123495

BY THE U.S. GENERAL ACCOUNTING OFFICE

Report To The Honorable Fortney H. Stark, Jr. House Of Representatives

The Impact Of International Cooperation In DOE's Magnetic Confinement Fusion Program

The U.S. fusion community participates in many cooperative projects with other countries conducting research in fusion energy--a new potential source of virtually unlimited nuclear power. Many of these projects involve routine exchanges of information. Others are pursued under formal agreements that allow U.S. and foreign scientists to participate in research at U.S. and foreign fusion facilities and may involve the contribution of funds and/or equipment.

U.S. fusion energy experts believe that international cooperative efforts benefit all participants and contribute to the advancement of U.S. fusion research objectives. International cooperative efforts, of themselves, do not directly affect the U.S. leadership position in fusion energy. Because fusion energy is in such an early stage of development, it is unlikely that any country could obtain a commercial advantage from information obtained from ongoing international cooperative efforts.

GAO/RCED-84-74

FEBRUARY 17, 1984

Request for copies of GAO reports should be sent to:

U.S. General Accounting Office
Document Handling and Information
Services Facility
P.O. Box 6015
Gaithersburg, Md. 20760

Telephone (202) 275-6241

The first five copies of individual reports are free of charge. Additional copies of bound audit reports are $3.25 each. Additional copies of unbound report (i.e., letter reports) and most other publications are $1.00 each. There will be a 25% discount on all orders for 100 or more copies mailed to a single address. Sales orders must be prepaid on a cash, check, or money order basis. Check should be made out to the "Superintendent of Documents".

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

RESOURCES, COMMUNITY, AND ECONOMIC DEVELOPMENT DIVISION

B-210947

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

Dear Mr. Stark:

In a July 19, 1982, letter you requested that we address a number of issues relating to fusion energy--a potential new source of virtually unlimited nuclear power. At that time, we were conducting a review of the Department of Energy's (DOE's) implementation of the Magnetic Fusion Energy Engineering Act of 1980 (Public Law No. 96-386) in response to an earlier request from you. After completing the audit work for our April 1983 report,[1] we agreed with your office to focus our efforts on international cooperation in fusion energy development. Specifically, we agreed to address the following questions:

--What is the United States' policy and strategy for international cooperation in fusion energy development?

--What are the different types of fusion international cooperative efforts?

--What is the possible impact of international cooperative efforts on the United States' ability to maintain its world leadership position in fusion energy development?

--What problems have been encountered in international cooperative fusion efforts and how have these been resolved?

--What is industry's role in international cooperative fusion efforts?

To answer these questions, we focused on DOE's plan for fusion development and other relevant documents. We also interviewed cognizant DOE, Department of State, and Office of Science and Technology Policy officials. We also spoke with key national laboratory officials and representatives from the Japanese Embassy and the Commission of the European Communities. Appendix I includes a detailed explanation of our objectives, scope, and methodology.

---

[1] Status of DOE's Implementation of the Magnetic Fusion Energy Engineering Act of 1980 (GAO/RCED-83-105, Apr. 29, 1983).

DOE's Office of Fusion Energy directs the U.S. fusion research and development (R&D) program on which over $3.5 billion has been spent from fiscal year 1950 through fiscal year 1983. Throughout the program's history, the United States has participated in international cooperative efforts to enhance fusion R&D. Because of budget constraints, DOE officials expect to increase their participation in international cooperative efforts to further the program. In summary we found that:

--DOE's policy on international cooperation in fusion energy development is to participate in those activities which provide scientific and technical benefits to the U.S. program. DOE's participation in international cooperative activities is coordinated with the Office of Science and Technology Policy of the Executive Office of the President, and the Department of State to ensure that the projects are in conformance with the administration's energy research policy and are politically and diplomatically acceptable. According to DOE officials, all international efforts are designed to contribute to DOE's fusion R&D program but are not considered critical to continued progress in the U.S. fusion program. Where feasible, DOE also strives to reduce the building and operating costs of facilities through international cooperation. To further identify and evaluate international options for the fusion program, such as joint construction projects, DOE has contracted with the National Academy of Sciences for a study of various aspects of international fusion activities.

--U.S. fusion scientists and program officials participate in numerous international cooperative efforts covering a broad spectrum of scientific and technical matters with the other countries conducting major fusion energy research and development programs--Japan, the Soviet Union, and the European Community. Many of these international cooperative efforts involve the routine exchange of information during conferences or through publication in scientific and technical journals. In addition, U.S. personnel periodically visit and participate in research at fusion facilities in other countries and, in turn, host visits of foreign fusion scientists at U.S. research and development facilities. The U.S. program is also involved in three joint projects arranged through formal government-to-government agreements, with Japan. Under those agreements, Japan is contributing about $84 million over a 10-year period to the operation of three research facilities in the United States in exchange for experimental time for Japanese scientists.

--At this time, the United States is generally regarded by U.S. fusion experts as the world leader in fusion energy R&D. This position is in jeopardy as other countries, particularly Japan and the European Community, pursue ambitious national magnetic fusion R&D programs. However, it is the general belief of these experts that all participants benefit from international cooperative efforts. Therefore, international cooperative efforts, of themselves do not directly affect the U.S. leadership position in fusion energy development. These experts also believe that fusion R&D is at such an early stage of development that it is highly unlikely any country could use, to its commercial advantage, information obtained during an ongoing international cooperative effort.

--The U.S. and foreign fusion energy experts we spoke to generally acknowledged that there is excellent cooperation in international cooperative activities between the United States and the other major participants. Problems, such as the timing of the release of research data, have generally been effectively resolved informally among the participants themselves.

--U.S. industry's role in international fusion cooperative projects is limited by cost and risk factors. In the overall U.S. fusion R&D program, the private sector is generally involved only in constructing facilities and fabricating components for DOE. In contrast, Japanese industry plays an active role in planning, designing, constructing, and operating Japan's fusion R&D facilities. This difference may give Japan a significant advantage as fusion energy development approaches commercialization.

Appendix I also contains a brief overview of DOE's fusion program and provides detailed answers to the questions we addressed.

- - - -

DOE and the Department of State believe that this report is a fair and accurate discussion of the topic. The views of appropriate officials of each agency and those of the Office of Science and Technology Policy have been incorporated in the report. Their complete comments are included in appendixes II, III and IV. As arranged with your office, we plan to make no further distribution of this report until 7 days after its issuance, unless you make its contents public. At that time, we will send copies to the Secretary of Energy and make copies available to others upon request.

Sincerely yours,

J. Dexter Peach
Director

Contents

ABBREVIATIONS

DOE	Department of Energy
GAO	General Accounting Office
OSTP	Office of Science and Technology Policy
R&D	research and development

INTERNATIONAL COOPERATION IN DOE'S MAGNETIC CONFINEMENT FUSION PROGRAM

By letter dated July 19, 1982, Representative Fortney H. Stark asked us to address a number of issues relating to fusion energy. After completing audit work on an ongoing review of the implementation of the Magnetic Fusion Energy Engineering Act of 1980 (Public Law No. 96-386),[1] we agreed with his office to focus our efforts on international cooperation in fusion energy development. Specifically, we agreed to address the following questions:

--What is the United States' policy and strategy for international cooperative efforts in fusion energy development?

--What are the different types of fusion international cooperative efforts?

--What is the possible impact of international cooperative fusion efforts on the United States' ability to maintain its world leadership position in fusion energy development?

--What problems have been encountered in international cooperative fusion efforts and how have these been resolved?

--What is industry's role in international cooperative fusion efforts?

OBJECTIVES, SCOPE, AND METHODOLOGY

To answer these questions, we interviewed cognizant DOE and national laboratory officials. For example, to obtain information about policy relating to international cooperation, we interviewed officials from the three agencies responsible for establishing this policy--the Department of Energy (DOE), the Department of State, and the Office of Science and Technology Policy (OSTP). In particular, to determine DOE's strategy for international cooperation, we interviewed officials from DOE's Office of International Affairs and the Office of Fusion Energy. In addition, we reviewed DOE's Comprehensive Program Management Plan, which describes DOE's policy and strategy on international cooperation.

To obtain information on (1) the different types of international cooperative efforts and how they relate to DOE fusion program objectives, (2) the impact of international cooperation on the United States' leadership position, and (3) problems encountered, we interviewed program officials and project managers at DOE's Office of Fusion Energy and DOE's main fusion research

---

[1]Status of DOE's Implementation of the Magnetic Fusion Energy Engineering Act of 1980 (GAO/RCED-83-105, Apr. 29, 1983).

facilities--the Lawrence Livermore and Oak Ridge National Laboratories, the Princeton University Plasma Physics Laboratory, and the Massachusetts Institute of Technology Plasma Fusion Center. To understand private industry's role, we interviewed officials from Westinghouse, Inc.; Union Carbide; and GA Technologies, Inc.

In addition, we reviewed relevant documentation, including congressional testimony, international cooperation agreements, data on personnel exchanges, and material prepared for a 1981 National Science Foundation workshop on international cooperation in fusion energy development.

Japan, the European Community, and the Soviet Union are the other countries with major fusion programs. The United States participates in cooperative efforts with each of them, as well as with Switzerland, Canada, and China. Personnel exchanges also occur with several other countries. We met with representatives from the Japanese Embassy and the Delegation of the Commission of the European Communities to obtain their views on international cooperative efforts in fusion research and development (R&D).

We conducted our review between May and September 1983 in accordance with generally accepted government auditing standards.

OVERVIEW OF THE U.S. MAGNETIC CONFINEMENT FUSION[2] PROGRAM

The United States, through DOE and its predecessor agencies--the Energy Research and Development Administration and the Atomic Energy Commission--has spent over $3.5 billion on fusion R&D efforts from fiscal year 1950 through fiscal year 1983. DOE's Office of Fusion Energy currently funds and directs the nation's fusion energy program. It also coordinates the R&D efforts of several national laboratories, some industrial participants, and

[2]Fusion energy is a from of nuclear energy that results when atoms of light chemical elements that have been heated and confined combine to form heavier elements and, in the process, release energy. It is, in effect, the opposite of nuclear fission, which powers today's reactors. During fission, atoms of heavy chemical elements are split, releasing energy. 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 in magnetic fields, where it is heated to the extreme temperature needed to initiate a fusion reaction. Inertial confinement uses lasers and particle beams to initiate a fusion reaction. This report only addresses the magnetic confinement fusion program. Another DOE program is investigating inertial confinement, primarily for its military applications.

many universities. DOE is concentrating its R&D resources on two mainline concepts--tokamaks and mirrors.[3] The following table identifies the principal tokamak and mirror fusion devices, their locations, and their fiscal year 1984 budgets including funds for both operating expenses and capital modifications.

Tokamaks	Location	1984 Budget
		(millions)
Tokamak Fusion Test Reactor	Princeton University Plasma Physics Laboratory Princeton, N.J.	$97.9
Doublet-III	GA Technologies, Inc. San Diego, Calif.	32.5
Princeton Large Torus and Poloidal Divertor Experiment	Princeton University Plasma Physics Laboratory, Princeton, N.J.	18.1
Alcator-C	Massachusetts Institute of Technology, Cambridge, Mass.	9.0
Mirrors		
Tandem Mirror Experiment, and its upgrade	Lawrence Livermore National Laboratory, Livermore, Calif.	22.7
Mirror Fusion Test Facility (under (construction)	Lawrence Livermore National Laboratory, Livermore, Calif.	54.8
TARA Tandem Mirror	Massachusetts Institute of Technology, Cambridge, Mass.	7.6

---

[3]The two mainline magnetic confinement approaches are categorized 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. Because of promising experimental results, tokamaks are the toroidal devices being examined most extensively, both in the United States and in other countries. Open magnetic confinement systems are generally referred to as mirrors. They consist of a long tube with large magnets at each end that reflect back and contain the fusion fuel.

On October 7, 1980, the President 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 R&D objectives such as demonstrating the engineering feasibility of magnetic fusion by the early 1990's.

Even though actual funding for fusion R&D has remained relatively high--$466.1 million in fiscal year 1983--the act envisioned funding at $615 million for fiscal year 1983 and $788 million by fiscal year 1988. Past and expected budget constraints have and will cause delays in DOE's fulfilling some of the act's requirements.[4] As budget constraints tighten, and the costs of large, more advanced fusion facilities increase, DOE officials have stated that they will be more dependent on international cooperative efforts to further the nation's fusion program.

POLICY AND STRATEGY FOR INTERNATIONAL COOPERATION IN FUSION ENERGY R&D

U.S. policy on international cooperative efforts in fusion energy research and development is formulated by three agencies: OSTP, the Department of State, and DOE. Participation in international cooperative research projects has to be consistent with administration interests and foreign policy. Administration interests are conveyed to DOE by OSTP and those related to foreign policy by the Department of State. The Department of State helps to ensure that proper diplomatic protocol is followed in negotiating an agreement and that an agreement is consistent with U.S. foreign policy.

DOE's policy on international cooperation in fusion energy development is described in its June 1983 Comprehensive Program Management Plan developed in response to Public Law 96-386. Briefly, that policy is that the United States participate, through the Office of Fusion Energy, in those international cooperative efforts which (1) benefit the overall fusion program and (2) allow the United States to maintain its leadership position in fusion activities. International cooperative efforts are used to complement the U.S. fusion program and, where feasible, reduce program costs by sharing the expense of building and operating selected facilities.

---

[4]For further information on the status of DOE's fusion R&D program, see our April 29, 1983, report, Status of DOE's Implementation of the Magnetic Fusion Energy Engineering Act of 1980 (GAO/RCED-83-105).

U.S. participation in a specific international cooperative effort may be motivated by technical or foreign policy considerations. DOE's Office of Fusion Energy routinely identifies opportunities for international cooperation which it perceives will benefit the fusion program technically. For example, in 1983 that office began negotiations with Germany for a joint fusion fuel impurity study when funding for the project was not included in the fiscal year 1983 budget. The Office of Fusion Energy also evaluates inquiries for cooperative efforts from its technical counterparts in other countries. Prior to entering into any agreement, DOE coordinates its plans, through its Office of International Affairs, with the Department of State to ensure that the proposed agreement is in consonance with the United States' overall foreign policy objectives. DOE does not enter into agreements that are diplomatically undesirable.

Occasionally, the Department of State also identifies fusion research opportunities which it perceives as enhancing relationships between participating countries. According to DOE officials, in those cases DOE tries to develop exchange efforts that will contribute to the U.S. program as well as meet diplomatic objectives.

International cooperation--a component of DOE's fusion program strategy

According to DOE officials, international cooperative efforts in the magnetic confinement fusion program have in the past provided valuable experience and information for U.S. fusion scientists. Further, because of the combination of projected high costs for more advanced fusion facilities and anticipated budget constraints, DOE expects international cooperation to assume an increasingly greater role in achieving the program's objectives. However, program officials stated that international cooperative efforts have been, and will continue to be, in areas which contribute to and complement, but are not critical to, continued progress in the U.S. fusion program. For example, the United States has extensive exchange programs with Japan involving peripheral aspects--computer modeling and diagnostics development--of its two mainline magnetic confinement fusion concepts.

The United States also participates in international cooperative exchanges to keep abreast of developments in alternative magnetic confinement fusion concepts. For example, it has informal arrangements with the European Community involving stellarator research activities. (Stellarators are another form of a toroidal fusion device.) The U.S. fusion program began with the stellarator concept in the early 1950's, but experienced many difficulties. The program shifted its emphasis to tokamaks in the late 1960's, after the Soviets achieved dramatic results using them. Now that stellarators are demonstrating renewed promise, U.S.

participation in this research provides U.S. scientists their main source of information on this concept.

An example of DOE's efforts to obtain budgetary relief through the use of international cooperative projects is its ongoing negotiations with potential partners to participate in the construction and operation of a fusion materials irradiation test facility. Fusion R&D facilities are expensive, and this test facility would be no exception; its cost is estimated to be over $100 million. The facility would expose various materials to intense neutron bombardment of the type that will occur in fusion reactors in order to identify those materials best suited for key components of fusion reactors. Although not considered essential at this time by DOE for continued progress on the mainline fusion concepts, it will ultimately be needed to identify the most suitable materials for constructing a prototype reactor.

All of these cooperative efforts serve to enhance the United States' understanding of fusion-related issues. But none, according to DOE officials, is critical to the continued progress of the fusion R&D program. According to DOE officials, without these projects, the U.S. program would still move forward, albeit with perhaps a greater risk of setbacks because of the narrower scope of research activity.

In light of the increasing likelihood of future constrained budgets, and the need for increasingly expensive fusion devices, DOE decided in 1983 to examine its strategy for the future role of international cooperation in the fusion area. Thus, DOE contracted in August 1983 with the National Academy of Sciences to perform a study exploring several aspects of international cooperation. The Academy, through its Committee on International Cooperation in Magnetic Fusion, will

--identify the most important issues in international cooperation in magnetic fusion energy development;

--review and discuss alternative courses of international cooperation, such as joint construction projects;

--review U.S. objectives for fusion energy development, and compare them with European and Japanese objectives to identify similarities and differences; and

--identify the long-term implications of alternative courses of international cooperation, and how they affect U.S. fusion development objectives.

The Academy expects to issue its report in October 1984.

INTERNATIONAL COOPERATIVE EFFORTS AND DOE'S STRATEGY TO ACHIEVE FUSION R&D OBJECTIVES

International cooperative efforts in the U.S. fusion program can be grouped into three broad categories: (1) information exchanges, (2) personnel exchanges, and (3) joint projects involving the transfer of funds or equipment. In the latter, one country contributes funds or equipment to another country's program to build or upgrade a facility in exchange for direct participation in the experimental activities at the facility. Within each of these broad categories, existing U.S. cooperative R&D efforts with the other countries that have major fusion programs cover a broad spectrum of scientific and technical areas.

Information exchanges

U.S. fusion scientists and program managers participate in numerous international cooperative efforts that primarily involve the exchange of information. This exchange often occurs at meetings, such as symposia, conferences, and workshops, or in the publication of information in technical journals. Meetings may vary in scope, both in terms of the material covered and in the number of participants involved. For example, the International Atomic Energy Agency[5] sponsors conferences, such as the biennial conference on fusion energy, which are attended by representatives from a worldwide membership. The conferences cover a variety of topics related to fusion energy research and development. Other meetings are much more focused, and are attended by a limited number of participants. In addition, information exchanges are carried out under International Energy Agency and bi-lateral arrangements.

The International Atomic Energy Agency also sponsors the International Tokamak Reactor workshop, a multinational study to produce an advanced tokamak reactor design. Under this study, the United States, Japan, the European Community, and the Soviet Union have met periodically since 1978 to define the characteristics of the next major tokamak facility. This facility would follow the current generation of large tokamaks such as Princeton's Tokamak Fusion Test Reactor and the Joint European Torus in Britain. Because of the myriad of problems involved in pursuing a large joint R&D construction project of this type, it is unlikely that such a facility will ever be built cooperatively. However, the

---

[5]The International Atomic Energy Agency is a United Nations organization that encourages the peaceful uses of atomic energy throughout the world. Its activities include organizing meetings, establishing nuclear activity safety standards, and advising governments on atomic energy programs.

study has been extremely useful in identifying design problems and enhancing the design talents of the participating countries.

Personnel exchanges

International cooperative personnel exchanges generally occur in two forms--visits and assignments. Visits are of short duration, i.e., several days to a few weeks, and involve a short-term admittance to one or more of a host country's facilities. The purpose of visits is to gain familiarity with the host country's fusion activities and facilities, but not to participate in experimental work. Assignments are of longer duration, i.e., several weeks, months, or years, and involve admittance to a single host-country facility. The purpose of assignments is to allow participation in actual experimental work to gain direct experience at a facility. During an assignment, the guest participants become members of the experimental team and engage in all aspects of experimental work, including planning and conducting experiments and analyzing results.

Visits may be arranged at several levels. For example, exchanges may be arranged at the national or university laboratory level, such as between the Princeton University Plasma Physics Laboratory or the Oak Ridge National Laboratory and a similar facility in Japan, Europe, or the Soviet Union. Personnel assignments may also be arranged under an international agreement under the auspices of an international organization such as the International Energy Agency,[6] or under a bi-lateral or multi-lateral international agreement.

Almost all of the personnel exchanges in the fusion program are with the other three major participants in magnetic fusion R&D--Japan, the European Community, and the Soviet Union. The United States has formal exchange agreements with Japan and the Soviet Union. The following table indicates that U.S. personnel exchanges with Japan occur about seven times more frequently than with the Soviet Union. DOE does not have accurate data for exchanges with the European Community because they are carried out on an informal basis.

---

[6]The International Energy Agency is part of the Organization for Economic Cooperation and Development. It is an alliance of 21 major oil-importing countries, including the United States, which was formed in November 1974 as part of an effort to reduce dependence on imported oil. It provides the legal framework enabling member countries to participate in international cooperative efforts to construct and conduct experiments at fusion research facilities. The International Energy Agency experiment-oriented activities in fusion complement those of the the International Atomic Energy Agency, whose activities are oriented toward information exchange.

Fusion Personnel Exchanges[a]

Japanese assignment-days[b] in the United States	2,170
U.S. assignment-days[b] in Japan	2,061
Soviet assignment-days[b] in the United States	380
U.S. assignment-days[b] in the U.S.S.R.	253

[a]Exchanges with Japan cover the year April 1983 through March 1984. Exchanges with the Soviet Union took place during calendar year 1983.

[b]"Assignment-days" refers to the total number of days all scientists spend in long-term assignments at all facilities. For example, if two scientists are assigned to a facility for 30 and 40 days respectively, the number of assignment-days is 70.

In the same time period, Japanese scientists will also spend an additional 4,100 days participating in the Doublet-III and Rotating Target Neutron Source joint projects described in the following section. In exchange for Japanese participation in these projects, the U.S. program is receiving about $84 million over 10 years.

Joint projects

Exchanges may also be arranged as joint projects under formal government-to-government bilateral or multilateral agreements. An example is the U.S.-Japanese bilateral agreement involving work on the Doublet-III fusion device located in San Diego, California. While Japan is benefiting from experimental time at this facility, the United States is benefiting from Japan's financial and technical contributions to the project. Under the agreement, Japan is contributing approximately $70 million to the Doublet-III project over a 5-year period. The Japanese funding contributions have allowed Doublet-III to be upgraded for advanced studies and have allowed an acceleration of its experimental timetable.

Another similar joint project is taking place at the Rotating Target Neutron Source facility at the Lawrence Livermore National Laboratory. Under this agreement, Japan is contributing approximately $9 million over a 5-year period in exchange for participation in the experimental work directed toward materials research for fusion reactors.

A third joint project with Japan was negotiated in November 1983. Under that agreement, Japan will contribute $5 million over 5 years to the operation of two fission reactors at the Oak Ridge National Laboratory in exchange for participation in ongoing fusion-related materials experiments at those reactors.

The only other fusion joint project is the Large Coil Project at the Oak Ridge National Laboratory. This project, arranged under the auspices of the International Energy Agency, is a multi--national effort involving the United States, Japan, Switzerland, and the European Community. Under this project, these countries are supplying large superconducting magnets--magnets that become excellent conductors of electricity at very low temperatures--to the Oak Ridge National Laboratory. Experiments are being conducted there to examine the performance of alternative designs in superconducting magnet technology, and to prove magnet design principles and fabrication techniques needed for the next generation of fusion reactors.

IMPACT OF INTERNATIONAL COOPERATIVE EFFORTS ON THE UNITED STATES' ABILITY TO MAINTAIN WORLD LEADERSHIP IN FUSION ENERGY DEVELOPMENT

At this time, the United States is generally regarded by U.S. fusion experts as the world leader in fusion energy development. This position is in jeopardy as other countries pursue ambitious magnetic fusion R&D programs. The fusion experts we talked to, however, do not believe that U.S. participation in international cooperative R&D projects directly affects its leadership position because all countries are benefiting from them, and because the construction of a commercial fusion reactor is so far in the future. Rather, leadership will depend on the United States' future commitments to its program compared with other nations' commitments to their programs.

According to the head of the experimental division at the Princeton University Plasma Physics Laboratory, the United States is the world leader in fusion R&D because it has constructed and is operating a fusion device which most closely approximates a commercial fusion reactor--the Tokamak Fusion Test Reactor at Princeton. However, both Japan and the European Community are constructing larger, more ambitious tokamak devices which will be in operation in the near future.

Leadership in the 1990's will depend on which country makes a commitment to a new, larger, more advanced fusion project to follow the current generation of fusion devices. Both Japan and the European Community are already designing and have definite plans to construct a next-generation fusion device. The United States does not yet have definite plans for such a device.

DOE's Comprehensive Program Management Plan for fusion development cites as one of its objectives the preparation of an engineering development program to follow the anticipated demonstration of the scientific feasibility[7] of fusion energy on Princeton's Tokamak Fusion Test Reactor. One way of implementing the engineering development program would be to construct a large-scale engineering device as the next major fusion reactor. DOE identifies this next reactor in the fusion program as an Engineering Test Reactor, but has not at this time defined its characteristics. This, according to DOE officials is partly due to the program's constrained budget, which has caused delays in developing the information necessary to define the next reactor in the U.S. fusion program.

DOE, national laboratory, and university fusion experts feel that all participants have benefited from international cooperative efforts. These experts also firmly believe that fusion R&D is so far from construction of a commercial reactor that it is unlikely any country could take information obtained in an exchange program and exploit it to its advantage. Therefore, they believe that international cooperative efforts will not directly affect the United States' leadership position. Rather, the degree of commitment and funding given the program in comparison with other countries' national efforts will determine who retains fusion development leadership.

The way in which a country benefits from international fusion projects depends on each participant's area of expertise. The U.S. program, for example, has benefited from exchanges with the Soviet Union because of its expertise in fusion theory. The tokamak confinement concept, currently the lead magnetic confinement fusion concept in the world, was developed by the Soviets and openly shared with scientists from the United States and other countries. Other aspects of the U.S. program have benefited similarly from exchanges of information with the Soviet program. These include exchanges relating to plasma[8] theory, mirror confinement, and compact toroids. Additionally, U.S. fusion experts noted that Soviet theoreticians often offer a totally different perspective and methodology for the solution of fundamental fusion problems.

---

[7]Demonstrating scientific feasibility for fusion means simultaneously achieving the temperature and confinement conditions necessary for a fusion reaction to occur and producing as much energy as is needed to sustain it.

[8]Plasma is the name given to the very hot, electrically charged gaseous form of the light chemical elements that combine in the fusion process.

The U.S. program has similarly benefited from cooperative efforts with Japan and the European Community. For example, it has benefited from Japan's financial and technical contributions to the GA Technologies and Lawrence Livermore projects. In addition, cooperation with Japan has provided valuable insight into the role of industry in fusion energy development, and Japan's ability to adapt, and improve upon, technological innovations from the U.S. fusion program. As noted previously, the United States is keeping abreast of advances in stellarators through exchanges with the European Community, as well as with Japan and the Soviet Union.

The foreign programs have also benefited from U.S. participation in international cooperative efforts. At a minimum, the foreign programs have benefited from U.S. technological advances in plasma-heating techniques, materials studies, and the development of the mirror and bumpy torus[9] concepts. Foreign efforts have also benefited from the U.S. program's fundamental advances in tokamak confinement physics.

PROBLEMS ENCOUNTERED

DOE fusion program officials and Japanese and European Community representatives state that there has been excellent cooperation among participants in international fusion R&D efforts. In all cases, once an agreement had been reached, the participants endeavored to adhere to its letter and intent. Any problems encountered after an agreement had been signed have been relatively minor. Problems have generally been resolved informally among the participants.

When preparing an agreement, participants attempt to preclude problems of a substantive nature from occurring. Thus, an agreement should clearly define each participant's rights and responsibilities before it is signed. Agreements, as a rule, establish committees to resolve any substantive problems that may occur.

Negotiation of an agreement can, at times, take more time to complete than is initially expected, for after technical scope of the cooperative efforts has been selected, agreement must still be reached on terms and conditions with respect to the liability of each participant, the treatment of intellectual property, and various procedures for the implementation of the particular program or projects under the agreement. Since the Freedom of Information Act is unique to the United States, the handling of

---

[9]Bumpy torus is an alternative magnetic confinement fusion concept. It is a hybrid (tokamak-mirror) device in which short mirror segments are connected in a circular configuration.

information also has to be carefully worked out. International cooperative efforts also require more time to implement than a comparable domestic effort. Not only do the distances involved make communications more difficult but each nation also has its own way of conducting such exchanges. The inherent political importance of these projects also necessarily requires the increased attention of program management.

In the first years of the implementation of the exchanges with the Soviet Union, misunderstandings arose over what each side wanted and expected in an exchange. This problem in communication has been resolved by first reaching agreement in writing on the details of the itinerary of the exchange, subjects to be discussed, personnel to be contacted, procedures for the exchanges of materials or equipment, and so forth. Since this procedure was implemented beginning in late 1979, exchanges with the Soviet Union have been comparable to those with Japan or the European Community.

INDUSTRY'S ROLE

With the exception of GA Technologies, Inc., private industry's role in the U.S. fusion R&D program is primarily that of a supplier to DOE-supported laboratories. Industry constructs facilities and fabricates components which conform to DOE contract specifications. It is not involved to any significant degree in the planning, design, or operation of fusion R&D facilities. The basic reason for this is that fusion R&D remains essentially a high-risk, very expensive scientific endeavor, still far removed from commercialization. According to DOE and industry representatives we talked to, industry does not feel it can undertake such large investments since the return is so distant and uncertain. Consequently, the program is funded by the federal government and conducted primarily at national laboratories and universities.

The participation of GA Technologies, Inc., in the fusion program is unique. While it is a private company, it conducts fusion R&D activities for DOE. The Doublet-III project funded by DOE is located at GA Technologies' facilities at La Jolla, California, and is a major component of DOE's tokamak research effort.

In contrast to the United States, many Japanese companies are significantly involved in Japan's fusion program. Engineers and scientists from Japanese industry participate in the planning, design, construction, and operation of fusion facilities. A recent report to DOE evaluating the United States-Japan fusion energy exchange program[10] states that Japan's institutional framework allows much greater industrial involvement in the Japanese program. The report also states that this difference is

---

[10] Collection of Background Information on the U.S.-Japanese Fusion Energy Exchange Program (Apr. 30, 1983).

a concern of U.S. fusion scientists. These scientists cite the Japanese industry's past successes in converting U.S. technological innovations into first-rate "products." The report predicts that the Japanese industry, because of its early involvement in fusion energy development, may eventually become the world supplier of fusion reactors.

DOE, in September 1983, asked its own Magnetic Fusion Advisory Committee to examine the role of industry in the fusion program. The committee, formed by DOE in May 1982, includes fusion experts from industry, academia, and the national laboratories and is charged with advising DOE on fusion development consistent with Public Law 96-386 objectives in a period of budget constraints. DOE expects the report to be completed by May 1984.

Department of Energy
Washington, D.C. 20585

1984

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 "The Impact of International Cooperation on the United States' Magnetic Confinement Fusion Program." The draft report is a fair and accurate discussion of the topic. This view is shared by the Department of State.

Sincerely,

Martha O. Hesse
Assistant Secretary
Management and Administration

Enclosure:
Revised Draft GAO Report

DEPARTMENT OF STATE
Comptroller
Washington, D.C. 20520

13 JAN 1984

Dear Frank:

I am replying to your letter of Decmeber 29, 1983, which forwarded copies of the draft report: "The Impact of International Cooperation on the United States' Magnetic Confinement Fusion Program."

The enclosed comments on this report were prepared in the Bureau of Oceans and International Environmental and Scientific Affairs.

We appreciate having had the opportunity to review and comment on the draft report. If I may be of further assistance, I trust you will let me know.

Sincerely,

Roger

Roger B. Feldman

Enclosure:
As stated.

Mr. Frank C. Conahan,
Director,
National Security and
International Affairs Division,
U.S. General Accounting Office,
Washington, D.C. 20548

GAO REPORT: "THE IMPACT OF INTERNATIONAL COOPERATION ON THE UNITED STATES' MAGNETIC CONFINEMENT FUSION PROGRAM"

We have given you most of the comments contained below orally and understand that they were incorporated in a later version of the study that we have not received. The memo below is for the record.

We find the report generally accurate; its brevity, however, may result in some misleading conclusions. For example singling out the INTOR project of the IAEA as the sole example of information exchanges gives this activity an inappropriate amount of emphasis; information exchanges carried out under IEA or bilateral arrangements are considerably more voluminous.

Specific suggestions that might clarify other portions of the report follow:

Appendix 1, Page 4, para 3, line 6
Insert "those related to foreign policy by" between "and" and "the". This insertion would describe more accurately the role of the Department of State.

Line 6

Eliminate the sentence beginning with "OSTP" and ending with "agreement".

This sentence is inaccurate.

Page 5, para 1, line 13

Insert "in consonance with our overall foreign policy objectives" in place of "diplomatically acceptable."

This change would reflect more accurately the role of the Department of State.

Page 5, para 2, lines 1-3

Insert the word "occasionally" before "The Department..." Eliminate the phrase "desirable for foreign policy reasons will"...

[GAO note: Page references in this appendix were changed to reflect their location in this final report.]

These changes would correct any impression that the Department of State sometimes encourages international fusion agreements for foreign policy benefits alone, State recognizes technical agreement should be based primarily on technical benefits to the participating program Agency.

James L. Malone
Assistant Secretary
Bureau of Oceans and International
Environmental and Scientific
Affairs

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

January 19, 1984

Dear Mr. Peach:

As requested in your letter of December 29, 1983, we have reviewed the GAO draft report entitled "The Impact of International Cooperation on the United States' Magnetic Confinement Fusion Program."

We basically agree with your description of U.S. policy for international cooperative efforts in fusion energy development and of the effectiveness and impact of existing bilateral programs to advance fusion science. I would like to make two suggestions. The first is a specific addition regarding OSTP's role in energy policy -- on Page 2, in in the third paragraph the second sentence should read, "... to ensure that the projects are in conformance with the Administration's energy research policy, and are politically and diplomatically acceptable." The second suggestion is general and affects several parts of the report. The text mentions that much of the international cooperation in the fusion programs could be considered complementary but not critical to the progress of U.S. programs. I believe the report should also recognize that when the U.S. agrees to participate in international projects, it does so on the basis that they are an integral part of U.S. program planning and that they will contribute to the advancement of U.S. fusion objectives.

If in the future you should draw any conclusions or make any recommendations regarding this study, we would be happy to review and comment once again.

Thank you for providing us the opportunity to review your draft report. Let us know if we can be of further assistance.

Sincerely,

Wallace R. Kornack

Wallace R. Kornack
Assistant Director

Mr. J. Dexter Peach
Director
United States General
Accounting Office
Washington, D.C. 20548

(301624)

27511

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES
GENERAL ACCOUNTING OFFICE
WASHINGTON, D C 20548

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE,$300

POSTAGE AND FEES PAID
U S GENERAL ACCOUNTING OFFICE

THIRD CLASS