Disastrous cuts in 1987 budget for fusion power

Charles B. Stevens reports on the consequences of amputating America's most promising energy source of the future.

Soviet physicist Academician Nikolai Basov, the scientist who shared the Nobel Prize for developing the laser, announced to the 27th Congress of the Soviet Communist Party in Moscow at the end of February, that inertial fusion could be perfected for industrial applications before the year 2000. Evidence is already emerging that Mikhail Gorbachov's chief science adviser, Yevgenii Velikhov, has perfected a combined form of inertial and magnetic fusion energy production for powering space-based beam weapons.

These developments serve to underline the shocking inadequacy of the budget for fusion power research and development proposed by the Reagan administration for Fiscal Year 1987. If passed by Congress, it will undermine any prospect for development of commercial fusion power on the timetable proposed by scientists during the Carter administration; it will put a brake on any effort to reindustrialize the U.S. economy over the coming decades and, more immediately, it will sabotage President Reagan's Strategic Defense Initiative (SDI) project for developing effective missile defenses, since the technologies required for achieving "breakeven" in fusion power, are closely interrelated with those required by an antiballistic missile defense system.

Although the proposed budget might appear to be a linear continuation of previous real cuts implemented each year since the Carter administration in 1976, the cumulative impact has reached a point where the very scientific base of this essential program is endangered. Further cuts mandated under the Gramm-Rudman bill will intensify this process.

The actual appropriations from 1976 to 1986, together with the FY 1987 Reagan request for magnetic fusion research, are shown in **Figure 1**. The dotted line plots the projections made by the government in 1976 for the budget necessary to realize commercial fusion electric power plants by the year 2005.

As the figure shows, the actual budget is now at about one-third the level needed for fusion energy development, by the government's 1976 projections. The proposed 1987 budget will cut deep, as funding descends to levels below those of 1976.

Whereas previous cuts have primarily undermined the technological prospects of realizing the commercial potentials of fusion energy, the current round of cuts will destroy substantial portions of the program's scientific base. The scientific manpower of the fusion program will be reduced to a fraction of what it was in mid-1970s. The proposed cuts will mean lay-offs for scientists, engineers, and other staff in university research programs throughout the country. Highly trained researchers working on basic theoretical issues will find themselves with no job in the plasma physics field.

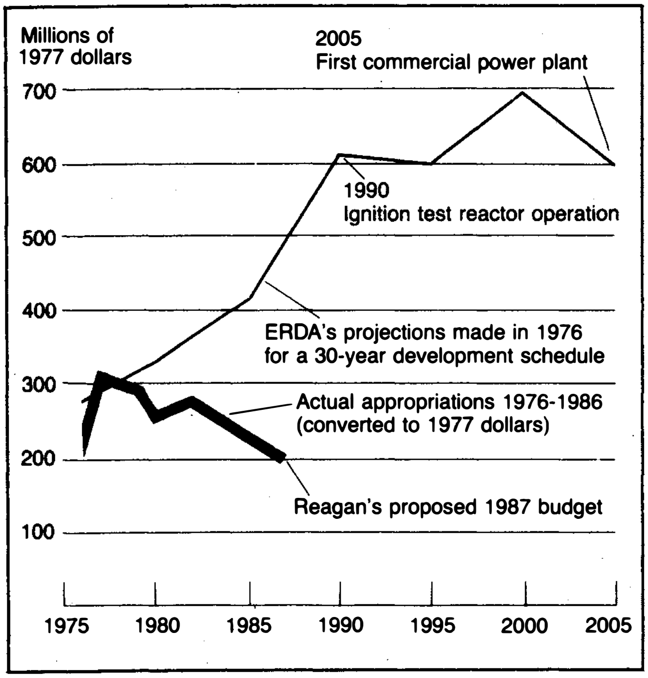
This disaster is exacerbated by the distribution of the remaining resources of the program. To a government accountant, it might appear more rational to maintain a large, capital-intensive experimental facility, than to fund a diversity of smaller efforts with higher operating costs per scientist. But the direct result of this reasoning is that the proposed budget cuts will wipe out large areas of basic fusion and plasma research. The situation is aggravated by the fact that government estimates of inflation rates are generally much too low, particularly for scientific R&D.

Ironically, despite the continuing trend of budget cuts since 1976, the U.S. fusion program has been able to meet—and in many cases substantially exceed—all of the scientific goals projected in the 1976 government study. As **Figure 2** shows, there has been consistent progress as fusion experiments have moved toward meeting the physical parameters needed for fusion energy production. It is now likely that both the European JET tokamak and the U.S. light ion beam PBFA-II (Particle-Beam Fusion Accelerator) at Sandia National Laboratory will demonstrate the conditions needed for substantial net energy production—despite the fact that neither device was originally designed to attain this goal.

As the budget has decreased, the economic stakes have increased. In recent years, studies of fusion's economic potential—such as those carried out under the direction of Dr. John Nuckolls of Lawrence Livermore National Laboratory—have shown that current economic potential for fusion energy is far greater than that originally projected in the mid-1970s. According to one 1983 study, fusion has the potential of producing electrical energy for as little as half the cost of current and future nuclear fission and fossil fuel power systems, and commercial prototypes could still be achieved before the year 2000.

FIGURE 1

Fusion budget versus requirements for fusion development



The actual fusion appropriations from 1976 to 1986 (solid line) are shown, in addition to President Reagan's proposed budget for Fiscal Year 1987. The Reagan budget, as can be seen, sinks significantly lower than the Carter administration's budget. More startling is the comparison of the actual funding with that projected in 1976 (dotted line) by the U.S. Energy Research and Development Agency, the predecessor to the Department of Energy, for the achievement of commercial fusion by the year 20005.

Source: Fusion Power Associates

A detailed review of the FY 1987 budget request demonstrates that this potential is being forfeited and that substantial segments of the scientific base are being gutted. **Figure 3** gives a breakdown for the magnetic fusion R&D program from FY 1985 to FY 1987 in current dollars.

It should be noted that it is impossible to give any comparable analysis for the inertial confinement laser and particle beam pellet fusion R&D effort, because this program was not even given a separate budget line in the current request. The detailed figures for this program will not be released until and unless the directors of the U.S. national laboratories—Los Alamos, Sandia, and Lawrence Livermore—decide to make them available. In FY 1986, the Reagan administration had proposed a zero budget increase for inertial confinement.

We present here the situation with each subprogram of the magnetic fusion program.

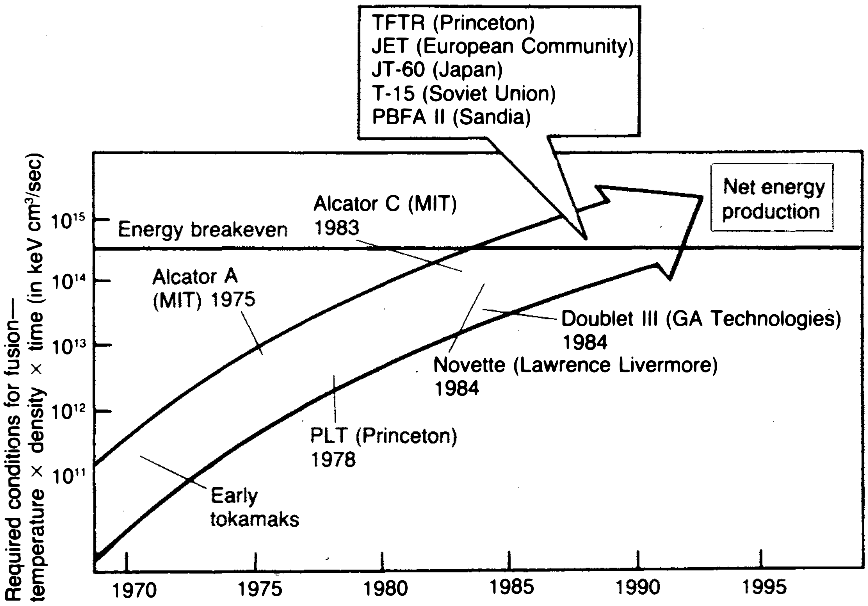
Applied Plasma Physics. This subprogram is directed at developing the fundamental scientific knowledge of the nuclear fusion process and the extremely high temperatures—from tens to hundreds of millions of degrees—needed to ignite it. This subprogram represents the scientific core of the fusion effort. It funds the small groups of theoreticians and experimentalists based within the universities and colleges of America. These smaller-scale efforts complement and reinforce the larger, national laboratory-based experiments, such as the Princeton Tokamak Fusion Test Reactor. The smaller, university-based programs provide the essential environment for a full scientific elaboration of discoveries made on these larger experiments. The Applied Plasma Physics subprogram relies on people and ideas more than hardware. It provides fertile ground for the development of entirely new concepts.

Most of the international exchange of concepts and research is carried out by this part of the fusion effort. International activities consist of joint workshops and study teams, together with exchange visits to experimental facilities, and sometimes exchange of experiments.

The primary mission of the Applied Plasma Physics division is the development of the theory of fusion, exploration of plasma behavior with small experiments, fusion-related atomic physics, and development of new diagnostic techniques required to determine fusion plasma behavior. The program also develops and tests alternative fusion confinement schemes. Through its support of university programs, it trains a large percentage of the scientists employed in all other areas of both the fusion and beam-weapon programs. It also manages the Magnetic Fusion Energy Computer Net-

FIGURE 2

Progress in achieving conditions required for fusion power



While the fusion budget has been steadily eroded, the major fusion experiments have proceeded to make more than the expected progress toward the goal of net energy production.

Source: Fusion Power Associates

work, which provides all of the large-scale computing used by the fusion program as a whole for experimental data analysis, theoretical and engineering modeling, experimental design, and system studies.

Confinement Systems. This subprogram works on two of the four key technical issues facing the realization of commerical fusion power—the development of the magnetic confinement systems to contain fusion plasmas at the high temperatures needed to maintain nuclear fusion reactions, and the exploration of the scientific principles governing the behavior of burning plasmas. This is achieved by conducting large-scale experiments, which are directed at producing the required conditions.

The tokamak, the stellarator, and the tandem mirror magnetic confinement concepts have been the major magnetic systems researched by this subprogram. The Princeton Tokamak Fusion Test Reactor is the largest such experiment, and is directed at producing the physical conditions for burning fusion plasmas with deuterium-tritium fuel by 1987. Actual fusion fueling with deuterium-tritium has now been set back to 1989 by the Reagan budget.

Development and Technology. This subprogram provides for the realization of the technologies and engineering science needed for existing experiments and future power reactors. Four major areas have developed: 1) superconducting magnets for generating the fields to confine hot plasmas; 2) specification of fusion plasma conditions from an engineering standpoint; 3) nuclear technology and knowhow essential for design and operation of fusion power reactors; 4) materials science for the realization of systems which can withstand the fusion reactor environment at economical costs.

Recent progress in this subprogram area has included tests of three large superconducting magnets in the International Fusion Superconducting Magnet Test Facility; operation of a multi-pellet pneumatic fuel injector on the Tokamak Fusion Test Reactor; successful demonstration of sources for long pulse neutral beam heaters; development of new concepts for compact, high-power radio frequency electromagnetic wave launchers for plasma heating and current drive; increased confidence in vanadium as a reduced activation material for power reactors; first results of steady-state erosion and deposition materials changes using the Plasma Interactive Surface and Components Experimental System.

Planning and Projects. This is the division of the magnetic fusion program which, in the past, has designed and built the program's major experiments and carried out studies for experimental and engineering test reactors.

'Phasing out the future'

As Figure 3 shows, Planning and Projects is now all but phased out. The budget request notes that it is hoped that "international collaboration" will lead to some kind of future development—a myth fostered by former presidential science adviser George Keyworth, a zero-growther.

While the overall Applied Plasma Physics subprogram budget does not appear to be taking a substantial cut—about an 8% reduction from FY 1985 levels—a closer examination of this subprogram's budget, as seen in **Figure 4,** shows that the most manpower-intensive portions of the division are the ones being targeted.

This can be immediately seen in the 42% overall reduction from FY 1987 levels in the experimental research oper-

FIGURE 3

Department of Energy FY 1987 congressional budget request

	FY 1985 Appropriation	FY 1986 Appropriation	FY 1987 Base	FY 1987 Request	Request vs Base
Magnetic Fusion Energy					
Applied plasma physics					
Operating expenses	$ 78,937	$ 69,692	$ 69,692	$ 70,700	$+ 1,008
Capital equipment	3,170	5,619	5,619	4,500	− 1,119
Subtotal	82,107	75,311	75,311	75,200	− 111
Confinement systems					
Operating expenses	26,395	188,650	188,650	177,500	−11,150
Capital equipment	15,400	14,529	14,529	7,100	− 7,429
Subtotal	221,795	203,179	203,179	184,600	−18,579
Development and technology					
Operating Expenses	67,900	57,059	57,059	50,510	− 6,549
Capital equipment	5,100	4,330	4,330	1,890	− 2,440
Subtotal	73,000	61,389	61,389	52,400	− 8,989
Planning and projects					
Operating expenses	12,201	5,528	5,528	4,780	− 748
Capital equipment	3,800	3,801	3,801	3,820	+ 19
Construction	32,500	12,653	12,653	8,200	− 4,453
	48,501	21,982	21,982	16,800	− 5,182
Program Direction					
Operating expenses	4,150	3,608	3,608	4,000	+ 392
	4,150	3,608	3,608	4,000	+ 392
Total					
Operating expenses	369,583	324,537	324,537	307,490	−17,047
Capital equipment	27,470	28,279	28,279	17,310	−10,969
Construction	32,500	12,653	12,653	8,200	− 4,453
Magnetic fusion energy	$429,553	$365,469	$365,469	$333,000	$−32,469

ations and the 18% reduction in the basic experimental plasma research budgets of this division—the first and third line of the table. These funds are used sity-based experiments. The proposed cuts will continue the devastation that has occurred to this essential scientific base of the fusion program over the past several years. The point is not that it will lead to simple reductions in staff and operations at these widely dispersed university facilities, but rather, that the result will be their total obliteration. The scientists involved will now be forced to seek work in areas outside the fusion program—in many cases, in totally different disciplines.

FIGURE 4

Budget breakdown in Applied Plasma Physics (thousand $)

	FY 1985	FY 1986	FY 1987 request
Experimental research	21,501	14,413	12,455
Fusion theory program	22,644	19,046	17,500
Basic experimental plasma research	16,024	14,866	13,215

The 23% reduction from FY 1985 levels proposed for the fusion theory program is even more catastrophic. Entire university-based groups will be dispersed as a direct result. These theoretical groups work as an organic team; they attack a specific problem in a combined effort, where various avenues of approach are combined to produce a solution or at least the elements of a solution. They cannot function with a half a tank of gas! Instead of facing the disintegration of the team through slow attrition of the group, they search out alternative fields for the work of the group as a whole.

The FY 1987 cuts will provide the straw to break the proverbial camel's back, in this case. Already, teams which have worked in the fusion field for three decades and more, are now planning to move to entirely different disciplines. In some cases, leading scientists are considering abandoning fundamental research altogether.

The devastation being wrought by the fusion cuts is being nonlinearly amplified by the effects of the explosion of the Space Shuttle Challenger. For example, many proposed basic plasma and directed-energy experiments have now been postponed by several years, as a direct result of the loss of one Shuttle and the delay in the launch of the others. These basic science experiments will now have to compete with full-scale hardware demonstrations of the Shuttle in the outlying years. Given the priority of the Strategic Defense Initiative, program managers are being forced to cancel these smaller experiments and cut them completely out of the SDI program.

The effects of the Shuttle disaster extend even to space-based experimental astrophysics. The net result is that there is nowhere for these basic plasma physics scientists to go, for work in their field.

Although it would appear that the Confinement Systems portion of magnetic fusion R&D—which has consisted of two main lines of approach, the linear tandem mirror and toroidal systems like the tokamak—is at least being maintained near previous levels, the actual budget proposal states that "to accommodate present fiscal constraints, further research on tandem mirrors is being deferred."

The result is that the world's largest fusion experiment,

What is fusion power?

Fusion, the fusing together of atomic nuclei, is the energy source that powers the Sun and the other stars, and will be the energy source of the 21st century. Unlike nuclear fission, which splits heavier elements like uranium up into lighter ones and makes use of the energy released, fusion fuses lighter elements into heavier ones. Fusion's basic fuels, deuterium and tritium, are found in sea water. Deuterium is sufficiently abundant that there is enough in sea water to fuel fusion reactors for millions of years.

When it fuses, a fusion fuel releases one million times more energy than burning a comparable weight of coal or oil, so it is a very efficient producer of energy. A single gallon of sea water can fuel as much fusion energy as five barrels of oil can fuel conventional energy. The fusion fuel produces about eight times more energy than a fission reactor produces from a comparable weight of uranium.

The electromagentic energy in the fusion-energized plasma will make it possible to build fusion reactors with a closed cycle of materials and energy flows that will have no waste and no radioactivity. Further, fusion would permit man to redefine his earthly supply of raw materials, through the use of plasma processing.

How will the reactors work? The key element in a fusion reactor is a fusion plasma, a very high-temperature gaslike mixture of ions and electrons. The gas is at such a high temperature that when the nuclei of the atoms in it collide, they fuse together and form new elements. Heat is released, which heats up a moderator; a coolant circulating around the moderator produces steam, which can be used to produce electric power.

The requirement for a "break-even" fusion reactor is to make a fusion plasma that has high temperatures, like those on the Sun, but very low density, so that it does not melt the materials with which it comes in contact. If the fusion plasma were to come in contact with the reactor wall, the wall would cool the plasma, stopping the fusion reaction.

The fusion reaction requires an energy investment to create the high-temperature plasma and a confining force to keep the plasma under control. In order to achieve net energy output, the following conditions are required: 1) the temperature must reach 50-100 million degrees C; 2) the density of the fusion fuel times the length of time it is confined—a measure of the energy output—must reach about 10^{14} particles per cubic centimeters times seconds (100,000 times less dense than the density of air in an ordinary room).

There are two basic approaches to confining the fusion plasma, magnetic confinement and inertial confinement.

For magnetic fusion, magnetic fields are generated either by external electric circuits, such as sets of copper coil magnets, or by electrical currents induced within the confined plasma itself. The magnetic field acts as a countervailing force to the gas pressure of expansion exerted by a hot plasma. There are two types of magnetic confinement devices: an open system or magnetic mirror, and a doughnut-shaped system (e.g., the tokamak).

Inertial confinement, on the other hand, makes it possible to eliminate the magnetic coils. Only the inertia of the fuel itself is utilized to confine it to a specific density while it is heated to fusion ignition temperatures. In inertial confinement fusion (also called laser fusion), a tiny hollow pellet is filled with deuterium and tritium fuel, then irradiated with a laser beam, ion beam, or electron beam. This force heats and compresses the pellet to produce a burst of energy, before the pellet flies apart. It is essentially a miniature explosion, the same process that goes on in the hydrogen bomb. But the pellets are so small that the microexplosions don't damage the reactor vessel.

the nearly completed MFTF-B (Mirror Fusion Test Facility) at Lawrence Livermore National Laboratory, will be "mothballed"; qualitatively speaking, half of the magnetic fusion confinement systems will be cut.

Cutting national security: the x-ray laser

The U.S. fusion R&D program has demonstrably provided the lion's share of the technology, science, and personnel for the Strategic Defense Initiative. Because of its broad scope, the fusion program has especially encouraged innovation in science and technology. The proposed FY 1987 fusion budget will significantly curtail any such future contributions.

Some measure of the resulting strategic loss to the national security may be judged by this example:

The most potent missile defense weapon yet developed is that of the nuclear-explosive-pumped x-ray laser. The first generation x-ray system could destroy a score or more ICBMs per x-ray nuclear explosive. Recent basic science advances indicate, that this capability could be vastly increased to a point where one x-ray nuclear explosive could take out the entire Soviet ICBM fleet. And the x-ray laser is just the first of an entire family of new types of directed-energy systems made possible by the high energy densities of fusion.

Currently U.S. researchers can access these high energy densities only with expensive nuclear weapons tests. This greatly hinders the development and perfection of the existing x-ray laser, as well as new possibilities, like the gamma-ray laser. An economical alternative is to use laboratory inertial confinement fusion, like that produced by laser or particle beams. Inertial confinement fusion in the laboratory, in fact, can attain even higher energy densities than those generated by thermonuclear weapons.

Recent intelligence reports from the Soviet Union indicate that under the direction of Academician Velikhov, Soviet scientists have succeeded in combining magnetic fusion with inertial confinement to obtain significant fusion plasmas on a laboratory scale.

It is reported that compact tori magnetic plasmas, in which the confining magnetic fields are primarily generated by induced electrical currents within the plasma "doughnut" itself, have been injected into metal cylinders that are then imploded—an approach generically known as the imploding metal liner. This combined magnetic-inertial approach appears to be the technologically most accessible means for laboratory generation of fusion plasmas. Is the United States researching this area of fusion development? No. The U.S. imploding liner R&D effort was killed in 1978 by Jimmy Carter's energy secretary, James Schlesinger. The Soviets, however, apparently maintained a program on the scale of the overall U.S. tokamak effort.

Having such a cheap and readily accessible source for laboratory high-density fusion would put Soviet researchers in a vastly superior position. The cost of conducting full-scale testing, for example, could be reduced by as much as three orders of magnitude, and the time span from conceptualization to actual test could be reduced from years to months.

Even more significant for the Soviets is that such laboratory experiments are virtually impossible to detect, while underground weapons tests are easily discerned—especially in the United States. In fact, the recent Soviet initiative to implement a comprehensive nuclear weapon test ban treaty may indeed be based on the ability to produce laboratory-scale undectable "weapons tests."

The direct potential for revolutionary spin-offs from the fusion program into the beam-weapon effort has already been demonstrated in the United States. Researchers at the Princeton Plasma Physics Laboratory—the flagship facility of the magnetic research program—began investigations into magnetically confined plasma x-ray lasers a few years ago. While initially scoffed at by more conventional x-ray laser scientists, there are recent indications that this Princeton work has directly led to revolutionary developments in nuclear-bomb-pumped x-ray laser systems.

Although this conclusion has not yet been fully confirmed, the example serves to demonstrate how the proposed Reagan fusion budget cuts could immediately result in a major national security deficit.