INTERNATIONAL FUSION ENERGY ACT OF 1993

THURSDAY, MAY 6, 1993

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 10:04 a.m. in room SD–366, Dirksen Senate Office Building, Hon. J. Bennett Johnston, chairman, presiding.

OPENING STATEMENT OF HON. J. BENNETT JOHNSTON, U.S. SENATOR FROM LOUISIANA

The CHAIRMAN. Good morning. I have a statement which is, I think, quite good which I will put into the record. But I wanted to say that this is my 21st year on this committee. It is my, I think, 19th year on the Energy and Water Appropriations Subcommittee, both of which have jurisdiction over magnetic fusion. I have been a long-time supporter of magnetic fusion. Indeed, we have spent some $10 billion on magnetic fusion.

It is, however, my very strong feeling that the time has come to decide whether or not magnetic fusion is worth pursuing. I ardently believe that it is. But if it is, then I am also strongly convinced that the way to do it is through the international arena. The benefits of magnetic fusion, if it can be commercialized, if it is the hope of the 21st century or the middle of the 21st century, will enure to all countries and all people everywhere. It should not be a burden that the United States should take on itself, even if we could afford it.

That is why I have introduced S. 646, which is designed to require the country, and particularly the Congress, to make a decision whether it is willing to go ahead with magnetic fusion. We are very much like the young man in college who, in his 7th or 8th year, still does not have a major, and his father writes him and tells him son, it is time to make up your mind or go to work.

It is time for us to make up our mind on magnetic fusion, in my view, and if we do not know enough, if we cannot safely make a decision, then perhaps it should be relegated to one of those nice subjects where we spend a few bucks, not much, and continue to study it at college and, in effect, put it on the shelf.

I do not believe we should put it on the shelf. But I believe we should stop this business of spending half a billion dollars a year or more in building new and exotic machines all around the country without focusing in on the central decision—ITER, the international tokamak experiment. That is we should decide whether we are going to build ITER.

Now, in order to do that, the administration must focus on ITER. I do not know that anyone in the administration at the highest levels who has focused on ITER and made a decision. Because if we are going to pursue ITER, we must make some fundamental decisions. First, are we willing to embark on our share of this $7 or $8 billion experiment, whatever the cost is. I am sure Dr. Rebut can tell us what the cost is.

And then secondly, do we insist on having it in this country. My own view is that the country who hosts ITER, in whose geographical boundaries ITER will be built, should pay the lion's share of it. Now, are we willing to pay, say, 60 percent of the cost of it in order to have it here? Or are we willing to pay 20, 25, 30 percent, whatever the figure would be, if it is in Japan?

Or can we find a way to divide up the responsibility for it and the development largess of it in such a way that even if it is in Japan we can build enough of the components to make it attractive to the other countries? I guess we can call it academic pork or whatever, but it is real jobs and real benefit for a country. I mean, these are the things that—this is the stuff of which political decisions are made.

These kinds of decisions need to be focused in on and focused in on now, before we proceed, in my judgment, to decide to build TPX or whatever. Because otherwise we just drift along year after year after year, and you can hear the Congressional critics saying whenever that decision time is, as some are trying to say now on SSC, oh, we cannot afford that. We cannot afford to go into science.

It is to some extent the critics on SSC that motivate me so strongly to try to get the country to make up its mind now on ITER and on magnetic fusion. I believe that we know enough about magnetic fusion now that ITER, which is on the critical path, as I see it, toward commercialization—in other words, you have got to build ITER, or some machine like ITER, of comparable size. Some say it is to conservatively designed.

But we will let you scientists argue about the exact design and the conservatism. But you have got to do something like ITER in order to be able to get to the next demonstration and to commercialization. It simply must be done. And if we cannot, after $10 billion, decide that now, then we had better decide it one way or the other, yes or no.

I hope the answer is yes. But I will do what I can, in every way I can, to make this Government, this Congress, this country, decide now on whether it is serious about magnetic fusion, whether it is serious about this option. And if so, let us decide, and let us get packing, and let us understand it is going to cost some dollars, but that it is important to the United States, it is important to the world. it is important to global warming, it is important to all of those things to which we give lip service.

[The prepared statements of Senators Johnston and Wallop and the text of S. 646 follow:]

Prepared Statement of Hon. J. Bennett Johnston, U.S. Senator From Louisiana

Good morning. Today the Committee will receive testimony on S. 646, the "International Fusion Energy Act of 1993".

S. 646, which I introduced earlier this year, directs the Secretary of Energy to refocus the Department's magnetic fusion energy program on the design, construction and operation of the International Thermonuclear Experimental Reactor, also known as ITER.

Over the last four decades we have spent almost $10 billion exploring ways to produce electricity from magnetic fusion. Many different approaches have been studied. The decades and billions of dollars of research have narrowed the magnetic fusion energy path to one approach—ITER. The purpose of ITER is to determine whether we can build a fusion demonstration reactor to generate electricity in commercial quantities. ITER will tell us whether fusion is the energy source of the 21st century.

The ITER design effort is well underway. Last year, the United States entered into an agreement with Japan, Russia and the European Community to design ITER. I am pleased that the U.S. is an active participant in that effort. But we must also be ready to take the next step to see this project to fruition.

We are at the point that our magnetic fusion program must be focused entirely on ITER. The days of unfocused fusion research are over. We must develop a plan to tell us how to get to ITER. We need to develop a budget for ITER, we need to find a host site, and we need to establish milestones and schedules. In short, we need a critical path that will get us from here to there.

S. 646 commits the U.S. to such a process.

It is my firm belief that this restructuring is necessary if the U.S. is to be in the position to realize the full potential of this energy source in the next century.

But I also believe that we should not continue to spend substantial amounts of money studying the engineering problems associated with fusion if we cannot reach an agreement with the international community to develop ITER or if we decide ITER will not lead to a fusion demonstration reactor.

While some level of basic research in fusion would still be appropriate in the absence of ITER, it would not be appropriate to continue the level of effort of today. Therefore, the bill directs the Secretary to reduce the magnetic fusion energy program to a basic energy program in the event it becomes apparent that we cannot or should not proceed with ITER.

We are at a critical juncture for the magnetic fusion program. The fusion community has sounded the rallying cry to design and build ITER. This bill answers that cry by committing the U.S. magnetic fusion program to ITER.

We have a distinguished group of witnesses who, I hope, will tell us whether ITER is the way to go and, if so, what we need to do to get there.

I'm looking forward to hearing from the witnesses on this legislation.

Prepared Statement of Hon. Malcolm Wallop, U.S. Senator From Wyoming

Fusion, the physical phenomenon that powers the sun, has the potential of being an unlimited source of electricity generation for the nation. That tempting carrot has been driving a research program at the Department of Energy that in the past thirty years has cost over $8 billion. Yet, scientists estimate they are still another thirty years away from being able to demonstrate the commercial feasibility of fusion.

It is little wonder, then, that Senator Johnston has introduced the bill that is the subject of this hearing. Faced with shrinking revenues and a deficit that is growing like a cancer on the fiscal health of this country, we all search for ways to streamline and economize our programs. This bill is an attempt to do just that. But, we need the scientific experts to tell us whether we're on the right track in this program. We need to know how we can best channel scarce taxpayer dollars. If ITER should be the primary goal for the short term, then how do we ensure that other aspects of the program necessary to its ultimate success remain viable? These are all issues raised by this bill. Hopefully, the witnesses today will give us some guidance on the most effective use of the resources we are putting into the fusion program.

I commend you, Mr. Chairman, for proposing a very focused objective for the fusion program. I look forward to hearing the comments of these witnesses on your approach.

II

103D CONGRESS
1ST SESSION

S. 646

To establish within the Department of Energy an international fusion energy program, and for other purposes.

IN THE SENATE OF THE UNITED STATES

MARCH 24 (legislative day, MARCH 3), 1993

Mr. JOHNSTON introduced the following bill; which was read twice and referred to the Committee on Energy and Natural Resources

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A BILL

To establish within the Department of Energy an international fusion energy program, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "International Fusion Energy Act of 1993".

SEC. 2. FINDINGS, PURPOSES AND DEFINITIONS.

(a) FINDINGS.—Congress finds that—

(1) fusion energy has the potential to be a safe, environmentally attractive, secure and economically affordable source of energy;

(2) the United States Department of Energy's magnetic fusion energy program has made significant progress toward realizing fusion as a viable source of energy;

(3) other industrial nations have also invested in significant magnetic fusion energy programs;

(4) an integrated program of international collaboration will be necessary for continued progress to demonstrate the scientific and technological feasibility of magnetic fusion energy;

(5) there is international agreement to proceed with the engineering and design of the International Thermonuclear Experimental Reactor to prove the scientific and technical feasibility of fusion energy and to lead to a demonstration reactor;

(6) the United States should focus the Department of Energy's magnetic fusion energy program on the design, construction and operation of the International Thermonuclear Experimental Reactor;

(7) the continuation of an aggressive fusion energy program requires the Department of Energy, industry, utilities, and the international fusion community to commit to the International Thermonuclear Experimental Reactor as soon as practicable; and

(8) an effective United States fusion energy program requires substantial involvement by industry and utilities in the design, construction, and operation of fusion facilities.

(b) PURPOSES.—The purposes of this Act are to—

(1) redirect and refocus the Department's magnetic fusion energy program in a way that will lead to the design, construction and operation of the International Thermonuclear Experimental Reactor by 2005, in cooperation with other countries, and operation of a fusion demonstration reactor by 2025;

(2) develop a plan identifying the budget, critical path, milestones and schedules for the International Thermonuclear Experimental Reactor;

(3) eliminate from the Department of Energy's magnetic fusion energy program those elements that do not directly support the development of the International Thermonuclear Experimental Reactor or the development of a fusion demonstration reactor; and

(4) select a candidate host site within the United States for the International Thermonuclear Experimental Reactor and to identify the steps necessary to lead to the selection of the final host site by the international community.

(c) DEFINITIONS.—

(1) "Department" means the United States Department of Energy;

(2) "ITER" means the International Thermonuclear Experimental Reactor; and

(3) "Secretary" means the Secretary of the United States Department of Energy.

SEC. 3. INTERNATIONAL FUSION ENERGY PROGRAM.

(a) PROGRAM.—The Secretary shall redirect and refocus the Department's magnetic fusion program in a way that will lead to the design, construction and operation of ITER by 2005 and operation of a fusion demonstration reactor by 2025. The Department's magnetic fusion program shall be referred to as the ITER program and shall be carried out in cooperation with the international community.

(b) REQUIREMENTS.—In developing the ITER program, the Secretary shall—

(1) establish as the main focus of the Department's magnetic fusion energy program the development of ITER;

(2) provide for the development of fusion materials and other reactor components to the extent necessary for the development of a fusion demonstration reactor;

(3) eliminate those components of the magnetic fusion energy program not contributing directly to development of ITER or to the development of a fusion demonstration reactor;

(4) select a candidate host site within the United States for the International Thermonuclear Experimental Reactor;

(5) negotiate with other countries involved in ITER to select a final host site for ITER and to agree to construct ITER as soon as practicable;

(6) provide for substantial United States industry and utility involvement in the design, construction and operation of ITER to ensure United States industry and utility expertise in the technologies developed; and

(7) provide for reducing the level of effort in the ITER program to the levels prescribed in section 4(b)(2) in the event the ITER program is terminated in accordance with subsection (g).

(c) MANAGEMENT PLAN—(1) Within one hundred eighty days of the date of enactment of this Act, the Secretary shall prepare and implement a management plan for the ITER program. The plan shall be revised and updated biannually.

(2) The plan shall—

(A) establish the goals of the ITER program;

(B) describe how each component of the Department's TIER program contributes directly to the development of ITER or development of a fusion demonstration reactor;

(C) set priorities for the elements of the Department's ITER program, identifying those elements that contribute directly to the development of ITER or to the development of a fusion demonstration reactor;

(D) provide for the elimination of those elements of the magnetic fusion energy program not contributing directly to the development of ITER, or to the development of fusion materials or other reactor components that are necessary for the development of a fusion demonstration reactor;

(E) describe the selection process for a proposed host site within the United States for ITER;

(F) establish the necessary steps that will lead to the final selection of the host site for ITER by the countries involved in the ITER program by the end of 1996.

(G) establish the necessary steps that will lead to the design, construction and operation of ITER by 2005 and operation of a fusion demonstration reactor by 2025;

(H) establish a schedule and critical path, including milestones, and a budget that will allow for the design, construction and operation of ITER by 2005 and operation of a demonstration fusion reactor by 2025;

(I) provide mechanisms for ensuring substantial industry and utility involvement in the design, construction and operation of ITER;

(J) set forth any recommendations of the Secretary on—

(i) the need for additional legislation regarding the ITER program; or

(ii) the possibility and desireability of accelerating the design and construction of ITER or the development of a fusion demonstration reactor; and

(K) provide for reducing the level of effort in magnetic fusion to the levels prescribed in section 4(b)(2) in the event the ITER program is terminated in accordance with subsection (g).

(d) INTERNATIONAL AGREEMENTS.—(1) The Secretary may negotiate or enter into agreements with any country governing the design, construction and operation of ITER or facilities related to ITER.

(2) The Secretary shall seek to enter into agreements with other countries to share in the cost of the facilities and components of the ITER program that contribute to the design, construction or operation of ITER or to the development of a fusion demonstration reactor.

(e) REPORT ON ITER NEGOTIATIONS.—The Secretary shall submit an annual report to the Congress on the status of negotiations with other countries regarding ITER. The report shall—

(1) identify the issues to be negotiated with other countries involved in the ITER program;

(2) identify impediments to reaching agreement on a host site for ITER, or on issues related to the construction or operation of ITER;

(3) identify the steps needed to reach agreement on a host site for ITER or on issues related to the construction or operation of ITER;

(4) establish the timetable for agreement related to the siting, operation and construction of ITER;

(5) assess the likelihood of reaching agreement on a host site for ITER and on issues related to the construction or operation of ITER; and

(6) set forth the Secretary's recommendation on whether a special negotiator should be appointed to carry out negotiations on behalf of the United States with the countries involved in the ITER program.

(f) CERTIFICATION.—Prior to seeking funds for construction of ITER, the Secretary shall certify to the Congress that there is agreement in place or there is a substantial likelihood agreement will be reached with the countries involved in ITER on the siting, construction and operation of ITER.

(g) TERMINATION.—(1) The Secretary shall report to Congress if the Secretary determines that—

(A) ITER is no longer essential to the development of a fusion demonstration reactor;

(B) no agreement can be reached on the final host site for ITER;

(C) no agreement can be reached on the final design of ITER or on issues related to construction of ITER; or

(D) there is an insufficient commitment to the final ITER design by United States industry and utilities.

(2) Within thirty days of submission of the report under paragraph (1), the Secretary shall initiate the termination of the ITER program.

(3) In the event the Secretary terminates the ITER program, the Secretary may continue to carry out research in magnetic fusion, but only at the levels authorized in section 4(b)(2).

SEC. 4. AUTHORIZATION OF APPROPRIATIONS.

(a) LIMITATION ON APPROPRIATIONS.—No more funds may be appropriated to carry out the purposes of this Act than the amounts set forth in subsection (b). This Act shall be the exclusive source of authorization of appropriations to support any activities of the Secretary relating to magnetic fusion energy.

(b) APPROPRIATIONS.—(1) There is authorized to be appropriated to the Secretary for carrying out the purposes of this Act $350,000,000 for fiscal year 1994, $390,000,000 for fiscal year 1995, $475,000,000 for fiscal year 1996, and such sums as may be necessary thereafter.

(2) In the event the Secretary terminates the ITER program, there is authorized to be appropriated to the Secretary $50,000,000 for 1994, $50,000,000 for 1995 and $50,000,000 for 1996 for activities relating to magnetic fusion energy.

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The CHAIRMAN. I welcome this outstanding panel today, which I hope can help give us some answers. We will begin with Dr. James F. Decker, who is the principal Deputy Director of the Office of Energy Research of the Department of Energy, and a man who knows this area very well. Dr. Decker, we are delighted to have you here, and we look forward to your leading off this panel.

STATEMENT OF DR. JAMES F. DECKER, DEPUTY DIRECTOR, OFFICE OF ENERGY RESEARCH, DEPARTMENT OF ENERGY

Dr. DECKER. Thank you very much, Mr. Chairman. I am pleased to be here today to give the Department of Energy's views on the International Fusion Energy Act of 1993. I have submitted a written statement for the record.

The commercial production of electricity is the ultimate goal of the Department's magnetic fusion energy program. The Department's strategy for the development of magnetic fusion energy is focused on two intermediate goals, to have an operating demonstration powerplant by about 2025, and an operating commercial powerplant by about 2040.

The Department is pleased that the International Fusion Energy Act affirms a strategy to develop fusion as an energy source. The Department is also pleased that the bill recognizes the essential roles that will be played by the international thermonuclear experimental reactor and a demonstration powerplant in achieving the commercial production of electricity for magnetic fusion energy.

I would like to take this opportunity to emphasize, however, that reaching the goal of commercial power production will be unattainable without a strong domestic program within the United States. A strong domestic program in physics research and in the development of materials and technical components is necessary to support both ITER and a demonstration powerplant. Furthermore, a strong domestic program is necessary to ensure that American industry is poised to compete internationally in the construction of future fusion research facilities, fusion components, and powerplants.

A key component in maintaining a strong domestic fusion program will be the tokamak physics experiment, a national project being designed to replace the tokamak fusion test reactor at Princeton. TPX will help us reach the goals of a demonstration powerplant and a commercial powerplant by showing us how to design more compact, simpler, and cost-effective fusion reactors. It will also be a vehicle by which U.S. industry will become substantially involved in the design and construction of a major fusion facility.

On TPX, all major components will be designed and built by industry. This experience on TPX plus industry's R&D experience on ITER will prepare U.S. industry to play a major role in building ITER.

Before I conclude my remarks I would like to briefly raise two concerns that the Department has with the International Fusion Energy Act. The first is that the bill would eliminate all research not specifically focused on ITER or the demonstration reactor. The fusion program currently maintains a small effort devoted to the exploration of innovative ideas, primarily by leveraging small research activities in the United States with larger research efforts supported in other countries.

Since fusion is far from commercial development, the fusion program should retain the flexibility to pursue, on a limited basis, innovative ideas that may be more promising than the tokamak in the long term. We currently spend less than 3 percent of the magnetic fusion energy budget on these activities.

The second concern relates to the provision to reduce the magnetic fusion energy program to $50 million per year if ITER is terminated. The Department is concerned that the termination provision will substantially limit the positions that the United States can take in future negotiations with our international partners on ITER. This bill gives our partners, in my opinion, an unfair advantage in future negotiations. They will be well aware of the high price the U.S. fusion program will pay if the ITER negotiations fail.

I think the threat of termination will therefore make it difficult, if not impossible, for the U.S. negotiators to negotiate an equitable agreement for the United States. In the event that ITER is terminated, the Department would suggest that a plan be submitted to the Congress for a restructured fusion program.

Before concluding, I would like to take this opportunity, Mr. Chairman, to thank you for your support of this program over the years, and also to thank you for the attention that you have paid to this very important issue of the international thermonuclear experimental reactor.

Thank you for giving me the opportunity to comment on this bill.

[The prepared statement of Dr. Decker follows:]

PREPARED STATEMENT OF DR. JAMES F. DECKER, DEPUTY DIRECTOR, OFFICE OF ENERGY RESEARCH, DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Committee, thank you for the opportunity to present the views of the Department of Energy on the bill concerning fusion development, S. 646, the "International Fusion Energy Act of 1993." The bill establishes, as the main focus of the Department's magnetic fusion energy program, the development of the International Thermonuclear Experimental Reactor (ITER) project, and calls for the elimination of program elements not contributing directly to the development of ITER or to the development of a fusion demonstration reactor. The bill also provides for the development of fusion materials and other reactor components necessary for the development of a demonstration reactor. With respect to ITER, the bill calls for the selection of a candidate site within the United States, the negotiation with other countries of a final host site, and an agreement to construct ITER. The bill also calls for U.S. industrial and utility involvement in various phases of the project. Lastly, the bill stipulates that the program would be reduced to the annual level of $50 million in the event ITER is terminated.

We believe the bill is a constructive step in furthering the development of magnetic fusion energy for civilian purposes. However, we have some important modifications to suggest to the Committee and appreciate this opportunity to comment on the bill. I would like to discuss first the areas in which we strongly agree with the thrust of the bill, briefly describe how our program is now focused on the development of ITER and a demonstration reactor, and then address additional areas where we believe changes in the bill would strengthen the resulting fusion development program.

The world will need new sources of energy in the next century. Fusion has the potential to provide an economically affordable, abundant energy source with relatively attractive safety and environmental features. The development of fusion as an energy source could help the energy security of the United States, help ensure the continued economic growth potential of this nation in the future, and make us a supplier of energy technologies to other countries.

The potential of fusion has been recognized in the recently passed Energy Policy Act of 1992. This Act directs the Secretary of Energy to conduct a fusion energy program that ". . . by the year 2010 will result in a technology demonstration which verifies the practicability of commercial electric power production." President Clinton's "Vision of Change for America" states: "Fusion offers the promise of abundant energy from readily available fuels with low environmental impact."

The Department has established a policy to proceed with a goal-oriented program with specific milestones for the development of fusion energy. The objective of the technology demonstration cited in the Energy Policy Act is consistent with the Department's long-term goal of having an operating Demonstration Power Plant by about 2025, and having an operating commercial power plant by about 2040. Achieving these goals requires that we gain an understanding of the complex processes involved in fusion, and that we develop the materials, technologies, and the industrial infrastructure needed for the practical application of fusion energy. It also requires an increased, long-term funding commitment to assure a balanced, comprehensive program that is goal-oriented with specific milestones and objectives. We believe that the proposed legislation would be a positive step in that direction.

The Department has conducted several extensive program reviews which have concluded that the program's past accomplishments provide a sound basis for proceeding with fusion energy development to meet the goals we have established. However, continued progress requires the development, construction and operation of advanced, larger, and more costly facilities. Given the general funding constraints being experienced in fusion programs worldwide, it seems clear that the most effective means to realize our goals is through integrated programs of international collaboration to demonstrate the scientific and technology feasibility of fusion power. The U.S. has been, and continues to be, a leader in encouraging this approach by fostering international collaboration in all aspects of fusion science and technology development. This collaboration is exemplified by the ITER project, a four-party collaboration among the U.S., the European Community, Japan, and the Russian Federation. President Clinton has called ITER "the centerpiece of the research effort in magnetic fusion energy. . . ."

The objective of ITER is to demonstrate the scientific and technological feasibility of using magnetic fusion energy for the production of electricity. The four ITER international parties have embarked on a six-year phase of work to complete the design of the device and to conduct the related research and development. The formal ITER Agreement and its first Implementing Protocol were signed in July 1992. The cost to the U.S. of participating in this six-year design effort is estimated to be about $450 million in as-spent dollars.

While I must make clear that no commitment has been made by any of the parties to construct ITER, the project does play a pivotal role in our strategy to develop fusion as an energy source. If constructed, ITER would provide: (1) an important part of the physics data base needed for a demonstration power reactor; (2) actual operating experience with many of the reactor technologies needed for fusion power; and (3) an opportunity for major industrial involvement in the fusion program.

Solicitations have been made for the participation of industrial teams to work with the national laboratories in accomplishing the tasks assigned to the U.S. by the ITER Director. Already, contracts have been awarded to industrial teams that include General Dynamics, McDonnell Douglas, Rockwell, Pittsburgh-Des Moines, Westinghouse, Ebasco, CIMCORP, and Grumman to participate in the ITER research and development activities. In this way, knowledge about the ITER design and component development will be transferred to U.S. industry in order to prepare it to compete, successfully, for the construction of ITER.

At the end of the engineering design phase, all data necessary to make a decision on construction will be available to the international parties. While it had been assumed that the selection of a site for construction would come at the end of this six-year engineering design phase, an earlier decision could allow a smoother transition to construction and reduce costs. We believe that the proposed legislation will provide the impetus for the U.S. to seek an ITER candidate site and to support an early decision by the international parties to proceed with construction.

It is also necessary to continue to conduct a strong domestic program to support the ITER project and to allow the U.S. to be in a position to use the information gained from ITER for a follow-on demonstration power plant and, ultimately, for commercialization. Key elements of the U.S. domestic program include: the deuterium-tritium experiments in the Tokamak Fusion Test Reactor at the Princeton Plasma Physics Laboratory; the proposed Tokamak Physics Experiment (TPX) to improve the tokamak concept and to support ITER; and the development of the components and systems that will be used in ITER and in subsequent fusion reactors. I will briefly describe these below.

The chief U.S. experimental device is the Tokamak Fusion Test Reactor (TFTR). The introduction of tritium in TFTR will significantly increase the amount of energy obtained from fusion reactions. During Fiscal Year 1994, we expect to demonstrate a 200-fold increase in fusion power over previous TFTR results with deuterium fuel, and verify extrapolations made from previous experiments. This will make TFTR the first tokamak to perform extensive deuterium and tritium experiments, which provide important data on plasma self-heating. These results are expected to set a world record for fusion, surpassing the performance achieved in the Joint European Torus in 1992. The additional improvement required to produce a practical fusion reactor is only a factor of about 10.

The Department has developed a conceptual design of an experimental facility to serve as a national focal point for fusion experimentation in the first decade of the 21st century based on recommendations from the Secretary of Energy Advisory Board Task Force on Energy Research Priorities and the Fusion Energy Advisory Committee. We are pleased that this new device, referred to as the TPX, is included as part of the investment package in the President's budget. The TPX, to be sited at the Princeton Plasma Physics Laboratory, would offer a unique facility to investigate tokamak improvements, which, if successful, could lead to the design of a cheaper, more compact, and simpler fusion reactor than that which follows directly from ITER. The TPX could also lead to improved operating modes for ITER. In addition, this project would provide the scientific focus to maintain the vitality of the U.S. program between the time of completing the TFTR program and the start-up of ITER. It would also provide a mechanism for increasing the expertise of U.S. industry in fusion and help U.S. industry compete for possible ITER construction. The Fusion Energy Advisory Committee and a task force of the Secretary of Energy Advisory Board have recommended beginning now on the detailed design and construction of TPX for operation in 2000.

Another area of research, the development of low-activation materials such as vanadium and silicon carbide, is essential for the full realization of the environmental attractiveness of fusion energy. The development of these materials could reduce the amount and lifetime of radioactive waste from fusion reactors by factors of hundreds up to one million; but it will require many years and will be costly. For instance, it will be necessary to test candidate materials in a fusion neutron source facility. Because we believe that such a facility should be an internationally shared resource, we have initiated discussions with our international partners on how it could be developed as a joint project. We also need to develop technology systems for ITER and the demonstration power reactor such as: blankets; high-field, large-bore superconducting magnets; remote handling and maintenance systems; vacuum vessels; and plasma facing components. These are areas in which we expect that increased industrial involvement will be particularly productive.

To carry out this program in an era of increasing budget stringency, the U.S. program has increasingly focused research efforts on fewer, more effectively used experimental facilities with staff scientists augmented by those from other institutions. All major confinement experiments at both the Los Alamos National Laboratory and the Lawrence Livermore National Laboratory have been closed down, and the Advanced Toroidal Facility at the Oak Ridge National Laboratory is being held in readiness for future operation. Scientists from those programs are now participating in the TFTR and Princeton Beta Experiment-Modified (PBX-M) experiments at Princeton, and the DIII-D at General Atomics. The PBX-M will be shut down at the end of this year in order to focus resources on TFTR.

The highest priority in the national fusion program is the introduction of deuterium and tritium fuel in the TFTR facility and carrying out the planned experiments. Another high priority is full participation in the ITER engineering design phase, including conducting research and development in the U.S. to support the design of ITER. In particular, experiments on DIII-D and the Alcator C-Mod at the Massachusetts Institute of Technology are addressing key ITER design issues and, therefore, are receiving funding priority. In order to improve the post-ITER tokamak reactor concept, priority is also being given to the design of the TPX, a steady-state tokamak. Thus, the base program is being redirected to support ITER, TPX and the development of materials and nuclear components required for a demonstration reactor.

We need to recognize that any research and development program, especially a long-term one such as fusion, should maintain a modest level of activity devoted to innovation. Previous experience in energy development programs has demonstrated the desirability of maintaining an ability to exploit innovative ideas. There is now significantly more activity on alternate magnetic fusion concepts in other countries than in the U.S. I propose that the U.S. fusion energy program should keep abreast of progress on such alternates through small-scale efforts here and in international collaboration. I am not proposing that we do any development-level work on alternates. However, maintaining a useful awareness of the work of others requires some minimal flexibility.

The bill contains a provision that if the ITER program is terminated, the Department may continue to carry out fusion energy research, but only at the level of $50 million per year. While I fully expect the ITER program to be successful, if for some reason we cannot go forward, I am concerned that such a precipitous reduction in the program would be unmanageable and not in the long-term interests of keeping fusion energy research as a viable activity. I am also concerned that such a provision could, in effect, give other nations a type of "veto" power over the U.S. fusion program, and substantially reduce our negotiating position on ITER and other related program elements. Should we find ourselves unable to continue with ITER for any reason, I would suggest that the Committee request that the Department prepare a plan for a restructured fusion energy program. Such a plan should consider the full impact of an ITER termination on ongoing activities and permit an orderly reflection on the appropriate content of a future fusion program in the context of an overall national energy plan.

Finally, I believe that the bill should explicitly recognize that if the U.S. is to participate in the construction of ITER and the other facilities needed to meet the objective of developing a demonstration power reactor, a substantial increase in the funding for the fusion energy program would be required around the turn of the century. While I recognize that it is premature to estimate the funding requirements to construct ITER and the other facilities, it would be useful for there to be a recognition of the need for funding increases to do so.

In summary, I welcome the Committee's continued commitment to the development of fusion energy. Thank you for this opportunity to provide our views during your deliberations on this legislation. I hope that the points I have raised in this statement provide a meaningful contribution to the Committee. I would be happy to answer your questions.

The CHAIRMAN. Thank you very much, Dr. Decker.

Dr. Decker, you say that the threat of termination would be such a terrible thing that it would therefore put the United States at a disadvantage in negotiating ITER with other countries. Why is it a greater threat to the United States than other countries?

Dr. DECKER. I think that failure of the negotiations, the idea that they could fail, that the U.S. fusion program would be essentially terminated, or very close to it, would cause the U.S. negotiators to be more willing to, let us say, give more away to ensure that an agreement is reached.

The CHAIRMAN. I know, but why is this a greater threat to the United States than to Japan, say?

Dr. DECKER. I do not think the other fusion programs have that threat hanging over their heads. In other words, they may be able to continue on their own or in partnership with one or another party.

The CHAIRMAN. You mean they would bear the cost of fusion worldwide?

Dr. DECKER. Potentially.

The CHAIRMAN. What is wrong with that?

Dr. DECKER. Well, then the United States and its industry are left out. I think that is what is wrong with it.

The CHAIRMAN. Well, is it your position that we do not know enough about tokamaks magnetic fusion, to make a decision at this point?

Dr. DECKER. No. No, I believe that we do know enough about the physics of tokamak to make a decision to proceed with ITER.

The CHAIRMAN. Well, why should we do ITER and pursue these alternative ideas, as well? I mean, at what point do we make a decision?

Dr. DECKER. I think that the tokamak works very well. It is a good vehicle for demonstrating ignition of a fusion plasma. It is a good vehicle for testing technology, and hopefully, it will be an approach that will lead to an acceptable fusion powerplant.

However, at this stage of development, with commercialization being as far away as it is, it would seem to me not to be prudent to say that we would not consider a new idea that came along that could, in fact, be a significant improvement. It is sort of like saying well, you are happy with the propeller driven aircraft and somebody comes along with the jet engine idea that we will not pursue. And that seems to be philosophically not correct.

The CHAIRMAN. Well, ITER is going to be a specific design. Dr. Rebut and his group are pursuing a specific design that is going to cost $7 or $8 billion. Is that figure correct, $7 or $8 billion? Are you going to do that and also do something else, or are we just going to delay doing that? I mean when do we make up our mind as to a technology?

Dr. DECKER. Oh, I think we have clearly made up our mind with regard to the technology for ITER and the importance of doing it. But as I say, it is not prudent to totally preclude innovation from a program.

The CHAIRMAN. There is nothing in there that precludes innovation. Dr. Rebut can change the ITER design—I mean, we do not have anything in this bill about design. Nothing in there. That is up to you all to design this thing. But we do not want to pursue all these alternatives to tokamak fusion. At least this bill says we do not pursue all these alternatives.

It says, in effect, we know enough now to focus on ITER. Now, suppose there would be no international sharing of costs. What would be the position of the Department of Energy and this country on whether we should build ITER all ourselves?

Dr. DECKER. I believe that our position, certainly the position of the U.S. fusion community, would be that ITER is the appropriate next step in fusion.

The CHAIRMAN. No, that is not the question.

Dr. DECKER. The issue would be whether or not the country feels that it could afford to pursue it on its own.

The CHAIRMAN. Well, I am not asking about the country. I am asking about the Department of Energy, you, Dr. Decker, this administration. What is your position? What is this administration's position on whether we should or could build the ITER machine ourselves, if we cannot get international cooperation?

Dr. DECKER. I do not know what the administration's position is. I do not know that it has been discussed.

The CHAIRMAN. That is the point. You see, that is the point. In my view, we are drifting, and this bill is designed to stop the drift and force the decisions. If we cannot afford to build ITER, then we cannot afford fusion energy. We have got very scare dollars. And if we decide we cannot afford ITER on our own, we had better decide, we had better find out whether others are willing to go with us on it.

Dr. DECKER. Could I add to my comment? The statements that I have seen come out of the administration are supportive of ITER, they are supportive of doing it internationally.

The CHAIRMAN. Sure. When? How?

Dr. DECKER. Right.

The CHAIRMAN. Who? You know. It is just this little lullaby somewhere in the distance, and no decisions, no clarity of thought, no focus, and we are spending serious money. I mean, look there are some people who want to terminate SSC again because we do not have enough money for SSC. And yet we are spending hundreds of millions of dollars on fusion, with out knowing whether this is the right technology, whether we would do it on our own, whether others are willing to do ITER with us.

I mean, this decision ought to be bucked right up to President Clinton, and he ought to bring it up at G–7 or when the Japanese, the Germans, the Russians or whoever comes into town, and say are we going to build ITER, and how are we going to build ITER, and how are we going to finance it and how are we going to decide where and how are we going to divide up responsibilities and who is going to put up the money and will you for sure, Mr. Prime Minister, put up your share. We will put up ours. And then we should focus that back into our own budgetary considerations. Then we ought to precede with TPX, we ought to proceed with whatever else it takes to get to that commercialization.

That is what I want us to do. But I do not want to wake up on this committee 10 years from now and, well, you know, say TPX was pretty good and we are going to start talks next year about whether we are going to build ITER, and we just drift along and waste money.

Dr. DECKER. Senator, I do not think we are allowing this program to drift along.

The CHAIRMAN. Dr. Decker, if you do not know the answer to these questions then the program is drifting. I do not mean to put the finger on you, because you are one of the good guys in this thing. But it is up to you to try to get some decision out of the administration. And if we do not get a decision out of the administration, I am going to do what I can to halt the program until they do make a decision. And I want you to understand that.

That is why—it is adrift. If you do not know whether we are going to do ITER alone, if you do not know when we are going to begin discussions or who we are going to discuss ITER with or what our strategy is for discussions, if you do not have a critical path, if you have not decided whether tokamak fusion is ready for these decisions, then we are drifting, in my view.

Senator Bradley.

STATEMENT OF HON. BILL BRADLEY, U.S. SENATOR FROM NEW JERSEY

Senator BRADLEY. Mr. Chairman, thank you very much for yielding, and I look forward to hearing the panel this morning in their testimony. And I think that we ought to know just a few things about what is going on in the Princeton plasma physics laboratory. The fact is that this facility has been in the forefront for decades. And next September at Princeton will begin the deuterium-tritium experiments that I think the world fusion community has been waiting for for a very long time. These are experiments that will produce unprecedented amounts of fusion power, and I think they will contribute directly to the ITER project in a very real way.

The scientific investments are difficult to calibrate, but one measure of their importance has to be the interest that other governments have in them. The fact is that the Europeans and Japanese have strong fusion programs of their own, and they have joined us and with the Russians in the ITER project. Fusion research has been successfully conducted internationally since the fifties, and the ITER project is now the focus of our international collaborative efforts.

I think that your legislation helps refine and reinforce that focus in a very direct way, and I believe it strengthens the ITER project in a very fundamental way, and I support your interest in giving the Department of Energy the authority to negotiate ITER agreements, and I believe that this country should put forward an ITER sight, without any question.

Having said that, I would like to take just a minute to focus on the American fusion program, because I believe it is important not to lose sight of what our home grown talents and expertise are. As we move ahead with ITER and toward the demonstration reactor, we need, I think, to move ahead from a position of strength. American contributions to ITER will be only as strong as the underlying U.S. program.

If it is worth investing in ITER, and I believe it is, it is worth investing in a solid domestic program. As I believe will be made clear in testimony today—I have not read all of the witnesses, but I think the general drift, clearly, that the next major step for our domestic fusion program is a tokamak physics experiment, which is TPX.

TPX will replace the large tokamak fusion test reactor at Princeton, taking advantage of existing machinery, technology, and talent. I think that we have to understand that this is not just a project in New Jersey like you build a bridge in Idaho or New Jersey or somewhere else. This is not pork, in the sense that Congress has become known for pork.

This is, instead, a national project with a scientific mission that is essential in the path to commercial fusion power and unique in the world fusion program. In other words, what exists there is unique.

They will make different contributions to ITER and the demonstration reactor as the staff analysis provided committee members, as I think, affirmed.

Most importantly, however, the TPX will create a needed focus and momentum for American industries' laboratories and universities. We will move forward as leaders and we will move with our international partners.

If I could, I would like to counter briefly those who criticize the program's pace and accomplishments. And I know it is sometimes difficult and I know that the chairman sometimes is maybe borders into that category.

I mean although fusion power research began in the fifties, it really was not until the mid-seventies that a serious financial commitment to move fusion to commercial viability was made, mid to late seventies.

In 1970, the most fusion power that could be produced in experiments was 100th of a watt. That was in 1970. In 1991, the joint European Torus JET achieved an output of almost 2 million watts.

When Princeton's tokamak fusion test reactor is fueled with deuterium and tritium, it is likely that an output of 5 to 10 million watts will be achieved. So from 100th of a watt in 1970 to 10 million watts in 1993.

And if we pursue the construction of ITER, we can look forward to a capability of producing 1 billion watts of fusion power by around 2005 to 2010. That is what to me is a startling prospect and a prospect that I think has international significance.

The bottom line is this is a successful program. It is a national program. It is a successful program. It is on the brink of a major breakthrough. It is, I think, essential to the future of fusion power in this country, if we are going to remain a leader in this field.

Unfortunately, since the 1980's, there has been a steady erosion of financial support. I mean, I came here in 1979, and it seems every year, I am fighting the fusion reactor appropriations battle and it keeps getting less and less. And it is too often the case that only a crisis allows us to refocus and resolve open questions.

When a crisis dissipates, so the interest in the commitment dissipates. You know, it was a big thing when over in the oil embargo. The oil embargo recedes, the price of oil drops and suddenly serious investment, steady over a long period of time is reduced.

And I think the chairman and I have seen this not only in fusion, but we have seen this in the strategic petroleum reserve over time and countless other areas.

But we have got to remember that the power generation focus and options for the next century and beyond are really not that many, if you come to think about it.

Fusion can be a secure environmentally safe source. The fuel supply is literally sea water. And there are no dangerous exhaust gases. It will not contribute to global warming. There is no chance of meltdown.

So as we think about this, I think we have to focus and know that our efforts today will take a little while before they come to fruition. I also note that when I was 20, 30 years seemed like an eternity. It does not seem so long now that I am no longer 20.

The CHAIRMAN. You just cannot remember.

[Laughter.]

Senator BRADLEY. I have vague recollections. At least I see the outline, though, of what the future can be. And I would hope that this committee looks at it in this hearing in that regard and recognizes the critical national importance of what is about to happen at Princeton with the deuterium and tritium experiments, which are going to come to the fore in the next year. And they are going to be really startling.

To kind of go at this and fence it or go at this and try to reduce it, to go at this and try to say well, we have got to decide, before you have that I think it would be a serious mistake. And of course we want to force decisions, but we also want to have the maximum amount of information. And it is like on the brink of the major breakthrough, you are going to switch off in another direction. I hope we will not do that. I do not think that we should do that. And I believe that, you know, I look forward to hearing the witnesses tell us what they expect.

[The prepared statement of Senator Bradley follows:]

PREPARED STATEMENT OF HON. BILL BRADLEY, U.S. SENATOR FROM NEW JERSEY

Mr. Chairman, I am very pleased that you have given the Committee this opportunity to consider the fusion energy program. As you know, I have been interested and involved in the fusion program since I came to the Senate in 1979. I believe that your bill considered today has the potential to reinvigorate the fusion program and set it on solid ground with the Congress, the executive branch, and with our international collaborators.

As you know, we are on the verge of attaining a fusion milestone at the Princeton Plasma Physics Laboratory. This New Jersey facility has been at the forefront of fusion research for decades. Next September, the scientists at Princeton will begin the deuterium-tritium experiments that the world fusion community has been waiting for. These experiments will produce unprecedented amounts of fusion power. They will contribute directly to the ITER project, the international collaboration that is such an important element of the bill before us, and a fusion demonstration reactor.

Scientific investments are difficult to calibrate, but one measure of their importance has to be the interest of other governments. The Europeans and Japanese have very strong fusion programs of their own, and they have joined with us and the Russians on the ITER project. Fusion research has been successfully conducted internationally since the 1950s, and the ITER project is now the focus of our international collaborative efforts. Your legislation helps refine and reinforce that focus and I believe it strengthens the ITER project. I support the Chairman's interest in giving the Department of Energy the authority to negotiate ITER agreements and I believe that this country should put forwarded an ITER site.

Having said that, I want to take a minute to focus on the American fusion program, because I believe it is important not to lose sight of our homegrown talents and expertise. As we move ahead with the ITER project and toward the demonstration reactor, we need to move ahead from a position of strength. American contributions to ITER will only be as strong as the underlying U.S. program. If it's worth investing in ITER—and I believe it is—it's worth investing in a solid domestic program.

As I believe will be made clear in testimony today, the next major step for our domestic fusion program is the Tokamak Physics Experiment (TPX). TPX will replace the large tokamak at Princeton, taking advantage of existing machinery, technology, and talent. This is a national project with a scientific mission that is essential in the path to commercial fusion power and unique in the world fusion program. TPX will make significant contributions to ITER and the demonstration reactor, as the staff analysis provided Committee Members affirms. Most importantly, however, the TPX will create a needed focus and momentum for American industries, laboratories and universities. We will move forward as leaders, with our international partners.

I would like to counter briefly, if I may, those who criticize the program's pace and accomplishments. Although fusion power research began in the early 50s, it wasn't until the mid-70s, that a serious financial commitment to move fusion to commercial viability was made. In 1970, the most fusion power that could be produced in experiments was one-hundredth of a watt. In 1991, the Joint European Torus (JET) achieved an output of almost 2 million watts. When Princeton's Tokamak Fusion Test Reactor (TFTR) is fueled up with deuterium and tritium, it is likely that an output of five to ten million watts will be achieved. And, if we pursue the construction of the International Thermonuclear Experimental Reactor

(ITER), we can look forward to the capability of producing 1 billion watts (1,000 MW) of fusion power around 2005 to 2010.

The bottom line: This is a successful program. These projects work as designed. The goals are met.

Unfortunately, since the early 1980s, there has been a steady erosion of financial support. As is too often the case, only a crisis creates a focus and resolve. When the crisis dissipates, so does the interest and commitment. The Chairman and I have seen this many times. You and I have noted for years that the Strategic Petroleum Reserve seems to be filled only when oil is scarcest and the price is the highest.

The power generation options for the next century and beyond are not many. Fusion can be a secure, environmentally safe energy source. The fuel supply is literally sea water. There are no dangerous exhaust gases. It will not contribute to global warming. There is no chance of a meltdown.

I know our efforts today will take a good while to come to fruition. I also note that, when I was twenty, thirty years seemed like an eternity. It doesn't seem so long a time anymore. We need to keep this program on track.

I look forward to working with the Chairman and the Committee on this important bill.

Senator BRADLEY. Dr. Decker, from the deuterium/tritium experiments, can you tell us how they contribute to the ITER design and also why TPX is an essential step in the development of fusion energy. If you could, I would appreciate it.

Dr. DECKER. The DT experiments on TFTR, are considered to be a very important step, because of several factors. One is that we will get our first look, I believe, at whether or not the alpha particles, which are generated by the fusion reactors, may excite some instabilities in the plasma. They could potentially be a problem for us.

We will also gain significant experience in handling tritium in a major fusion device here. I think that will also be a very important experience for us.

With regard to the tokamak physics experiment, it has a number of important missions. First of all, it will be a superconducting tokamak which will use superconducting magnets. This will allow it to operate for very long pulses and potentially in a steady state mode.

The CHAIRMAN. If the Senator would yield, what is the cost of TPX, total cost?

Dr. DECKER. Present estimate, I believe, is around $550, $570 million, something like that in fiscal year 1993 dollars. Anyway, it will be a very important facility to look at steady state operation; how we handle the heat loads and diverters, how we handle impurity control.

It will be very important in terms of learning how to use various RF current drives to drive a current steady state. We would like tokamak reactors eventually to run steady state and TPX potentially provides a means to do that.

TPX will also investigate operating regimes of higher pressure and hopefully regimes that provide more efficient confinement. So there is a lot that we will learn from TPX, given the schedule.

I believe that what we will learn from essentially a steady state operation in TPX will provide at least guidance on how we operate ITER. The schedule is such that I believe, and Dr. Rebut can correct me, it probably will not affect the design or probably cannot affect the system very much. But it could affect operations of ITER, certainly in the early stage from what we learned.

Senator BRADLEY. How much fusion power will be generated?

Dr. DECKER. In TPX? Sorry, I do not know that number off hand.

Senator BRADLEY. Five or 10 megawatts, something like that?

Dr. DECKER. There is no tritium planned in TPX. It would operate on deuterium. And I am sorry, I do not know what the equivalent fusion power number would be.

Senator BRADLEY. But, under the DT experiments, it is 5 to 10 megawatts?

Dr. DECKER. On TFTR, the deuterium/tritium experiments, we expect to be in the 10 to 20 megawatt range. That is the amount of fusion power that we expect to be produced.

The CHAIRMAN. For how many nanoseconds?

Dr. DECKER. We are doing much better than nanoseconds, I am pleased to say.

The CHAIRMAN. Senator Craig, Dr. Decker has made his statement. We are questioning him at this time and then we will go to the panel. Do you have any questions for Dr. Decker?

Senator CRAIG. I have no questions. I apologize for coming late. I came to listen.

The CHAIRMAN. Dr. Decker, if you do not mind staying, it might be useful to have questions after the panel has spoken.

Dr. DECKER. Sure.

Senator BRADLEY. Can I ask one last question?

The CHAIRMAN. Sure.

Senator BRADLEY. Will this be unique in the world?

Dr. DECKER. Yes, it will. This will be a unique facility in the world to do the kinds of things that I mentioned. At least it is unique certainly in having the capability to put all these things together and investigate them over long periods of time with very long pulses on the order of 1,000 seconds or potentially steady state.

The CHAIRMAN. Before I introduce the panel, let me say, Senator Bradley, by my supercilious comment about nanoseconds, that I am not a strong supporter of TPX. I am. I have been to Princeton. They are doing great work.

In my view it is essential to do TPX to complement ITER. But my view is that—well, you know my view—that if you are not going to do ITER, and you cannot afford to do it yourself, then you also cannot afford TPX and you better decide that up front.

I just wanted to be sure you understood that I am a supporter of the great Princeton program and that they are making, in my view, great progress and that we ought to do that in conjunction with the ITER program.

So now we will hear from——

Senator BRADLEY. I am glad I came to this hearing, Mr. Chairman.

The CHAIRMAN. Now we are going to hear from Mr. ITER himself, Dr. Paul-Henri Rebut, who is director of the International Thermonuclear Experimental Reactor at La Jolla.

Dr. Rebut, welcome.

STATEMENT OF DR. PAUL-HENRI REBUT, DIRECTOR, INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR, LA JOLLA, CA

Dr. REBUT. Thank you, Mr. Chairman and members of the committee. I am grateful for this opportunity to testify before the Congress on the progress on fusion towards an experimental reactor.

Since the mid-seventies, a 1000-fold increase has been achieved in the overall performance of experimental fusion device. We are now within a factor of five of what is required for a fusion reactor, a full fusion reactor.

This factor will be gained by an increase in the size of the plasma. On November 9, 1991, a deuterium-tritium fuel mixture introduced in JET that was only 10 percent tritium produced over a megawatt of fusion power for more than 2 seconds.

We now have to focus our effort on the fusion reactor. In fact, ITER is the core of a power reactor. The ITER device is foreseen to be the first experimental reactor and will be able to produce high grade heat from controlled fusion reactions well over 1 billion watts. It will also test the major new technologies required for a fusion power station taking account of environmental aspects.

As the ITER director, I am committed to seeing it built, therefore I support the objective of your legislation.

But for me the real goal is not any one specific device, however important, but the establishment of fusion as a major source of energy. ITER should therefore be seen as the leading element of a balanced fusion program.

ITER should be built, but at the same time there should be a complementary program providing an intense neutron source to test the durability of advanced materials, continued development of new and innovative aspects of the reactor, and the continued study of the detailed physics of fusion.

The balanced program seems to me to be composed of half of the program directly focused on ITER, including the development of new technologies and diverters, which is a key element of the machine and the other half on complementary activities.

Such a program undertaken on an international basis will develop a balanced support by all parties concerned, be efficient and cost-effective, and require managerial, political and industrial skills.

I support the intent of the bill to pursue international agreements to achieve these broad objectives. And a steady increase in funding is required, as described in your bill.

ITER is designed on the basis of the experience with JET and DIII–D. It also incorporates elements like design simplicity to ease manufacturing and thereby effectively reduce costs; flexibility to accommodate the evolution of fusion science; the ability and quality and safety of reactor relevance in corporation wherever possible of technologies of the demonstration reactor, including, I hope, activation materials.

Here I must say that ITER burns a deuterium/tritium mixture, but it could also burn other fuel. These other fuels are much more demanding in terms of confinement and impact on the machine. So

I have some doubts that they can be of any use in a reactor in the future.

Since the signature of the ITER EDA agreement, progress has been rapid. This was only possible with strong support from the international fusion community among which I can particularly commend the U.S. fusion community. It cannot be built without the participation of industry. It will help to develop some new technology with potential applications in science and industry, advanced materials and superconducting technology. I see U.S. industry as a cornerstone of these activities.

Strong participation and leadership of the United States in the ITER project is fundamental to the success of this novel venture. An early site decision for the construction of ITER is needed to complete the EDA according to schedule as many of other site characteristics must be incorporated into its final design. If a site can be selected within 3 years, construction could start at the end of the EDA in 1998.

I should like to encourage the U.S. government to pursue with its partners an early agreement on a site and the creation of the legal structure for the construction of this unprecedented international project.

The challenge facing the world today is to develop a solution for an economical and environmentally attractive large-scale energy source for the benefit of mankind. I believe that fusion will enter into that solution, ITER being a major milestone in this process. However, ITER has to be built in this decade and operated in the next, if we want fusion to progress.

I thank you, Mr. Chairman and members of the committee for inviting me to testify. I would like also to invite all of you to visit or revisit the Joint Work Site at San Diego. I shall be pleased to answer any questions.

[The prepared statement of Dr. Rebut follows:]

PREPARED STATEMENT OF DR. PAUL-HENRI REBUT, DIRECTOR, INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR, LA JOLLA, CA

Mr. Chairman and Members of the Committee on Energy and Natural Resources, I am grateful for this opportunity to testify before the U.S. Congress on the progress in Fusion towards an Experimental Reactor.

Fusion could make a significant contribution to energy production from the middle of the 21st century comparable to other energy sources. Once the technology is developed there should be enough fuel on Earth to meet mankind's energy requirements indefinitely.

The annual cost to develop a fusion reactor would amount to approximately 0.1% of the electric power costs incurred annually by countries of the OECD [Organization for Economic Cooperation and Development]. This is a small investment for the capability to produce electricity necessary to sustain the long-term development of the world economy.

SUCCESS OF THE PHYSICS PHASE IN FUSION

In recent years the progress in fusion energy research has been most impressive. Since the mid-seventies a 1000-fold increase has been achieved in the overall performance of experimental fusion devices. We are now within a factor of five of the fusion performance required for a fusion reactor. This factor will be gained by an increase in the size of the plasma. On November 9, 1991, a deuterium-tritium fuel mixture introduced in the JET [Joint European Torus] device produced over a million watts of fusion power for more than two seconds. These achievements are the result of the determined pursuit of strong and focused programs with involvement of industry.

Having effectively demonstrated the scientific feasibility, the subsequent development stages leading to fusion power stations can now be defined. Drawing on experimental results from JET and from the other major devices in the U.S., Europe, Japan and Russia we are able to define a fusion reactor.

TOWARDS A FUSION REACTOR

As we have demonstrated that we can control the kind of plasma required for thermonuclear reactions, now we have to focus our effort on the Fusion reactor. In fact, the International Thermonuclear Experimental Reactor, ITER, is the core of a power reactor.

With the signing of the ITER Engineering Design Activity Agreement on 21 July 1992 the world fusion community as a whole has engaged on the path towards a fusion reactor.

The ITER device is foreseen to be the first experimental reactor and will be able to produce high grade heat from controlled fusion reactions well over one billion watts. It will also test the major new technologies required for a fusion power station taking account of environmental aspects.

By its existence, the ITER EDA project is already focusing the fusion programs of the world. As ITER Director, I am committed to seeing ITER built. Therefore, I support the objectives of your legislation, S. 646, the International Fusion Energy Act of 1993. But, for me, the real goal is not any one specific device, however important, but the establishment of Fusion as a major source of energy. ITER should therefore be seen as the leading element of a balanced Fusion Reactor Development Program. To that end, ITER must be built but, at the same time, there should be a complementary program providing, for example:

- an intense neutron source to test the durability of materials;
- continued development of new and innovative aspects of the reactor;
- continued study of the detailed physics of fusion power; and
- the education and training of a new generation of scientists and engineers required to carry the program forward.

A balanced program seems to me to be composed of half of the program directly focused on ITER, including the development of new technologies and divertors, and the other half on complementary activities.

For these reasons, I would suggest an alternative program name might be "the Fusion Reactor Development Program" which would help to focus the program in line with the goal of your bill. Such a Program undertaken on an international basis, would allow a balanced approach for all parties concerned, be efficient and cost-effective, but require a development in managerial, political, and industrial skills. I support the intent of the bill to pursue international agreements to achieve these broad objectives. And, in order for the U.S. to maintain its prominent position in the world fusion program a steady increase of the funding is required, as described in your bill.

ITER

The philosophy of ITER is to design on the basis of experience acquired with present machines such as JET and DIII-D. It also incorporates the following principles:

- design simplicity—to ease manufacturing and thereby effectively reduce costs;
- flexibility—to accommodate the evolution of fusion science that will occur during its operating life time;
- reliability and quality—to ensure operation of key components without fault for decades;
- safety—to demonstrate the potential of fusion as an environmentally attractive source of energy; and
- reactor relevance—incorporation, wherever possible, of technologies that are relevant to a Demonstration Reactor.

Since the signature of the ITER EDA agreement, progress has been rapid with the preliminary design being presented just seven months after the start of assembly of the core Joint Central Team (See Attachment). This achievement was only possible with the strong support from members of the international fusion community among which I can particularly commend the U.S. fusion community for its commitment. It is also the result of having a well-defined objective focusing the fusion community towards a common goal.

ITER is now the leading element of the world fusion programs and is creating a dynamic movement from which new ideas and solutions are continually emerging and evolving. From this process, key areas of technology R&D are being addressed, using the competence of the Parties' industries and fusion laboratories. ITER will incorporate very advanced technologies and cannot be built without participation of industry. In that sense, ITER should prove invaluable in developing some technologies with wide potential application in modern science and industry, for example, advanced materials and superconducting technologies. I see U.S. industry as a cornerstone of these activities.

ITER is an experimental machine and not yet a prototype reactor. ITER's conceptions and operations must reflect this aspect. A machine which must incorporate large flexibility and new technologies cannot be built with the constraints and costs of a reactor which will work in a fixed domain of parameters. I welcome the participation of the utilities in this research program, but it seems to me a premature stage for this program to be driven by the present-day economic situations of the energy supply.

THE U.S.—A LEADING PARTNER

Strong participation and leadership by the U.S. in the ITER project is fundamental to the success of this novel venture. An early site decision for the construction of ITER is needed to complete the EDA according to schedule as many of the site characteristics must be incorporated into its final design. If a site can be selected within three years, construction could start at the end of the EDA in 1998.

The final results of the Engineering Design Activities will be made available for each of the Parties to use as part of an international collaborative program or in its own domestic program. I believe that the U.S. is uniquely placed to play a leading role in progressing towards the construction of ITER. I should like to encourage the U.S. Government to pursue with its partners an early agreement on a site and the creation of the legal structure for the construction of this unprecedented international project.

The challenge facing the world today is to develop a solution for an economical and environmentally attractive large-scale energy source for the benefit of mankind. I believe that fusion will enter into that solution—ITER being a major milestone in this process. However, ITER has to be built in this decade and operated in the next, if we want fusion to progress.

With the commitment and leadership of the U.S., I am confident that ITER will be built and fulfill its objectives.

I thank you, Mr. Chairman and Members of the Committee, for inviting me to testify. I invite all of you to visit the Joint Work Site at San Diego, but today I shall be pleased to answer any questions that you may have for me.

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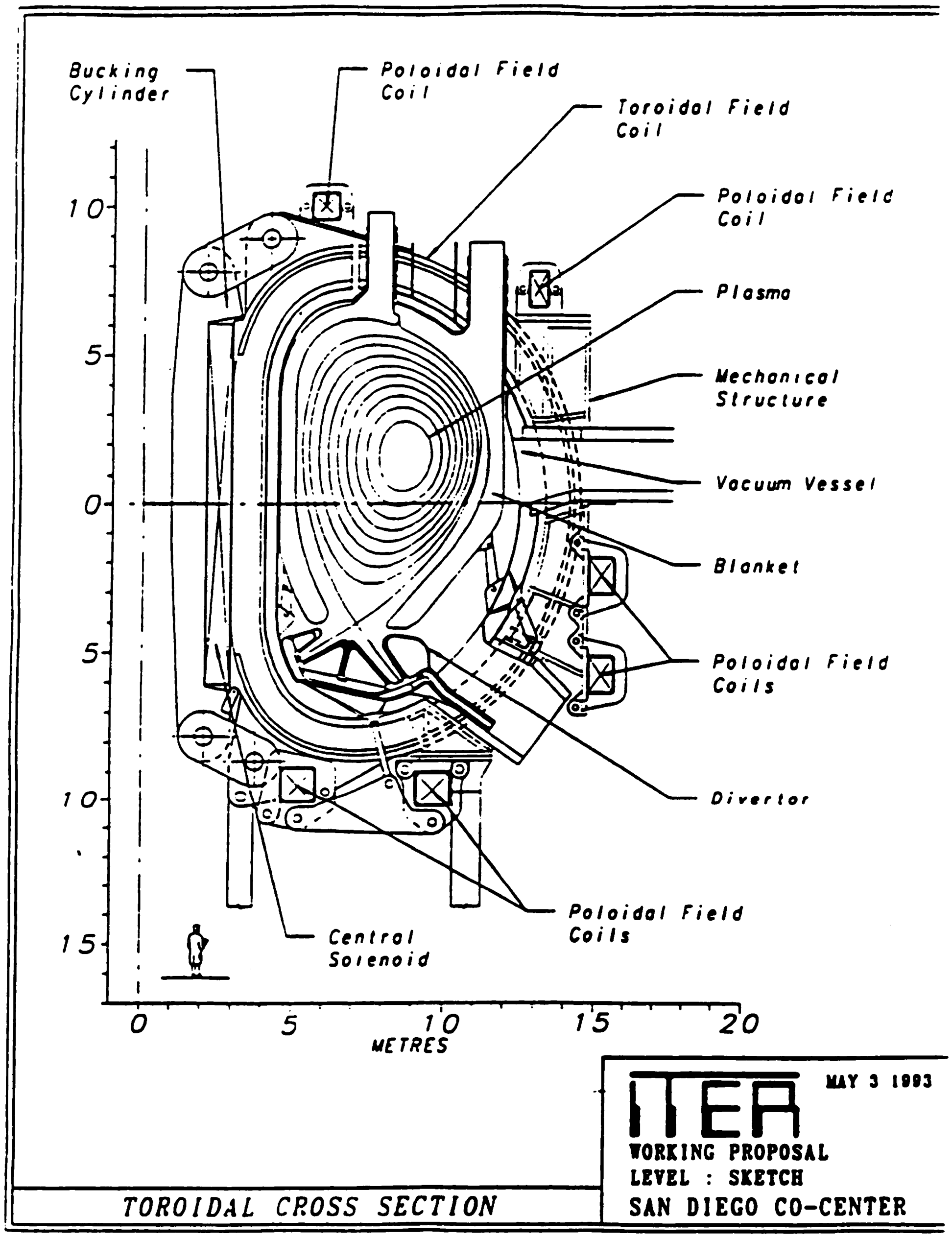
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The CHAIRMAN. Thank you, Dr. Rebut, and I, as you indicated, have been to your site and I would urge committee members to go both to Princeton and to La Jolla and see these facilities, because I think this is one of our major decisions that we need to make.

Next we will hear from Dr. Robert Hirsch, who is vice president of Electric Power Research Institute here in Washington.

Dr. Hirsch.

STATEMENT OF DR. ROBERT L. HIRSCH, VICE PRESIDENT, ELECTRIC POWER RESEARCH INSTITUTE

Dr. HIRSCH. Mr. Chairman, Senator Craig and staff, I appear before you today to urge further study before the United States commits to ITER.

In the few minutes that I have for my prepared remarks, I will share some of my credentials for speaking on this subject; explain why I believe there may be serious questions regarding the current path of fusion research; describe why there may be greater hope for a redirected fusion energy program; and finally I will suggest ways to resolve some of these very complex issues.

I am Dr. Robert Hirsch, a vice president of the non-profit Electric Power Research Institute, EPRI, which is the $650 million per year privately funded research arm of the U.S. electric utility industry.

In my career, I have conducted hands on fusion research and I managed the Federal fusion program from 1972 to 1976. I maintained contact with this area of research ever since. In addition, I have spent roughly 20 years in private industry, managing research programs and facing the problems of commercializing a wide array of energy-related technologies, some of which were used in the State of Louisiana in the oil and gas industry.

I believe that fusion power can become a major producer of economical and environmentally attractive electric power in the 21st century. For this to happen, we must develop fusion powerplants that are more attractive than fission nuclear reactors and other baseload electric power options. If not, there will be little incentive for that technology to be utilized.

To be acceptable to the public, to a rational investor and to a public utility commission, any new electric power source must meet a number of stringent criteria. The three most important to me are first, power costs; second, environmental attractiveness, including safety; and third, high reliability.

Let us consider the current emphasis in fusion research against these criteria. Almost 100 percent of the current Federal fusion program is focused on deuterium/tritium or DT fuel cycle and the tokamak concept for plasma confinement.

Scientists and engineers have been doing paper studies of fusion reactors based on this approach for roughly 20 years. In that time, they have done some extremely clever thinking to develop a small family of conceptual DT tokamak reactors.

The problem is that the best DT tokamak designs appear to less attractive than the advanced light water reactor, the ALWR, which many hope will be acceptable in the U.S. electric generation marketplace in the 21st century.

First, DT tokamak reactors are projected to have power costs 20 to 50 percent higher than the ALWR. Since these are based on paper studies that are far removed from any fusion reactor construction and operating experience, realities emerging over time are certain to increase fusion power costs, making them even less competitive. And this does not take into account the effects of regulation which will drive up costs.

Second, while there are many environmental and safety issues related to both fission and fusion, let me focus on perhaps the most important one, the production of radioactive waste. According to fusion reactor design studies, DT tokamak fusion reactors, using the best available steel in their construction, will produce more radioactive waste than an advanced light water reactor.

While it can be argued that new structural materials could reduce fusion radioactive waste, the development of those materials will be both very costly and very time consuming.

Finally, DT tokamak reactors, as currently envisioned, will be extraordinary complex machines. Even assuming significant learning and new technology between now and the advent of fusion, complexity always mean higher cost and unforeseen problems in achieving good reliability.

This is a particular disadvantage for DT tokamaks when compared to the advanced light water reactor with its inherently greater simplicity, reliance on proven technology and decades of operating experience.

Despite my conviction that fusion has great potential, I believe that DT tokamak fusion reactor that follows the current path of development is likely to be quite unpromising as compared to compared to a light water reactor and other baseload options.

In that case, a multi billion dollar investment in ITER may not be prudent. If not DT fuels and large tokamaks, then what? Fortunately, there are a number of other, more favorable fusion fuel cycles to choose from. The related physics for most of those alternatives appears more difficult than for the deuterium/tritium cycle, but the reactor characteristics appear progressively more attractive.

It would thus appear reasonable and prudent to consider reorienting the U.S. thinking on fusion and targeting our research on those potentially more attractive systems. The end result could be a clearly superior new power source that could provide mankind with electric power for centuries to come and which would be enthusiastically welcomed in the marketplace.

This better path or paths to desirable fusion power would likely involve lower cost steps than ITER-sized tokamaks. This is because a competitively priced fusion power system will inherently be smaller in size and therefore less expensive. But fusion research and development is likely to be costly no matter what so that continued international collaboration will be highly desirable.

In order of for fusion research to be successful, marketplace realities must have an essential role in fusion program directions and decisions. Electric utilities represent the marketplace in today's world. Unfortunately, utilities have never been involved in fusion research in a serious role.

Both Dr. Davies, the head of the fusion program, and I recognized this shortcoming roughly a year ago, and we have taken steps to close that gap.

To begin to formulate some utility views on fusion, last year EPRI created a panel composed of some of its executives to consider the practical aspects of fusion reactors. Our report, dated November 1992, forward to this committee, reached a number of conclusions some of which I think are important to review now.

First of all, the Federal fusion program represents an important national investment. Second, in the relative near-term, burning deuterium tritium in the tokamak fusion test reactor should continue to be a high priority.

Third, program diversity beyond tokamaks is important. In diversifying the fusion program, the DOE should give special consideration to concepts that are less complex in powerplant designs based on fuel cycles other than deuterium and tritium. Lastly, the eventual needs of the marketplace should become a critical element in fusion program planning and decision-making.

Adding all of this up, what would I suggest that you do? I believe you ought to consider the following.

First, do not make a national commitment to ITER until these issues are adequately addressed. Second, request the Secretary of Energy to assemble a user community panel of utility experts and managers to evaluate the arguments for and against the DT-tokamak approach. These people know the marketplace best and can provide you an evaluation that is free from any near-term self-interest.

Third, if the conclusion of this panel is that DT-tokamak reactors are not attractive, then the panel should determine if there are, indeed, attractive opportunities in fusion. If the answer to that question is yes, then drawing on appropriate utility expertise DOE should be able to provide a meaningful program plan to assure the development of a fusion system that could be extremely attractive and acceptable in the marketplace, and good to power this planet for many, many centuries in the future.

Thank you for your kind consideration.

[The prepared statement of Dr. Hirsch follows:]

Prepared Statement of Dr. Robert L. Hirsch, Vice President, Electric Power Research Institute

Mr. Chairman, distinguished committee members and staff, I appear before you today to urge further study before the United States commits to an International Thermonuclear Experimental Reactor, the proposed next step in the current line of tokamak fusion energy research.

In the few minutes that I have for my prepared remarks, I will share some of my credentials for speaking on this subject, explain why I believe that there may be serious questions regarding the current path of fusion research, describe why there may be greater hope for a redirected fusion energy program, and, finally, I will suggest ways in which to resolve some of these very complex issues.

I am Dr. Robert L. Hirsch, a Vice President of the non-profit Electric Power Research Institute (EPRI), the $650 million/year research arm of the U.S. electric utility industry. In my early career I conducted hands-on fusion research, and I managed the federal fusion research program from 1972-1976. I have maintained contact with this area of research ever since. In addition, I have spent roughly 20 years in private industry, managing research programs and facing the problems of commercializing a wide array of energy-related technologies.

I believe that fusion power can become a major producer of economical and environmentally attractive electric power in the 21st century. For this to happen, we must develop fusion power units that are more attractive than fission nuclear reactors and other baseload electric power options. If not, there will be little incentive for utilities to utilize this technology.

To be acceptable to the public, a rationale investor, and a Public Utility Commission, a new electric power source must meet a number of stringent criteria. The three most important of these are first, low power cost; second, environmental attractiveness, including safety, and third, high reliability.

Let's consider the current emphasis in fusion research against these criteria. Almost 100% of the current federal fusion program is focused on the deuterium-tritium (DT) fuel cycle and the tokamak concept for plasma confinement. Scientists and engineers have been doing paper designs of fusion reactors based on this approach for roughly twenty years. In that time they have done some extremely clever thinking to develop a small family of conceptual DT tokamak fusion reactors.

The problem is that the best DT tokamak designs appear to be less attractive than the Advanced Light Water fission reactor, the ALWR, which many hope will be acceptable in the U.S. electric power generation marketplace in the 21st century.

First, DT tokamak reactors are projected to have power costs 20-50% higher than an ALWR. Since these paper studies are far removed from any fusion reactor construction and operating experience, realities emerging over time are certain to increase fusion power costs, making them even less competitive.

Second, while there are many environmental and safety issues related to both fission and fusion, let me focus on perhaps the most important one—the production of radioactive waste. According to reactor design studies, DT tokamak fusion reactors using the best available steel in their construction will produce more radioactive waste than an ALWR. While it can be argued that new structural materials could reduce fusion radioactive waste, the development of those materials will be both very costly and very time consuming.

Finally, DT tokamak fusion reactors, as currently envisioned, will be extraordinarily complex machines. Even assuming significant learning and new technology between now and the advent of fusion, complexity always means higher costs and unforeseen problems in achieving good reliability. This is a particular disadvantage for DT tokamaks when compared with an ALWR, with its inherently greater simplicity, reliance on proven technology, and decades of operating experience.

Despite my conviction that fusion has great potential, I believe that a DT tokamak fusion reactor that follows the current path of development will be quite unpromising as compared to the advanced light water reactor. That being the case, a multibillion dollar investment in ITER may not be prudent.

If not DT fuels in large tokamaks, then what? Fortunately, there are a number of other, more favorable fusion fuel cycles to choose from. The related physics for most of those alternatives is more difficult than for the deuterium-tritium cycle, but the reactor characteristics appear progressively more attractive. It would thus appear reasonable and prudent to consider reorienting the U.S. thinking on fusion and targeting our research on those potentially more attractive systems. When we are successful with one or more of these systems, the end result should be a clearly superior new power source that could provide mankind with electric power for centuries to come.

This better path or paths to desirable fusion power will likely involve lower cost steps than ITER sized tokamaks. This is because a competitively priced fusion power system will inherently be smaller in size, and, therefore, less expensive. But fusion research and development is likely to be costly no matter what, so that continued international collaboration will be highly desirable.

In order for fusion research to be successful, marketplace realities must have an essential role in fusion program directions and decisions. Electric utilities represent the marketplace in today's world. Unfortunately, utilities have never been involved in fusion research in a serious role. Both Dr. Davies and I recognized this shortcoming roughly a year ago and we have been taking steps to close that gap.

To begin to formulate some utility views on fusion, last year EPRI created a panel composed of some of its executives to consider the practical aspects of fusion reactors. Our report, dated November 1992, reached a number of conclusions, some of the more important of which are as follows:

The federal fusion research program represents an important national investment.

In the relative near term producing deuterium-tritium fusion power in the 10-20 megawatt-thermal range in the Princeton TFTR is an important program milestone and should continue to be a high priority.

Program diversity beyond tokamaks is important. In diversifying its fusion program, the DOE should give special consideration to concepts that are less complex and power plant designs based on fuel cycles other than deuterium-tritium.

The eventual needs of the marketplace should become a critical element in fusion program planning and decision-making.

Adding all of this up, what should you do? I believe that the following recommendations should be considered:

First, do not make a national commitment to ITER until these issues are adequately addressed.

Second, request the Secretary of Energy to assemble a user community panel of utility experts and managers to evaluate the arguments for and against the DT tokamak approach to fusion. These people know the marketplace best and can provide you an evaluation that is free from any near-term self-interest.

Third, if the conclusion of this panel is that DT tokamak reactors are not attractive, then the panel should determine if there are indeed more attractive opportunities in fusion. If the answer to that question is "yes", then drawing on appropriate utility expertise, DOE should be able to provide a meaningful program plan to assure the development of a fusion system that could be extremely attractive and acceptable in the marketplace.

Thank you for your kind attention and your consideration of these thoughts.

The CHAIRMAN. Thank you very much, Dr. Hirsch. Next, we will hear from Dr. David Overskei, who is senior vice president of the Fusion Group in General Atomics in San Diego.

Dr. Overskei.

STATEMENT OF DR. DAVID O. OVERSKEI, SENIOR VICE PRESIDENT, GENERAL ATOMICS, SAN DIEGO, CA

Dr. OVERSKEI. Mr. Chairman, Senator Craig, and staff members, I am very pleased to testify before you today in support of S. 646. And with the permission of the Chairman I would like to merely summarize my statement and ask that my written testimony be included in the record.

The CHAIRMAN. Yes.

Dr. OVERSKEI. I am David Overskei, senior vice president of General Atomics, and our corporation has had a long standing commitment to the development of advanced energy systems and sources. We are known for the ultrasafe modular helium gas cooled reactor, which is an advanced fission system, and we have applied our diligence and expertise to fusion energy research as well.

We are presently the conceivers, engineers, fabricators, and operators of the DIII–D tokamak facility, which is the second largest magnetic fusion research facility in the United States. And I think I can say, with a great deal of pride, it is one of the most productive magnetic fusion research programs in the world.

The bill that is being discussed here is addressing the issue of whether or not we are ready to proceed with ITER and whether or not fusion is ready to make the transition from a science program to an applied energy research program. And I would like to strongly endorse this transition, and speak to specific issues that are in the proposed legislation.

First, I believe this bill appropriately does focus the Department of Energy by requesting that they develop a plan for the future U.S. participation in ITER, and requesting the department to effectively utilize the existing U.S. fusion resources, whether it is infrastructure, personnel, or the monies the tax payers provide to the U.S. Government. And also, it appropriately directs the Department of Energy to develop the new resources, technologies, and infrastructure that will ultimately be needed to make fusion energy a reality.

I believe that ITER is scientifically and technologically the logical next step in the U.S. fusion program, and that it is appropriate to embark upon that next step. I support the bill specifically in directing the Department of Energy to develop a plan and a schedule for how the domestic program will compliment the ITER program, and a domestic program that will meet the needs of a demo, and calling for full U.S. participation in ITER including selection of a U.S. candidate construction site for ITER.

I would also propose and support that it is appropriate for the United States to best serve its interests by having a Presidentially appointed, authorized negotiator to negotiate U.S. participation in ITER, including the siting and construction, and eventual operation of the ITER facility.

As we embark upon this sort of endeavor, it is appropriate to consider some adjustment to the U.S. fusion program, again, as I said earlier, such that we can make the transition from a scientific research program to an applied energy development program with a strong science foundation.

I would propose we make an adjustment in the present skill mix which at present is approximately 20 percent industrial participation and 80 percent national lab and university participation in the U.S. program, and transition to a program that is dominated by U.S. industry with universities and national labs playing a support role in the R&D and the scientific efforts, and in the continued development and improvement of the concept of and the approaches to magnetic confinement.

As we do this, is it also appropriate to have further involvement of those industries that have a history and an experience in developing the energy sources that are presently used by the American utility industries. These are those individuals and those corporations that have developed fission plants and the major architectural engineers and fabricators. It would be appropriate to have them further involved and, indeed, at present some of them are already involved in the R&D and the design efforts for ITER.

With regards to utilities, I would submit that the U.S. fusion program is not at present sufficiently advanced to benefit from the experience that utilities have. Their experience is largely in the operation of electricity producing facilities and the transmission of electricity. We are not yet at the stage where we produce electricity or transmit it. Therefore, their experience is not necessarily appropriate to our task at hand.

Rather, I would say that we could benefit by having utilities participate even in a leadership role in reactor design activities. And as we develop the source, fusion as the source of energy, and then work on the conversion of that energy into electricity, it is very appropriate to get broader utility participation.

With regards to another element in the bill, I would say that I disagree with the proposal that the U.S. magnetic fusion effort should be brought down to $50 million if the Secretary of Energy does not proceed with a commitment to the ITER process. The reason for this is that ITER, and the mission and the objectives of ITER, have been agreed upon in the United States and the international community. That mission and those objectives are appropriate for the U.S. fusion program regardless as to whether or the ITER as presently perceived goes forward.

Therefore, I would think it would be more appropriate that the secretary is empowered, if the ITER process is not consummated on a timely fashion—by consummation I mean site selection and initiation of construction. The Secretary of Energy should have the prerogative of proceeding with either a part or all of the ITER mission either on our own in the United States or with some combination of other foreign partners.

I also disagree with renaming the Department of Energy's magnetic fusion program the ITER program. ITER is at present an international activity. It is not strictly domestic. ITER merely represents the right next step for the United States. Therefore, I would say it is just more appropriate that we would call the program the U.S. fusion reactor development program.

And lastly, I would submit that an appropriate funding level for this program would be to have fiscal 1994 and 1995 funding levels and authorization levels of approximately $380 million and $425 million respectively.

The reason for this is these funding levels would be more consistent with the National Energy Policy Act that was passed in 1992, and it would also make the funds available for us to initiate a siting evaluation for ITER in the United States, which has not started and funds are not available.

It would allow us to fully meet the commitments of the United States to the ITER activity. In other words, fully funding the central design activity, which is not presently being done. And it would allow us to bolster our low activation materials and our future fusion reactor technology development programs, which I would say at present are sorely underfunded.

With that, I would like to summarize by just saying that I am deeply appreciative of the long standing support that the chairman has given the U.S. fusion program, and at this point I would like to just close my oral remarks and say that I would be please to answer any questions that the committee may have.

Thank you.

[The prepared statement of Dr. Overskei follows:]

PREPARED STATEMENT OF DR. DAVID O. OVERSKEI, SENIOR VICE PRESIDENT, GENERAL ATOMICS, SAN DIEGO, CA

Mr. Chairman and members of the Committee on Energy and Natural Resources, I am pleased to testify before you today in support of S. 646, which is, in my opinion, a landmark bill in support of the international effort to demonstrate controlled thermonuclear fusion—a long term, environmentally attractive, large-scale energy production technology for the future. This bill appropriately focuses the DOE to develop a plan for future U.S. participation in the International Thermonuclear Experimental Reactor (ITER), to effectively utilize the existing U.S. fusion resources, and to develop new resources and technologies to make fusion energy a reality.

Through my testimony I will make the following points:

1. Support of ITER as the scientifically and technologically correct next step for the U.S. fusion program.
2. Support of this bill directing the Department of Energy to develop a plan and schedule for establishing a domestic program that complements ITER, meets the needs of a DEMO, and calls for full U.S. participation in ITER, including selecting a U.S. candidate site for ITER.

3. Support of the proposal to appoint a Presidentially authorized negotiator to negotiate U.S. participation in ITER with the other Parties.

4. Support of an adjustment in the fusion research skill mix to increase the level of U.S. industry participation in the U.S. fusion program. However, I do not see that utilities have the scientific or technology expertise to contribute to the present fusion research program.

5. Disagreement with the proposal that the U.S. Magnetic Fusion effort should be reduced to $50M if the Secretary of Energy decides not to proceed with the presently conceived ITER. The ITER mission is scientifically and technically credible, therefore, the U.S. should have the option of pursuing all or part of the ITER mission on its own or with any number of international partners if the presently conceived ITER process fails.

6. Disagreement with renaming the Department of Energy's Magnetic Fusion program the ITER program. ITER is an international program and is merely the next step in our national fusion program.

7. Recommendation that the authorized funding levels for fiscal 1994 and 1995 should be $380M and $425M, respectively, consistent with the National Energy Policy Act of 1992. This funding level will allow us to meet our ITER and national program schedules.

BACKGROUND

For you to fully appreciate the context of my testimony, it is important that you know my personal background and the industry perspective in fusion which I represent.

I am David Overskei, Senior Vice President of General Atomics, responsible for all fusion research, technology, and component development conducted at General Atomics. Prior to my joining General Atomics in 1981, I participated in the Alcator series of fusion programs at the Massachusetts Institute of Technology. General Atomics is unique in the U.S. fusion program, if not the world. Our corporate conduct of fusion research draws upon more than 35 years of experience in servicing nuclear utilities, in the innovation and development of the ultra safe helium gas-cooled fission reactor, and the development and sale of more than 70 TRIGAs, an innovative fission research reactor, throughout the world. Under contract to the Department of Energy, General Atomics conceived, constructed, and now operates the DIII-D tokamak, the second largest Magnetic Fusion Energy research facility in the United States. In addition, we perform design, engineering, and fabrication services, and sell components and technology to the university and national laboratory programs in the United States and numerous laboratories, universities, and industries in Europe and Japan. Over the years we have established a reputation for scientific excellence and technology innovation. A hallmark of our program has been unprecedented collaboration and cooperation with other national and international fusion research entities. In particular, the Japanese Atomic Energy Research Institute invested more than $70M in our present facility and has been an active participant in the conduct of fusion experiments at General Atomics since 1979. At present we have scientists and engineers from five U.S. national laboratories, thirteen universities, and five foreign countries (including all four ITER Parties) participating in our fusion research programs. We are also asked to apply our expertise to their programs.

Although best known today for our fusion plasma theory and our experimental innovation in tokamak research, General Atomics has also patented and conducted experimentation with a wide variety of non-tokamak fusion concepts. This body of experience leads me to believe that the tokamak is the most scientifically and technologically mature fusion confinement concept and is the only fusion concept that is presently capable of demonstrating a controlled, sustained thermonuclear burn.

THE CONTEXT OF THE U.S. FUSION PROGRAM

Over the last 15 years the international magnetic fusion energy research programs have made enormous progress. Owing to significant strides in the theory and science of high temperature plasmas and the development of fusion-relevant technologies, there has been an approximate doubling in the performance of fusion experiments every two years. Although numerous confinement concepts have been explored, it is the tokamak concept that has led this progress in overall performance.

Along with the progress there have been numerous reviews of magnetic fusion and the DT burning tokamak. A common unifying theme in all reviews is the endorsement of the tokamak as the primary vehicle to establish the scientific and technological feasibility of magnetic fusion energy without committing to the tokamak as the ultimate reactor. These panels have also identified the need to continue concept improvement, and conduct an ambitious, well-funded materials development program focused on the needs of future fusion reactors suitable for utility service. The International Thermonuclear Experimental Reactor (ITER) has been identified in all review panels and reports as a high priority for the U.S. magnetic fusion energy program. This unanimity is not unique to the U.S. The ITER has also obtained endorsement from Europe, Russia, and Japan.

Based on this scientific and technological data base, we are now ready to embark on the demonstration of a sustained controlled thermonuclear burn and an integrated testing of fusion-relevant nuclear technology. This will initiate the transition from a strictly scientific research program to an applied energy research program at the cutting edge of science and technology.

THE PROPOSED LEGISLATION

To successfully make the transition, the DOE must define the technology and demonstration/testing steps necessary to realize a fusion demonstration reactor while adjusting the skill mix and increasing the emphasis on the fusion materials and technology required for the DEMO. The first step in the process is the demonstration of a sustained, controlled thermonuclear burn, and the integration of reactor-relevant technology. This is the stated mission objective for the International Thermonuclear Experimental Reactor (ITER), and I strongly support the U.S. participation in this effort. The ITER design draws upon years of experience in both large and small scale tokamak operation, incorporating wherever possible the technologies that are relevant to future demonstration fusion reactors with particular attention being paid to demonstrating the environmentally attractive aspects of fusion as an energy source.

Although challenging, from a scientific and technology perspective, the proposed schedule for ITER is credible. However, history indicates that political indecisiveness and lack of resolve on the part of the U.S. or any of the other ITER parties could result in significant delay and, therefore, increased cost. I, therefore, strongly endorse your legislation which directs the Department of Energy to identify a proposed ITER site in the U.S. and a plan for reaching an international siting agreement of the ITER project by 1995.

However, ITER alone will not provide all the answers or the technology that we envision in a fusion power electricity generating demonstration reactor. The U.S. fusion community has identified the need for a superconducting tokamak device that can test fusion technologies necessary for long pulse operation and explore new physics regimes that could lead to higher performance and ultimately smaller, thus less expensive, fusion reactor designs. General Atomics supports the mission of such a device, called the Tokamak Physics Experiment (TPX), and the appropriateness of locating that project at the Princeton Plasma Physics Laboratory.

In parallel with continued concept improvement, through science and experimentation, the DOE should place more emphasis absolutely and relatively on the development of fusion reactor technologies with particular emphasis placed on low activation materials.

These materials will be necessary for us to build upon the success of ITER and the Tokamak Physics Experiment and design an environmentally attractive, operating fusion power plant constructed out of well characterized low activation materials, thus realizing one of the major advantages of fusion over fission.

An additionally required international facility, complementary to ITER, is an intense accelerator-based 14 MeV neutron source. This facility is necessary to test the radiation characteristics of advanced materials that will be utilized in future demonstration reactors. The DOE should take a leadership role in discussing with the international parties the initiation, design, and subsequent construction of such a 14 MeV neutron source.

The implementation of the above program will require an adjustment in the present skill mix in the U.S. fusion program. In particular, we need to evolve from the present 20% industrial and 80% national laboratory and university participation to a point in the near future where industry plays a dominant role in the program with R&D support from the university and national laboratory systems as needed. There is also a clear need for universities to modify their programs, training the new scientists and engineers with the skills needed for the future, not the present. This change in the composition of the domestic program will position the U.S. to be technologically competitive in international fusion development while increasing U.S. industrial competitiveness in the high technologies of the future. I feel that this is consistent with the spirit of the proposed legislation.

However, I disagree with the proposed involvement of the utility industry in the design, construction, and operation of ITER or in the development of the fusion-relevant technologies. U.S. utilities have no relevant expertise in the development of fusion energy and generally have little expertise in the development and engineering of large-scale energy sources. Rather, utilities have focused on the distribution of electricity and have contracted with high technology industries, such as General Atomics, Ebasco, Pittsburgh-DesMoines, Westinghouse, and Stone and Webster, to provide their power producing and electricity producing facilities. In fact, all of the above named companies, in addition to numerous aerospace firms, Rockwell, McDonnell Douglas, Grumman, and TRW, are presently working on ITER and can contribute more to the fusion program.

I believe utilities have no credible role to play in ITER or the associated science and technology development of fusion concepts. However, as fusion research matures from a science to an energy technology, we could benefit from utility participation in defining the operating requirements for energy production. In particular, utility involvement in fusion reactor design studies would be useful.

The last implementation aspect of a more focused fusion program is better utilization of present facilities and the identification of future fusion research facilities. At present the Princeton Plasma Physics Laboratory, the General Atomics DIII-D facility, and the Massachusetts Institute of Technology Plasma Fusion Center, are the largest national laboratory, industrial, and university fusion facilities respectively. The U.S. fusion program would be well served by the Department of Energy making greater use of these facilities and re-directing hardware, human resources, and talent that exist throughout the U.S. community to strengthen the programs that exist at these three facilities. However, none of the present U.S. sites is a credible candidate location for future large-scale deuterium-tritium fusion experiments. Therefore, the DOE should immediately proceed to identify and establish a new site, the National Fusion Energy Demonstration Site. This site would be the U.S. candidate location for siting ITER in the U.S., or for the intense 14 MeV neutron source, and for the future demonstration fusion power reactor.

To reach agreement on U.S. participation in ITER and ITER siting, the U.S. needs a Presidentially appointed negotiator and a strong negotiating position. The threat of terminating the domestic fusion research program if agreement is not reached on ITER undermines that position. I, therefore, recommend alteration of the proposed termination clauses that come into effect in the event international agreement on ITER is not reached. At present the U.S. and the other international Parties have agreed with the appropriateness and the timeliness of the ITER project. I endorse ITER and support U.S. leadership in this international project. However, the ITER mission and objectives are central to the logic of the U.S. fusion program and constitute the next step on the path to a fusion power reactor. Thus, if agreement on ITER is not consummated in a timely fashion, the Secretary should be required to submit to you a new plan indicating how and when the U.S. will accomplish the ITER objectives.

SUMMARY

I strongly support the general thrust and the intent of this legislation directing the DOE to develop a plan and schedule for fusion, including ITER. I firmly believe that the U.S. should take a strong leadership position in ITER, should identify a candidate site in the U.S. for ITER, and should have a Presidentially authorized negotiator. The ITER is the obvious next-step on a path to a demonstration fusion reactor, is scientifically and technically credible, and should be based on the D-T tokamak concept. Other U.S. initiatives that should be conducted in parallel with ITER are the Tokamak Physics Experiment, continued concept improvement, a much enhanced fusion technology and advanced materials development program, and coordination with the international community on the development of an intense accelerator-based 14 MeV neutron source to test reactor-relevant low activation materials. The DOE should make better use of its main fusion research facilities and should prepare for the future by transitioning to a program that has greater industrial involvement in the development of fusion energy. National laboratories and universities should continue to provide R&D and scientific support as required, and universities should focus on training the people needed in the future. The legislation should allow the U.S. to embark on all or any part of the ITER mission on its own if international collaboration on the ITER construction is not realized. Lastly, to meet ITER and domestic program needs, the authorized funding levels for fiscal 1994 and 1995 should be $380M and $425M, respectively, consistent with the National Energy Policy Act of 1992.

I thank you for your continued support. I would be pleased to answer any questions you may have.

The CHAIRMAN. Thank you very much, Dr. Overskei. Finally, we have Mr. Joe Gavin, who is former president of Grumman Aerospace Corporation.

Mr. Gavin.

STATEMENT OF JOSEPH G. GAVIN, JR.

Mr. GAVIN. Thank you, Mr. Chairman. It is a real privilege for me to be here to offer some comments with regard to S. 646. You, Mr. Chairman, and you, Senator Craig, can refer to the written testimony as to how it is that this aeronautical engineer winds up sitting at the same table with a group of experts on fusion.

But I have been involved, and I do have some views on the subject. And I must tell you at first that these are my own views. I do not represent any organization, company or agency. There are some advantages to being retired.

First of all, I would like say that it is certainly desirable to support the ITER commitment that has already been made for the design phase. You know we, as Mr. Bradley pointed out, over the period from the early eighties until now, have cut back on our efforts, we have delayed things, and consequently the Europeans and Japanese, in my view, have forged ahead and taken the leadership that we once had in fusion research. And I think that we need to regain some ground.

Now, energy from the fusion process remains one of the two or three that has really long-term potential. And in looking at it—perhaps I am reflecting my own age when I say this. I would like to see fusion demonstrated as being feasible sooner rather than later. Anything we defer is going to build up additional costs, maybe not all in one year, but over a period of time it adds up to real money.

Certainly, the burning of fossil fuels, coal and oil, face potential long-term environmental objections. And I might point out that the largest known oil reserves appear vulnerable to fundamentalist, anti-Western extremism. You know, it is only a short time ago that we spent a war to protect the Gulf oil. And I think that in some respects developing nonfossil energy for the future is a matter of national security. It is not as obvious, perhaps, as somebody planting a bomb in the World Trade Center, but it is a matter of national security.

Now, the demand for energy is not just a domestic concern, and we should look at the global situation rather than just being concerned with our own national problems. In discussing the development of the Third World, it is quite clear that they would like to have the standard of living that we enjoy, and this implies industrialization. And if they proceed to do this at any real rate using fossil fuels, we are going to have a worsening problem in the environment.

Now, there is a matter of the population growth in the Third World, and that has been discussed in forums. I would point out that in some of these discussions one thing is overlooked, and that is the growth in both size and number of urban areas; the flight of the population to urban centers. And this puts another factor into the demand for energy which sometimes, I think, is overlooked.

And this is a global problem. It is not a U.S. problem. And one could say that cooperating with the other partners in ITER, making it an international undertaking is a fitting way to make a first step toward a global problem solution.

Now, you could say this is a complicated affair, having four major parties involved in the design and so forth of ITER. But the collaboration of the Europeans for the successful Joint European Torus gives some evidence that it can be done, and I am sure that if you had gone back 10 years earlier, before the start of JET, that there would have been people that said, well, it cannot be made to work. But they did make it work, and I think we can learn some lessons from what was done there.

And I am happy to see that Dr. Rebut is leading the ITER effort. And while this is a young organization that he has, it is young, it appears to be off to a good start, and the challenge of it is attracting first class talent. And that is very important because you are asking people to devote large fractions of their potential professional career to take part in it.

Now, we should not underestimate the problems in coordinating the design phase, which has been started because, again, you are dealing with people from different cultures and from different sites. Nor should we underestimate the real challenge that will come later when we start to look for the site, on the one hand, and the matter of actually going ahead with the construction. I think that sitting here today it is impossible to anticipate how complex those decisions might turn out to be.

Now, I have said earlier that I would like to see something demonstrated sooner rather than later. But ITER is not by itself. It was clear in the discussions that led up to the ITER design agreement that the national programs would have to contribute some support to ITER outside of the ITER budget.

And as I understand the planning for our own national program it seems to me that there are two major items that stand out as providing support to ITER and, for that matter, any subsequent demonstration machine which will, incidentally, qualify this country as a competent, vigorous partner. And those are the DT test program for later this year at TFTR in Princeton, and the replacement of the TFTR reactor core at a later date with the TPX.

I must point out that somewhat similar plans have been talked about and deferred from year to year for at least the last half-dozen years. I think now is the time and we have to buckle down and do it.

And we need to face the fact that the Europeans and Japanese seem to be much more aware than we seem to be of the long-term commercial and industrial potential. This is something that one can talk about. It is hard to quantify.

As I noted in a report dating from 1984 entitled, "The Cooperation and Competition on the Path to Fusion Energy," since I was the chairman of that committee, I am happy on rereading to find out that the basic truths still seem to be there. But clearly in that report we have pointed out that the United States should be concerned about our ability to maintain a long-term commitment.

The fact of the matter is, this country has in the past abrogated more or less unilaterally some interesting international commitments, and I think that in the discussions leading up to the ITER agreement there was always a hidden question of, how does your government work? How can you make a long-term commitment?

I think there are some lessons in budgeting practices that have been demonstrated by the Europeans in the Joint European Torus that we could learn from.

In any event, it is a real concern in the design phase, and it could be a vital factor in trying to reach a decision on the siting and the construction. I do not think any of this is insurmountable, but it is something that this committee could really help on because of the fact that the annual budgeting process does not seem to provide all that much assurance about long-term commitments. And I am saying this very bluntly, but that is the fact and that is the way it is.

Now, in talking about this bill, which I support in general, I am not going to comment on the numbers in the budget. I am really not qualified to do that. But I would like to point out and get on the record a basic truth that has always been ignored in the past. And that is that if a project is truly innovative and on the cutting edge of either science or engineering, there are going to be surprises. And that means that the schedule and cost cannot be known precisely at the beginning.

I have been an admirer of how Jim Webb handled the Apollo budgets back in the days of Apollo. I did not find this out until after that program was over and I had a chance to have dinner with him one evening, but he faced the fact in the beginning and told the various chairmen involved, I am going to be back almost every year asking for more money. And he said, there are too many unknowns to be precise at the beginning.

Now, to summarize briefly, we are already committed to be an equal partner in the design, and I think we should support that effort vigorously and adequately. I think we have the talent to do that. And I think our national program can support that talent. And it seems—you asked a question, Mr. Chairman, about what would we do if we had to go it alone, and I can only express an opinion. It seems to me unlikely that we would or could proceed by ourselves to demonstrate a burning plasma as ITER will do. We might do it in the long run, but the delay would be considerable beyond ITER. ITER is long enough.

We cannot afford to be left out, and I think we should look carefully to identify some of the opportunities in the long run that our partners seem to have a better grasp on than we do.

Now, I recognize that there is today reasonable speculation concerning the future impact of the continued and probably growing use of fossil fuels. I also recognize that predicting today the economic parameters of a practical fusion powerplant, putting electricity into the net, is certainly less than convincing.

My position is simply that we need to prove the feasibility of an ignited plasma soon. And once we have done that, the potential for making considered investments in proceeding to something that is of practical use will be much more straight forward.

Today there has not been demonstrated, in my view, a burning plasma, and we need to do that. ITER will do it. ITER is perhaps conservatively designed to make sure it will do that, and that is one of the reasons it is so large, as I understand it.

I listened to my friend Bob Hirsch talk about utility involvement, but might I suggest that involving the utilities strongly today is a little bit like asking the railroad barons to evaluate the future use of the Ford trimotor of 1930 for transoceanic passenger service.

I have said my piece, Mr. Chairman. I will be happy to answer any questions.

[The prepared statement of Mr. Gavin follows:]

PREPARED STATEMENT OF JOSEPH G. GAVIN, JR.

Mr. Chairman and members of the Committee on Energy and Natural Resources of the United States Senate, it is a distinct privilege to appear before you to comment on S. 646, a bill "to establish within the Department of Energy an international fusion energy program, and for other purposes"; also known as the "International Fusion Energy Act of 1993".

I wish to speak in general support of this bill. I do have some comments to make. In making them I present my own views; I do not represent any agency or organization.

My comments flow from my background and experience. These differ considerably from those of the other witnesses. I am not a physicist; I have had long experience in innovative and complex engineering programs for aircraft and spacecraft in particular the Lunar Module for Apollo. As the Apollo program came to an end, my colleagues and I identified energy as a potentially critical area of interest. This was prior to the first oil crisis. Our company chose to pursue non-fossil energy technologies; of these the activity pertinent to today's discussion was participation in the design of the fusion reactor at Princeton, the TFTR. Subsequently I became a member of the Energy Research Board of the Department of Energy, serving until that Board was abolished.

In 1984, I chaired a National Research Council committee that examined in considerable depth the potential for international collaboration in fusion research. We visited both Europe and Japan, holding discussions with senior figures in government and science. In 1986, I chaired the subcommittee of the Energy Research Advisory Board to produce the triennial reviews of magnetic fusion research required by Public Law 96-386, the Magnetic Fusion Engineering Act of 1980. Comments based on these two reports are presented in App'x I; App'x II presents the executive summary from the second report.

In the period 1988-1990, I was a member of the working group that laid the basis for the ITER design phase agreement signed by the four parties, the European Community, the United States, Russia and Japan in July of 1992.

Turning now to S. 646, I would like to make the following comments:

(A) It is certainly desirable to support the commitment, already made by this country to participate in the ITER design. In the early 80's the United States seemed to be leading in fusion energy research. As budgets were cut here, the Europeans and Japanese forged ahead and now lead. We need to be vigorous and respected parties in the ITER enterprise; we have much ground to regain.

(B) Energy from the fusion process remains one of two or three potential, long term, non-fossil energy sources. It is an option we need to have. I believe that there is real advantage in demonstrating the scientific feasibility of fusion sooner rather than later. Coal and oil face potential long term environmental objections and the largest known oil reserves appear vulnerable to fundamentalist, anti-western extremism. In hindsight, we have recently "spent a war" to keep the Iraqi's from seizing the entire Gulf!

(C) The demand for energy is not just a domestic concern, it is a global one. Industrial development and exponential population growth in the third world can well aggravate the impact of fossil fuel usage on the global environment. In discussing population growth, we often overlook the fact that much of this population growth is taking place in urban areas, which have themselves grown and increased in number in unprecedented fashion since WWII. This trend puts additional complexity into the prediction of future energy demand. Because the problem is global, it seems to me to be quite fitting that this country be a partner in developing non-fossil fusion energy within an international undertaking.

(D) The collaboration by the Europeans for the successful Joint European Torus provides evidence that an international venture can work in consonance with national programs and objectives. While the ITER organization is young and innovative, it appears to be off to a good start. The challenge of this program attracts first class talent. While the evolving design appears conservative, we should not underestimate the coordination and management task facing ITER leadership. Nor should we underestimate the challenge facing the four collaborating parties in selecting a site and deciding to proceed with construction.

(E) I have said earlier that we should be a vigorous partner in ITER; S. 646 focuses attention on support of ITER. In the discussion leading up to the ITER agreement, it was clear that the national programs would have to contribute support in a variety of ways outside of the ITER design budget. As I understand the planning for our national program in fusion research, there are two major items that will serve to support ITER and any subsequent demonstration machine—and that will qualify the U.S. as a component, vigorous partner, namely the deuterium-tritium tests programmed for 1993 in the TFTR at Princeton and the replacement of the TFTR reactor core with the TPX at the end of the decade. I must point out that somewhat similar plans have been deferred from year-to-year for sometime. I believe it is essential to press on now; we need to regain a competitive position. We need to face the fact that the Europeans and Japanese seem to be more aware than we are of the long term commercial and industrial potential—as well as the social impact—that fusion energy offers.

(F) As noted in the NRC report of 1984 "Cooperation and Competition on the Path to Fusion Energy" and as evident in the discussions of the working group of '88-'89, there is a clearly expressed concern about the ability of the United States to maintain a long term commitment. This is a real concern for the design phase of ITER and could be a critical factor in reaching an agreement for construction and siting. This committee can help in this matter.

(G) You will note that I have not commented on the budget numbers spelled out in S. 646. I would like to call to your attention a very basic truth that has all to often been ignored: "If a project is really innovative and on the cutting edge of science and engineering, there will be surprises. The schedule and cost, therefore, cannot be precisely defined at the outset". Conversely, if the schedule and cost can be completely defined, the undertaking may already be obsolete. The manner in which James Webb, the NASA administrator, handled the budget for the Apollo program should be a case study required of all budgeters.

To summarize briefly, we are already committed to be an equal party in the ITER design phase. We should support this international effort vigorously. Our national program can contribute usefully to this support. It seems unlikely that we would or could proceed by ourselves, to demonstrate a burning plasma as ITER will without a very substantial delay compared to the ITER schedule. We cannot, in my opinion, afford to be left out. Our partners foresee, in time, opportunity for a high technology industry and a global business.

I recognize that there is today reasonable speculation concerning the future impact of the continued and probably growing use of fossil fuels. I also recognize that predicting today the economic parameters of a practical fusion power plant feeding electricity into the net is less than convincing. My position is simply that we need to develop the fusion option soon as insurance against a future critical need—as soon as we can will be long enough indeed.

Thank you.

[Appendix I]

COMMENTS ON KEY REFERENCES

Ref A: "Cooperation and Competition on the Path to Fusion Energy" a report of the National Research Council 1984.

Page 1 and 2 Conclusions and Recommendations.

From this report three of the conclusions deserve highlighting:

> "On balance, there are substantial potential benefits of large-scale international collaboration in the development of fusion energy."
>
> "International collaboration will require stable international commitments."
>
> "Past cooperation provides a sound basis for future efforts."

Among the recommendations, one deserves emphasis:

> "The first priority should be the establishment of a clear set of policies and objectives and a considered program plan for future U.S. fusion activities."

In hindsight the reports' conclusions appear to have been valid. The recommendation quoted above was made in the belief that a clearly defined and positive program would insure the U.S. position as an undeniably valuable partner in any joint undertaking. History shows, however, that the U.S. has, as a result of reduced funding and delayed or cancelled plans, given up its leadership in fusion research. The European Community, which is an example of international collaboration, has taken a very clear lead, and Japan has been making steady progress to catch up with the Europeans.

A further comment in reviewing this report and the fact finding conversations the committee held in Europe and Japan is the importance of the conclusion concerning stable commitments.

Ref B: "Report of the Technical Panel on Magnetic Fusion of the Energy Research Advisory Board"—a report of the Energy Research Advisory Board to the U.S. Department of Energy November 1986.

The executive summary of this report is attached in Appendix II. Rereading of this summary reveals that international collaboration is recommended. This report recommends strongly that an "ignited plasma" project be undertaken before the larger Engineering Test Reactor (now called ITER) to "enhance the credibility and the likelihood of success of a future Engineering Test Reactor." The U.S. did not proceed in this direction. The later successful results in the Join European Torus have persuaded the Europeans and the fusion community that such an intermediate demonstration is not necessary. Consequently the efforts of the four powers, from 1988 onward, have been to agree on a preliminary engineering description for ITER and an agreement concerning the management and execution of the engineering design of this device.

An agreement was signed July 21, 1992. The announcement is attached. Worthy of note is the statement of the "equality of the four parties" and that construction and siting are left to future agreement.

[Appendix II]

Copy of Executive Summary from Ref B

EXECUTIVE SUMMARY

The Energy Research Advisory Board Panel on Magnetic Fusion, charged by Secretary of Energy John Herrington (Appendix A) to conduct the required triennial review of the Magnetic Fusion Energy (MFE) program, set six days between May 1986 and October 1986, and received information from 23 speakers. The principal findings, conclusions, and recommendations are outlined below, with a more detailed exposition presented in the main body of this report.

Findings

1. Magnetic fusion energy continues to be a uniquely attractive potential power source for the future.
2. Throughout the program, considerable progress has been achieved since 1983. This has culminated in the recent advances on the TFTR tokamak at Princeton. Important progress has also been made in Europe with JET and in Japan with JT-60. In addition, significant progress has been made in several alternate confinement concepts under active investigation in the U.S. program as well as abroad.
3. The Office of Fusion Energy has dealt effectively with budget reductions, making difficult decisions. Three successive years of budget reductions have curtailed and eliminated some program elements and postponed others. Deferring MFTF-B (the large tandem mirror facility at Livermore) was a difficult, though necessary decision.
4. The disaster at Chernobyl and the domestic controversy concerning fission waste storage have resulted in renewed concern about the environment. There are also long term concerns about the use of fossil fuels due to the buildup of carbon dioxide in the atmosphere.
5. International collaboration in fusion research is being addressed at many levels of government and plays an important role in both the technical and financial aspects of the program.

Conclusions

1. Because of the uncertainty of energy supply early in the next century, there is an advantage in testing the scientific feasibility of fusion sooner rather than later. This requires studying the physics of an ignited plasma.
2. An ignited plasma experiment, such as the Compact Ignition Tokamak (CIT), is an essential and timely project. In addition, it will enhance the credibility and the likelihood of success of a future Engineering Test Reactor (ETR) whether or not the ETR is a multi-lateral or domestic project. This report does not attempt to

define the ETR. The CIT is a useful experiment whether the ETR is a tokamak or an alternative confinement configuration. An ignited plasma experiment will require incremental funding above the FY 87 level.

3. Further budget reductions, beyond the three years cited above, will jeopardize the overall technical integrity of the program, and will make the U.S. fusion program a substantially less desirable partner for international collaboration.

4. A good start has been made toward international collaboration, but collaboration on a large device, such as an ETR is a complicated process that will take time and substantial negotiating effort. The potential savings due to collaboration are considerable and will occur later.

5. Today's environmental concerns about fission and fossil energy cannot yet be extrapolated into the future, but these trends could be of significant importance to the role of fusion. Furthermore, environmental impact and public safety questions must be addressed during early stages of the development of fusion energy.

6. Fusion R&D advances plasma physics, a sophisticated and useful branch of applied science, as well as technologies important to industry and defense. This contribution to a strong national science and technology base warrants a substantial level of investment in its own right.

Recommendations

1. Proceed expeditiously with an ignited plasma experiment, such as the CIT, using existing facilities to the greatest extent possible to minimize the additional funding that will be necessary. Early completion of this project will help to determine whether there are unanticipated phenomena associated with a burning plasma that would alter the prospects for proceeding with fusion development. Incremental funds will be needed in order to proceed with the CIT in a timely fashion and to maintain the strength of the base program.

2. While the tokamak configuration is the mainline of present national and international experimental efforts, exploration of selected non-tokamak concepts as well as tokamak improvements should be pursued. The budget reductions have already resulted in a substantial narrowing of effort. Further reductions would endanger key areas of the program.

3. Continue to study urgently the question of possible atmospheric changes from continued massive use of fossil fuels. The Panel notes that DOE is the lead agency in a multi-agency effort to determine the consequences of the buildup of CO_2. Fusion, second generation fission, and solar technologies are the primary energy options for the future if the atmospheric CO_2 trend is determined to be harmful to the environment. This is a global problem with very significant economic and political consequences.

4. Proceed with the required negotiations to establish major international collaboration in fusion R&D. This should be done recognizing that it will take time and that considerations external to the U.S. program may make it necessary to proceed independently. Reviews of the NRC report of 1984, "Cooperation and Competition on the Path to Fusion Energy", and the ERAB report of 1985, International Collaboration in the U.S. Department of Energy's Research and Development Programs" indicate that the conclusions of those reports appear to be valid today.

5. The Panel believes that fusion R&D deserves a priority greater than that provided at present by the U.S. Government. We recommend that the Secretary of Energy press vigorously for a higher national priority within the Administration.

The CHAIRMAN. Thank you very much, Mr. Gavin. It has been a very good panel. Dr. Hirsch, in your view, should TPX be done if we are not going to do ITER? In other words, would TPX be useful for an alternative fuel cycle?

Dr. HIRSCH. It seems to me that we need to take a look at where we are going overall, and then fit things like TPX into a different framework, if, indeed, a different framework is what is called for.

The CHAIRMAN. Well, would it be putting words in your mouth to say that you are saying, in effect, we ought to decide what we are going to do about ITER before we decide on TPX, or we ought to decide which direction we are going in before we decide on TPX?

Dr. HIRSCH. It seems to me the reason why I am here today and the reason why I brought these issues to you is to consider these issues in the framework of this bill, which I think calls the question, which I think is quite appropriate.

I think in that context one needs to take a look at where are the best directions, and it is possible that these directions that are presently being pursued by DOE and others in the world are appropriate, but there are serious issues. Those issues need to be addressed, and depending on the answers to those issues, then one comes to the answers to questions like you are asking.

The CHAIRMAN. Well, you say that we should not do ITER, that we ought to convene this panel and in effect make these decisions up front, and I must say that part of your statement very much appeals to me, but we need to get our best minds together in whatever the right forum is, whether it is here, or DOE, or wherever, and decide which direction we are going in, rather than just continue to shovel out money at this program.

You know, in the Energy & Water Appropriations Subcommittee we have got very scarce dollars. The administration this year wants to terminate the actonide program that my friend from Idaho is so interested in, that I am interested in.

They would terminate the modular helium reactor program, which I just had a meeting with the Russian energy minister yesterday, and they are very excited about this program. They want to do it in a joint way. They wanted to terminate that program.

We have got the LIGE program, laser intervalometer gravity experiment, I think is a very good program. I certainly strongly believe in the SSC, the space station is another very expensive program, and all of these are under intense pressure, and it is time, on this program, it seems to me, to make a decision on what we are going to do and how we are going to do it, and not just drift.

I mean, it seems to me that with all the good science, we are drifting in our decisionmaking, and I am glad, Dr. Hirsch, that you are posing these kinds of questions. I mean, we need to answer these kinds of questions as best we can now.

There may not be a definitive answer to the question of waste, for example, but we need to take it, look at it squarely, and if in fact the experts say we cannot solve the problem of waste on magnetic fusion, then put that in our calculations. I know others may not agree with you on that conclusion, but we need to ask these questions, ask them now, and make some decisions.

On that question, Dr. Overskei, tell me about your view of Dr. Hirsch's statement that the problem of waste may not be solvable, that you may have more waste from this than with an advanced light water reactor.

Dr. OVERSKEI. If you are discussing ITER specifically, one can address that. If you talk about a future fusion device, that is a future electricity-producing fusion device, it is still a concept that has been in paper only.

If you project forward, and you build a device out of the low activation materials, some of which are presently available, if you used ferritic steels rather than stainless steels, present fusion devices are predominantly stainless steels, ferritic steels have about one-fifth the activation that stainless steels do.

If you go to vanadium, you pick up another factor of 2 to 5, and if you go to advanced materials like silicon carbide and silicon carbide composites that the fission program would like to develop, you pick up another factor of—well, in total it is about a factor of 100 better than the materials that are presently used in fission devices.

The CHAIRMAN. We are talking about the reactor vessel now, and not about the waste.

Dr. OVERSKEI. Yes, so am I. So am I.

The CHAIRMAN. Is that what you were talking about, Dr. Hirsch?

Dr. OVERSKEI. I am talking about the vessel, the structural materials out of which you would actually build the device.

The CHAIRMAN. Now, the fusion device is not expected to produce any nuclear waste, as in fuel rods, other than this dust. What do you call it?

Dr. OVERSKEI. Helium. That is basically the product of the reaction. The DT reaction is helium gas.

The CHAIRMAN. Well, you do have that dust in the bottom. is that not radioactive?

Dr. OVERSKEI. Dust. Well, let us see, if you are talking about—you are probably referring to—there is some erosion that occurs. This is one of our technical problems that we are dealing with in fusion, where the particulars, the energetic particles that impinge the first wall material out of which the vessel is constructed, there is some erosion of this material.

The CHAIRMAN. So, something akin to dust that you were explaining to me out there you have to clean out every now and then, do you not?

Dr. OVERSKEI. Yes. Well, it depends upon the material, but yes, I suppose one could loosely call it dust. There is another—you mean the ash.

The CHAIRMAN. The ash.

Dr. OVERSKEI. Well, this ash, that is what we call helium, the helium gas is the "ash."

The CHAIRMAN. Ash is a solid, is it not?

Dr. OVERSKEI. No. Well, we use the word ash somewhat crudely here. It is because of the comparisons with combustion, or burning. We call this a burning plasma, and as you burn you produce the waste of a burning process, an oxidation is ash.

The CHAIRMAN. The point is, you have got to clean it out.

Dr. OVERSKEI. Yes, but it is helium gas. That is the basic waste product.

The CHAIRMAN. So there is no waste akin to fuel rods.

Dr. OVERSKEI. No, not at all.

The CHAIRMAN. It is just the reactor vessel we are talking about.

Dr. OVERSKEI. Correct. As a matter of fact, let me just expand upon this. The fission system has an enormous infrastructure in the fuel process. You have to mine the uranium, you have to process the uranium, you have to enrich the uranium, then you burn it, and then you have to reprocess it again.

The beauty about the deuterium-tritium approach is that the entire fuel process, everything is within the device. You produce the tritium in the blanket and it flows back into the system, and then it is burned, and then it reproduces the tritium that you are burning again. It is entirely self-contained.

A fission system has this enormous external infrastructure that the Department of Energy is presently paying for which supports the fission concept, and I do not think people have appropriately recognized this, what I think is a fundamental difference.

Dr. HIRSCH. Mr. Chairman, may I clarify something?

The CHAIRMAN. Yes.

Dr. HIRSCH. The way you posed this question was whether or not these problems can be solved. I believe there is no question that these problems can be solved, and these people here believe they can be solved also.

The fundamental question is the price. What is the cost of all of this, and what does it mean in terms of the cost of power? You have played a leadership role in the National Energy Act which was passed this past year, and one of the things that is involved there is making the utility industry more competitive in generation in order to bring the costs of power down. Costs are very, very, very important.

You can do things—you can do many different things, but can you do them at a right price, and that is an issue.

The CHAIRMAN. Well, I think it is—it is the fundamental issue of this bill. That is the reason I introduced this bill, is to try and get some rationalization of the program so that we decide whether we should do it, whether we can afford it, how we can afford it, whether we can get an international decision.

Now, I heard Mr. Gavin say that he does not think we could afford to go forward alone. What do you think, Dr. Overskei?

Dr. OVERSKEI. In the greater context of things, the amount of money that we are discussing here is actually quite small. I would say that we could go forward with the entire ITER alone, if we chose to do so. The cost is not that great.

There are significant advantages in participating with the international community in ITER, and I believe that is why it is a correct thing to do. We can leverage off the results that exist elsewhere and the programs that exist elsewhere by doing this, but I think it is a smart thing to do, but I also think that the objectives are sufficiently important to this country that if we cannot consummate the agreement, we ought to do it ourselves.

The CHAIRMAN. Of course, that may be another Ford Trimotor question for a fusion scientist, to ask him whether we should go forward with the program.

Dr. Hirsch, what do you think? Do you think we should go forward, do it alone?

Dr. HIRSCH. Again, sir, I would go back to the issues that I raised, which are, should we be taking this half, and I can understand Mr. Gavin's comment about Trimotors and so forth.

There are in any field of endeavor people who have shortsighted views, but I would hope that—and I believe that in the utility industry there are people who have long views.

There are many, many people in the utility industry who think that fusion is very important, want to see it go forward, want to see it produce something that is practical and useful. It will not happen, probably, but that is not clear, in their lifetimes, but it is important to this country and to the world.

The CHAIRMAN. Well, this question of cost, I think we ought to be spending a lot more money on science in this country, a lot more. I think basic science, particularly at a time of economic difficulty, is more important, not less important, and I think that this science, along with a lot of other basic science, is more important and not less important.

Unfortunately, my enthusiasm for science is not shared by the Congress generally, and we do not get as much money as we should, and I suspect that if we told the Congress that we are embarking on a program that in steps is going to lead to a cost of $8 or $10 billion, or whatever the program would be between here and a U.S.-financed ITER alone, I suspect they would probably say no, or they may say yes in the early stages and then say no halfway in between, which is the worst of all worlds, which some would suggest is what we should do on SSC and which I am going to resist as strongly and I hope successfully as I can.

We were successful last year. We were successful the year before, but it is to a large extent that experience which motivates me here, and I want the Congress to know what it is getting into, and focus and decide, just as I want the Department of Energy to focus and decide.

Should we be doing this magnetic fusion program, or should we go to another alternative fuel cycle? These are serious questions, Dr. Hirsch.

Believe me, I have great regard for EPRI and for the work you all do, and you ask serious, real time, real world questions. Somebody better start trying to get answers to these questions.

Dr. Rebut, what would it take to get a negotiation successfully concluded on ITER? How long would that take?

Dr. REBUT. Well, it is inside a new system, so it is difficult for me to estimate. I would simply say that for JET, from the point at the end of the design phase to get an agreement on the site has taken 1½ years inside Europe.

The CHAIRMAN. 1½ years.

Dr. REBUT. So yes, I would expect from the time a site is proposed by the different parties, or those parties who want to propose a site, it may take 2 years to get a decision, because a decision is not simply a decision on the site.

There are several elements which are required together, first to have a good idea of the overall costs, to know what is the fraction of this cost which is extra for the host country, to know what kind of structure, if it is an international structure or not, what generally the kind of structure will be for ITER, and all these elements may require, even in certain countries—it depends what country—new legislation. So this will take quite some time.

The CHAIRMAN. It would not surprise me at all that it would take 2 years to negotiate it. It would not take nearly that much time for the heads of State to meet and determine to do it, and that is the essential decision that needs to be done.

President Clinton and Yeltsin met north of Seattle, in Vancouver, and just decided to go forward with a program to purchase HEU from the Soviet Union. They must come back now and negotiate the agreement, but they made the decision, and both sides are under an expedited mandate to come to a conclusion.

Now, that is what needs to happen before we decide to go forward with these other things—the heads of State need to decide what they want to do. We have to pick a site, and the other countries have to pick a site, before you can determine internationally which country and how you divide up the work.

That is very complicated to decide how to divide up the work and where it is going to be done, and what percentages, and what degree of assurance you have for the funding, all of those things, but it is not that complicated for President Clinton to decide that we want to go forward with this program, with the ITER program, and that he will make it a high priority in his administration to defend these budgets against the Flat Earth Society, which will be in great evidence—they always are—but it is important, I think, to clarify the thinking on what kind of program.

Dr. Decker, what did you think of Dr. Hirsch's idea of convening a panel to make some of these decisions?

Dr. DECKER. It seems to me that the fusion program has been reviewed numerous times over the last 5, 10 years. My observation is that essentially every group that has come together to look at the fusion program has essentially endorsed the direction that we are on. Most recently, the Fusion Policy Advisory Committee that Secretary Watkins convened came to that conclusion.

I believe that the present course we are on is also endorsed by the Energy Policy Act. I believe we ought to get on with this program, the one that has been laid out. I really do not feel the need for a new review.

The CHAIRMAN. Well, for one thing, you are not likely to get the money for you program, if I have anything to do with it, unless you make up your mind as to what the program is.

Dr. DECKER. Right.

The CHAIRMAN. I mean, I can say that over and over again, but I want to try to drive it home. There is a lot of competition in this budget.

I mean, you have heard Dr. Hirsch. He says this is not the right direction to go, and that you ought to convene a group and decide what the right direction to go is.

Dr. Rebut, Dr. Overskei, Mr. Gavin say that this is a good direction to go, and you say, well, we ought to do both, study alternative fuel cycles and—am I correct on that?

Dr. DECKER. No. Let me try to clarify my position. I believe strongly that we ought to move forward with ITER. I believe that is the appropriate direction for the program. My concern was that if a new idea came along we would not have the ability to pursue it at all.

Realistically, the idea that something is going to come along and displace the tokamak as a candidate for an experimental power reactor, the probability of that is slim to none.

The CHAIRMAN. In your view, then, the tokamak—the administration has decided, is this fair, that the tokamak is the technology that should be pursued, and that while we do not want to close our ideas, our minds to any design innovations for something else, that we should pursue the tokamak.

Dr. DECKER. That is correct.

The CHAIRMAN. And that is well enough decided at this point.

Dr. DECKER. Yes, that is my view.

The CHAIRMAN. The administration has not decided whether or not we should do the ITER-type experiment on our own if the international community would not support it.

Dr. DECKER. That is correct. I do not believe that has been considered by the administration to date.

The CHAIRMAN. In light of the SSC, do you think that would be appropriate to make that decision?

Dr. DECKER. Well, I think that I agree with you that the sooner that we can make that kind of decision, the sooner we could commit to construction of ITER, clearly the better it is for this program.

We need to get that decision made before, I think, we can really move forward with the site selection in this country. Clearly, the sooner we get a construction decision made and a site decision made, the sooner we can focus on a site-specific design, which is very important to Dr. Rebut.

The CHAIRMAN. Dr. Rebut, what is the fastest we could move, and what would be the budget implications if they said, Dr. Rebut, you design, negotiate, and build ITER, what is the fastest that could be done, and how much money would have to be committed?

Dr. REBUT. First, on the technical side of it, I believe we can go a little faster than the time which is foreseen for the ITER. To me, really, a prototype, first element of the machine could start to be built within 3 years from now.

The CHAIRMAN. That is for the construction.

Dr. REBUT. That is the construction, prototype for the construction, make full-scale coils and elements like this, which means that all the tooling required for the construction of the coil, for example.

I do not believe that we can have a decision ready by this time of the questions of an international agreement, and so on. For the construction, I believe the construction will require 8 years from the time zero where the money is available that you have said.

My estimate today, which is in a very early stage, but I believe a reasonable estimate, could be what I have now, around $7.2 billion for the constructions until the first plasma, if I may say.

Of course, there will be the operation costs. ITER will operate for maybe 20 years. We will demonstrate that we can produce high power, and when I say high power, I am speaking of several billions of watt, so it is the same power as a power reactor, and in fact our main limitation, it is that power that we can take on the first wall. It is a power limitation for the time being.

The CHAIRMAN. Is it your present plan to actually make power?

Dr. REBUT. Well, we will go as fast as we can. Of course, we have to test the fuel element and we will check that this element is correct, and when you have to modify one of the elements, because we will have to modify some of the elements. I believe in 8 to 10 years we will reach the full power capability of ITER.

The second 10 years after will be used to test materials, the blanket element, basically, for a demonstration reactor, so in the life of it there is foreseen two periods, one which is to make the demonstration of the ITER, the first 10 years, then another one which is to use the machine for testing purposes.

The CHAIRMAN. Now, it will take about 3 years to design ITER.

Dr. REBUT. To design it. The design will go on even during the construction, but at least to be able to start with some of the long-term elements to be constructed, we would need 3 years to be able to start on these elements.

The CHAIRMAN. Will you have funding, or do you have funding? Are there plans to get to that point where you should be to begin construction 3 years from now?

Dr. REBUT. I believe that the funding which is received now in the four parties is, I believe, adequate. The questions or the problems that we are facing are questions that there have been so many rules even to spend this money that to agree on some R&D developments take quite a long time. The problem is we have four different countries, which makes it very very difficult to proceed.

The CHAIRMAN. Well, what I am saying is the probabilities of getting to that point 3 years from now.

Dr. REBUT. Is high.

The CHAIRMAN. Is hard?

Dr. REBUT. No, is high. I believe we will achieve it.

The CHAIRMAN. Is high.

Dr. REBUT. All right, Dr. Overskei, you are out there in San Diego very close to Dr. Rebut. Do you agree with that?

Dr. OVERSKEI. Yes, I do. The process that we are going through now is merely—from my perspective, we are selecting options and approaches. It is not as though we are devoid of ideas of what to do. We are in the process of narrowing down amongst options, any of which would work. So, yes, we can do it, and we are ready to go.

The CHAIRMAN. Do you think there will be funding forthcoming to reach that point 3 years from now?

Dr. OVERSKEI. You mean from the administration.

The CHAIRMAN. Well, we are talking about design.

Dr. OVERSKEI. Yes.

The CHAIRMAN. And Dr. Rebut says he thinks that the funding has been or will be adequate over the next 3 years to reach the point 3 years from now where you could begin construction if you had the money to start it.

Dr. OVERSKEI. Okay, I will start maybe by making a little bit of a flip comment. We are all optimists. That is why we are doing fusion. We are sure it is going to work, and therefore this optimism transfers forward. I am sure the Department will fund us at the level to make sure that this can happen.

But I would say that they have not necessarily funded the activity to the degree that would allow one to make progress at the limits of one's technical ability. And unless some action, as a consequence of this bill, takes place, I would say that there will be some continued hesitancy on the part of the Department in the future.

The CHAIRMAN. Even in funding the design over the next 3 years.

Dr. OVERSKEI. Yes, yes. San Diego could use more design people. They have requested this of the Department. They would like more support and I think that this would be the right thing to do.

The CHAIRMAN. Well, Dr. Decker, it looks to me like if 3 years from now we could be in a position to begin construction, and if, as Dr. Rebut says, it would take probably 2 years to negotiate this agreement to be able to begin construction, then do you not think it is prudent that at the highest level we should convene some kind of international agreement, or maybe a national group if another one of those is decided, so that 3 years from now we would have an agreement as to where we are going to build this and if we are going to build it and how we are going to split up the cost?

I mean it looks like now is the time if it takes 2 years, and my guess is 2 years would be an optimistic time schedule unless it is given the very very highest imprimatur by the heads of state. But should we not be making those decisions now?

Dr. DECKER. Yes. Well, I think the sooner we can make those decisions, certainly the better. It would be nice to be making them now. One of the limitations I think that we have to realize, is that, under NEPA, going through the process of selecting a candidate site for the United States by itself is going to take some amount of time.

The CHAIRMAN. Sure.

Dr. DECKER. I cannot give you an estimate as to how long that will take, because it depends on sort of which direction the Department might decide to choose. But having gone through it for the SSC, which I know you are aware of, that is a fairly lengthy process. So we have that to keep in the back of our minds.

The CHAIRMAN. Well, the Department does not, at this point, have a critical path, one of these flow charts where you begin to do these things.

Dr. DECKER. We have been looking at it, yes.

The CHAIRMAN. You mean you have been looking at a blank sheet of paper?

Dr. DECKER. No, we have been looking at schedules and how long it takes to do things to make the decision and so forth.

The CHAIRMAN. But you do not have the schedules now, is the point.

Dr. DECKER. No, we do not.

The CHAIRMAN. I mean there is no plan to begin an international negotiation.

Dr. DECKER. That is correct.

The CHAIRMAN. How would you—who should decide when that negotiation should begin and where should that negotiation begin?

Dr. DECKER. Well, with four parties, it is going to have to be mutual consent. I do not know how else to answer that question.

The CHAIRMAN. Well, would you agree with me that that ought to be made at the highest level.

Dr. DECKER. Absolutely.

The CHAIRMAN. That is, at the Presidential level.

Dr. DECKER. Absolutely; yes, sir.

The CHAIRMAN. And when should the President make that decision?

Dr. DECKER. I think part of the consideration is going to be when he feels that he has enough information from the design activities and so forth to fully understand what he is committing to.

The CHAIRMAN. In your judgment, when would he have enough information on that? For example—I want to ask you all this question. Suppose I wrote the President a letter and said, Mr. President, we just had a meeting and decided that you should make the decision on fusion and we think it ought to go forward as soon as practical to have an international negotiation.

The President calls you in and says, yes, I agree with that, when should I do it. What would be your advice to him? That is when should I bring it up to G–7 or wherever it is, when should he do that?

Dr. DECKER. I do not, off the top of my head, have a date in mind. I mean I think by looking at the schedule for Dr. Rebut's activities, that we could, you know, figure out a reasonable date.

The CHAIRMAN. What do you think, Dr. Rebut?

Dr. REBUT. Well, there are two elements in this. First, the EDA. The EDA does not decide if this has to be constructed by one, two, three, or four parties, so I believe the decision of construction is outside the EDA, first thing.

And it seems to me that we are committed, basically, to almost give a general blueprint of the design and of its cost in the next 4 months, so before the end of the year I suppose technically all the information required to define this kind of thing will be ready.

The CHAIRMAN. Well, understand I am not saying when the actual international negotiations about exactly how you split everything up and what it costs and what the design should be begin. I am saying that there is a step preceding that where heads of state meet and say should we go forward with a definite commitment to negotiate this agreement, and I am dealing with that first stage now.

Dr. REBUT. My point of view is tomorrow is right.

The CHAIRMAN. Is tomorrow——

Dr. REBUT. Is right.

The CHAIRMAN. What do you think about that, Dr. Hirsch?

Dr. HIRSCH. I would go back to what I said before, Mr. Chairman, and say that I think it would be appropriate after a panel from the user community takes a hard look at this approach and determines whether or not it makes sense. And if it does support this approach, then I think by the time that review is done a commitment could be made at that point.

The CHAIRMAN. Dr. Overskei.

Dr. OVERSKEI. This will probably be a little bit longer answer, but it addresses a couple of things that are undercurrents here. There have been multiple reviews of this program over the past several years. I have got a list that I could introduce here for the record, if you would like, but one of the more extensive reviews was by the National Research Council.

And I could just read off the members of utility industries or those people that represent utilities that participated in that review, and it is substantive. There are members of General Electric Corporation, Gas Research Institute, Westinghouse, Texas Utilities Company.

The CHAIRMAN. And then concluded what?

Dr. OVERSKEI. Well, they said that the program was ready to go. And they discussed ITER, and there was support for ITER at that time. This was in 1989. There was also the Fusion Policy Advisory Committee. I believe the problem is that there have been sufficient committees, and rather that the Government tends to postpone. And the way you prevent taking action is you study it to death.

And I believe that we are ready to proceed and that in January 1994 you will have sufficient technical information about the scope of this project, what it will actually—estimated costs and the sighting requirements and specifications, such that any Government, with consultation with their internal technical advisors, can make an informed and learned decision about what should be done in this project. And I do not think we need to study it anymore.

The CHAIRMAN. So if the President calls you in and said when should I bring this up—would G–7 be the place to bring it up in?

Dr. OVERSKEI. I would say it would be a wonderful location.

The CHAIRMAN. All right. There is a G–7 meeting every month for the next 3 years; which G–7 meeting should we bring this up at?

Dr. OVERSKEI. At the next meeting, I would say that this is going to be on the agenda for January of 1994. At the next meeting I would say gentlemen, be prepared to discuss it in January of 1994.

The CHAIRMAN. All right.

Mr. Gavin.

Mr. GAVIN. Being a veteran of the Apollo program, I am more impatient than some of the other people sitting at this table. I think things can be done faster if they have an adequate agreed upon priority. My view on when the President should speak on this matter is he should introduce the subject right away.

This is something that is going to take a series of conversations. It is not going to be solved in some nice logical fashion in one meeting, It is going to take a number of meetings and a number of meetings of the mind along the way to reach a point where perhaps there will be a compromise that can be acceptable to the four parties. I think it is going to be tough.

The CHAIRMAN. Well even before that, you have to decide whether you want to negotiate. And then if everybody says, well, this is a good idea, then the next step is who is going to negotiate for the United States, and that takes a while. And then where is the first meeting of the negotiators and all of those things. But it seems to me that would you not agree, Mr. Gavin, that very soon the President ought to bring up the subject?

Mr. GAVIN. Yes, sir.

The CHAIRMAN. And say we have this thing called ITER that might cost $8 billion and we want to share the cost. Are you, my friends, serious about whether we should do this or not. And they would probably say, well, this catches me unaware, let me go back and talk to my scientists. And then the next meeting of G–7, they, I hope, would come back and say yes, this is—or no, and proceed from there.

It is going to be an iterative process, I am sure, but we are not even at the point now of having somebody ask the question of the President, and I think that is what we need to do. And, Dr. Decker, we are to some extent treating you as if you are the one that is the obstruction in the bowel of progress.

But you are not, because this is a brand new administration and not everybody is on board yet. But I am trying to say in my own repetitive way that it is past time for the administration to make some fundamental decisions. I mean we cannot decide in the next few months exactly how we would negotiate an international agreement. Of course we cannot.

But we can decide what we think about tokamak fusion, about whether ITER is the logical and, indeed, essential next step. I mean some kind of burning plasma experiment that will show a sustained break even plus, I mean that has got to be done if you—you have got to go through that step before you can ever get to commercialization. And you need to decide whether we know enough to go to that step.

And if we do, then those other experiments, TPX, materials experiments, all of those things are in aid of doing that central thing which is on the critical path. And if you do not—if you are not deciding to do that which is on the critical path, then you do not need to do that which is in aid of it. And if you do not have a way to get across the river, there is no need to drive up to the river's edge.

Just one or two more questions Mr. Gavin. Do you think there is anything about this threat of termination that if our negotiators went and they knew they had to get an agreement on ITER or scale back the U.S. efforts, that is not really going to be a hindrance to getting an agreement, is it?

Mr. GAVIN. That is a tough question for me to answer, because I see two pieces to the argument. One is I understand your position in putting the pressure on the Department of Energy, and I can realize how that came about. On the other hand, I am very sensitive to the fact that there is this continued skepticism amongst the partners as to whether this country really will maintain its commitment. And I think that it might be just a matter of rewording that part of the bill a little bit to get across the fact that you are conscious of this problem and that you are not intending to cause a problem in that area.

The CHAIRMAN. Well, it is quite the opposite. The problem is now that before the Congress decides, before the administration decides on whether you are going to do something, that, of course, they are not going to live up to their commitment. I mean we need to decide in advance and at the highest levels, then it seems to me that they will have more confidence.

I mean if the President says let us convene the G–7, let us do fusion, let us negotiate it, and I will stand behind it, there is a lot better chance of getting this international cooperation.

I mean on SSC the administration kept telling us that the Japanese were going to come up with $1 billion. I did not believe they would, I did not think it was necessary to do it, and I am not all that anxious for them to do it, frankly. But the administration went into SSC telling everybody that they were going to do it. Now, we should not make that mistake here. We ought to determine what the other countries are going to do, and indeed what we are willing to do, and decide on that in advance and soon.

Well, gentlemen, this has been very very helpful to me, and I hope to the administration. This bill is very much addressed to the administration. I want it to be more than just provocative. I mean I want you to know I am deadly serious on this, because we are going to have to cut back on some other things and it is time to decide on whether we are serious about fusion, recognizing that it is going to be an expensive proposition, and determine whether we are ready for it now, whether we are ready for the decision.

There has got to be a way to answer that question. And then if so, are we ready to seek and live up to an international agreement. Or if not, are we willing to do it alone. And I think the answer to that, probably—given today's budgetary situation, is probably no.

And not just—I know you do not like the word drift, Dr. Decker, but I think it is drift in terms of making those key decisions. And it is ripe now. We have been studying this. We have had a lot of high-level panels and I expect if we had another high-level panel it would say the same thing, and they would all say it is a great program, go forward, do DT. Well, we are certainly going to do DT and do TPX and do ITER, but I think it is time to make this decision now.

Thank you. Does anybody have anything to add before we close the program down? Dr. Rebut.

Dr. REBUT. Well, I believe that the——

The CHAIRMAN. I do not mean to say close the program down.

[Laughter.]

The CHAIRMAN. Before we terminate today's hearing.

[Laughter.]

Dr. REBUT. Yes. But I believe it is quite important that the United States is taking a kind of leadership in this program. I do not believe that an international program will be possible if the United States is not in this program.

Thank you, Mr. Chairman.

The CHAIRMAN. Does anybody else have anything else to add?

[No response.]

The CHAIRMAN. Well, thank you very much, gentlemen, you have been very helpful.

[Whereupon, at 12:05 p.m., the hearing was adjourned.]

APPENDIXES

APPENDIX I

Responses to Additional Questions

DEPARTMENT OF ENERGY,
CONGRESSIONAL, INTERGOVERNMENTAL, AND PUBLIC LIAISON,
Washington, DC, July 2, 1993.

Hon. J. BENNETT JOHNSTON,
Chairman, Committee on Energy and Natural Resources, U.S. Senate, Washington, DC.

DEAR MR. CHAIRMAN: On May 6, 1993, Dr. James F. Decker, Deputy Director, Office of Energy Research, testified before your committee, regarding S. 646, the "International Fusion Energy Act of 1993."

Following the hearing, Senator Bumpers submitted 10 written questions to supplement the record. Enclosed are the answers to those questions to complete the record.

If we can be of further assistance to you or your staff, please contact our Congressional Hearing Coordinator, Barbara Campbell.

Sincerely,

ELIZABETH A. CECCHETTI,
Acting Assistant Secretary.

[Enclosures.]

RESPONSES OF JAMES F. DECKER TO QUESTIONS FROM SENATOR BUMPERS

MAGNETIC FUSION ENERGY

Question 1. How much did the Department of Energy spend in Fiscal Year 1992 on International Thermonuclear Experimental Reactor research and development? How much has the Department of Energy spent in Fiscal Year 1993?

Answer. In Fiscal Year 1992 the Department spent $42 million on International Thermonuclear Experimental Reactor research and development. In Fiscal Year 1993 the Department of Energy has spent about $18 million through March 1993 and is planning to spend a total of $52 million.

Question 2. How much money has been contributed by the other participating nations for International Thermonuclear Experimental Reactor research and development?

Answer. A basic principle of the International Thermonuclear Experimental Reactor Engineering Design Activities is that each party share equally in the costs and benefits. The activities are divided into two parts—research and development (75 percent of total costs) and design (25 percent of total costs). The U.S. is spending $42 million in Fiscal Year 1992 and $52 million in Fiscal Year 1993. Our best information indicates that each of the parties is providing its share of the resources for research and development. The U.S., Japan, and the European Community are providing their share of the resources for design activities. However, Russia is currently having difficulty sending personnel on foreign assignment to the three International Thermonuclear Experimental Reactor Co-Centers, due to problems obtaining hard currency. This difficulty is expected to be resolved in the near future.

Question 3. In your opinion, is any domestic tokamak research and development redundant with international efforts. If so, please elaborate.

Answer. In general, U.S. domestic tokamak research and development is complementary rather than redundant when compared to research going on in other countries. Although the facilities themselves may sometimes appear similar on the surface, the actual detailed research efforts are all unique programs which take advantage of novel diagnostics, heating systems, or operational techniques. We avoid duplication of effort by participating directly in almost all of the world's leading tokamak experiments. An ongoing domestic effort is necessary (1) to support the International Thermonuclear Experimental Reactor design work, (2) to fully realize its operating potential, and (3) to provide for an improved tokamak demonstration power reactor.

Question 4. How much will it cost to commercialize the tokamak reactor concept?

Answer. The major milestones in the strategic plan for the magnetic fusion energy development program, which is based on the tokamak reactor concept, are as follows: (1) by 2010, verify the practicability of commercial electric power production (Energy Policy Act of 1992), (2) by 2025, operate a demonstration reactor that would demonstrate the economic feasibility of fusion-generated electricity, and (3) by 2040, operate a fusion power plant providing cost-effective electricity to the public utility grid. Due to the long range nature of the fusion program, the schedule uncertainties that are inherent in all leading-edge, high-tech research efforts, and the increasing dependency on international collaboration and cost-sharing for major fusion facilities and development activities, it is not possible at this time to accurately estimate the cost to commercialize tokamak reactors. It is clear, however, that the increasing size and performance requirements of future tokamak reactors and supporting facilities will necessitate substantial budget growth to achieve commercialization.

Question 5. How much money has the utility industry (or any other private parties) contributed towards the International Thermonuclear Experimental Reactor and tokamak research and development?

Answer. During the late 1970's and early 1980's, the utility industry's Electric Power Research Institute spent an average of about $2.0 million per year on fusion research. We do not know, however, how much may have been related to the International Thermonuclear Experimental Reactor or tokamak research and development. Although accurate cost figures are not available, several industrial firms have entered into nominal cost-sharing arrangements with the Government on a variety of fusion research and development design contracts. About $0.6 million has been pledged by the San Diego business community to help support Russian members of the International Thermonuclear Experimental Reactor central design team located in San Diego (the State of California has pledged $4.0 million to help support the project's design team facility). In addition to their direct financial contribution through the Electric Power Research Institute, the utilities have provided individual representatives for most of the many fusion program advisory committees, panels, and review groups of the past decade.

INERTIAL FUSION

Question 6. How much money has the Department of Energy spent on research and development of inertial confinement fusion projects.

Answer. The Inertial Confinement Fusion program is managed by the Office of Defense Programs within the Department. The goal is to achieve pure thermonuclear ignition and burn in the laboratory for military applications and with a view to possible civilian applications.

From Fiscal Year 1972, (when inertial fusion was identified as a separate activity within Defense Programs) through Fiscal Year 1993, $3.2 billion will have been spent on inertial confinement fusion by Defense Programs.

From Fiscal Year 1982 through Fiscal Year 1993, $65.6 million will have been spent on inertial confinement fusion by the Office of Energy Research.

MAGNETIC FUSION ENERGY

Question 7. Please assess the radioactive waste impact associated with magnetic fusion?

Answer. Unlike the burning of fission fuels, which inherently produces radioactive waste, the burning of fusion fuels does not itself produce radioactive waste. However, fusion reactors would produce radioactive waste by the interaction of neutrons (generated in fusion fuel burning) with the structural materials of the reactor. As neutrons interact with these structural materials, they induce radioactivity through nuclear interaction processes. The resulting radioactive materials, while not as long-lived and toxic as those produced in fission reactors, must eventually be disposed of as radioactive waste. The amount and degree of hazard of the radioactive wastes will depend on the types of fusion fuel and structural materials that are used in a fusion reactor. With near-term types of fuel (deuterium and tritium) and structural materials (conventional steels), the amounts of radioactive wastes produced by a fusion reactor could be as large as those from an equivalent sized fission reactor, although the lower toxicity and longevity of the fusion waste would result in a much lower degree of hazard than that of the fission waste. Based on the most meaningful measures of radioactive waste risks, including volume, toxicity, and longevity, the hazards of radioactive wastes from fusion are expected to be at least 100 times smaller than those from fission with present-day fuels and structural materials. Structural materials under long-term development for fusion reactors beyond the International Thermonuclear Experimental Reactor would produce thousands of times less radioactivity than conventional steels, potentially allowing for waste disposal by shallow land burial procedures.

Question 8. What material or materials are needed for thermal blankets? How many tons of these elements would be needed?

Answer. Thermal blankets in a fusion reactor would perform the functions of converting fusion energy into heat, of extracting heat in a useful form, of shielding reactor components and personnel from excessive radiation exposure, and of internally producing the tritium needed for reactor fueling. The types of materials needed to perform these functions include coolant materials, structural materials, shielding materials, and tritium-producing materials. Candidate coolant materials include ordinary water, helium gas, organic fluids, and liquid metals. Candidate structural and shielding materials include conventional steels (for near-term applications) and advanced materials (including modified steels, vanadium alloys, and ceramic composites) that become much less radioactive when used in thermal blankets than do stainless steels. Candidate tritium-producing materials include lithium-bearing liquid metals and ceramics. Because a thermal blanket would need to be thick (about one yard) and surround the entire fusion reaction chamber to perform all of its functions, it would be one of the largest components of any fusion reactor. A thermal blanket would be made up of many blanket elements joined together to form an integral blanket system, the cumulative weight of which would range from 5,000 to 15,000 tons, depending on the specific choices for coolant, structural, shielding, and tritium-producing materials.

Question 9. When the tokamak reactor becomes commercially viable, what size reactor would be operating?

Answer. The potential size of commercial tokamak reactors was estimated by the Advanced Reactor Innovations Evaluation Study, a five-year study that was completed In late 1992. Several tokamak reactor approaches to commercial electricity generation were analyzed. It was estimated that the size for a commercial tokamak reactor capable of generating 1000 megawatts of electricity was such that the unit would be contained in a cylindrical structure no larger than approximately 110 feet in diameter and about 100 feet high. This is comparable to the size of a conventional coal-fired plant. Smaller tokamak reactors may be possible with reasonable advances in physics and technologies.

Question 10. What is the Department of Energy doing to work with the utility industry in mapping out the Department's fusion strategy?

Answer. The Department, and in particular the Office of Fusion Energy, has worked with the utility industry and its representatives for many years in developing a fusion program strategy. Utility executives have been involved in several committees that have reviewed the fusion program over the last five years. Without exception, these reviews have supported the directions of the fusion program. In addition, utility persons have been involved in the forward-looking studies of possible reactors producing electricity using fusion. Recently, the Electric Power Research Institute has formed a Fusion Working Group. The Department is supporting that group by providing information directly through presentations by Departmental officials, and by enabling the Department's contractors to participate in meetings of the group when they are invited.

APPENDIX II

Additional Material Submitted for the Record

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.,
IEEE-USA ENERGY POLICY COMMITTEE,
Washington, DC, May 13, 1993.

Hon. J. BENNETT JOHNSTON,
Chairman, Committee on Energy and Natural Resources, Senate Hart Office Building, Washington, DC.

DEAR SENATOR JOHNSTON: The Energy Policy Committee of the Institute of Electrical and Electronics Engineers—United States Activities (IEEE-USA) is pleased to submit its views on fusion research and, in particular, on the International Fusion Energy Act of 1992 (S. 646). Toward that end, this letter addresses the specifics of S. 646, while the attached statement presents the views of IEEE-USA on the fusion issue more broadly.

The Energy Policy Committee is encouraged by the strong support of the fusion power program expressed in S. 646. The Committee believes that the timely demonstration of fusion as a viable ad environmentally advantageous option for central station electrical power production is important to the environment, economy, and energy security of the United States.

The Committee also endorses the bill's support of international collaboration on the International Thermonuclear Experimental Reactor (ITER) as a demonstration of the feasibility of fusion power. However, the Committee suggests several amendments to S. 646 both to improve the end-product fusion demonstration plant and to assure U.S. competitiveness in the design and construction of a attractive reactor:

(1) Rename the Act to the "Magnetic Fusion Energy Act of 1993," in recognition of the domestic as well as international aspects of the fusion program;

(2) Focus on developing the technological and scientific base for a attractive demonstration fusion reactor by roughly 2020;

(3) Add the development of low-activation materials for fusion to the international program;

(4) Add "tokamak concept improvement" as an important element of an effective fusion program, in parallel with ITER. The Tokamal: Physics Experiment (TPX) is the next concept improvement step advocated by the U.S. fusion community and should be specifically supported in the Act as a national facility. TPX is targeted at steady-state advanced tokamak studies;

(5) Direct DOE to reevaluate and fund a strong domestic fusion program at an appropriate level rather than automatically reducing program funding to $50 million per year in the event that the ITER program is terminated.

Our assessment and recommendations on the overall U.S. fusion energy program are provided in the attached statement on the FY 1994 budget request for Department of Energy fusion research. In closing, the IEEE-USA Energy Policy Committee thanks you for this opportunity to make our views known and stands ready to assist you as a resource for technical advice and policy perspectives on the critical issues confronting the nation and its energy policy.

Sincerely,

JAMES FANCHER, *Chairman.*

[Enclosure.]

STATEMENT OF THE ENERGY POLICY COMMITTEE, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, UNITED STATES ACTIVITIES

The Energy Policy Committee of the Institute of Electrical and Electronics Engineers—United States Activities (IEEE-USA) is pleased to submit its views on the Department of Energy's FY 1994 budget request for fusion energy.

The Energy Policy Committee believes a adequate energy supply is vital to the economic growth and security of the nation and the world and to the nation's international competitiveness. The nation's electrical supply system must be reliable and continuous and must have minimal impact on the environment and on global climate change. Extensive research and development will be required to improve present energy sources and to develop new ones that have reduced environmental impact and can provide increased energy security. Research aimed at timely demonstration of fusion as a viable power source for base load electrical power generation will insure that fusion can become a important element in a balanced portfolio of energy technologies in the future.

The Energy Policy Committee's vision of the long-term energy configuration emphasized energy efficiency, conservation, safety, and a diversification of energy sources that include photovoltaics and renewable energy, advanced nuclear fission technology, and fusion. Near-term government policy should be targeted at the development of a portfolio of technologies that will permit a balanced mix of energy resources in the future. We believe that increased efficiency and increased energy production are essential to insure adequate supplies of reliable, low cost, and environmentally acceptable energy. We view fusion as a critical component of a future energy technology mix that could supplement and eventually reduce the need for burning fossil fuels. In this statement we document our position on fusion energy research and development within the context of the nation's overall energy package.

FUSION PROGRAM OVERVIEW

The Fusion Energy Program is targeted at developing fusion energy as long-term energy source characterized by:

1. universally available and virtually inexhaustible fuel,
2. well controlled radiological hazards,
3. proliferation risks significantly less than with fission power,
4. negligible atmospheric emissions, and
5. limited impacts on ecological and geophysical processes.

In its most easily attainable form, fusion consists of the nuclear burning of deuterium and tritium. Fusion powers the sun. Commercial utilization of fusion as a alternative energy source has proven difficult and fusion is not expected to play a major role in commercial power production until well into the next century. The recent experiment on the Joint European Tokamak has produced a average of 1 megawatt of fusion power for 2 seconds. U.S. experiments on the Tokamak Fusion Test Reactor in FY 1993-94 are forecast to generate more than 10MW of fusion power, a level at which the power produced will nearly match the power invested in heating the plasma.

Fusion can be a solution to the long-rage national and international energy challenge. Fusion research contributes to the United States economic competitiveness, environmental safety, and national security. Because of its long lead time and precompetitive status, fusion research must be almost exclusively funded by the Government.

The specific aim of the current DOE fusion energy program is a operating demonstration plant by 2025, and the design and construction of a commercially viable plant by 2040.

The DOE fusion energy program pursues both the magnetic and the inertial approaches. The magnetic fusion energy (MFE) approach employs intense magnetic fields to confine hot (>100 million degrees Celsius) plasma, which is heated by a combination of neutral particle beams and/or radio frequency waves and which burns to produce power. In the inertial fusion energy (IFE) approach, high intensity laser or particle beams implode a small pellet of fusion fuel, producing ignition temperatures and releasing energy.

MFE research in the United States has been pursued at a number of laboratories, with the largest devices (TFTR and Doublet DIII-D) located at the Princeton Plasma Physics Laboratory and General Atomics. Research is focused mostly on the tokamak concept, a doughnut-shaped Russian design, although studies of alternative magnetic field configurations (such as the ATF stellarator at Oak Ridge National Laboratory) are being resumed.

IFE research using laser beams and high-power light and heavy ion beams to implode fusion pellets has been centered at the national nuclear weapons laboratories (Livermore, Los Alamos and Sandia), chiefly because of classification restrictions that derive from similarities between a imploding fusion pellet and a nuclear weapon. While all fusion research is funded through the Department of Energy (DOE), most of IFE is funded under Defense Programs. While inertial fusion research will have increasing military relevance in simulating the effects and the physics of nuclear weapons because of the planned elimination of U.S. underground testing by 1997, IFE remains a long-term energy technology along with MFE. Non-defense funding of IFE focuses on improvement of the driver beams for reactor application.

In November 1992, the Secretary of Energy Advisory Board (SEAB) recommended that the MFE fusion program receive a budget increase in excess of 5% in real purchasing power in order to proceed with the program proposed by the Fusion Energy Advisory Committee (FEAC). This program assures timely completion of the TFTR deuterium-tritium experiments, construction of the steady-state advanced tokamak physics experiment (TPX), continued operation of existing facilities, participation in the international ITER and support of alternative fusion concepts. Recommendations for the IFE program are under development by FEAC. The passage of the Energy Policy Act of 1992, which calls for a fusion demonstration plant by 2010, provides welcomed support and a challenge for the fusion community, although achievement of the 2010 goal will require increased funding.

The Energy Policy Committee believes that fusion power is a highly desirable goal because of its potential advantages with respect to electrical power generation. We also realize that research and development in the fusion area generates valuable high technology spin-offs that can improve our nation's economic competitiveness in international markets and increase the jobs available to our citizens. These spin-offs include superconducting magnets, industrial plasma processing, high-performance computing, high power lasers, robotics, diagnostics, radio-frequency sources, and high-power microwave devices for industrial applications.

DOE'S MAGNETIC FUSION ENERGY PROGRAM PROGRESS AND PROSPECTS

The production of a average of 1 megawatt (peak 1.7 MW) of fusion power for a duration of two seconds by using a deuterium and tritium mixture in the Joint European Torus (JET) in November, 1991 represented a milestone in the fusion program. This was the first use of a significant amount of the more reactive tritium fuel and the first production of significant fusion power.

The production of 10-20 megawatts of fusion power with a deuterium-tritium fuel mixture in the TFTR at Princeton in FY 1993-1994 will be the next step in the progression toward understanding the physics of fusion plasmas and demonstrating fusion power production in the laboratory.

Another advance in MFE is the observation that plasma confinement and stability depend critically on the spatial distribution of the plasma current, the plasma shape, and the radial electric field. These properties are controllable and provide directions for improving tokamak performance. The achieved factor of three containment enhancement is good enough for a breakeven reactor.

In 1991, the SEAB Task Force on Energy Research Priorities recommended that the Burning Plasma Experiment (BPX) not be constructed due to budgetary constraints; cancellation of BPX was explicitly not due to the quality of the proposed program. During 1992, the Fusion Energy Advisory Committee (FEAC) engaged in an intense process of program review and development, targeted at the proposal of a ~$400M (FY 1992 dollars) device that would be affordable. The magnetic fusion community examined a spectrum of next-device missions and determined that study of steady-state advanced tokamak issues was the appropriate mission for a $400M (FY 1992) device. The FEAC recommended this mission to the SEAB Task Force, which in turn recommended the construction of the Tokamak Physics Experiment (TPX) to DOE. President Clinton has listed TPX as an element of his "economics investment package."

DOE'S INERTIAL CONFINEMENT FUSION PROGRAM PROGRESS AND PROSPECTS

In inertial confinement fusion, steady progress is being made in reaching higher fuel temperatures and controlling the instabilities that limit achievable compressions. In the past year, technical achievements in the ICF program have included advances by Lawrence Livermore National Laboratory and Los Alamos National Laboratory in modeling laser-target interactions for pulse-shaped radiatively-driven targets on NOVA, progress on construction of a direct-drive KrF laser facility at the Naval Research Laboratory, and development of plans to upgrade the OMEGA glass laser at the University of Rochester. In addition, international collaboration in experiments on PBFA II (at Sandia National Laboratories), LION (at Cornell University), KALIF (in Germany), and Reiden IV (in Japan) has led to improvements in the focusing of light ions.

Five of twelve milestones established by the National Academy of Sciences (NAS) as prerequisites to an ignition facility have been accomplished on the Nova laser. The NAS review concluded that glass lasers offered the only viable driver option for the ignition demonstration step (NIF) and endorsed the NOVA Upgrade proposal as the optimal ignition facility. DOE recently granted approval for proceeding with the conceptual design of the NIF.

DOE has established an inertial fusion energy (IFE) program within the DOE Office of Energy Research's Office of Fusion Energy. This program complements the target physics supported by Defense Programs by addressing the critical problem areas of efficient, high-power heavy-ion drivers, the production of affordable, high-gain targets, and the design of appropriate reactor chambers and systems.

DOE program plan includes device upgrades and research leading to the demonstration of ignition and modest power gain in the laboratory and the understanding of the physics of high-current, heavy-ion beam accelerators and direct drive, as recommended by the National Academy of Sciences.

CONTRIBUTIONS OF FUSION RESEARCH TO OTHER AREAS OF SCIENCE AND TECHNOLOGY

Fusion R&D generates valuable high technology spin-offs in areas such as superconducting magnets, plasma processing, high-performance computing, high-power lasers, robotics, instrumentation, and radio-frequency sources.

Fusion research on hot plasmas has synergy with astronomy and astrophysics. Waves and magnetohydrodynamic instabilities have been studied in both tokamaks and the earth's magnetosphere. Picosecond pulse lasers, developed from inertial fusion technology, can generate very high frequency oscillations in a plasma. Microwave tube technology is being extended to continuous-wave powers that approach megawatt levels at millimeter wavelengths via the development of the gyrotron tubes for heating plasmas in the fusion program; such microwave power levels provide benefits to industry, for example the rapid, low-temperature sintering of ceramics. The mathematics used to model the behavior of the hot fusion plasma is applicable to the development of unique, high-power microwave tubes such as the vircator, and is driving the development state-of-the-art numerical computations for many other purposes.

DISCUSSION AND RECOMMENDATION

Substantial investment in energy research is critically important to the welfare and economic competitiveness of our nation. The SEAB Task Force recommended that budgetary constraints on energy research be relieved and that "every effort should be made to secure a future ER budgetary profile that is more in keeping with the outstanding scientific opportunities before the nation and the traditional role of the DOE as a major source of support for fundamental science and engineering research." Consistent with this position, the IEEE-USA Energy Policy Committee encourages appropriate investment in energy-related research and development.

The Committee believes that fusion must be developed as an element of a portfolio of long-term electrical energy production technologies because of fusion's potential as a inexhaustible and environmentally attractive technology. We support DOE's intent to fund fusion research in the context of an energy program with a strong emphasis on scientific and technological content. We urge DOE to maintain the schedule for the demonstration fusion power plant by the year 2025 and construction of a commercial fusion power plant by 2040.

The Committee recognizes the need for international collaboration on large scale projects such as ITER to advance the fusion research effort and to demonstrate scientific feasibility. However, a strong, complementary domestic program is necessary to assure the nation's competitiveness in the production of future power systems.

The development of fusion energy has significant environmental, foreign policy, and national security advantages. Stable Government funding of energy research is an essential requirement for the development of fusion energy technologies and the emergence of substantial investment in fusion by private industry.

The IEEE-USA Energy Policy Committee recommends that DOE:

Commit to the steady, long-term development of fusion power. This requires stable funding of fusion research and development, despite periods of temporary economic and political change.

Participate as a major partner in international efforts (such as ITER) to develop fusion as a viable future energy source. Currently, the United States fusion budget is considerably smaller than that in Europe and that in Japan.

Maintain a strong domestic research program to complement international programs. The domestic program might emphasize new and improved concepts and broad-based research on basic plasma science to complement the international focus on complex, integrated demonstrations such as ITER. The United States should have a strong domestic program that includes a spectrum of fusion research devices and programs in both science and technology.

Pursue innovative ideas to improve fusion concepts. Basic physics studies should exist in parallel with large integrated demonstration devices such as ITER. DOE should maintain a broad enough focus so that shortcomings of one approach do not preclude the development of an ultimate fusion program that combines economic attractiveness with significant environmental and safety advantages. Fusion research should include development of advanced configurations, advanced materials, and alternative confinement configurations with emphasis on low activation. This breadth is essential because it is too early to know what is the optimum fusion energy system for ultimate commercial development.

Create new funding sources for university-based research in both MFE and IFE to provide an intellectual stimulus, objective criticism, and innovative thinking that universities foster and to train future scientists and engineers. A recent NRC Research Briefing on Contemporary Problems in Plasma Science highlighted many exciting opportunities for university research, including the innovative use of fusion facilities. These facilities are not being exploited because funding sources for basic plasma sciences are extraordinarily limited. Universities and the international community can play a larger role in the IFE effort in lasers and light and heavy ion drivers once the completed classification guidelines recommended by the National Academy of Sciences are approved.

Enhance the fundamental scientific and engineering base in the sphere of energy research to ensure that the nation acquires the technological expertise necessary to establish U.S. industry as a major supplier of fusion power systems in the future.

The IEEE-USA Energy Policy Committee thanks you for this opportunity to comment on the FY 1994 budget request for fusion energy. IEEE-USA and its committees stand ready to assist the new Congress as a resource for technical advice and policy perspectives on a wide range of issues that affect the career and technology policy interests of the nearly 250,000 electrical and electronics engineers and computer scientists who comprise our U.S. membership.

STATEMENTS OF RICHARD D. HAZELTINE, DIRECTOR, INSTITUTE FOR FUSION STUDIES, AND ALAN J. WOOTTON, DIRECTOR, FUSION RESEARCH CENTER, THE UNIVERSITY OF TEXAS AT AUSTIN, AUSTIN, TX

I am Richard Hazeltine, a professor of physics at The University of Texas at Austin. I became interested in the physics of controlled fusion while doing postdoctoral research at the Institute for Advanced Study in Princeton, and have remained devoted to the fusion energy program since then. I have been at The University of Texas since 1971.

The University of Texas has had leading programs in fusion research for many years; indeed, I am still impressed at how many people in Texas—and I don't mean exclusively academic people—know and care about fusion energy. The Fusion Research Center, directed by my colleague, Alan Wootton, stems from the pioneering university fusion program in Texas, begun in 1965. In 1979, the Department of Energy decided to establish a center for excellence in theoretical studies of controlled fusion; Texas was very proud to be chosen as the site for that center. Called the Institute for Fusion Studies, it is supported by the Department of Energy and by matching funds from the State of Texas. It exists along side of, and in close scientific communication with, the eryerimentally oriented Fusion Research Center. I am the Institute's director.

The mandate of the Institute for Fusion Studies is to explore and elucidate the theoretical physics of controlled fusion, with special emphasis on fundamental and long range issues. As the largest university-based fusion theory group, the Institute has a special role in training students and postdoctoral researchers. But beyond its academic duties, and its primary devotion to applied theoretical research, the Institute has adopted certain fusion-program responsibilities. For example, we try to be a center for critical evaluation of the evolving science of fusion, as well as a source of innovative, useful ideas and theoretical tools. By arranging visitor exchanges, conferences and workshops, the Institute encourages scientific communication within the international fusion theory program. It is in particular the principal U.S. site for the exchange activities of the U.S.-Japan Joint Institute for Fusion Theory.

The research being pursued at the Institute is diverse—including such topics as plasma turbulence, numerical simulation, stability theory and nonlinear plasma dynamics—and interdisciplinary. The Institute's staff includes about 25 PhD scientists (including physics faculty, research scientists and postdoctoral fellows) and approximately 20 doctoral students. It sponsors a vigorous visitor program, with about 10 visiting scientists typically in residence, as well as a very large number of research collaborations with laboratories and universities throughout the world. Such connections, along with our close relationship to experimental scientists in the Fusion Research Center, maintain the essential contact between Institute theorists and the realities of fusion experiments.

Since the testimony represents the views of both Professor Wootton and myself, I would now like to give Professor Wootton a chance to tell something about himself and the Fusion Research Center.

I am Alan Wootton, a professor of physics at the University of Texas at Austin. I have devoted my research career to the pursuit of fusion, working in England, Germany and the United States. I am presently director of the Fusion Research Center at the University of Texas at Austin.

The Fusion Research Center has operated a medium sized tokamak (the Texas Experimental Tokamak, "TEXT") since the early 1980's. This machine is devoted to a combination of four topics, namely (1) basic physics experiments, (2) testing of innovative concepts, (3) providing a User facility for outside organizations, and (4) education and training. A short description of each topic now follows.

Basic Physics. TEXT is extremely well instrumented, allowing detailed comparisons between experimental results and the theoretical predictions provided by our sister organization, the Institute for Advanced Studies. The understanding which follows translates into better designs of next generation machines. For example, in the area of plasma transport we identified turbulence as the cause of the particle and energy losses at the edge of tokamaks, and showed how to control this turbulence using a space-dependent rotation velocity. These concepts have been incorporated into designs for achieving "improved confinement" in larger machines.

Innovative Concepts. The flexibility of our organization and machine, and our inexpensive operational costs, allow rapid testing of new concepts. For example we developed, in collaboration with General Atomics (see below, "User Facility"), the "Ergodic Magnetic Limiter", in which the magnetic topology is purposely destroyed at the plasma edge. Our successful results convinced the French to incorporate such a system into their machine Tore-Supra, and both the JET and DIII-D groups have considered such systems. We are currently developing a technique to de-stabilize waves in the plasma edge and spread out the heat load. If successful this will reduce the constraints on fusion reactor materials.

User Facility. We provide a User facility for outside groups without their own plasma device, or with a device with restricted availability, to perform experiments. Examples of these Users include Universities (e.g. the University of California at Los Angeles, Rensselaer Polytechnic Institute, Auburn University), Industries (e.g. General Atomics, who helped develop the "Ergodic Magnetic Limiter"), and National Laboratories (e.g. Oak Ridge National Laboratory). Often these groups come to develop new diagnostics, which are ultimately required on large machines. Our flexibility, and reliable and inexpensive operation, are an important asset when this development is being undertaken.

Education and training. There are currently 25 graduate students working towards their thesis on the TEXT device. In addition to students from the University of Texas we also have students from other institutions (e.g. MIT, Auburn) who perform their experimental work at the Fusion Research Center.

As Professor Hazeltine has already said, the following testimony represents both his views and mine. We appreciate an opportunity to share our comments on S. 646, the International Fusion Energy Act of 1993. We applaud Senator Bennett Johnston, Chairman of the Senate Committee on Energy and Natural Resources, for his interest in fusion research and we look forward to working with this committee to strengthen this bill.

COMMENTS ON THE FUSION PROGRAM

The quality of any industrial society depends in large part upon how it produces and uses energy: how much of the earth's finite resources it consumes, how much mess it leaves for future generations to clean up. While controlled fusion does not provide a complete solution to all the environmental and societal issues of energy production, its intrinsic advantages—especially with regard to fuel abundance, air quality, global warming and inherent safety—assure its ultimately central role in world energy production. Recognizing this fact, the major industrialized nations have marshaled large, coordinated efforts to produce fusion power early in the next century. The United States, after sadly losing its historical lead in fusion research, has clear and very practical reasons to remain near the front of this international campaign.

No fusion plant will enter the power grid during the next decade; it is a long-term fix to an infinite-term problem. But fusion is real, it is going to happen, and it will dramatically affect human productivity and well-being. Moreover, the short-term benefits of fusion research, in terms of technology spin-offs, general scientific progress and international prestige, already display a growing impact.

Fusion research has made impressive, even dramatic, progress in recent years. For example, the key experimental parameters that measure capability for reactor performance have been improved by a factor of roughly ten-million since 1970. We believe that such achievements reflect a dedication and concentration of effort that is a credit to the fusion research community. Nonetheless many fusion workers are concerned about the future of fusion power. There is widespread fear that as the technical situation continues to improve, administrative developments may obstruct the program's goal: cheap, abundant, clean energy.

The cause of concern is not a shortage of funds. Most researchers find the present rate of support to be appropriate—consistent with the long-term nature of the quest and with competing national needs. Nor is the issue any lack of research "focus," a topic that has entered the recent debate. Indeed, the technical progress already mentioned reflects a creditably precise targeting of key fusion obstacles and goals. The issue is administrative direction of the program, particularly with regard to the International Thermonuclear Experimental Reactor (ITER).

The great majority of fusion scientists are excited by ITER, eager to contribute to its successful operation, and confident it will accomplish several critical tasks. We expect ITER to yield scientific proof of the basic feasibility of fusion as an eventual power source, as well as providing a test bed for critical engineering and nuclear physics issues that cannot be studied in any existing device. Thus building ITER is regarded as both a good idea and a timely one.

Nonetheless, it must be stressed that ITER is neither the sole end nor the sole means of the international fusion program.

Three types of accomplishment are necessary before fusion can begin to realize its promise. First, there must be convincing proof of basic scientific feasibility. Second, a number of "second tier" technical issues, such as energy transfer and fuel breeding, must be resolved. Third, the fusion reactor concept must be developed to the point of offering an attractive option to energy planners and utility executives: it must evolve into an economically competitive energy source. ITER addresses the first of these hurdles directly, and will have much to contribute regarding the second. But it does not effectively address the third: the major technical advances necessary for a competitive fusion reactor can only evolve out of a broad research program, not tied to any single machine.

As a strictly experimental device, ITER is not to be viewed as the prototype for a commercial reactor—anymore then the Kitty Hawk craft was a prototype for a 767. Moreover the technical basis for extrapolating from ITER to such a reactor does not presently exist. Most importantly, the development of such a scientific foundation will depend crucially upon research efforts and devices separate from the ITER enterprise. Indeed, as those closest to ITER often emphasize, the device's very special purpose (together with the scale and rigidity of design implied by that purpose) is not consistent with the sort of exploratory investigations required for the development of a true reactor prototype.

Thus ITER is only part of the campaign to realize fusion power. Equally essential—if less visible and marketable—is a parallel program aimed at developing the scientific knowledge that will make fusion an attractive energy option. Such a program is in place today, in the U.S. and in every nation that pursues fusion power. It includes most university fusion research, together with major contributions from national laboratories; its experimental facilities comprise a number of tokamaks and related devices, including some of significant size. This parallel program works, and should continue to work, in close communication with ITER, but it has distinct goals. Rather than attempting to achieve historic breakthroughs in fusion parameters, it focuses on the fundamental physics and engineering issues, still poorly understood, whose resolution would allow cheaper, more compact and simpler reactors. More concretely it tends to look beyond ITER toward the demonstration reactor and other devices, still below the horizon.

Strict limitation of this second arm of the fusion program would, in the long run, delay the application of fusion power to U.S. national needs. In the shorter term, it would harm physics and engineering research at numerous U.S. sites, including both universities and national laboratories. It would especially damage university fusion research, raising a number of questions concerning future manpower needs. If university fusion programs are allowed to wither, where will the U.S. find the young scientists and engineers needed to reap the benefits of fusion research? Where will we find the human resources needed to advance from ITER to a demonstration reactor?

We are concerned that the research programs at The University of Texas and other institutions around the country are at risk if we place all our resources, effort and commitment solely behind the ITER effort. As currently drafted, S. 646 would explicitly eliminate all parts of the fusion program not directly in support of ITER or a demonstration reactor. We would urge the committee to clarify the intent of the legislation, to include support for fusion programs that are focused on the true objective—making fusion energy a reality—whether or not they are devoted exclusively to the ITER project.

The goal of the fusion program is not to get fusion on the evening news, but to put it on the power grid. That goal calls for scientific depth, for relevant innovation, for planning with both technical and temporal scope. Along with the engineering and developmental efforts associated with large devices, the goal of fusion calls for scientific research of the highest quality. A sound national fusion program requires ITER, but it emphatically requires much more.

In summary, we support the committee's interest in fusion and look forward to working with you to clarify the intent of S. 646. As currently drafted however, the legislation may unintentionally stifle essential fusion research, and thus impair our nation's ability to contribute to this vital international program.

May 19, 1993.

Hon. J. BENNETT JOHNSTON,
Chairman, Committee on Energy and Natural Resources.

DEAR MR. CHAIRMAN: On behalf of the undersigned organizations who are committed to eliminating unnecessary federal spending on programs which damage the environment and waste of taxpayer money, we urge that the Department of Energy budget for Fusion Energy be cut by $200 million. Current federal research programs focus on a technology that is uneconomical, would generate large amounts of radioactive waste, and may never lead to a commercially-viable source of energy. In a time of tough budget choices, fusion is far less promising than its competitors. While we do not propose elimination of the fusion program, we recommend that it be scaled back dramatically, and that future fusion research be cost-shared with industry.

As you are well aware, the inherent challenge of fusion energy is one of recreating, in a commercially-sized reactor, conditions similar to those found at the center of the sun. Nuclear fusion, which powers the sun and hydrogen bombs, occurs when atomic particles combine or fuse at extremely high pressure and temperature to form heavier elements. The end product is lighter than the sum of its parts, with the excess emitted as high energy particles. The energy from these particles can then be captured and used to generate electricity.

Enormous scientific and engineering problems associated with achieving and sustaining the conditions necessary for fusion energy are far from being solved. Over the last 40 years, U.S. taxpayers have paid more than $9 billion for research on fusion energy, yet none of the research efforts has achieved "break-even", the point at which the fusion reaction generates the same amount of energy as is put in. Of course, to produce commercial power, a fusion reactor has to generate more energy than is put in, and there is no guarantee that this will happen in our lifetimes. Even fusion proponents admit that fusion energy will not be commercially viable until at least 2040. This means that the public is slated to pick up the tab for almost a century of research with no guarantee of success.

Nuclear fusion has been described as a safe, environmentally benign, affordable, and potentially limitless source of energy. In reality, DOE's current research program focuses on a technology which is expensive and generates large amounts of radioactive waste. The majority of DOE's $348 million FY94 budget request for civilian nuclear fusion funding is for research on "tokamaks", doughnut-shaped machines that "squeeze" the fuel using magnetic fields. The fuel ultimately used in these reactors is deuterium (a form of hydrogen found in seawater) and tritium (a radioactive form of hydrogen used to make nuclear bombs, which must be generated from lithium). When deuterium and tritium fuse, they form helium, an inert gas, and very energetic neutrons (subatomic particles), which can be used to heat water and generate electricity. These energetic neutrons also collide with the walls of the reactor vessel and other parts of the fusion reactor, making these components radioactive and brittle. In fact, a 1990 study by the Office of Technology Assessment estimated that the walls of a fusion reactor would have to be replaced and disposed of every five to ten years. This means a large volume of radioactive waste would be generated over the lifetime of the reactor. According to Dr. Robert Hirsch of the Electric Power Research Institute (EPRI) these reactors would produce more radioactive waste than an Advanced Light Water Reactor. Other parts of these exceedingly complex machines would also be damaged by the constant barrage of neutrons. Because of the high radioactivity, maintenance would have to be done remotely, adding to the cost and unreliability of the reactor.

Given the cost and environmental problems inherent with the deuterium-tritium fueled tokamak, it is imprudent that the DOE is requesting funds for not one but two new tokamaks, the TPX (Tokamak Physics Experiment) and ITER (International Thermonuclear Experimental Reactor). There are basic physics questions which should be resolved, and alternative fuels and approaches to fusion which should be evaluated before more money is spent on the next generation of complex, expensive tokamak machines.

In light of the pressing need to reduce spending on low-priority items, the fusion energy budget should be appropriately scaled back. The fusion program is a prime candidate for an increased private sector role. Future fusion research and development efforts should be cost-shared by industry to reduce taxpayer costs, institute a mechanism for ongoing merit-based independent evaluation, and help insure that the program ultimately leads to either a commercially-viable design or termination. We respectfully urge you to cut $200 million from the FY94 fusion energy budget, and institute a cost-shared approach with industry.

Sincerely,

Anna Aurilio, U.S. Public Interest Research Group; Ralph De Gennaro, Friends of the Earth; Jill Lancelot, National Taxpayers Union; Michael Mariotte, Nuclear Information & Resource Service; Bill Magavern, Public Citizen; Martin Gelfand, Safe Energy Communication Council; and Melanie Griffin, Sierra Club.

University of Wisconsin - Madison
Department of Physics

Professor Stewart C. Prager
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May 4, 1993

The Honorable J. Bennett Johnston
136 Hart Office Building
Washington, D.C. 20510

Dear Senator Johnston,

I write to request that the attached letter, previously sent to you, and the present letter be placed in the public record in connection with the hearing of the Senate Sub-Committee on Energy and Water Development on May 6, 1993. Please regard the comments below as an addendum to the letter.

Beyond the general points in the attached letter we wish to comment more specifically on the wording in the bill. The attached letter interprets the intent of the bill as requiring that nearly all activities focus on ITER. However, many point out that the bill actually requires eliminatio only of activities not contributing to "ITER or to the development of a fusion demonstration reactor."

The bill seems to be inconsistent in the following sense. At present t, virtually all activities in the U.S. fusion program directly support the demonstration reactor or ITER. The fusion program has in the past 5 years already undergone an extreme focusing (in fact to the point of being too narrowly focussed). Thus, the bill strictly interpreted would not eliminate existing research, since all research satisfies the bill's criteria. On the other hand, the bill calls for a refocusing and redirection of the program. If activities supporting the demonstration reactor are permitted, then the bill's directives would be followed without restructuring the fusion program.

We would suggest wording alterations in the following three directions.

1. Change words such as "redirect" and "refocus" to "direct" and "focus."

2. Include in the list of allowable research topics scientific issues which require resolution for practical fusion power. If desired a list of examples could be included (such as current drive, plasma transport, reactor size reduction, materials research, disruption control and others).

3. Refer to the Department's magnetic fusion program as the "Fusion Energy Program" rather than the ITER program.

Thank you for your attention.

Sincerely,

Stewart C. Prager
President
University Fusion Association

University of Wisconsin - Madison
Department of Physics

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April 21, 1993

The Honorable Bennett Johnston
136 Hart Senate Office Building
Washington, D.C. 20510

Dear Senator Johnston,

I write in my capacity as president of the University Fusion Association (UFA) to express our view of Senate bill S.646, "The International Fusion Energy Act of 1993." The UFA is a national organization of fusion researchers from every U.S. university active in fusion research. Our members are involved in all aspects of the fusion program, from small experiments to ITER design. Thus, we believe that our view (as developed by the executive committee listed in the attached sheet) is not a parochial one.

We admire and appreciate your support of the development of fusion energy. The bill's "findings" captures both the potential of fusion and the significant progress to date. We fully share your desire to accelerate the pace of the development of fusion power, and we are pleased that the bill aims to strengthen the commitment of the U.S. to a long-term program. The restructuring proposed in the bill presents a useful opportunity for frank discussion of the various paths for fusion research and development, from which the optimal route to fusion can be devised. In this spirit we offer our comments.

We wish to sound a clear alarm that the redirection proposed by the bill, as we interpret it, would have consequences opposite to your intention. The proposed restructuring would severely retard progress in fusion.

As we understand it, the bill sends the following very strong message. ITER will address nearly all the scientific issues of fusion necessary to build an economical fusion reactor. The present knowledge base is sufficient to predict with some confidence that a tokamak of the ITER type will prove successful. Thus, the U.S. should focus the research program to eliminate nearly all work which is not directly tied to the ITER project. This major streamlining of fusion program will be symbolized by hereafter referring to the entire fusion program as the ITER program.

We make the following three points. (1) ITER is a major milestone in fusion research, but will likely not by itself provide sufficient information to proceed to a practical reactor. (2) Additional research of equal importance is essential. (3) The time scale for fusion demands a strong and innovative research effort in addition to ITER. We elaborate on each item below.

(1) The Role of ITER

ITER will be the first experiment to produce a large amount of fusion power, to achieve ignition, and to test many key aspects of fusion technology. It will be an exciting and worthwhile experiment. We emphasize that we support ITER and all of our comments should be viewed in that context. However, ITER is not a blueprint for a fusion reactor. ITER is a large and complex machine. It remains an open question whether a tokamak of the ITER design will extrapolate to a practical reactor. In addition, we anticipate that in the next 40-50 years fusion research will evolve in ways that we cannot predict. It is likely that a commercial reactor will look quite different than ITER. These statements do not diminish the role of ITER. ITER represents an enormous scientific and engineering milestone in fusion research. It will prove the reality of fusion, much as the initial Wright airplane of 1903 proved the reality of flight.

(2) The Need for Additional Research

Research not directly coupled to ITER is essential. There are specific problems which must be resolved (but will not be solved in ITER) and many ideas for reactor improvements which must be pursued. To name a few issues, there is need and opportunity to improve current drive techniques, to develop inherently steady state reactors, to develop more compact reactors, to develop reactors with reduced magnetic field requirements, to develop disruption control techniques, to investigate and reduce transport in plasmas, to develop reactors without the need for auxiliary heating. This is only a small list of the critical topics for which there are existing ideas and plans, but which are not directly tied to ITER. They fall into two categories : those which attempt to solve known problems in the tokamak and those which aim to improve our concept of a fusion reactor ("advanced tokamaks" or close relatives of the tokamak).

To put a halt to such research, would eliminate the program which has given us the knowledge to build ITER. This is the base research program which has been and will continue to be the lifeblood of the development of fusion. Without it we will likely fail. The non-ITER research is necessary to proceed beyond ITER. It is also needed to operate ITER most effectively, and to fully utilize the results from ITER. Both Europe and Japan are maintaining strong programs in addition to ITER. It is not clear that the U.S. will continue to be a viable partner in the ITER research project without a a comparably strong program.

(3) The Structure of a Long-Term Development Program

The present fusion program is expected to culminate in a commercial fusion reactor in 40-50 years. There is no scientific predictability on this timescale. It is drastically premature to commit the fusion program to a well-defined reactor concept at this time. To do so is analogous to terminating aviation research at the Wright airplane or computer research at the first vacuum tube computer. At those times, neither jet aircraft nor solid state supercomputers were foreseeable some 50 years later. To stop non-ITER research now would condemn us to a 2040 reactor based upon 1993 science.

Often the planning of the fusion program is framed as a choice between two undesirable alternatives. The first is that we have an ITER-only program, based on the belief that our present view of a reactor will prevail decades into the future. The second is that we do not build ITER and abandon fusion energy, based on the belief that after all these years we still do not know how to build a reactor. This is a false choice, not in the best interests of the country. The truth is that progress has been steady, remarkable, and tangible. The benefits, both to science and technology have been enormous. We have come a long way, but there is still a long way to go. We are about to fly for the first time, but not commercially. It is precisely the time that a renewed national commitment is appropriate, as you propose. However, the extreme narrowing of the effort will not accomplish your aim. Virtually every external and internal fusion review committee, including the recent Fusion Energy Advisory Committee, has lauded the progress in fusion, and recommended a strong base program in addition to ITER. Such advisory committees have included senior industrial representives, as well as members of the scientific community.

Our aim here is to assist you in formulating the most expeditious route to fusion power. To this end, we strongly urge you to enlarge the focus of the bill (consistent with the energy act of 1992 which calls for a "broad-based" fusion energy program in addition to ITER).

Thank you for your consideration. I would be happy to provide any further input which would be useful to you.

Sincerely,

Stewart C. Prager
President
University Fusion Association

c.c. Dr. W. Happer, Department of Energy
Senate Sub-Committee on Water and Energy

University Fusion Association Executive Committee

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California Institute of Technology

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Dr. Harold Weitzner
New York University

Fusion Power Associates

Stephen O. Dean, President

April 21, 1993

The Honorable J. Bennett Johnston
136 Senate Hart Office Bldg.
Washington, D. C. 20510

Dear Senator Johnston:

As you know, I will not be testifying to your Energy Committee's hearing on fusion May 6. I am sure that the witnesses your staff has chosen will do an admirable job of covering the subject.

Fusion Power Associates represents the public's interest in reaping practical benefits from their investment in fusion research. Our Board of Directors has approved the enclosed two statements on fusion policy. I would appreciate it if these statements can be included in the hearings record.

Thank you for your consideration.

Best regards,

Stephen O. Dean

Enclosure

cc: Paul Barnett w/encl.

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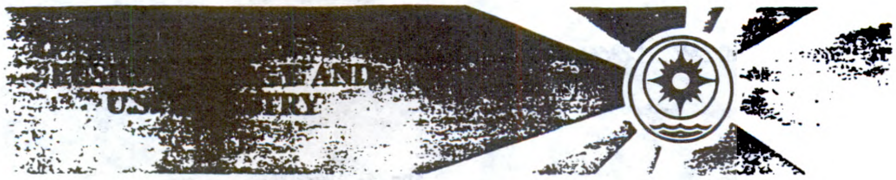

NEW ENERGY SOURCE

Fusion offers the promise of a safe, environmentally attractive large-scale energy source and an unlimited fuel supply. It can be available on a timetable commensurate with the projected increase in world energy demand and decreased reliance on fossil fuels.

MAJOR INTERNATIONAL VENTURE

The importance attached to fusion by other countries is evident in the unprecedented agreement among the U.S., European Community, Japan, and Russia to support the ***International Thermonuclear Experimental Reactor (ITER),*** the world's first operating fusion reactor. Each party will contribute equally to the development and share the benefits.

FOREFRONT SCIENCE AND TECHNOLOGY

Fusion is at the leading edge of many areas of science and technology such as superconducting magnets, advanced computer applications high performance materials, and materials processing, among others. Such technologies are important to U.S. commercial competitiveness in the Twenty-First Century.

PRACTICAL BENEFITS

An industrial infrastructure must be established to derive practical benefits from past and ongoing research and to position the U.S. to win an *ITER* site competition. To accomplish these objectives, U.S. industry must be used to develop engineering designs, fabrication approaches and advanced technology for all major new national fusion facilities and in the management of their construction. In addition industry should perform much of the R&D and engineering design for *ITER*, to prepare for U.S. participation in *ITER* construction.

WHAT IS NEEDED

During the past 12 years, the levels of fusion research and development in Europe and Japan have approximately doubled and now each exceeds the effort of the United States. It is essential that the U.S. Government provide adequate support to ensure that U.S. industry participates in the important fusion technological advances and in their utilization.

"Research and development should continue vigorously, especially in technologies like fusion power which offer the prospect, however distant, of somewhat safer and more abundant sources of electricity."
Vice President Albert Gore, Jr.
Earth in the Balance

"Fusion Energy holds great promise as an element of the nation's long-term energy supply."
Hazel O'Leary, Secretary of Energy
Testimony to Senate Energy and Natural Resources Committee
January 19, 1993

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POLICY STATEMENT

The Board of Directors of Fusion Power Associates, on behalf of the association, urges that fusion power development be based upon the following:

RECOMMENDED POLICIES

- Research and development toward an economically-competitive fusion power system should receive high national and international priority.
- Engineering sciences, technology development, systems analyses and plasma sciences should all be considered essential elements in a balanced fusion effort.
- Timely commitments to necessary new and improved experimental facilities are needed to ensure continued program momentum and progress into the 1990's.

The above recommended policies are based upon the following:

FINDINGS AND RECOMMENDATIONS

- Fusion research, world-wide, continues to make outstanding progress.
- Concept improvements are emerging at a rapid rate, giving increasing confidence that an economically-competitive fusion power plant can be developed. Innovative ideas that reduce costs or accelerate knowledge should be expeditiously pursued in all aspects of the fusion program.
- It would be premature, at this stage, to judge which of the variety of magnetic and inertial fusion concepts will ultimately succeed commercially. This fact should not discourage use of the best available concepts in the design and construction of needed fusion test facilities.
- The fusion programs in the U.S., U.S.S.R., Europe and Japan have comparable accomplishments, facilities and momentum. The present rate of progress in the world program is based on capital investment commitments made in the 1970's. Progress will predictably diminish unless next step facilities are developed in a timely manner.
- International cooperative agreements have been a substantial factor in fusion progress and should be encouraged. Such agreements, however, are not an effective substitute for focused national efforts, needed national experimental facilities and subsequent engineering test devices.
- Governments should encourage and promote the full participation of industry in the planning, research and development as well as in engineering and operating aspects of fusion programs. If industry participates in the government – funded R & D programs now, industry will be better prepared to assess the commercial potential of fusion power in the future.
- Governments should foster innovation and optimize utilization of resources by encouraging and strengthening interrelationships among industry, laboratories and universities.
- Fusion – related programs in universities should be selectively strengthened and encouraged to ensure an adequate supply of engineers and physicists with knowledge in this field.
- The governments of the world have made a sustained investment in fusion research. The time has come to begin to capitalize on this investment by placing increased emphasis during the next decade on the engineering and systems design aspects of practical fusion energy systems.

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