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REPORT BY THE U.S.

RELEASED

General Accounting Office

Status Of DOE's Implementation Of The Magnetic Fusion Energy Engineering Act Of 1980

The Magnetic Fusion Energy Engineering Act of 1980 authorized an accelerated and ambitious research and development program directed toward the commercial demonstration of nuclear fusion--a potentially inexhaustible source of energy--by the end of the century. Although progress has been made, funding for the program has not been sustained at the levels envisioned in the act. Consequently, DOE has adjusted its fusion research program and revised its fusion development strategy to fit available and projected funding levels.

GAO believes that DOE needs to explain and justify its revised fusion development strategy to the Congress. The appropriate place is the act's required comprehensive program management plan to be submitted to relevant congressional committees. According to DOE, budget uncertainties initially delayed preparation of the plan and its final issuance is now being held up by extensive reviews both internally and by the Executive Office of the President.

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UNITED STATES GENERAL ACCOUNTING OFFICE

GAO/RCED-83-105
APRIL 29, 1983

525559

UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

RESOURCES, COMMUNITY,
AND ECONOMIC DEVELOPMENT
DIVISION

B-210947

The Honorable Marilyn L. Bouquard
Chairman, Subcommittee on Energy
Research and Production
Committee on Science and Technology
House of Representatives

The Honorable Fortney H. Stark, Jr.
House of Representatives

You requested that we determine the Department of Energy's (DOE's) progress in fully implementing the Magnetic Fusion Energy Engineering Act of 1980 (Public Law 96-386). We examined all aspects of DOE's fusion program in relation to specific requirements contained in the act.

DOE is pursuing a large-scale fusion research and development program. However, since program funding levels are below those that the act envisioned we believe it is imperative that DOE communicate clearly to the appropriate congressional committees its intended strategy for satisfying the act's requirements. DOE can accomplish this by preparing and transmitting to the appropriate congressional committees the comprehensive program management plan which the act requires.

J. Dexter Peach
Director

REPORT BY THE
GENERAL ACCOUNTING OFFICE

STATUS OF DOE's IMPLEMENTATION OF THE MAGNETIC FUSION ENERGY ENGINEERING ACT OF 1980

D I G E S T

Harnessing fusion energy--the physical reaction that occurs naturally in the Sun and other stars--has been a long-time dream of scientists. Unlike present day nuclear reactors which generate power through fission (the breaking apart of atoms), fusion energy is generated by combining atoms. The great attraction of fusion energy is that much of its fuel is readily available from ordinary seawater; therefore, it is a potentially inexhaustible source of energy. Also, the problems of radioactive waste disposal may be significantly less than those of nuclear fission reactors.

The scientific feasibility of fusion energy has not yet been demonstrated. Fusion reactors will have to generate extreme temperatures (about 180 million degrees Fahrenheit) and be able to confine the hot fusion fuel, called plasma, long enough to generate a self-perpetuating fusion reaction.

The Congress, in hopes of accelerating the commercial development of fusion energy, enacted the Magnetic Fusion Energy Engineering Act of 1980. The act established fusion development goals and set forth related program and administrative requirements.

The Department of Energy (DOE) is pursuing the development of fusion power through a large research and development (R&D) program. However, when it became clear that funding levels would be less than the act envisioned, DOE revised its fusion energy R&D program and development strategy. According to DOE, funding constraints and uncertainties have also prevented it from fulfilling certain administrative requirements of the act, including the submission to certain congressional committees of a comprehensive program management plan directing the fusion development program.

GAO conducted this review for Representative Fortney H. Stark, Jr., of California and Representative Marilyn L. Bouquard, Chairman, Subcommittee on Energy Research and Production, House Committee on Science and Technology, who requested that GAO determine the status of the implementation of the act.

THE MAGNETIC FUSION ENERGY ENGINEERING ACT OF 1980

The Government spent over $2.25 billion on fusion energy research and development through fiscal year 1980. The Congress, however, wanted an accelerated development program leading to the demonstration of the commercial viability of fusion.

The act called for a phased R&D program involving the sequential construction of progressively larger fusion test reactors following demonstration of the scientific feasibility of fusion energy and scientific breakeven--the ability to sustain a fusion reaction that generates as much power as it consumes. The act then foresaw the construction of a Fusion Engineering Device that would demonstrate fusion power by 1990 at a scale beyond the laboratory stage, and provide a necessary "stepping stone" to a commercial-sized reactor. By the end of the century, the act envisioned the Government's construction of a commercial-sized reactor demonstrating the economic viability of fusion energy.

The act also requires DOE to pursue a number of fusion energy concepts so that the advantages and disadvantages of each can be assessed and an optimal design clearly identified as the Government moves toward demonstrating the commercial viability of fusion. (See pp. 7 and 8.)

CURRENT RESEARCH AND DEVELOPMENT PROGRAM

DOE's Office of Fusion Energy directs the Nation's magnetic fusion energy program and coordinates the R&D efforts of several national laboratories and universities. While past and ongoing programs have focused on understanding the physics of fusion, efforts are now being directed at achieving simultaneously the conditions necessary for a fusion reaction to occur.

DOE is concentrating its R&D efforts on two "mainline" concepts--tokamaks and mirrors. It is also pursuing other alternative fusion confinement concepts and related materials research efforts but at relatively low funding levels. (See pp. 9 to 15.)

Tokamaks are doughnut-shaped devices using large magnetic fields to confine nuclear fusion fuel, called plasma. Tokamak-based experiments have to date yielded the most information about the fusion process. It is the concept being pursued most extensively in the United States and in other countries. DOE hopes to demonstrate scientific breakeven on Princeton's $314 million Tokamak Fusion Test Reactor, the flagship of the fusion program, in 1986. That reactor produced its first burst of plasma in December 1982. (See pp. 9 to 11.)

The other mainline fusion concept is mirrors. These devices consist of long tubes with large magnets at each end that reflect charged plasma particles. The major mirrors fusion test facility is under construction at the Lawrence Livermore National Laboratory in California. (See pp. 11 to 13.)

Even though about $1 billion has been budgeted for the magnetic fusion energy program since 1980, overall budget cutbacks throughout the Government have resulted in fusion program budget levels below what the act envisioned. For example, the $466.1 million fiscal year 1983 fusion energy budget is 24 percent less than called for in the act. According to DOE, the reduced funding has prevented it from pursuing certain aspects of the fusion program, such as materials R&D and alternative confinement concepts research, at the pace the act envisioned.

According to DOE officials, funding constraints have also prevented mirrors from being developed at the same pace as tokamaks. Funding requested for tokamaks reached over $170 million for fiscal year 1983 while funding requested for mirrors was about $96 million. Construction of the mirrors test facility at the Lawrence Livermore National Laboratory has been delayed, and some fusion scientists now believe that its development is at least 3 years behind the tokamak concept. However, DOE officials say that they will demonstrate scientific feasibility with the mirrors concept before deciding which concept to use in the next-generation fusion reactor.

DOE's REVISED FUSION DEVELOPMENT STRATEGY

DOE, citing budget constraints, does not now plan to build the Fusion Engineering Device or the commercial demonstration reactor called for in the act. Rather, after demonstrating scientific feasibility and breakeven on the Princeton reactor, and developing the mirrors concept to a comparable level, it plans to build only one more reactor. DOE expects to select a design concept after 1988 and then begin constructing an engineering test reactor that will be intermediate in performance between what would have been the Fusion Engineering Device and the commercial-sized demonstration powerplant. (See p. 16.)

DOE believes that the information to be obtained from the existing Princeton reactor, the intermediate-sized engineering test reactor, and other fusion development program components such as the materials testing program will give industry enough data to assess the potential for the commercialization of fusion. Thus, DOE's revised strategy anticipates a much earlier and more extensive industry input into fusion development than the act foresaw.

DOE's Magnetic Fusion Advisory Committee, a group of fusion experts, is examining the fusion development program in an attempt to identify other program alternatives within the broad intent of the act in an era of budget constraints. The Committee has established three panels examining different aspects of the fusion program. The panels are (1) reviewing the mirrors and tokamak programs and evaluating their possible consideration for an experimental test reactor project, (2) evaluating other concepts as backups to the mainline programs, and (3) considering using the

Tokamak Fusion Test Reactor and the mirrors test facility as engineering test facilities for advanced fusion experiments. (See pp. 22 and 23.)

MANAGEMENT AND PLANNING REQUIREMENTS OF THE ACT

The act establishes several planning, organizational, and reporting requirements to move the program toward its technical goals. Several of these have not been met. For example, the act's required comprehensive program management plan, due in January 1982, has not yet been submitted to the appropriate congressional committees. DOE, citing budget uncertainties, delayed initiating the plan until January 1982, and its final issuance has been held up by extensive review by both DOE and the Executive Office of the President. (See pp. 20 and 21.)

Because DOE, faced with reduced funding, is revising its fusion energy development strategy, GAO believes that it is particularly important that a comprehensive program management plan be submitted to the congressional committees. The plan is needed to explain and justify DOE's evolving fusion development strategy.

AGENCY COMMENTS

DOE, after reviewing a draft copy of the report, stated that it accurately assessed DOE's position and actions in the fusion program relative to the act. However, DOE also cited several statements which it believed needed to be clarified or corrected. We have modified the final report to reflect the agency's comments. Appendix I contains DOE's comments.

Contents

ABBREVIATIONS

DOE	Department of Energy
EURATOM	European Atomic Energy Community
GAO	General Accounting Office
R&D	research and development

CHAPTER 1

INTRODUCTION

Nuclear fusion has the potential to satisfy the Nation's future energy needs. If proven viable, it could provide an essentially inexhaustible source of energy since much of the fuel for fusion reactors is readily available from ordinary sea-water. Also, the problems of radioactive waste disposal for a fusion reactor may be significantly less than those of today's nuclear reactors.

Progress has been made toward harnessing fusion power through past and ongoing research efforts. However, complex scientific and engineering problems remain to be solved. Decades will probably pass before it is known whether fusion energy will be a commercially viable source of power.

WHAT IS FUSION ENERGY?

Nuclear fusion is the basic physical reaction that occurs naturally in the Sun and other stars. During nuclear fusion, atoms of light chemical elements combine to form heavier elements and in the process release energy. It is, in effect, the opposite of nuclear fission, which powers today's nuclear reactors. During fission, atoms of heavy chemical elements are split, releasing energy. Fusion and fission are kinds of nulear energy because the central core, or nucleus, of the atom reacts and in the process releases energy.

The simplest nuclear fusion reaction involves forms (or isotopes) of hydrogen. The nucleus of each hydrogen isotope--hydrogen, deuterium, and tritium--contains one proton (P). While the nucleus of the hydrogen atom in its simplest form has no neutrons (N), the deuterium nucleus has one neutron, and tritium two neutrons. Deuterium is readily available from sea-water, while tritium, although not naturally abundant, can be formed as part of the fusion process.

When a mixture of deuterium and tritium is sufficiently heated, the hot gas is known as plasma. If the plasma is also sufficiently confined or contained, the nuclei of the deuterium and the tritium atoms strike each other, fuse into helium atoms, and simultaneously release an extra neutron and large amounts of energy. Figure 1 illustrates this fusion reaction.

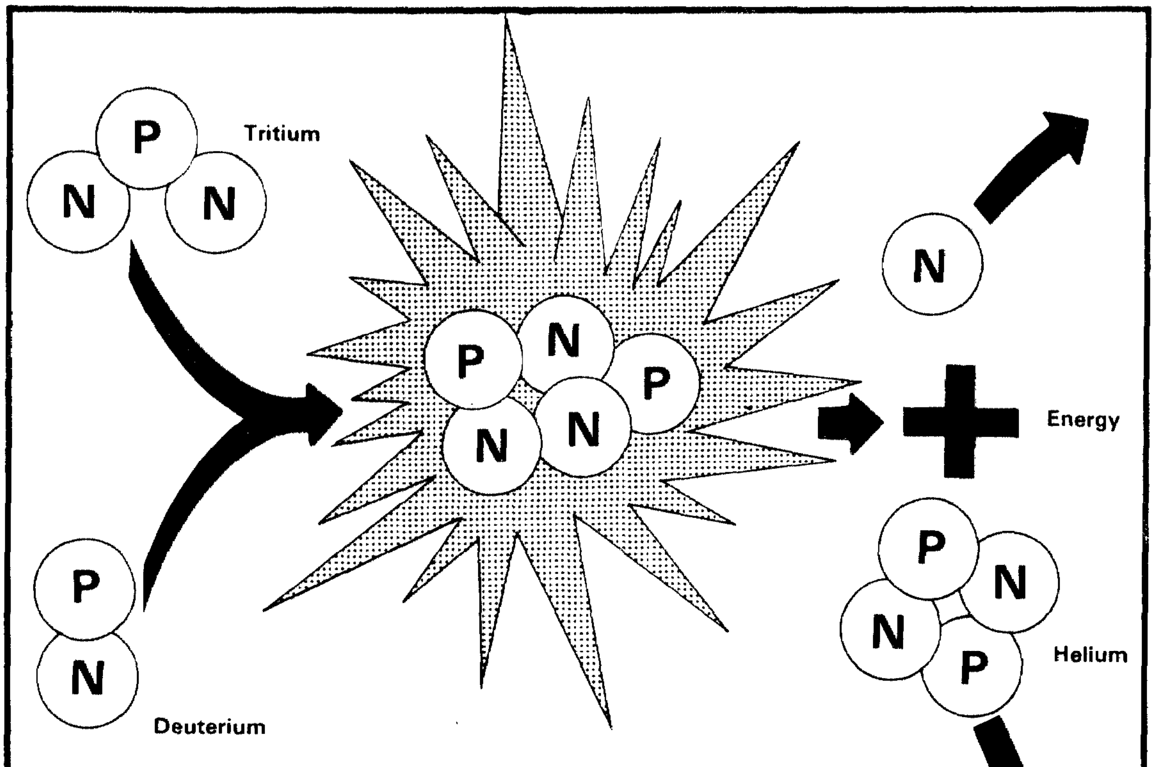

Figure 1

A Fusion Reaction

Source: Princeton Plasma Physics Laboratory

HARNESSING NUCLEAR FUSION

In order for a fusion reaction to occur, several extreme physical conditions must be achieved simultaneously. They are temperature, density, and confinement time. Temperature refers to the amount of heat necessary for fusion to occur; density refers to the number of plasma particles present in a given volume; and confinement time refers to the amount of time the plasma particles are confined to the given volume.

Temperatures of approximately 180 million degrees Fahrenheit are necessary to ensure that fusion will take place on Earth. (As a point of reference, the temperature of the Sun's surface is about 10.8 million degrees Fahrenheit.) Simultaneously, in order for fusion to occur, about 3 hundred trillion plasma particles per cubic centimeter need to be confined for at least 1 second. While the temperature requirement may seem at first glance the most imposing, the density and confinement time values are also extremely difficult to achieve since the charged plasma particles move at extremely high velocities and naturally repel each other.

Scientists have achieved temperatures of about 144 million degrees Fahrenheit on fusion test devices with significant but lower than necessary density and confinement time values. Similarly, they have achieved near reactor level density and confinement time values for fusion with significant but lower than necessary temperatures. Much of the current fusion research and development (R&D) effort is directed toward achieving these necessary fusion conditions simultaneously.

The United States is generally recognized by the scientific community as the world leader in fusion research. However, other countries, notably Japan, the U.S.S.R., and nine European countries in a consortium called the European Atomic Energy Community (EURATOM), are also pursuing ambitious fusion programs.

THE U.S. FUSION PROGRAM

The United States, through the Department of Energy (DOE) and its predecessor agencies, the Energy Research and Development Administration and the Atomic Energy Commission, has supported fusion R&D efforts since 1951. DOE's Office of Fusion Energy in Germantown, Maryland, under the Office of Energy Research, is responsible for directing the Nation's magnetic confinement nuclear fusion program.[1] Laboratory R&D programs are conducted at several national laboratory, university, and private sector facilities. These include

--Oak Ridge National Laboratory,

--Lawrence Livermore National Laboratory,

--Los Alamos National Laboratory,

--Princeton University,

--Massachusetts Institute of Technology, and

--GA Technologies, Inc.

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[1]Currently there are two major approaches to developing fusion energy: magnetic confinement and inertial confinement. Magnetic confinement, the main approach being explored for commercial energy generation, involves the confinement of fusion fuel, called plasma, by magnetic fields. Another DOE program is investigating inertial confinement, primarily for its military applications. Inertial confinement uses lasers and particle beams to initiate a fusion reaction.

THE MAGNETIC FUSION ENERGY ENGINEERING ACT OF 1980

The President, on October 7, 1980, signed into law the Magnetic Fusion Energy Engineering Act of 1980 (Public Law 96-386). The act recognized the need to develop an essentially inexhaustible energy resource to offset the impending worldwide scarcity of many exhaustible, conventional energy resources. It established several objectives intended to accelerate the demonstration of magnetic confinement fusion as a socially acceptable, environmentally safe method of producing electric power. These include

--demonstrating the engineering feasibility of magnetic fusion by the early 1990's;

--operating a magnetic fusion engineering device, based on the best available confinement concept, by 1990; and

--operating a magnetic fusion demonstration powerplant at the turn of the 21st century.

The act also cited several organizational, planning, and reporting requirements with which the Secretary of Energy was to comply. These requirements were intended to ensure that the act's objectives were achieved. They include

--preparing a comprehensive program management plan,

--developing a plan for the creation of a national magnetic fusion engineering center, and

--creating a technical panel on magnetic fusion to review the conduct of the national magnetic fusion energy program.

The Federal Government's annual investment in fusion research and technology has grown from less than $1.1 million in fiscal year 1951 to $451.2 million in fiscal year 1982. About $2.3 billion was spent in the years leading up to the passage of the act. Since fiscal year 1980, approximately another $1.3 billion has been budgeted.

Even though funding for fusion R&D under the 1980 act has remained relatively high, the levels are not as high as those set forth in the 1980 act, which visualized an accelerated fusion R&D program. The act called for a 25 percent funding increase in each of fiscal years 1982 and 1983, and a doubling of the base-year funding level within 7 years, without considering inflation. The following table summarizes this information.

Magnetic Fusion Program Budget History

Fiscal year	Budget envisioned by the act	Budget submitted to OMB	Budget submitted to the Congress	Budget appropriation
	(000 omitted)			
1981 (original)	base year ($394,117)	$393,430	$403,617	(a)
1981 (revised)	base year ($394,117)	(a)	396,117	$394,117
1982 (original)	492,646	531,670	506,170	(a)
1982 (revised)	492,646	(a)	460,000	451,231
1983	615,808	532,300	444,100	b/466,100
1984	(c)	505,000	467,000	(d)
1988	788,234	N/A	N/A	N/A

a/Due to a change in administrations and the President's initiative to balance the Federal budget, DOE was asked to resubmit its FY 81 and FY 82 budget requests to the Congress. DOE did not receive an appropriation on its original FY 81 and FY 82 budget requests. Also, DOE did not have to formally resubmit a revised request to OMB, although OMB reviewed and approved DOE's revised budget submitted to the Congress.

b/Operating under a continuing resolution as of March 1983.

c/The act does not contain specific reference to an envisioned FY 84 budget.

d/Since the FY 84 budget process is currently ongoing, no appropriation has yet been made.

N/A - Not Applicable.

OBJECTIVES, SCOPE, AND METHODOLOGY

Congressman Fortney H. Stark, Jr., of California and, subsequently, Congresswoman Marilyn L. Bouquard, Chairman of the Subcommittee on Energy Research and Production, House Committee on Science and Technology, requested that we determine the status of DOE's implementation of the Magnetic Fusion Energy Engineering Act of 1980. Thus, our objective during this review was to determine whether and how DOE is complying with the act's requirements.

We conducted our review between April 1982 and April 1983 at DOE's Office of Fusion Energy in Washington, D.C., and several of DOE's main fusion research facilities--the Lawrence Livermore and Oak Ridge National Laboratories; the Hanford Engineering Development Laboratory in Richland, Washington; the Princeton University Plasma Physics Laboratory; and the Massachusetts Institute of Technology Plasma Fusion Center. We interviewed key managers, including research officials, project managers, facility directors, and other project personnel. We also contacted GA Technologies, Inc., to discuss industry's role. GA Technologies, Inc., exhibits an important aspect of private sector involvement in fusion energy development and participates in an international cooperative effort with Japan.

In addition to interviewing program and project officials, we also reviewed relevant documentation, including congressional testimony and committee reports, budget requests, policy statements, project descriptions and status reports, and the reports of scientific review panels. We also reviewed reports prepared by such groups as the National Research Council and the American Nuclear Society which addressed relevant issues contained in the act.

The act established objectives and requirements for the Nation's magnetic fusion program. We used the information obtained from interviews and from the above documentation to determine DOE's efforts in addressing the act's requirements.

Our audit was performed in accordance with generally accepted government auditing standards.

CHAPTER 2

DOE's MAGNETIC CONFINEMENT

FUSION R&D PROGRAM

DOE is pursuing the development of fusion energy through a large R&D program. Funding for magnetic confinement R&D efforts had increased to about $466.1 million[2] in fiscal year 1983; however, that was only about 76 percent of what the act envisioned. Accordingly, DOE has had to adjust certain aspects of its fusion energy R&D program to fit available and anticipated funding levels. Because of funding constraints, DOE is pursuing a revised fusion development strategy that differs from its original strategy. Also, DOE will not undertake certain program goals set forth in the act. This chapter describes the ongoing R&D efforts of DOE's magnetic fusion program and its changing fusion development strategy.

THE ACT'S R&D PROGRAM AND OBJECTIVES

The act contains several requirements intended to direct magnetic fusion activities toward the achievement of its overall objective--demonstrating the commercial feasibility of nuclear fusion. We have grouped these requirements into two broad categories: (1) research and development programs and (2) planning, management, and reporting requirements of DOE's fusion program. The planning, management, and reporting requirements of the act will be discussed in the next chapter.

The act contains the following four program requirements for research activities:

--Initiate or accelerate activities in research areas in which the lack of knowledge hinders achieving the act's objectives.

--Maintain an aggressive plasma confinement research program in the current lead concept.

--Maintain a broadly based research program on alternative concepts and advanced fuels.

--Ensure adequate materials research.

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[2]Although the budget submitted by DOE to the Congress for fiscal year 1983 was for only $444 million, as of March 1983 DOE's fusion program continued to be funded under a continuing resolution at the rate of $466.1 million for the year. (See p. 5.)

The act also outlines a series of objectives directed toward the construction of a demonstration fusion plant. Following the demonstration of scientific feasibility and breakeven, the act envisioned the construction of two fusion devices that would first demonstrate engineering feasibility and then commercial viability.

Demonstrating scientific feasibility and breakeven requires the construction of a device in which a controlled fusion reaction produces as much energy as is needed to sustain it. Demonstrating engineering feasibility refers to the development and construction of a fusion reactor that will sustain a fusion reaction beyond a laboratory scale, test the engineering requirements of a larger scale reactor, and provide a "stepping stone" to a commercial-sized reactor. The act calls for the Secretary of Energy to initiate design activities leading to the operation of what it called a Fusion Engineering Device, demonstrating engineering feasibility by the early 1990's.

The act also called for the Secretary of Energy to initiate at the earliest practical time activities necessary to ensure the operation of a demonstration plant illustrating commercial feasibility at the turn of the 21st century. Demonstrating commercial feasibility is essentially an economic issue. It implies developing fusion energy technology on a scale and at a cost that is economically competitive with other power-producing technologies.

Another important part of the act's development strategy was the intended availability of alternative fusion concepts as the program moves foward. For example, at the time when a decision would be made to construct the Fusion Engineering Device, the act envisioned that several alternative concepts would be available so that DOE could choose the best confinement concept. The act intended DOE to develop alternative concepts so that it could clearly identify the advantages and disadvantages of each and ultimately choose the best for commercial development.

DOE's MAGNETIC FUSION RESEARCH PROGRAM

Past fusion research efforts focused on obtaining a basic understanding of the physics of fusion. While the act requires an ongoing basic research effort in areas where the lack of knowledge limits fusion development, it also requires an aggressive development program for the lead confinement concept and a broad-based research program on alternative concepts so that technical options remain available.

DOE continues to do basic fusion research. For example, it is investigating plasma behavior and other aspects of the fusion reaction. However, much of DOE's current effort is directed at simultaneously achieving the conditions necessary for a fusion reaction. DOE's present fusion R&D program is largely focused on two "mainline" approaches that it hopes can be used to develop a commercial fusion reactor.

The two mainline magnetic confinement approaches are classified as closed and open. Closed magnetic confinement systems are doughnut-shaped devices generally referred to as toroids. There are several kinds of toroidal devices including tokamaks, stellarators, and compact toroids. Tokamaks are the toroidal devices being examined most extensively, both in the United States and in other countries. Open magnetic confinement systems are generally simply referred to as "mirrors". They consist of a long tube with large magnets at each end that reflect back and contain the plasma particles. Figure 2 illustrates open and closed magnetic confinement systems.

Tokamaks

The current lead concept in magnetic fusion is tokamaks. Tokamaks vary but the basic design is constant, consisting of doughnut-shaped devices wrapped with electrical coils that induce a magnetic field. DOE is supporting research on several variations including Princeton's Tokamak Fusion Test Reactor, Princeton Large Torus, and Poloidal Divertor Experiment; the Massachusetts Institute of Technology's Alcator C; and GA Technologies, Inc.'s Doublet III.

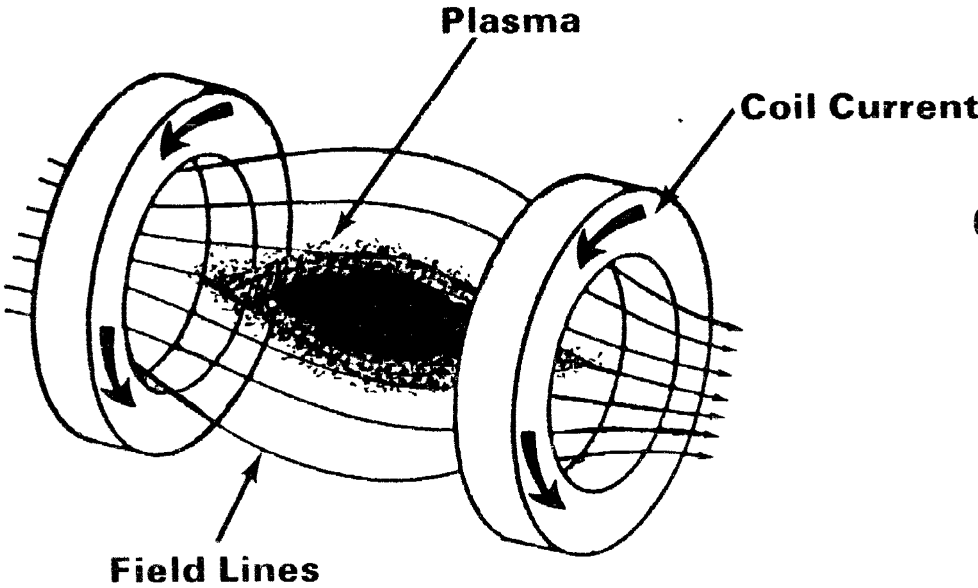
The Tokamak Fusion Test Reactor shown on p. 12 is a $314 million facility that has been called the "flagship" of the fusion program. It is the device with which DOE plans to first demonstrate scientific breakeven in magnetic fusion. DOE expects this will occur in 1986. In December 1982, scientists were successful in producing a first burst of plasma at 180,000 degrees Fahrenheit in the newly constructed reactor.

The other tokamak devices focus on various aspects of the fusion process. For example, work in the Princeton Large Torus is aimed at achieving necessary reactor level temperatures, while work in the Alcator C is directed at achieving high density and confinement time values. Research on the Poloidal Divertor Experiment focuses on reducing or eliminating plasma impurities. Finally, research on the Doublet III is directed at determining the behavior of noncircular plasmas. But while these are the main experimental objectives of the various devices, scientists also use them to study many other aspects of the fusion process.

Program funding for tokamaks is provided for two main purposes: (1) to support construction activities and (2) to conduct experimental work. Total funding for tokamak R&D has increased steadily since 1981 as shown in the table on p. 11.

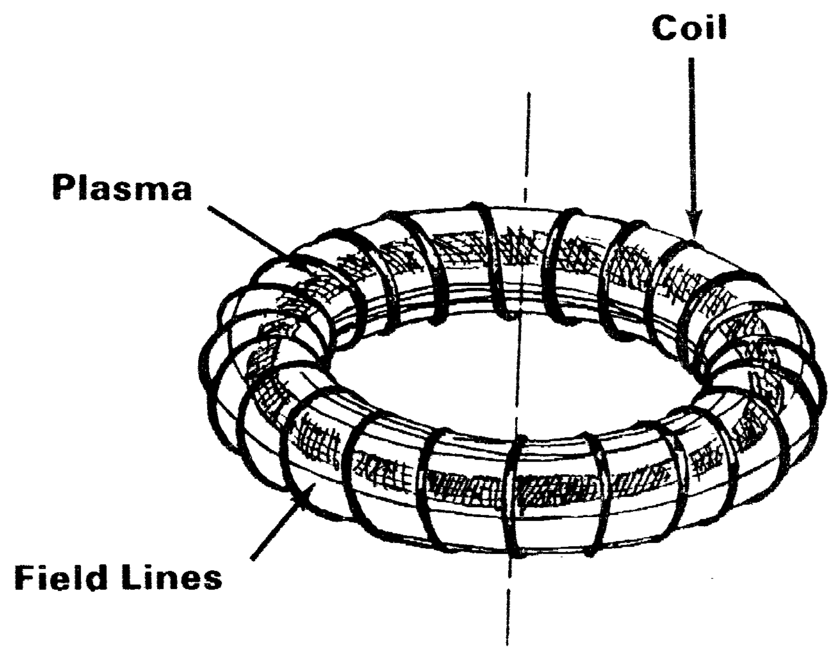
Figure 2

THE TWO BASIC MAGNETIC CONFINEMENT CONFIGURATIONS FOR NUCLEAR FUSION



Open System-
Simple Magnetic Mirror

Closed System-Simple Torus



Source: Lawrence Livermore National Laboratory

Tokamaks Funding (note a)

Fiscal year	Experiments	Construction	Total
	----------------(000 omitted)----------		
1981	$ 76,162	$52,350	$128,512
1982	101,665	58,710	160,375
1983	153,300	17,500	170,800

a/Amounts for fiscal years 1981 and 1982 are based on appropriations. Amounts for fiscal year 1983 are based on DOE's budget request.

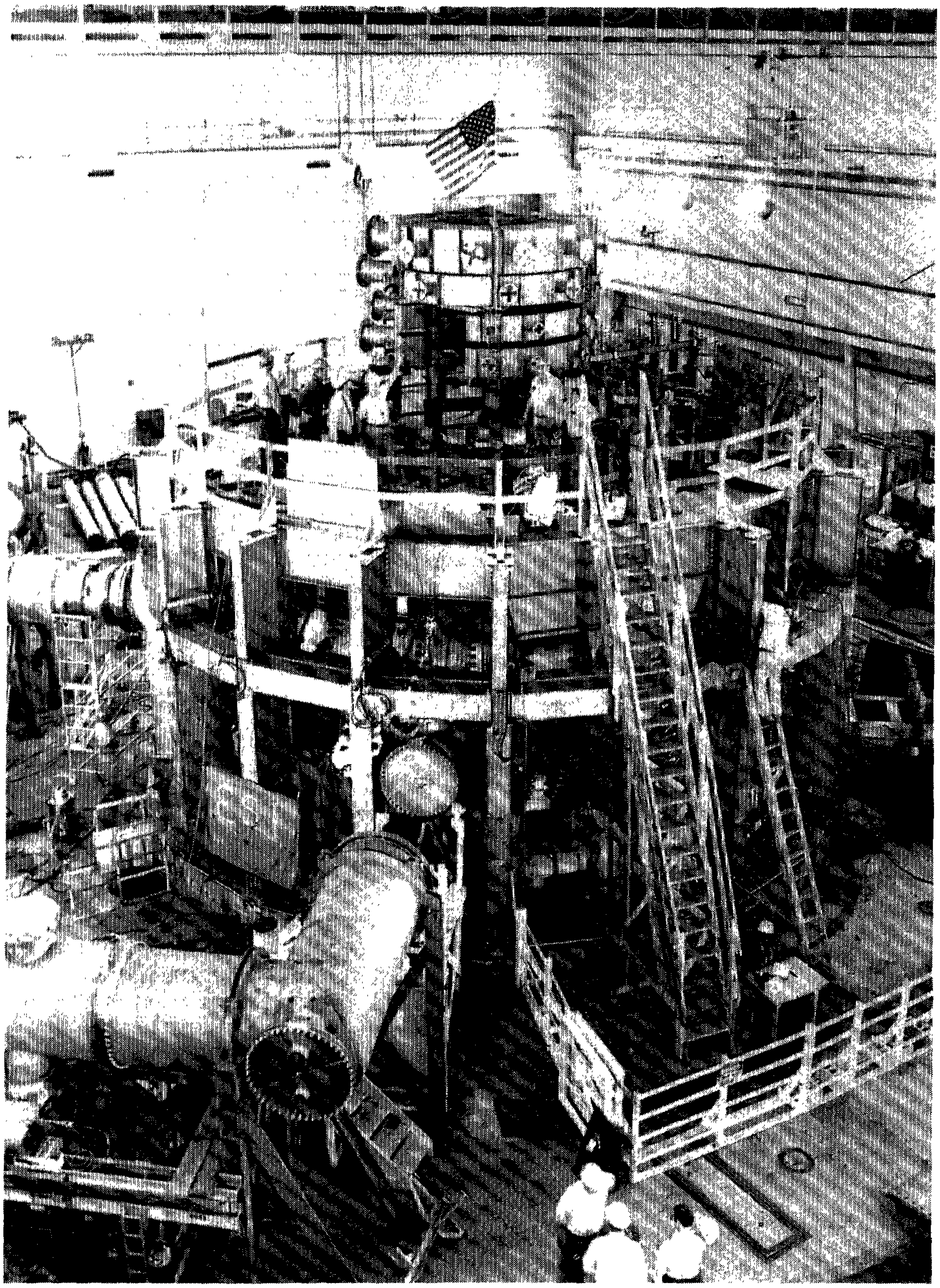
Mirrors

DOE considers its other mainline concept to be mirrors. Mirrors fusion facilities are not as numerous, nor is the program as scientifically advanced, as tokamaks. The major mirrors research activities are located at the Lawrence Livermore National Laboratory. They consist of the Tandem Mirror Experiment and the Mirror Fusion Test Facility. Additional mirror studies are being conducted at the Massachusetts Institute of Technology and other locations.

The Tandem Mirror Experiment project embodies both experimental and construction activities. Construction of the basic facility was completed in 1978 and experiments were conducted until 1980. At that time construction activities were resumed to upgrade the facility which is once again being used for experimental studies.

The Mirror Fusion Test Facility is presently under construction. (See p. 14.) It is larger than the Tandem Mirror Experiment, comparable in size to the Tokamak Fusion Test Reactor. According to DOE, scientists will demonstrate equivalent scientific feasibility on the Mirror Fusion Test Facility before DOE makes a decision on the confinement concept to be used in the next-level fusion reactor. DOE expects to be able to make this decision after 1988.

Included in the mirrors program budget is funding for another fusion concept called the ELMO Bumpy Torus (EBT), located at the Oak Ridge National Laboratory. It is a hybrid device which connects short mirror segments in a circular configuration. Although it is funded from the mirrors program budget, it is not a mainline concept. DOE considers it an alternative concept at a much earlier stage of development than either mirrors or tokamaks. Funding for the EBT program was cut back in fiscal year 1983, and further cuts may occur in fiscal year 1984.



The Princeton University Plasma Physics Laboratory Tokamak Fusion Test Reactor. It is the Nation's first magnetic confinement device capable of producing a significant quantity of fusion energy and is the largest construction project to date in the U.S. fusion program. A major objective of the reactor is to demonstrate scientific feasibility and breakeven using the tokamak principle to magnetically confine plasma.

Source: Princeton Plasma Physics Laboratory

The mirrors program funding history since 1981 is shown in the following table.

Mirrors Funding (note a)

Fiscal year	Experiments	Construction	Total
	(000 omitted)		
1981	$43,700	$29,200	$ 72,900
1982	53,718	48,893	102,611
1983	49,500	48,262	97,762

a/Amounts for fiscal years 1981 and 1982 are based on appropriations. Amounts for fiscal year 1983 are based on DOE's budget request.

Alternative confinement concepts

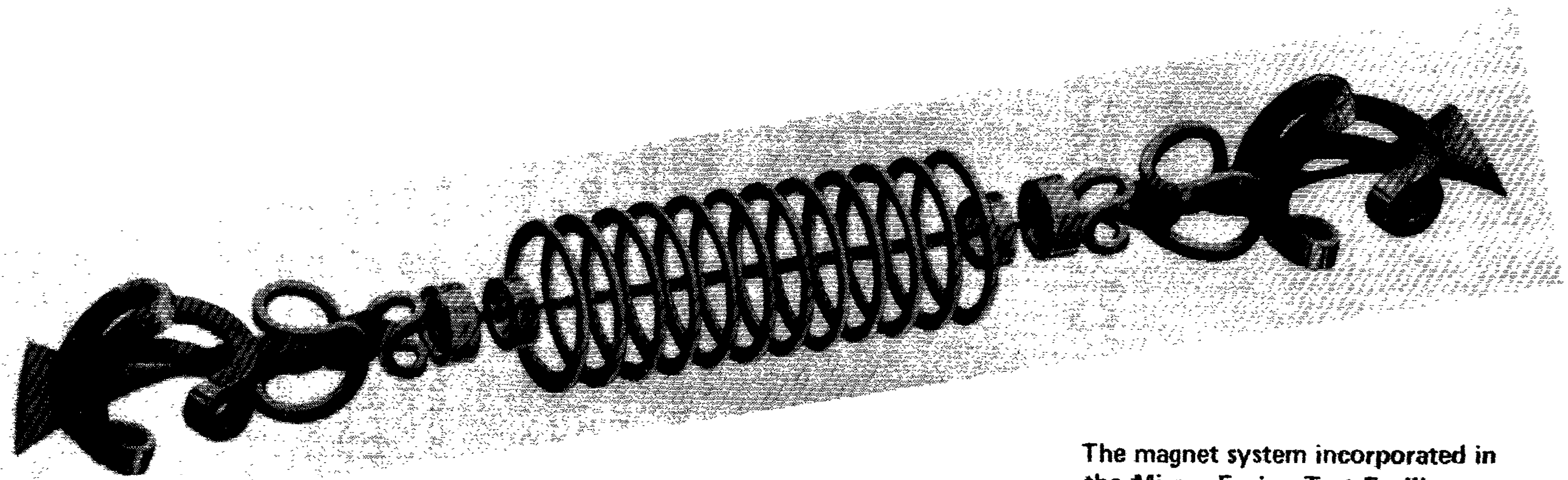
The act requires the Secretary of Energy to maintain a broad-based research program on alternative confinement concepts and advanced fuels at a sufficient level of funding to achieve optimal design of each successive magnetic fusion facility. By exploring more than one design concept, theoretically a choice will be available when more advanced facilities are constructed.

DOE is conducting research on various alternative magnetic confinement concepts. For the most part they are variations of the toroidal approach, including reversed field pinch and compact toroids, and a toroidal confinement device called a stellarator. A final concept, mentioned earlier, is the ELMO Bumpy Torus. The total funding for all alternative concepts was $45.4 million in fiscal year 1982, less than for either tokamaks or mirrors.

DOE is devoting little effort to advanced fusion fuels. DOE fusion scientists know that elements other than deuterium and tritium can be used to achieve energy-producing fusion reactions; but because the requirements (temperature, density,and confinement time) are so much greater using heavier elements, they are focusing their efforts on a D-T (deuterium-tritium) reaction. According to fusion experts, future generation fusion reactors may use different fuels because of other advantages such as reduced radioactivity.

Materials research

The act requires that research be conducted so that the materials necessary to construct future fusion devices are



Source: Lawrence Livermore National Laboratory

The magnet system incorporated in the Mirror Fusion Test Facility will be the largest superconducting system yet built in the world. The system represents a significant step towards demonstrating the feasibility of superconducting magnet systems for future mirror fusion reactors. A magnet becomes a superconductor, and thus uses relatively little energy, when it is cooled to an extremely low temperature. For the test facility magnet this temperature will be 4.5 C above absolute zero (the temperature at which all atomic motion of particles ceases). A large cryogenic system external to the vessel supplies liquid helium to the magnet coils and liquid nitrogen to the thermal shields to maintain the magnets at temperatures of superconductivity.

available when needed. The physical requirements of materials used in a nuclear fusion reactor will be extreme. For example, huge magnets in the reactor will be operated at cryogenic temperatures (close to absolute zero) while the walls of the reactor will be exposed to heavy neutron bombardment and extremely high temperatures. Thus the importance of developing materials that can be used in such a technology is crucial to its demonstration.

Fusion scientists are collecting materials stress and performance data at several facilities. For example, the Rotating Target Neutron Source-II at the Lawrence Livermore National Laboratory measures the effects of neutron bombardment on materials. Scientists are also obtaining materials data from operating fission reactors. However, fission reactors do not generate the same amount or intensity of neutron bombardment as will fusion reactors, and the Rotating Target Neutron Source-II is not capable of providing all the needed materials data in a timely manner.

Citing budget stringencies DOE has halted construction of the Fusion Materials Irradiation Test Facility, to have been built in Richland, Washington. That facility was to be used to examine how different materials behave under the intense neutron bombardment conditions which will exist in a fusion reactor. Based on the results of those tests, program officials were planning to select the most suitable materials for constructing a prototype commercial fusion reactor.

According to the Director of the Office of Energy Research, the Fusion Materials Irradiation Test Facility is the only facility that could have irradiated the volume of materials under the necessary conditions to allow proper materials identification in a reasonable time frame--about 3 to 5 years. According to him, comparable research in the smaller Rotating Target Neutron Source-II will take between 500 and 2,000 years to accumulate the same data. Thus, although materials needs are not currently a problem, he and others question whether DOE will be able to perform the needed materials research for advanced fusion reactors in a timely manner.

DOE is exploring the possibility of constructing and operating a materials irradiation test facility as part of an international cooperatiave effort. (See p. 24.)

A CHANGING FUSION DEVELOPMENT STRATEGY

Fusion is a complex process which requires an understanding of such diverse subject areas as how to adequately heat and confine plasma and how to control impurities. Without an in-depth understanding of these and other areas, the program cannot progress in an orderly fashion from one phase to the next.

The results of our review indicate that much of DOE's fusion program is directed at understanding those issues which prevent the program from moving forward. For example, the program is pursuing ways to improve magnetic confinement by developing and using superconducting magnets, and to achieve higher temperatures using various heating techniques.

As scientific research developed needed data, DOE envisioned the engineering progress of the program proceeding in several phases. DOE would first construct a device that would demonstrate scientific feasibility and breakeven. (This is expected to be accomplished on Princeton's Tokamak Fusion Test Reactor in 1986 (see p. 9).) Then, as the act envisioned, DOE would construct and operate the Fusion Enginering Device which would demonstrate the engineering feasibility of fusion energy. The Fusion Engineering Device was to have been followed by a demonstration powerplant to illustrate the commercial feasibility of magnetic fusion energy. Throughout these three phases--scientific feasibility, the engineering device, and the demonstration plant--the Congress envisioned a major Federal Government role in the development of fusion energy.

Citing budgetary constraints, DOE no longer plans to follow this development strategy. For example, it is not planning to build the Fusion Engineering Device. Instead, after demonstrating scientific feasibility and breakeven on the Princeton reactor, and developing the mirrors concept to a comparable level, it plans to build only one more fusion reactor. It will be an engineering test reactor that will be intermediate in performance between what would have been the Fusion Engineering Device and a demonstration powerplant.

DOE does not now plan to construct a commercial-sized demonstration plant after the engineering test reactor. Rather, it plans to limit Federal Government involvement in the fusion program after constructing the engineering test reactor. DOE now believes that the information obtained from the Princeton Tokamak Fusion Test Reactor, the engineering test reactor, and other program components will give industry the data base necessary to assess the potential for the commercialization of fusion energy. Thus, this revised development strategy anticipates an earlier and more extensive industry input into fusion development than the act foresaw.

The Electric Power Research Institute's program manager for fusion power, and other industry representatives, have said that private industry is willing to participate in the development of fusion power, but the costs and risks involved will prevent a large-scale financial commitment until a prototype fusion reactor demonstrating the commercial feasibility of fusion is constructed.

Alternative concepts

As described on pages 9 to 13, DOE's magnetic fusion program supports research activities on several fusion concepts. These include tokamaks and mirrors, the mainline program concepts, and alternative concepts like stellarators. The act envisioned funding for these concepts at a level that would ensure comparable development so that construction of each successive magnetic fusion facility could use the best available confinement concept.

Funding for a major mirrors program test facility has lagged, causing construction delays to the point where the former director of the Office of Fusion Energy concluded in early 1982 that the development of mirrors has fallen at least 3 years behind the tokamak program. Other concepts like the ELMO Bumpy Torus are even further behind, and its proposed funding for fiscal years 1983 and 1984 has been further reduced.

A panel of DOE's own Magnetic Fusion Advisory Committee (see p. 22) has in recent meetings recognized that there is a problem with the widening gap between tokamaks and other concepts. The Committee panel examining alternate concepts stated that it

> "does not consider the present balance between the mainline and alternate concepts to be appropriate * * *. Strengthening of the alternate concepts is essential to provide more economically attractive fusion options."

The Committee recommended that the mirrors concept be pursued vigorously so that it can provide a development option as the act intended. We believe that unless this occurs, DOE may be prematurely committing itself to the tokamak concept for commercial development before it has had the opportunity to adequately assess the advantages and disadvantages of other concepts. A DOE official states, however, that a decision will not be made on the confinement concept to be pursued in its engineering test reactor until both the mirror and tokamak concepts have been used to investigate plasma behavior at reactor level temperatures, densities, and confinement times.

CONCLUSIONS

DOE is pursuing a wide-range, large-scale fusion R&D program. Efforts are focused on basic research needs as well as directed to the ultimate design and construction of a fusion device. Two mainline fusion concepts and related alternatives are being examined.

However, funding levels lower than the act envisioned pose a number of difficult development decisions for DOE's fusion program. For example, should the program's milestones be delayed while alternative concepts, including mirrors, "catch up" to tokamaks?

DOE and its Magnetic Fusion Advisory Committee are reevaluating the strategy for developing and commercializing magnetic fusion technologies. DOE, however, already plans to deviate from its original fusion development strategy by not proceeding with the Fusion Engineering Device or a commercial demonstration reactor. Instead it will construct an intermediate performance engineering test reactor. This change anticipates an earlier and more extensive industry participation with fusion development.

CHAPTER 3

THE ACT'S MANAGEMENT REQUIREMENTS

The Magnetic Fusion Energy Engineering Act of 1980 establishes several planning, organizational, and reporting requirements to be met as the Nation's fusion program moves toward its technical goals. Several of these requirements have not yet been met, including the completion of a comprehensive program management plan. Acording to DOE, funding constraints and other considerations have slowed progress in these areas.

DOE's development of a new strategy for the fusion program accentuates the need for a plan that adequately justifies and directs the Nation's fusion program. Funding and other strategic decisions made today may have long-term implications for the development of fusion power in the United States. Thus, the plan is also needed to assist timely congressional oversight.

THE ACT'S REQUIREMENTS

The act establishes the following planning, organizational, and reporting requirements designed to ensure that the Secretary is moving toward the objectives of the act, and to aid the Congress in its oversight of DOE's fusion development program.

--Prepare a comprehensive program management plan and submit it to the House Committee on Science and Technology and Senate Committee on Energy and Natural Resources by January 1, 1982.

--Prepare a plan for creating a national magnetic fusion engineering center and submit the plan to the House Committee on Science and Technology and Senate Committee on Energy and Natural Resources by July 1, 1981.

--Establish a technical panel to review the magnetic fusion program and submit a report to DOE's Energy Research Advisory Board, and the Secretary, at least every 3 years.

--Enter into, or strengthen existing, international cooperative agreements for magnetic fusion activities and report the results of these activities to the House Committee on Science and Technology and Senate Committee on Energy and Natural Resources by October 7, 1982.

--Assess the adequacy of the projected United States supply of engineers and scientists required to achieve the act's objectives and report to the President and the Congress by October 7, 1981.

--Report to the Congress on the fusion program's activities as part of the annual report required by the Department of Energy Organization Act (Public Law 95-91).

--Ensure that information relevant to the national magnetic fusion program is available to industry, universities, and the public at large.

The following sections discuss DOE's efforts to satisfy these requirements.

A COMPREHENSIVE MAGNETIC FUSION PROGRAM MANAGEMENT PLAN HAS NOT BEEN SUBMITTED

The 1980 act requires the Secretary of Energy to prepare a comprehensive program management plan for conducting fusion research, development, and demonstration activities and to transmit it to the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources no later than January 1, 1982. The act requires the plan to include

--a program strategy that will achieve the purposes of the act;

--a 5-year program implementation schedule, including detailed milestones with associated budget and resource requirements;

--risk assessments;

--supporting R&D needed to solve problems inhibiting development of fusion energy systems; and

--an analysis of institutional, environmental, and economic considerations limiting the program.

DOE had not submitted the required program plan to the House Committee on Science and Technology and Senate Committee on Energy and Natural Resources as of March 1983. Citing budget uncertainties, DOE delayed initiating work on the fusion program plan until January 1982.

In a letter dated January 29, 1982, to various Congressmen, the Secretary of Energy wrote

"* * * the uncertainty which has accompanied development of the budgets for Fiscal Years 1982 and 1983, and the fact that these budgets do not support the pace of program development envisioned in the Act, have made it impossible to prepare a Comprehensive Program Management Plan by Jan. 1, 1982. * * * However, since the Fiscal Year 1982 magnetic fusion budget is now established, and since we have a clearer picture of the budget prospects for Fiscal Year 1983, we can now start preparation of the plan and will submit it to Congress by Oct. 1, 1982."

While the plan has yet to be submitted, the Office of Fusion Energy has prepared a draft plan that has undergone extensive review by both DOE and the Executive Office of the President. DOE officials told us that they hope to submit the plan to the congressional committees in the near future.

A CENTER FOR FUSION ENGINEERING HAS BEEN POSTPONED

The act called for the Secretary to develop a plan for creating a national magnetic fusion engineering center to accelerate fusion technology development by concentrating and coordinating major magnetic fusion engineering devices and associated activities. The center was also to be responsible for managing and overseeing the design, construction, and operation of the Fusion Engineering Device. The plan was to be submitted to the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources by July 1, 1981.

DOE has not created a national magnetic fusion engineering center nor has it submitted to appropriate congressional committees a plan for creating the center. In a July 7, 1981, letter to cognizant congressional committees, the Secretary of Energy stated that it was premature to establish fully the national magnetic fusion engineering center. The letter stated that budget constraints and DOE's belief that the Center should evolve over a few years have caused DOE to postpone the program expansion. As discussed in chapter 2, DOE also is no longer planning to construct a Fusion Engineering Device, but rather is planning to construct an engineering test reactor which will be intermediate in performance between what would have been the Fusion Engineering Device and a demonstration powerplant. As of March 1983 DOE still had no plans to organize a center for fusion engineering in the near future.

Although DOE has apparently decided not to establish a national magnetic fusion engineering center, the program is not without management direction and guidance. DOE's Office of Fusion Energy maintains program oversight and coordinates program activities at various universities, the national laboratories, and in the private sector. Further, the Office sponsors frequent seminars and other initiatives through which participants discuss program progress, problems, and alternative courses of action. The Office, in establishing the Magnetic Fusion Advisory Committee, has also sought outside expert help in determining the program's direction.

FORMATION OF A TECHNICAL PANEL HAS BEEN DEFERRED

The act requires that a DOE Energy Research Advisory Board (ERAB)[3] technical panel be established to review the conduct of the fusion program and report to ERAB on at least a triennial basis. The technical panel is to include experts from the fusion community and is not limited to ERAB members.

ERAB is waiting to form the technical panel until the Magnetic Fusion Advisory Committee completes its ongoing review of the program. This Committee, formed by DOE in May 1982, includes fusion experts from industry, academia, and the national laboratories. It is charged with examining ways of maintaining progress in fusion development consistent with the act's objectives, during a period of budget constraints.

Specifically, DOE asked the Committee to undertake three analyses pertaining to the fusion program: (1) an evaluation of the tokamak and tandem mirror programs, (2) a review of other alternative fusion confinement concepts like the stellarator, ELMO Bumpy Torus, and reversed field pinch concepts, and an evaluation of their relative priority as backups to the mainline tokamak and tandem mirror programs, and (3) an evaluation of the use of the Tokamak Fusion Test Reactor as a substitute for the Fusion Engineering Device (see ch. 2). The Committee established three panels to examine these issues.

The panels examining the first two issues reported to the Committee in October 1982. They found that the existing data base implies that it is possible for tokamaks to achieve net power production; i.e., more power produced than is required to initiate and sustain the fusion reaction. They also concluded that mirrors research is at an earlier stage of development and recommended that the mirrors concept be pursued vigorously to develop a comparable data base.

The panels also reported that it is important to maintain at least the present level of experimentation for alternative concepts. They found that each of the backup confinement approaches is characterized by a rapidly evolving and encouraging data base and that each concept offers potential advantages

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[3]ERAB, whose membership represents private industry, academia, and science interest groups, is one of a number of expert advisory committees DOE has chartered. It concerns itself with long-range R&D policy matters and renders advice on specific energy systems as required. ERAB reports to the Secretary of Energy through the Office of Energy Research, where a support staff is maintained.

relative to the mainline approaches. However, none of the backup concepts will be at levels of development comparable to the mainline concepts when it is time to select the base concept for the next-generation test reactor.

In August 1982 the Committee expanded the third issue to include consideration of upgrade options for the Mirror Fusion Test Facility in addition to those for the Tokamak Fusion Test Reactor. These upgrade options would be considered as substitutes for constructing a separate engineering test reactor. The panel examining these issues has until mid-1983 to report to the Committee.

DOE IS PURSUING INTERNATIONAL COOPERATION OPPORTUNITIES

The 1980 act calls for the Secretary, in consultation with the Secretary of State, to (1) enter into, or strengthen existing, international cooperative magnetic fusion R&D agreements of mutual benefit to all parties, (2) seek to achieve an equitable exchange of information, data, scientific personnel, and other considerations with technically advanced countries, (3) examine the potential impacts of an international effort to construct fusion devices, and (4) explore the prospects for joint financial participation in the construction of a fusion engineering device. The Secretary was to report on such activities to the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources by October 1982. DOE submitted the required report in December 1982.

DOE conducts cooperative fusion activities through two international organizations, the International Atomic Energy Agency and the International Energy Agency, and through formal government-to-government bilateral exchange agreements. International Atomic Energy Agency programs are primarily conference and information exchange activities. An example is the International Tokamak Reactor design workshop series--an ongoing series of conferences that considers the status and direction of the magnetic fusion effort. Workshop series participants include the United States, Japan, EURATOM (see p. 3), and the U.S.S.R.

International Energy Agency activities complement those of the International Atomic Energy Agency in that they involve the mutual construction and operation of fusion experiments. The United States is party to several international cooperative agreements of this type. An example is the Large Coil Project at the Oak Ridge National Laboratory. The project involves the design and fabrication of superconducting magnets needed for large tokamak fusion reactors. Participants in the project include the United States, EURATOM, Switzerland, and Japan.

The United States also participates in three major bilateral fusion exchanges, one each with the U.S.S.R., EURATOM, and Japan.

Notwithstanding its current involvement in several international cooperative efforts, DOE is seeking to expand those activities. According to the Secretary's report, DOE believes that due to budgetary stringencies, international cooperative programs are becoming increasingly important to complete necessary aspects of fusion development which the United States cannot afford to do alone. For example, DOE is investigating the possibility of constructing and operating the Fusion Materials Irradiation Test Facility as an international facility. (See p. 15.) Similarly, DOE is currently negotiating agreements for international cooperation in stellarator research efforts. However, the report also recognizes that there are problems associated with joint international projects of this type, including management problems and related delays and the loss of information and property control.

Nevertheless, DOE is initiating the first formal technical exchange between the U.S. "next step" design team and its Japanese counterparts. According to DOE's report, this exchange could evolve into the basis for serious consideration of an international cooperative effort to construct the next major fusion device. A similar exchange is under discussion with EURATOM.

DOE HAS COMPLETED THE REQUIRED MANPOWER ASSESSMENT

The act requires the Secretary of Energy to report on the adequacy of the projected U.S. supply of engineers and scientists required to achieve the act's purposes, taking cognizance of the other demands likely to be placed on such personnel. DOE submitted the required report to the Congress in October 1981.

DOE's report concluded that the supply of scientists and engineers is likely to be adequate to successfully implement the program outlined in the act. The report focused on the need for key people with specialized fusion training and recommended that DOE's Office of Fusion Energy maintain its university research efforts and its fusion technology fellowship program. The report also recommended that universities be encouraged to develop joint engineering programs with industry and/or the national laboratories.

DOE IS PREPARING TO REPORT ANNUALLY ON ITS MAGNETIC FUSION PROGRAM

The act also requires the Secretary of Energy to include, as a separate part of the annual report required under the

Department of Energy Organization Act (Public Law 95-91), an examination and analysis of activities pursuant to the 1980 fusion act. DOE has yet to comply with this requirement. According to a DOE official within the Office of Fusion Energy, the 1981 annual report was written before the act was passed and therefore did not address the fusion program. The 1982 annual report also did not address the fusion program because, according to this official, it was written during a time of budgetary uncertainties. However, DOE is currently preparing the 1983 annual report and is working to satisfy the act's requirement.

DOE CONTINUES TO ENCOURAGE PRIVATE INVOLVEMENT IN THE NUCLEAR FUSION PROGRAM

One objective of the 1980 act is to foster cooperation in magnetic fusion research and development among government, universities, industry, and national laboratories. Consequently, the Secretary is also required to assure that technical information relevant to the status and progress of the national magnetic fusion program is made readily available to interested persons in domestic industry and universities in the United States.

Although most of the research in nuclear fusion is funded by the Government, both industry and universities are actively involved in the magnetic fusion program. For example, GA Technologies, Inc., currently operates a tokamak-type fusion device called the Doublet III. Similarly, McDonnell Douglas Astronautics Company is the prime contractor for the ELMO Bumpy Torus facility. The company will be responsible for the design, construction, operation, and management of the facility if it once again receives sufficient DOE funding. Officials and scientists from industry are in frequent contact with DOE program officials. They also attend, and actively participate in, technical meetings and fusion seminars sponsored by DOE and others.

GA Technologies, Inc., and McDonnell-Douglas are not the only companies actively involved in the fusion program. Numerous others are also currently involved, primarily as equipment suppliers, but increasingly in design and management activities. Further, DOE intends for industry to become more involved in the design, construction, operation, and management of fusion facilities.

University involvement is also widespread. For example, the Princeton University Plasma Physics Laboratory is the site of the Tokamak Fusion Test Reactor. The Massachusetts Institute of Technology has programs involving both tokamak and mirrors fusion devices. The program directors and scientists involved in these university fusion programs also actively participate in and/or chair fusion seminars or panels sponsored by DOE and other groups.

Besides participation in a variety of conferences and joint projects, DOE tries to respond to all public inquiries about fusion energy. Information can be obtained either through the Office of Fusion Energy or through the Office of Public Affairs. The Office of Fusion Energy will generally respond in writing to a request for information. The Office of Public Affairs will provide, on request, whatever printed matter it has available on fusion energy.

CONCLUSIONS

Several factors, such as funding constraints and the reevaluation of program strategy, have delayed DOE's fulfillment of some of the act's management requirements. These include preparing a comprehensive program management plan, planning for a national magnetic fusion engineering center, establishing a technical panel, and annually reporting on the program's activities. In other areas DOE has complied with the act. It is pursuing international cooperative agreements; it has assessed the supply of engineers and scientists; and it provides information to industry and academia.

We believe that the preparation of a comprehensive program management plan is the most important management requirement of the act. DOE, citing funding uncertainties, delayed initiating the plan and has yet to submit it to the appropriate congressional committees. Its issuance has been further delayed by an extended review by both DOE and the Executive Office of the President. DOE hopes to submit the plan in the near future.

We believe that the program plan is the appropriate place to explain and justify DOE's evolving fusion development strategy. The program plan should clearly describe and justify the process and phases DOE hopes to follow to achieve the fusion program's objectives. Rather than be deterred by funding uncertainties, the plan should also be sufficiently flexible to adapt to changing funding levels. The timing of various program projects needs to be "mapped out" so that the Congress and other appropriate officials can constructively evaluate the program's progress and direction.

AGENCY COMMENTS

DOE, after reviewing a draft copy of the report, stated that it accurately assessed DOE's position and actions in the fusion program relative to the act. However, DOE also cited several statements which it believed needed to be clarified or corrected. We have modified the final report to reflect the agency's comments. Appendix I contains DOE's comments.

Department of Energy
Washington, D.C. 20545

MAR 17 1983

Mr. J. Dexter Peach
Director, Resources, Community and
Economic Development Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Peach:

The Department of Energy (DOE) appreciates the opportunity to review and comment on the GAO draft report entitled "Status of the Department of Energy's Implementation of the Magnetic Fusion Energy Engineering Act of 1980." We believe that the draft report accurately assesses the Department's position and actions in the fusion program relative to the Act. There are, however, a number of statements in the draft report that are incorrect or incomplete. The most significant of these statements are commented on below, and the full list of comments is being provided directly to members of the GAO audit staff.

The draft report refers to the Act and the Congress "envisioning a $20 billion program." Although the original House bill did contain this language, neither the Senate bill nor the Act contains such language. The draft report also indicates that the Department revised its FY 1983 program because funding had "reached only 70 percent of what the Act envisioned." This statement is misleading. DOE revised its fusion program beginning in 1981 when the FY 1981 and FY 1982 budgets were reduced from previous plans. The program revision was based upon the magnitude of the budget, not the percentage of the Act's projection.

In discussions of the Mirror Fusion Test Facility-B (MFTF-B) project, the draft report states that the project will demonstrate scientific breakeven. MFTF-B is designed to study reactor-like mirror plasmas in hydrogen and deuterium, not deuterium and tritium, so that the statement should say "equivalent scientific feasibility" rather than "scientific breakeven." Also, the draft report states that the delay in MFTF-B construction will make the selection between tokamaks and mirrors by 1987 unlikely. The Department's strategy for fusion is based upon making a selection between the long-pulse tokamak and the tandem mirror after both concepts have explored reactor-level plasma conditions; this exploration is presently scheduled to occur by 1988, but it is clearly the technical preparation rather than a given date that governs the decision.

In making reference to the views of the National Research Council and the Magnetic Fusion Advisory Committee (MFAC) on the role of alternate concepts, the draft report uses the terms "questioned", "concerned", and "warned" and also presents a quotation that MFAC "does not consider the present balance between the mainline and alternate concepts to be appropriate..." These terms and the quotation are not correct. The two groups acknowledged the status of alternate concepts and said that continued attention was prudent; there certainly was no questioning or warning. The quotation is from a subordinate panel report to MFAC which appeared in the minutes of an MFAC meeting but did not become accepted by MFAC as part of its statement to the Secretary.

With regard to the delay in the issuance of the comprehensive program management plan, the draft report should indicate that the extended review is being done by both the Department and the Executive Office of the President, not just the latter.

In another section, the draft report states that "most of DOE's efforts are now directed at the actual construction of a device that will sustain and control a nuclear fusion reaction." This statement is incorrect. If the reference is to the Tokamak Fusion Test Reactor (TFTR), then the program is devoting less than 25%, certainly not "most", of its resources to the TFTR program whose objective is the scientific feasibility demonstration. If the reference is to the engineering facility being considered for the next decade, then the fraction of the program devoted directly to this effort is a few percent, certainly not "most". The draft report also states that TFTR is the device with which DOE plans to demonstrate scientific feasibility by 1986; the schedule calls for these experiments "in" 1986 rather than "by" 1986. Further, with regard to TFTR, the draft report cites a statement in the DOE Inspector General report "which noted that there was no approved plan" that dealt with the overall completion of TFTR. While the citation is strictly correct, its use in the draft report is somewhat misleading without including the dissenting view of the Director of Energy Research whose statement that he "did not agree, however, that there was not an approved plan" for TFTR completion follows directly in the Inspector General's Report.

In a discussion about the end-of-decade concept selection, the draft report states that unless vigorous mirror development is conducted, "... DOE may be prematurely committing itself to the tokamak concept for commercial development before it has had the opportunity to adequately assess the advantages and disadvantages of other concepts." This analysis makes an incorrect assumption that the near term concept selection is for commercial development; it is not. The end of decade concept selection is for the engineering test reactor core. As stated earlier, the selection date will be based upon technical readiness, not a given schedule. Furthermore, alternate concepts would be pursued beyond that selection to ensure the widest possible development and assessment before commercialization decisions would be made.

Finally, the statement that "the Department conducts cooperative fusion activities through two international organizations, the International Atomic Energy Agency and the International Energy Agency" should be continued with the phrase "and two formal bilateral Agreements with the Japanese and the Soviets."

DOE appreciates the opportunity to comment on this draft report and trusts that GAO will consider the comments in preparing the final report.

Sincerely,

Martha O. Hesse
Assistant Secretary for
Management and Administration

(302555)

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