research proposals are increasing again, in sharp contrast to last year's cuts. A proposed increase of $45 million or 10 percent makes a total of $488 million. This will bring the number of new and renewal research grants to 5000. During the past 5 years the number of these grants has varied widely. In fiscal 1979, for instance, there were some 6000, while in 1980 there were only 4800. "A major objective of the President's budget," according to Health and Human Services Secretary Patricia Harris, will be the "stabilization" of these grants at 5000 each year, thus easing the task of long-range planning in the research community.

Unlike last year when four of the eleven individual institutes at NIH faced cuts, this year all the institutes are looking forward to across-the-board increases—if inflation is ignored. The leader is the National Institute of Environmental Health Sciences, which has a proposed 1981 budget of $96 million, up $13 million or 15 percent from last year. The loser is the National Cancer Institute, which already has a budget of $1 billion but is slated for an increase of only $7 million or 0.6 percent.

In the recent past, Congress has often pushed the NIH budget over the President's proposal. Fiscal 1979 saw an additional $340 million go to the institutes and in 1980 the figure stood at $275 million. This year's increases in the President's proposed budget are said by some observers to be in anticipation of a cooling climate on Capitol Hill for research in the biomedical sciences. It is also said that there might soon be a change in command in the Senate appropriations subcommittee responsible for medical research and that among potential candidates is William Proxmire (D-Wis.), no great friend of the research community.

While the Administration tries to stabilize the "science base" of its health research program, a few areas in health are showing definite growth. Slated for increases in the overall health budget are funds for disease prevention and mental health. For prevention, the President has requested increases of $87 million or 11 percent. Included in this figure are plans to start work on a $25 million facility so that the National Institute for Occupational Safety and Health has a place to conduct research on health hazards to miners. The facility is to be located in Morgantown, West Virginia. Funding for programs in mental health and alcoholism is slated to increase by $55 million or 7 percent.

Cuts in funds to support the education of physicians and other health professionals are proposed. Harris is asking Congress for a recision of $88 million appropriated in fiscal 1980 for capitation grants to medical schools. Working on a "per head" basis, these grants were originally meant to entice medical schools to increase the size of their classes. But the problem, according to Harris and her predecessor Joseph Califano, is no longer one of supply but of distribution. Too many physicians are going into lucrative practices in large metropolitan centers while avoiding the vast under-served rural areas of the country, she says. To help alleviate the problem, Harris has proposed a hefty increase in the size of the National Health Service Corps. The 1981 budget would top out at $134 million, an increase of 63 percent. This money pays for part of the tuition of medical students who promise to serve in rural areas or urban ghettos for 2 years after graduation, or it pays directly for the resettlement of practicing physicians. With the proposed increases, a total of 4528 Corps members would be delivering health care in poorly served parts of the country.

—WILLIAM J. BROAD

Agriculture

Agricultural research fares better in the 1981 budget than it did last year, primarily because research officials at the USDA now have more clout, and because they were able to make a persuasive case for their needs at the White House. While overall R & D funding went down last year, this time it increases by nearly 6 percent. Funding for basic research increases by 12 percent. The Administration plans to increase in-house federal research funds by more than $20 million and extramural funds by $13 million. Most of the increase in the extramural research category is being sought for the competitive grants program, which rewards those who submit to a rigorous peer review process. This program would grow by $9 million, or 56 percent. Formula-funded research would get a general raise of 6.1 percent, just enough, according to the White House, to pay for inflation.

If Congress goes along, the competitive grants program would be funded at $25 million, less than the $30 million sought last year. People in the Administration who have been pushing for more peer-reviewed research have agreed to push a little less insistently this time.

—ELIOT MARSHALL

Environment

More than at many other federal agencies, disruptions of attention and emphasis have been a persistent problem at the Environmental Protection Agency (EPA), as its managers struggle to cope with the latest in a long string of environmental disasters. Five years ago, Congress had the foresight to enact the Resource Conservation and Recovery Act in order to regulate hazardous waste dumps. Today, in the wake of Love Canal and Valley of the Drums, EPA still struggles to catch up in administering the act.

Thus, in its 1981 budget, EPA intends to shift both personnel and funds out of long-standing programs on air and water quality into hazardous wastes and toxic substances. The agency proposes to increase spending on the former by 50 percent (to $125 million), and on the latter by 14 percent (to $90 million), whereas air and water will increase by only 1 percent each. The agency is also seeking an immediate supplement of $14 million in 1980 funds for hazardous wastes, and intends to hire 222 more employees overall, primarily for wastes enforcement ac-

tivities. The budget also contains a provision for $45 million in federal funding for cleanup of existing waste sites, in a project yet to be approved by Congress that also calls for industry contributions.

Overall, the agency's budget is slated to rise by 11 percent in operating funds, with specific increases in the areas of:

- drinking water (15 percent), for studies of small water systems, and of the effects of polluted water on reproduction and early human development;
- pesticides (10 percent), for exposure assessments and the disposal of a suspended pesticide, silvex; and
- management and support (28 percent).

Because the agency has traditionally had a poor record in handling toxic substances and pollution from its own installations, it recently hired an expert from the industrial sector who intends to spend 25 percent more on laboratory management.

Basic research at EPA will remain steady with an overall increase of 9 percent. Research will increase on solid waste, radiation, and toxic substances—but at the expense of research on air, water, and pesticides. The agency intends to look into airport noise, as well as the nonauditory health effects of noise, even though the noise program will decline overall; the emphasis in energy research will also shift from modeling of nitrous oxide caused by coal burning to the effects of synthetic fuels.

—R. JEFFREY SMITH

Fusion Energy in Our Time

Congressman McCormack proposes an Apollo-type project to generate electricity with a magnetic fusion reactor before the year 2000

Fusion energy has always been the farthest away of the long-term solutions to the energy scarcity. But commercialization of fusion could come a lot sooner than projected, says Representative Mike McCormack (D-Wash.). In a mid-January press briefing, McCormack announced that he is urging the Administration to make a national commitment to fusion now—somewhat in the spirit of the Apollo project to put a man on the moon. McCormack estimates the cost of the project to be about $20 billion and says we could have electricity from a demonstration magnetic fusion reactor by the turn of the century, at least 15 years ahead of the Department of Energy's current timetable.

The first major step toward accelerated development of magnetic fusion would be to begin immediately to design a $1 billion Engineering Test Facility (ETF), which would be the first fusion project to concentrate on engineering issues instead of basic plasma physics. McCormack is asking President Carter to make the ETF a line item in the fiscal 1981 budget. Although annual expenditures for the entire magnetic fusion program would not increase greatly during the early design phase of the ETF, they would rise to about $1 billion within 2 years, not quite three times the current level.

McCormack has already made the rounds within the Administration, touching bases with the Energy Department, the Office of Management and Budget (OMB), the Office of Science and Technology Policy (OSTP), and the White House Domestic Council. He has not been able to meet with President Carter, however. While McCormack claims to be encouraged because nowhere has anyone responded with a flat "No," what signs there are are not so sanguine. Secretary of Energy Charles Duncan has been quoted as saying that the Administration plans to "turn a deaf ear" to entreaties to build an ETF soon. (The fiscal 1981 budget of $404 million for magnetic fusion contains no new funds for an ETF.) And in an election year with constituents worried about fuel shortages and balanced budgets, says a Senate staffer, it is unlikely that Congress will be making additional large financial commitments to fusion, which will not be able to produce large amounts of power for decades to come. Nonetheless, on 22 January McCormack introduced a bill (H.R. 6260—the Fusion Energy Research, Development, and Demonstration Act of 1980) providing for the fusion program he sees as necessary if the technology is going to be ready to contribute when the short-term energy options run out in the early part of the next century. Thirty-six of the 42 members of the House Science and Technology Committee have agreed to be cosponsors.

The source of McCormack's optimism is a succession of encouraging experiments at the Princeton Plasma Physics Laboratory, the Massachusetts Institute of Technology, the Oak Ridge National Laboratory, and elsewhere. Taken together, says McCormack, the data from these experiments mean "we can now predict with certainty that the conditions required for a successful fusion reaction can be obtained in devices now under construction." Because of this happy situation, he argues, it is time to shift the emphasis in fusion research from basic science to the related technological and engineering problems that must be solved before fusion can be a commercially attractive source of energy.

In magnetic fusion, it is necessary to heat a deuterium-tritium mixture to at least 50 million degrees Kelvin while simultaneously holding the resulting hot ionized gas (plasma) together with a magnetic field. A plasma with a density of about 10^{14} ions per cubic centimeter confined for 1 second or longer would do the trick. Energetic neutrons and helium nuclei are the products of the fusion reactions in the plasma, with the kinetic energy of the neutrons being converted to heat to power an electricity generator or to produce synthetic fuels and the energy of the helium helping to keep the plasma hot.

As recounted by Melvin Gottlieb, director of the Princeton laboratory, 25 years ago fusion researchers were in a sorry situation. Nearly all the experimental results were surprises, and the first test device even fell apart. Now, thanks in part to the larger fusion research budgets that began appearing after the 1973 Arab oil embargo, a temperature higher than that needed to start a fusion reaction has been achieved at Princeton, and a value of a parameter called the density-confinement time product that is higher than required for fusion has been reached at MIT. Cur-

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