DOE/ER-0720

Panel Report To Fusion Energy Sciences Advisory Committee (FESAC)

"Recommendations on the Nature and Level of U.S. Participation in the International Thermonuclear Experimental Reactor Extension of the Engineering Design Activities"

January 1998

U.S. Department of Energy
Office of Energy Research

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Section 1

OAK RIDGE NATIONAL LABORATORY
MANAGED BY LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE U.S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2008
OAK RIDGE, TN 37831-6248

PHONE: (423) 574-5510
FAX: (423) 576-6118
INTERNET: oji@ornl.gov

January 23, 1998

Dr. Martha A. Krebs, Director
Office of Energy Research
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Dr. Krebs:

The FESAC members were delighted to have the opportunity to meet with you and hear about the Office of Energy Research programs. The discussions about the fusion program with you and Dr. Davies were particularly helpful to our later deliberations on the final version of the Grunder Panel report. We enclose this report, noting that it has changed very little from the version we reviewed in October. The FESAC reaffirms its letter to you of last October 23 concerning the report. At this meeting the FESAC heard from DOE that encouraging progress is being made in explorations with our ITER partners about the inclusion, during the transition period, of an examination of lower cost design concepts to achieve reduced sets of the ITER detailed technical objectives. FESAC notes that one of the Grunder Panel's four recommendations called for studies of such lower cost design concepts, and we urge DOE to support this effort, preferably with international partners. In this context, FESAC endorses the planned U.S.-community involvement in the activities and workshops to begin developing reduced-cost options.

The FESAC takes this opportunity again to compliment Dr. Hermann Grunder and his Panel for producing such a thoughtful and searching report on a complex subject.

Sincerely,

John Sheffield

John Sheffield, Chair
on behalf of the Fusion Energy
Sciences Advisory Committee

JS:djb

Enclosure

cc: N. A. Davies, DOE-OFES
FESAC
H. Grunder, TJNAF

Fusion Energy Sciences Advisory Committee Meeting, January 22, 1998

Dr. John Sheffield, Chair
Dr. Ira B. Bernstein
Dr. Richard J. Briggs
Dr. James D. Callen
Dr. Robert W. Conn
Ms. Melissa Cray
Dr. Katharine B. Gebbie
Dr. Samuel D. Harkness
Dr. Richard D. Hazetine

Dr. Joseph A. Johnson, III
Dr. Charles F. Kennel
(Dr. Michael L. Knotek)
(Dr. John D. Lindl)
Dr. Earl S. Marmar
(Dr. D. Bruce Montgomery)
(Dr. Marshall N. Rosenbluth)
Dr. Tony S. Taylor
Dr. Nermin A. Uckan
Dr. Stewart J. Zweben

Ex-officio members:

Dr. Nathaniel Fisch
Dr. William Hogan
Dr. Ned Sauthoff

*Absent members in ()

Section 2

THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

Hermann A. Grunder
Director

Jefferson Lab

December 19, 1997

Dr. John Sheffield
Chairman
Fusion Energy Sciences Advisory Committee (FESAC)
Oak Ridge National Laboratory
1 Bethel Valley Road
Oak Ridge, Tennessee 37831-6248

Dear Dr. Sheffield:

On behalf of the FESAC panel, I am submitting our final report on the nature and level of U.S. participation in possible International Thermonuclear Experimental Reactor (ITER) activities. Given the evolutionary nature of the charge to the panel, our deliberations have emphasized the nearer term transition phase and deferred any specific recommendations on U.S. participation in construction activities to a later time.

The panel held meetings in July, August, September, October and December and heard comments from the fusion community including the Project Director, members of the U.S. Home Team, ISCUS, university representatives, U.S. industry, the Office of Fusion Energy Sciences, and many other interested parties. In addition, the panel presented a mid-term report to FESAC at a public meeting on October 20-21, 1997.

As Chairman of the panel, I wish to thank the many people who supported our efforts by providing detailed information and thoughtful comments. On a personal note, I would also like to thank the panel members who worked so hard on behalf of the fusion community.

Sincerely,

H. Grunder

Hermann Grunder
Chairman
FESAC Panel

Enclosure

letters:pas

Jefferson Lab • Located in Hampton Roads • 12000 Jefferson Avenue • Newport News, VA 23606
(757) 269-7552 • Fax: (757) 269-7398 • email: grunder@jlab.org

Report of FESAC Panel
January 1998

The DOE Office of Energy Research chartered through the Fusion Energy Sciences Advisory Committee (FESAC) a panel to "address the topic of U. S. participation in an ITER construction phase, assuming the ITER Parties decide to proceed with construction." (Attachment 1: DOE Charge, September 1996). Given that there is expected to be a transition period of three to five years between the conclusion of the Engineering Design Activities (EDA) and the possible construction start, the DOE Office of Energy Research expanded the charge to "include the U.S. role in an interim period between the EDA and construction." (Attachment 2: DOE Expanded Charge, May 1997).

This panel has heard presentations and received input from a wide cross-section of parties with an interest in the fusion program. The panel concluded it could best fulfill its responsibility under this charge by considering the fusion energy science and technology portion of the U.S. program in its entirety. Accordingly, the panel is making some recommendations for optimum use of the transition period considering the goals of the fusion program and budget pressures.

INTRODUCTION

Fusion is the process that powers the stars. Harnessing that process to contribute to the global energy system is the vision of this panel and the fusion community. The pursuit of this vision also supports basic research and plasma science which are important in their own right.

The U.S. Fusion Energy Sciences Program focuses on the scientific foundations that underpin the fusion process. The three specific objectives of the program, as identified the 1996 FEAC Report are: (1) advance plasma science in pursuit of national science and technology goals, (2) develop fusion science, technology, and plasma confinement innovations, and (3) pursue fusion energy science & technology as an international partner. This "three-leg" strategy has been endorsed by the fusion community, Congress, and the Department of Energy. This panel also endorses it and observes that an implementation plan is needed.

The panel has addressed the near-term plan for the fusion energy science & technology objective of the program, the central near-term goal of which is the demonstration of a self-heated, energy-producing fusion plasma. The experimental study of self-heated plasmas has been recognized worldwide as the next frontier for fusion research. The panel supports this objective, both for the important science it involves, and as a requirement for fusion power-plant development. The major activity supporting this objective of the program is participation in the International Thermonuclear Experimental Reactor (ITER) Engineering Design Activities (EDA), consisting of physics analysis, engineering design, and supporting technology R&D activities.

By its nature, a facility capable of producing a self-heated, energy-producing fusion plasma will be technically challenging and expensive. By working collaboratively, the ITER Partners (European Union, Japan, Russia, and the United States) have benefited through cost-sharing. Additionally, the ITER collaboration has increased the integration

and effectiveness of the world fusion community during the development of the physics basis and the engineering design for a next-step experimental device capable of exploring controlled ignition and extended fusion burn of deuterium-tritium (D-T) plasmas. The imminent conclusion of the presently defined EDA makes this an appropriate time to assess our continued participation in ITER. Available options include the whole range from total withdrawal from the ITER process to full participation as the host country.

Independent technical reviews by FESAC and all the partners have concluded that the ITER engineering design is a sound basis for the project and for DOE to enter negotiations with the Parties regarding construction. The panel accepts the conclusion of these prior in-depth reviews. If a decision to construct ITER were being sought today, this panel would recommend U.S. participation at an appropriate level.

However, because construction phase financing is not presently available, a construction decision has been delayed, and a 3-year transition period proposed. In the panel's view, this 3-year period necessitates an assessment of the proper form and scale of the activities that support the third objective of the overall U.S. Fusion Energy Sciences Program.

CENTRAL RECOMMENDATIONS

The ITER mission includes the demonstration of controlled ignition, extended fusion burn, and integrated power-plant technologies. The panel supports this mission. However, if the financial resources continue to be unavailable, the U.S., in collaboration with its international partners, should develop a set of contingency plans and should be willing to consider a modification of the ITER mission. In the short term, it is important to keep the present ITER option open. In the longer term, it is critically important to get a D-T burning plasma machine internationally approved and built.

Therefore the panel's central recommendation is:

In concert with our international partners, a burning plasma facility should be built at the earliest possible time.

STRATEGIC PLAN

To implement the central recommendation, we propose the following elements for a U.S. strategic plan for the next three years to pursue the third objective of the Fusion Energy Science Program:

1. **Pursue near-term opportunities for research supporting energy-producing fusion plasma science using existing unique large-scale facilities abroad.**

   DISCUSSION:

   Recent experimental and theoretical results point to new approaches to achieving high levels of energy production in tokamak plasmas, and the potential

for common benefits provides an impetus for the U.S. to pursue this challenging physics research with its international partners. Continuing development of these advanced tokamak scenarios may provide new paths for cost reduction in pursuing the central recommendation stated above.

In experimental research, we recommend increased participation in the large foreign experiments, JET and JT-60U. The objective is to establish advanced tokamak physics in large tokamaks as a design basis for burning plasma experiments. This effort would be supportive of ITER. With the recent shutdown of TFTR, there is now only one operating physics experiment in the world capable of conducting meaningful D-T burning experiments, namely the JET device in the EU. We suggest that the U.S. explore with our European colleagues the possibility for increased collaboration in JET. Enhanced U.S. participation in JT-60U should be discussed with our Japanese colleagues. As part of these collaborations, the partners should consider developing and testing techniques for remote experimentation on foreign fusion devices.

In addition, we recommend an expanded effort on broad-based theoretical and computational activities to understand high-temperature confined plasmas in the energy-producing regime, in support of the international effort in this area.

2. **Restructure the fusion energy technology development effort to more broadly support the fusion energy objective of the program.**

DISCUSSION:

Much of the U.S. fusion technology effort has been devoted to ITER over the past five years because of the strong overlap between work carried out specifically for ITER and work that would be carried out under our normal fusion energy technology R&D activities. It is important to continue U.S. industry involvement in fusion technology R&D, which at the present time is largely carried out through the ITER EDA.

The U.S. should continue to participate in those aspects of ITER technology R&D which are dual-purpose, in the sense that they are both critical for a variety of approaches to fusion energy and they also help complete the R&D required for the ITER design. In regard to the ITER design, prior technical reviews have concluded that the designs of most major components are now detailed and well integrated. Validation of the designs, however, depends on completion of the ITER R&D program. To derive full benefits of the EDA investments and reduce risks on open technical issues, these technology efforts should be completed or otherwise brought to an appropriate conclusion.

In addition, the U.S. should continue to make use of international collaboration in fusion technology development to realize the full potential of fusion as an environmentally and economically attractive energy source. Here, non-ITER-specific fusion energy technology R&D should be conducted, including, for example, development of low activation materials. We recommend a community review to determine the role and scope of these technology development activities and their relation to existing technology activities in the rest of the program.

3. **Continue to participate in and support the ongoing ITER joint design work at a lower level.**

DISCUSSION:

To date the ITER design concept has been developed as an international collaboration. Two of the design partners, the EU and Japan, now have much larger fusion programs than the U.S. Continued involvement gives us the opportunity to participate in the construction and operation of ITER, should the parties decide to go forward with it. In the strategic context of the U.S. science-focused fusion program, our involvement in the construction and operation of ITER would clearly be beneficial.

ITER joint design work includes both JCT and U.S. Home Team activities. We support efforts to explore opportunities for cost reduction and for enhanced scientific flexibility within the ITER scope. Some of these efforts could be carried out in conjunction with the physics research and technology R&D recommended above.

4. **Undertake design efforts on lower cost fusion-energy-producing plasma concepts.**

DISCUSSION:

Given the present situation where construction commitments have not been secured for the full-mission ITER device, we believe that it is prudent for the international community to examine options that involve reconsideration of the fundamental trade-offs between cost, risk and mission. This effort should be directed at examining lower-cost, reduced scope options in the interest of achieving a fusion-energy-producing plasma experiment on the fastest possible schedule. These options provide a contingency plan that will be necessary in the event that the financial commitments cannot be secured for the full-mission ITER machine.

Design studies carried out in the past by the U.S. and by our international partners have explored a range of mission options from short-pulse ignition to ITER-like sustained burn, covering a cost range from $2B to the present ITER cost. These studies, with modifications reflecting the new experimental findings from present large-scale tokamaks, could form the basis for an international activity to develop contingency plans for building a facility.

In preparation for this international activity, it is essential that the United States initiate a domestic study with broad fusion community involvement to explore the many options.

BUDGET CONSIDERATIONS

For the fusion energy science and technology objective of the program, we recommend the following annual funding allocations (FY99$) for the 3-year plan outlined above:

REC. 1:	**Research on Existing Large-Scale Facilities Abroad** (supporting energy-producing-fusion plasma science)	**$10-20M**
REC. 2:	**Fusion Energy Technology Development** (including dual purpose technologies critical for ITER and other fusion approaches)	**$20-25M**
REC. 3:	**Continued ITER Joint Design Work**	**$15M**
REC. 4:	**Design Efforts on Lower Cost Concepts** (in collaboration with our international partners)	**$5-10M**

We recommend these levels in the recognition that the entire fusion program is funding-limited and all three of its components require additional resources. Our recommendations are made within the context of the 1997 PCAST funding profile for fusion energy science research. We endorse this PCAST executive summary report and the FEAC 1996 program restructuring report, both of which called for a $200M minimum support level for the plasma science and confinement innovations program objectives. These objectives comprise an important element of the country's basic science portfolio and include: nurturing basic research in plasma science; supporting both alternative concepts and advanced tokamak physics research; and developing enabling technologies in support of these concept innovation efforts. Achievement of these objectives is essential to provide the knowledge needed for development of fusion energy in the long run.

ITER Panel Membership

Dr. Hermann Grunder	grunder@jlab.org Tel: (757) 269-7552 Fax: (757) 269-7398	Thomas Jefferson National Accelerator Facility 12000 Jefferson Avenue Newport News, VA 23606
Dr. Lee Berry	lab@ornl.gov Tel: (423) 574-0998 Fax: (423) 576-7926	Oak Ridge National Laboratory PO Box Y Mail Stop 8071 Oak Ridge, TN 37831
Dr. William Ellis	wellis@panix.com Tel: (212) 839-3398 Fax: (212) 839-3528	Raytheon 2, World Trade Center New York, NY 10048
Prof. Raymond Fonck	fonck@engr.wisc.edu Tel: (608) 263-7799 Fax: (608) 265-2364	Univ of Wisconsin Madison 1500 Engineering Drive Room 343 ERB Madison, WI 53706
Prof. Jeffrey Freidberg	freidberg@pfc.mit.edu Tel: (617) 253-8670 Fax: (617) 253-5805	Plasma Fusion Center NW16-243 Massachusetts Institute of Technology 167 Albany Street Cambridge, MA 02139
Dr. Katherine B. Gebbie Anita Sweigert (secretary)	kgebbie@nist.gov Tel: (301) 975-4201 Fax: (301) 975-3038 anita.sweigert@nist.gov (Sec. - Tel: (301) 975-4200)	National Institute of Standards and Technology Physics Bldg. B-160 Gaithersburg, MD 20899-0001
Dr. Richard J. Hawryluk Head of Plasma Confinement Dept.	rhawryluk@pppl.gov Tel: (609) 243-3306 Fax: (609) 243-3248	Princeton Plasma Physics Lab James Forrestal Campus P.O. Box 451 Princeton, NJ 08543-0451
Dr. Bruce Montgomery	dbm@pfc.mit.edu Tel: (617) 253-5552 Fax: (617) 253-0807	Plasma Fusion Center NW17-288 Massachusetts Institute of Technology 175 Albany Street Cambridge, MA 02139
Prof. Gerald Navratil	navratil@cuplvx.ap.columbia.edu Tel: (212) 854-4496 Fax: (212) 854-8257	Columbia University Plasma Physics Laboratory Department of Applied Physics S. W. Mudd Building New York, NY 10027

Dr. Hutch Neilson	hneilson@pppl.gov Tel: (609) 243-2726 Fax: (609) 243-3315	PPPL PO Box 451 Princeton, NJ 08543
Joanne Savino (secretary)	jsavino@pppl.gov	
Dr. John Perkins	perkins3@LLNL.gov Tel: (510) 423-6012 Fax: (510) 424-6401	Lawrence Livermore Natl. Lab P.O. Box 808 (L-637) Livermore, CA 94551
Dr. Stephen L. Rosen	stephen-rosen@hlp.com Tel: (512) 972-7138 Fax: (512) 972-7073	Houston Lighting and Power South Texas Project Electric Generating Station P. O. Box 289 Wadsworth, TX 77483
Dr. Kurt Schoenberg	kurts@lanl.gov Tel: (505) 667-1512 Fax: (505) 665-3552	Plasma Physics (P-24) Los Alamos National Labs MS E-526 PO Box 1663 Los Alamos, NM 87545
	shawrl@lanl.gov (secretary)	
Prof. Harold Weitzner	weitzner@cims.nyu.edu Tel: (212) 998-3267 Fax: (212) 995-4121	CIMS-NYU 251 Mercer Street New York, NY 10012
*Sally Fisk (Panel Staff)	fisk@jlab.org Tel: (757) 269-7569 Fax: (757) 269-7398	Thomas Jefferson National Accelerator Facility 12000 Jefferson Avenue Newport News, VA 23606

Section 3

OAK RIDGE NATIONAL LABORATORY
MANAGED BY LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE U.S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2009
OAK RIDGE, TN 37831-8070

Fusion Energy Division
PHONE: (423) 574-1311
FAX: (423) 576-6118

October 23, 1997

Dr. Martha A. Krebs, Director
Office of Energy Research
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Dr. Krebs:

This letter is an interim response to your charge of September 23, 1996, expanded in your letter of May 19, 1997, regarding the level and nature of U.S. participation in the International Thermonuclear Experimental Reactor (ITER) construction, if the ITER parties decide to go forward, as well as the expanded charge to consider the U.S. role in an transition period between the EDA and construction.

To assist FESAC in answering your charges, I formed an expert Panel chaired by Dr. Hermann Grunder, Director of the Thomas Jefferson National Accelerator Facility. A list giving the membership of the Panel is enclosed. This Panel has provided FESAC with the attached interim report. The FESAC compliments the Panel and its chairman for producing a thoughtful and searching report on a complex subject. The FESAC endorses the strategic plan of the Grunder Panel and makes comments on it below.

The FESAC was fortunate to receive, in addition, the executive summary of the President's Committee of Advisors on Science and Technology (PCAST) "Federal Energy Research and Development for the Challenges of the Twenty-First Century." We also heard a presentation from Dr. Robert Conn who participated in the PCAST study. The section (enclosed) on "Challenges and Opportunities: Fusion" was very important in our deliberations. Finally, we had the benefit of public comment.

FESAC would like to emphasize the significance of ITER's impact over the past decade. By working collaboratively, the ITER partners (European Union, Japan, Russia, and the U.S.) have benefited immensely through cost sharing and program focus. It is desirable to continue this process of international collaboration, as the Grunder Panel stated: "If a decision to construct ITER were being sought today, this Panel would recommend U.S. participation at an appropriate level." Similarly, PCAST recommended that if "any of the parties states its intention to offer a site for ITER in the next year or two, the US should be prepared to continue and to maximize its participation in ITER."

The U.S. Fusion Energy Sciences Program is focused on the scientific foundations that underpin the fusion process. The three specific objectives of the program, as identified in the 1996 FEAC Report are: (1) advance plasma science in pursuit of national science and technology goals, (2) develop fusion science, technology, and plasma confinement innovations, and (3) pursue fusion energy science & technology as an international partner. This "three-leg" strategy has been endorsed by the fusion community, Congress, and the Department of Energy.

In response to the charge regarding the criteria for a decision on the level and nature of U.S. participation in the ITER construction, FESAC supports the central recommendation of the Grunder Panel: "In concert with our international partners, a burning plasma facility should be built at the earliest possible time." This recommendation should have priority as our vital interest in entering ITER negotiations. In the context of a Fusion Energy Sciences budget totaling $250 million, we believe that an appropriate FY 1999 funding level for the activities which are in direct support of the central recommendation is approximately 20% of that total.

In response to the charge regarding the possible scenarios for U.S. participation in ITER activities, FESAC commends the Grunder Panel for its realistic assumptions regarding future funding profiles. It also notes that the Grunder Panel concentrated its findings on the nearer term transition phase.

The Panel concluded that it could best fulfill its responsibility under this by considering the ITER charge within the fusion energy science and technology portion of the U.S. program.

The FESAC agrees with the Grunder Panel recommendation that the content and balance of the ITER activities should be restructured during the transition phase. The baseline design is well advanced, much of the dedicated R&D in support of it will be completed by the end of the EDA, and site-specific work does not involve a U.S. site. FESAC therefore accepts the Grunder Panel suggestion that U.S. participation in ITER's joint work on the baseline design proceed at a lower level during the transition phase.

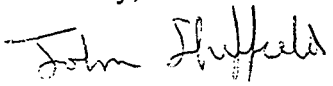
The FESAC agrees with the Grunder Panel that "Given the present situation where construction commitments have not been secured for the full mission ITER device... it is prudent...to examine options that involve reconsideration of the fundamental trade-offs between cost, risk and mission." In view of the cost of burning plasma experiments, such examination should be conducted with our international partners and if possible, within the ITER framework.

The FESAC concurs with the Grunder Panel recommendation that the fusion energy technology effort be restructured to support the energy objective of the program more broadly. Much of the U.S. fusion technology effort has been subsumed under ITER during the past five years. It has also largely been of a dual use nature, to meet the needs of ITER and those of the general U.S. fusion program. The FESAC agrees that this dual use aspect should be the focus, and the U.S. industry involvement in fusion technology should continue.

In the spirit of the Grunder Panel's suggestion "that the US explore with our [international] colleagues the possibility for increased collaboration in JET [and] JT-60U," FESAC recommends a vigorous experimental program aimed at burning plasma physics issues as well as the physics basis for possible cost reduction through plasma optimization. Such a program should take advantage of domestic devices such as DIII-D and C-Mod and the U.S. fusion theory program, in addition to international experimental collaboration.

Finally, to act on the central recommendation of the Grunder Panel, and consistent with the PCAST recommendation, FESAC considers it critically important that DOE enter future international negotiations with a high level, long-range commitment to support a "next step facility aimed at a mutually agreed upon set of scientific objectives," as stated by PCAST.

Sincerely,



John Sheffield, Chair
on behalf of the Fusion Energy
Science Advisory Committee

Enclosures

cc: N. A. Davies, DOE-OFES
FESAC
H. Grunder, TJNAF

Fusion Energy Sciences Advisory Committee Meeting October 20-21, 1997

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(Dr. Ira B. Bernstein)
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Ex-officio members:

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Membership of the FESAC Expert Review Panel

Dr. Hermann Grunder (Chair)
Thomas Jefferson National Accelerator Facility

Dr. Lee Berry
Oak Ridge National Laboratory

Dr. William Ellis
Raytheon

Prof. Raymond Fonck
University of Wisconsin Madison

Prof. Jeffrey Freidberg
Massachusetts Institute of Technology

Dr. Katherine B. Gebbie
National Institute of Standards and Technology

Dr. Richard J. Hawryluk
Princeton Plasma Physics Laboratory

Dr. Bruce Montgomery
Massachusetts Institute of Technology

Prof. Gerald Navratil
Columbia University

Dr. Hutch Neilson
Princeton Plasma Physics Laboratory

Dr. John Perkins
Lawrence Livermore National Laboratory

Dr. Stephen L. Rosen
Houston Lighting and Power

Dr. Kurt Schoenberg
Los Alamos National Laboratory

Prof. Harold Weitzner
CIMS-NYU

*Sally Fisk
(Panel Staff)Thomas Jefferson National Accelerator Facility

Interim Report of FESAC Panel
October 20, 1997

The DOE Office of Energy Research chartered through the Fusion Energy Sciences Advisory Committee (FESAC) a panel to "address the topic of U.S. participation in an ITER construction phase, assuming the ITER Parties decide to proceed with construction." (Attachment 1: DOE Charge, September 1996). Given that there is expected to be a transition period of three to five years between the conclusion of the Engineering Design Activities (EDA) and the possible construction start, the DOE Office of Energy Research expanded the charge to "include the U.S. role in an interim period between the EDA and construction." (Attachment 2: DOE Expanded Charge, May 1997).

The panel has been requested to provide an interim report in letter form by October 1997. This panel has now heard presentations and received input from a wide cross-section of parties with an interest in the fusion program.

The panel concluded it could best fulfill its responsibility under this charge by considering the fusion energy science and technology portion of the U.S. program in its entirety. Accordingly, the panel is making some recommendations for optimum use of the transition period considering the goals of the fusion program and budget pressures.

INTRODUCTION

Fusion is the process that powers the stars. Harnessing that process to contribute to the global energy system is the vision of this panel and the fusion community. The pursuit of this vision also supports basic research and plasma science which is important in its own right.

The U.S. Fusion Energy Sciences Program is focused on the scientific foundations that underpin the fusion process. The three specific objectives of the program, as identified in the 1996 FEAC Report are: (1) advance plasma science in pursuit of national science and technology goals, (2) develop fusion science, technology, and plasma confinement innovations, and (3) pursue fusion energy science & technology as an international partner. This "three-leg" strategy has been endorsed by the fusion community, Congress, and the Department of Energy. This panel also endorses it.

The panel has addressed the fusion energy science & technology objective of the program, the central near-term goal of which is the demonstration of a self-heated, energy producing fusion plasma. The experimental study of self heated plasmas has been recognized worldwide as the next frontier for fusion research. The panel supports this objective, both for the important science it involves, and as a requirement for fusion power-plant development. The major activity supporting this objective of the program is participation in the International Thermonuclear Experimental Reactor (ITER) Engineering Design Activities (EDA), consisting of physics analysis, engineering design, and supporting technology R&D activities.

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and effectiveness of the world fusion community during the development of the physics basis and the engineering design for a next-step experimental device capable of exploring controlled ignition and extended fusion burn of deuterium-tritium (D-T) plasmas. The imminent conclusion of the presently defined EDA makes this an appropriate time to assess our continued participation in ITER. Available options include the whole range from total withdrawal from the ITER process to full participation as the host country.

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However, because construction phase financing is not presently available, a construction decision has been delayed, and a 3-year transition period proposed. In the panel's view, this 3-year period necessitates an assessment of the proper form and scale of the activities that support the third objective of the overall U.S. Fusion Energy Sciences Program.

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Therefore the panel's central recommendation is:

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STRATEGIC PLAN

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   DISCUSSION:

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benefits provides an impetus for the U.S. to pursue this challenging physics research with its international partners. Continuing development of these advanced tokamak scenarios may provide new paths for cost reduction in pursuing the central recommendation stated above.

In experimental research, we recommend increased participation in the large foreign experiments, JET and JT-60U, with the objective of establishing advanced tokamak physics in large tokamaks. This effort would also be supportive of ITER. With the recent shutdown of TFTR, there is now only one operating physics experiment in the world capable of conducting meaningful D-T burning experiments, namely the JET device in the EU. We suggest that the U.S. explore with our European colleagues the possibility for increased collaboration in JET. Enhanced U.S. participation in JT-60U should be discussed with our Japanese colleagues. As part of these collaborations, the partners should consider developing and testing techniques for remote experimentation on foreign fusion devices.

In addition, we recommend an expanded effort on broad-based theoretical and computational activities to understand high-temperature confined plasmas in the energy-producing regime, in support of the international effort in this area.

2. Restructure the fusion energy technology development effort to more broadly support the fusion energy objective of the program.

DISCUSSION:

Much of the U.S. fusion technology effort has been devoted to ITER over the past five years because of the strong overlap between work carried out specifically for ITER and work that would be carried out under our normal fusion energy technology R&D activities. It is important to continue U.S. industry involvement in fusion technology R&D, which at the present time is largely carried out through the ITER EDA.

The U.S. should continue to participate in those aspects of ITER technology R&D which are dual-purpose, in the sense that they are both critical for a variety of approaches to fusion energy and they also help complete the R&D required for the ITER design. In regard to the ITER design, prior technical reviews have concluded that the designs of most major components are now detailed and well integrated. Validation of the designs, however, depends on completion of the ITER R&D program. To derive full benefits of the EDA investments and reduce risks on open technical issues, these technology efforts should be completed or otherwise brought to an appropriate conclusion.

In addition, the U.S. should continue to make use of international collaboration in fusion technology development to realize the full potential of fusion as an environmentally and economically attractive energy source. Here, non-ITER-specific fusion energy technology R&D should be conducted, including, for example, development of low activation materials. We recommend a community review to determine the role and scope of these technology development activities and their relation to existing technology activities in the rest of the program.

3. Continue to participate in and support the ongoing ITER joint design work at a lower level.

DISCUSSION:

To date the ITER design concept has been developed as an international collaboration. Two of the design partners, the EU and Japan, now have much larger fusion programs than the U.S. Continued involvement gives us the opportunity to participate in the construction and operation of ITER, should the parties decide to go forward with it. In the strategic context of the U.S. science-focused fusion program, our involvement in the construction and operation of ITER would clearly be beneficial.

ITER joint design work includes both JCT and U.S. Home Team activities. We support efforts to explore opportunities for cost reduction and for enhanced scientific flexibility within the ITER scope. Some of these efforts could be carried out in conjunction with the physics research and technology R&D recommended above.

4. Undertake design efforts on lower cost fusion-energy-producing plasma concepts.

DISCUSSION:

Given the present situation where construction commitments have not been secured for the full-mission ITER device, we believe that it is prudent for the international community to examine options that involve reconsideration of the fundamental trade-offs between cost, risk and mission. This effort should be directed at examining lower-cost, reduced scope options in the interest of achieving a fusion-energy-producing plasma experiment on the fastest possible schedule. These options provide a contingency plan that will be necessary in the event that the financial commitments cannot be secured for the full-mission ITER machine.

Design studies carried out in the past by the U.S. and by our international partners have explored a range of mission options from short-pulse ignition to ITER-like sustained burn, covering a cost range from $2B to the present ITER cost. These studies, with modifications reflecting the new experimental findings from present large-scale tokamaks, could form the basis for an international activity to develop contingency plans for building a facility.

BUDGET CONSIDERATIONS

For the fusion energy science and technology objective of the program, we recommend the following annual funding allocations (FY99 $) for the 3-year plan outlined above:

REC. 1:	**Research on Existing Large-Scale Facilities Abroad** (supporting energy-producing-fusion plasma science)	**$10-20M**
REC. 2:	**Fusion Energy Technology Development** (including dual purpose technologies critical for ITER and other fusion approaches)	**$20-25M**
REC. 3:	**Continued ITER Joint Design Work**	**$15M**
REC. 4:	**Design Efforts on Lower Cost Concepts** (in collaboration with our international partners)	**$5-10M**

We recommend these levels in the recognition that the entire fusion program is funding-limited and all three of its components require additional resources. Our recommendations are made within the context of the 1997 PCAST funding profile for fusion energy science research. We endorse this PCAST executive summary report and the FEAC 1996 program restructuring report, both of which called for a $200M minimum support level for the plasma science and confinement innovations program objectives. These objectives comprise an important element of the country's basic science portfolio and include: nurturing basic research in plasma science; supporting both alternative concepts and advanced tokamak physics research; and developing enabling technologies in support of these concept innovation efforts. Achievement of these objectives is essential to provide the knowledge needed for development of fusion energy in the long run.

EXCERPTS FROM THE PCAST REPORT

FEDERAL ENERGY RESEARCH AND DEVELOPMENT FOR THE CHALLENGES OF THE TWENTY-FIRST CENTURY

REPORT OF THE ENERGY RESEARCH AND DEVELOPMENT PANEL

THE PRESIDENT'S COMMITTEE OF ADVISORS
ON SCIENCE AND TECHNOLOGY (PCAST)

SEPTEMBER 30, 1997

THE PRESIDENTS COMMITTEE OF ADVISORS ON SCIENCE AND TECHNOLOGY
ENERGY RESEARCH AND DEVELOPMENT PANEL

John P. Holdren (Chairman)
Teresa and John Heinz Professor of Environmental Policy
Harvard University

John Ahearne
Adjunct Professor of Civil and Environmental Engineering, and Lecturer in Public Policy
Duke University, and
Director, Sigma Xi Center

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Electric Power Research Institute

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New England Electric System

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Dean, School of Engineering
University of California, San Diego

William L. Fisher
Barrow Chair
Department of Geological Sciences
University of Texas at Austin

Thomas L. Fisher
Chairman, President and CEO
NICOR Inc. and
Northern Illinois Gas

Robert A. Frosch
BCSIA
John F. Kennedy School of Government
Harvard University

William Fulkerson
Senior Fellow, Joint Institute for Energy and Environment
University of Tennessee
Former Associate Director
Oak Ridge National Laboratory

Hal Harvey
Executive Director
The Energy Foundation

Daniel A. Lashof
Senior Scientist
Natural Resources Defense Council

Diana MacArthur
Chair and CEO
Dynamac Corporation

Lawrence T. Papay
Senior Vice President and General Manager
Technology and Consulting
Bechtel Corporation

Donald L. Paul
Vice President for Technology and Environmental Affairs
Chevron Corporation

Maxine Savitz
General Manager
AlliedSignal Ceramic Components

Laura Tyson
Class of 1939 Professor of Economics and Business Administration
University of California, Berkeley

Charles M. Vest
President
Massachusetts Institute of Technology

Virginia V. Weldon, M.D.
Senior Vice President, Public Policy
Monsanto Company

Robert H. Williams
Senior Research Scientist
Center for Energy and Environmental Studies
Princeton University

Lilian Shiao-Yen Wu
Research Scientist
IBM Watson Research Center

John Young
Former President and CEO
Hewlett-Packard Co.

Panel Associates:

Brian C. Elliott[1]
Vice President
Northern Illinois Gas

Jefferson W. Tester[2]
H P. Meissner Professor of Chemical Engineering, and
Director, Energy Laboratory
Massachusetts Institute of Technology

Study Executive Director

Samuel F. Baldwin
National Science and Technology Council
Agency Representative

[1] Deputy to Thomas L. Fisher
[2] Deputy to Charles Vest

STAFF:

Jim Bartis
RAND Corporation

Mark Bernstein
Office of Science and Technology Policy

Ellison Burton
Dynamac Corporation

Paul de Sa
Harvard University

Miriam Forman
National Science and Technology Council
Agency Representative

Beverly Hartline
Office of Science and Technology Policy

Rod Judkins
Oak Ridge National Laboratory

Nikki Kelly
National Renewable Energy Lab

Cluster Myers
National Renewable Energy Lab

David Pelly
Harvard University

Susan Resetar
RAND Corporation

Ambuj Sagar
Harvard University

This was a Panel of twenty-one persons of diverse backgrounds and viewpoints, tackling an immensely complex subject. Inevitably, not every member of the Panel is entirely happy with every formulation in the report. But we are unanimous that the main messages and overall balance in this joint product are correct and appropriate,

Federal Energy Research and Development for the Challenges of the Twenty-First Century

Panel on Federal Energy R&D,
President's Committee of Advisors on Science and Technology
Executive Office of the President of the United States

30 September 1997

EXECUTIVE SUMMARY

The United States faces major energy-related challenges as it enters the twenty-first century. Our economic well-being depends on reliable, affordable supplies of energy. Our environmental well-being – from improving urban air quality to abating the risk of global warming – requires a mix of energy sources that emits less carbon dioxide and other pollutants than today's mix does. Our national security requires secure supplies of oil or alternatives to it, as well as prevention of nuclear proliferation. And for reasons of economy, environment, security, and stature as a world power alike, the United States must maintain its leadership in the science and technology of energy supply and use.

All of these energy-related challenges to the well-being of this country are made more acute by what is happening elsewhere in the world. The combination of population growth and economic development in Asia, Africa, and Latin America is driving a rapid expansion of world energy use, which is beginning to augment significantly the worldwide emissions of carbon dioxide from fossil-fuel combustion, increasing pressures on world oil supplies, and exacerbating nuclear proliferation concerns. Means must be found to meet the economic aspirations and associated energy needs of all the world's people while protecting the environment and preserving peace, stability, and opportunity.

Improvements in energy technologies, attainable through energy research and development, are the key to the capacity of the United States to address – and to help the rest of the world address – these challenges.

Many of the energy R&D programs of the Federal government, which are primarily conducted by the Department of Energy (DOE), have been well focused and effective within the limits of available funding. But these programs, taken as a whole, are not commensurate in scope and scale with the energy challenges and opportunities the twenty-first century will present. (This judgment takes into account the contributions to energy R&D that can reasonably be expected to be made by the private sector under market conditions similar to today's.) The inadequacy of current energy R&D is especially acute in relation to the challenge of responding prudently and cost-effectively to the risk of global climatic change from society's greenhouse-gas emissions, of which the most important is carbon dioxide from combustion of fossil fuels. Much of the new R&D needed to respond to this challenge would also be responsive to the other challenges.

SYNOPSIS OF MAIN RECOMMENDATIONS

To close the gap between the current energy R&D program and the one that the challenges require, the Panel recommends strengthening the DOE applied energy-technology R&D portfolio by increasing funding for four of its major elements (energy end-use efficiency, nuclear fission, nuclear fusion, and renewable energy technologies) and restructuring part of the fifth (fossil-fuel technologies). We also recommend better coordination between the Department's applied energy-technology programs and the fundamental research carried out in the program on Basic Energy Sciences; increased Department efforts in integrated analysis of its entire energy R&D portfolio and the leverage the portfolio offers against the energy challenges of the next century; targeted efforts to improve the prospects of commercialization of the fruits of publicly funded energy R&D in specific areas; increased attention to certain international aspects of energy R&D; and changes in the prominence given to energy R&D in relation to the Department's other missions, coupled with changes in how this R&D is managed.

Applied Energy-Technology R&D Recommendations

The overall budgets we propose for applied energy-technology R&D to the year 2003, based on analyses summarized in our main report and set out in more detail in its appendices, are summarized in Table ES-1. (The table provides these figures both in as-spent dollars, which are the usual currency of official budget planning, and in constant 1997 dollars, which are more informative about what is really happening to the size of the effort.)

The applied energy-technology R&D programs, which have been the main focus of the Panel's study and which are shown in Table ES-1, contain only part of the activities constituting DOE's Congressional budget lines for "Energy R&D". Table ES-2 shows the relation, under the FY 1997 Congressional appropriation and the FY 1998 DOE request, between the amount budgeted for the activities included in our "applied energy-technology R&D" category and the amounts budgeted for the other activities included under "Energy R&D" in the Congressional budget lines.

The Panel was not able to review in detail the Basic Energy Sciences budget line (which includes research in materials science, chemistry, applied mathematics, biosciences, geosciences, and engineering that is not directed at the development of a particular class of energy sources), and it did not review at all the other "Energy R&D" budget lines shown in Table ES-2 (which contain mostly items that are either not very closely linked to advances in civilian energy technology or are not really R&D at all). Accordingly, we do not offer any recommendations about the future sizes of these budgets. We note, however, that because advances produced by research in the Basic Energy Sciences (BES) category provide an important part of the expanding knowledge base on which progress in applied energy-technology R&D in the public and private sectors alike depends, the Department may want to consider expanding its support for BES as the applied energy-technology R&D areas grow.

As indicated in Table ES-1, our proposals for the applied energy-technology R&D programs would increase spending in that category from $1.3 billion in 1997 to $2.4 billion in 2003, in as-spent dollars. In constant-dollar terms, the increase from 1997 through 2003 is 61 percent, amounting to an average real growth rate of 8.3 percent per year. The proposed figure for 2003 would return the DOE's real level of effort in applied energy-technology R&D in that year to about where it was in FY 1991 and FY 1992.

Table ES-1. **Recommended DOE Budget Authority for Applied Energy-Technology R&D**

In millions of as-spent dollars

	1997 actual	1998 request	1999	2000	2001	2002	2003
Efficiency	373	454	615	690	770	820	880
Fission	42	46	66	86	101	116	119
Fossil	365	346	379	406	433	437	433
Fusion	232	225	250	270	290	320	328
Renewables	270	345	475	585	620	636	652
TOTAL AET	1282	1416	1785	2037	2214	2329	2412

In millions of constant 1997 dollars

	1997 actual	1998 request	1999	2000	2001	2002	2003
Efficiency	373	442	584	638	695	721	755
Fission	42	45	63	80	91	102	102
Fossil	365	337	360	376	391	384	371
Fusion	232	219	237	250	262	281	281
Renewables	270	336	451	541	559	559	559
TOTAL AET	1282	1379	1695	1885	1998	2047	2068

Note: What is called "energy end-use efficiency" in this report and is abbreviated as "efficiency" in these tables appears as "conservation" in many budget documents.

Of the Panel's proposed increases in DOE's applied energy-technology R&D accounts, the largest in dollar magnitude is in the end-use-efficiency programs, in which annual spending in FY 2003 would reach $880 million, about $500 million more than in 1997 (as-spent dollars). This large increase is appropriate because of the high promise of advanced efficiency technologies for relatively quick-starting and rapidly expanding contributions to several important societal goals, including cost-effective reductions in local air pollution and carbon-dioxide emissions, diminished dependence on imported oil, and reductions in energy costs to households and firms.

Improvements in energy efficiency reduced the energy intensity of economic activity in the United States by nearly one-third between 1975 and 1995, an improvement that is now saving U.S. consumers about $170 billion per year in energy expenditures and is keeping U.S. emissions of air pollutants and carbon dioxide about a third lower than they would otherwise be.

. . . . . .

Fusion R&D is proposed for the third largest increase: annual spending for it in FY 2003 would reach about $100 million more than the 1997 figure in as-spent dollars. In this scenario, fusion funding would reach by 2002 the $320 million figure recommended in the 1995 PCAST study of fusion-energy R&D as a constant level of spending in as-spent dollars to be maintained from FY 1996 onward. (This earlier PCAST recommendation did not prevail, and fusion funding fell instead from $369 million in FY 1995 to $232 million in FY 1997.)

The Panel judges this amount warranted for two reasons: (1) About $200 million per year of it would continue a very productive element of the country's basic science portfolio (comparing favorably in cutting-edge contributions and valuable spinoffs with other fields in that category); and (2) the rest is easily justified as the sort of investment the government should be making in a high-risk but potentially very-high-yield energy option for society, in which the size and time horizon of the program essentially rule out private funding.

. . . . . .

Challenges and Opportunities: Fusion

The objective of DOE's fusion energy sciences program is to develop the scientific and technological basis for fusion as a long-term energy option for the United States and the world. The fusion R&D program is strongly centered in basic research and supports the important field of plasma science. Results and techniques from fusion plasma science have had fundamental and pervasive impact in many other scientific fields, and they have made substantial contributions to industry and manufacturing. Since 1970, fusion power in experiments has increased from less than 0.1 watt to more than 10 megawatts.

The nation's fusion energy research program has received three major reviews since 1990, the most comprehensive being the 1995 study by the PCAST Panel on the U.S. Program of Fusion Energy Research and Development.(PCAST-95). PCAST-95 recommended an annual budget of $320 million. In FY 1996, Congress reduced the fusion budget by about one-third and directed DOE to restructure its fusion energy program. The present funding level of $230 million is too low in the view of the PCAST Energy R&D panel; it allows no significant U.S. activity relating to participation in an international program to develop practical low-activation materials; reduces the level of funding for the design of the International Thermonuclear Experimental Reactor (ITER); forced an early shutdown for the largest U.S. fusion experiment; and canceled the next major U.S. plasma science and fusion experiment. It also limited the resources available to explore alternative fusion concepts.

Budgets, Goals, and Initiatives: Fusion

Based on its analysis of the potential of fusion power and the challenges and opportunities in this field, as just described, the PCAST Energy R&D Panel recommends that fusion R&D funding be increased from its annual level of $232 million in the FY 1997 appropriation to reach $320 million per year by FY2002 (as-spent dollars). This would restore fusion R&D funding to the level
which the 1995 PCAST study of fusion-energy R&D recommended be maintained from FY 1996 onward.

Our Panel reaffirms support also for the specific elements of the 1995 PCAST recommendation that the program's budget-constrained strategy be around three key principles: (1) a strong domestic core program in plasma science and fusion technology; (2) a collaboratively funded international fusion experiment focused on the key next-step scientific issue of ignition and moderately sustained burn; and (3) participation in an international program to develop practical low-activation materials for fusion energy systems. The Panel makes the following further observations about the fusion R&D effort:

International Collaborations. The U.S. program should establish significant collaborations with both the JET program in Europe and the JT-60 program in Japan. Such collaboration should provide experience in experiments that are prototypes for a burning plasma machine, such as ITER, and that can explore driven burning plasma discharges

ITER. The Panel judges that the proposed 3-year transition between completion of the EDA and an international decision to construct is reasonable and that the ITER effort merits continued U.S. involvement. It would be helpful to all parties in the ITER enterprise if at least one of the parties would express, within the next year or two, its intention to offer a specific site for ITER construction by the end of the 3-year period. Clearly, one major hurdle to ITER construction is its total project cost, most recently estimated to be $11.4 billion, with the host party expected to fund a substantial share. If the parties agree to move forward to construction, the U.S. should be prepared to determine, with stakeholder input, what the level and nature of its involvement should be. The PCAST Energy R&D Panel believes that if no party offers to host ITER in the next three years, it will nonetheless be vital to continue without delay the international pursuit of fusion energy. A more modestly scaled and priced device aimed at a mutually agreed upon set of scientific objectives focused on the key next-step issue of burning plasma physics may make it easier for all parties to come to agreement. .....

Section 4

Department of Energy
Washington, DC 20585

September 23, 1996

Dr. John Sheffield
Chair, Fusion Energy Sciences
Advisory Committee
Oak Ridge National Laboratory
Bethel Valley Road
Oak Ridge, Tennessee 37831

Dear Dr. Sheffield:

In its report to the Department of Energy on January 27, 1996, the Fusion Energy Advisory Committee (FEAC) recommended that criteria be established for a decision on the level and nature of U.S. participation in the International Thermonuclear Experimental Reactor (ITER) construction, if the ITER Parties decide to go forward. The Office of Fusion Energy Sciences (OFES) has prepared such criteria in draft form, enclosure 1, as well as a list of typical activities in which the United States might participate during an ITER construction phase, enclosure 2. I am requesting by this letter that the Fusion Energy Sciences Advisory Committee (FESAC) review these draft criteria and typical activities and respond to the following questions.

- Are the criteria appropriate; are there any recommended changes?
- What is the relative importance among the criteria?
- Considering the criteria and the current OFES program strategy, what are some possible scenarios for U.S. participation in ITER construction activities and what would be the priority among the various activities. This information would be useful during any negotiations of task sharing among the Parties.

The FESAC answers to the above questions will provide important information for the U.S. preparations for ITER negotiations along with the results of the current explorations and the results of the separately chartered FESAC technical review of the ITER Detailed Design Report. Please provide a response by May 1, 1997.

Sincerely,

Martha A. Krebs
Director
Office of Energy Research

Enclosures

Enclosure 1

Draft Criteria for a Decision on the Level and Nature of U.S. Participation in ITER Construction

These criteria are based upon the relevant policy goal for the U.S. fusion program contained in the January 1996 FEAC Report, i.e., "Pursue fusion energy science and technology as a partner in the international effort."

- U.S. participation should support the needs of the project.
- U.S. participation should be in areas where the United States has strong scientific, technological and project management capabilities.
- U.S. participation should involve all elements of the U.S. fusion community, i.e., laboratory, academic, and industrial.
- U.S. participation in the construction phase should provide a logical basis for subsequent U.S. participation in the ITER scientific and technological testing phases.

Enclosure 2

Typical Activities During the ITER
Construction Phase

- U.S. Home Team completion of remaining design and R&D tasks.
- Joint Central Team engineering and project management associated with remaining design and R&D, hardware procurement, assembly, installation, preparation for operation, architect/engineering, project integration and safety/quality assurance.
- Hardware Fabrication.
- U.S. Home Team Physics involvement in the physics design, as well as planning for operations.
- U.S. Blanket Test Module research.
- Voluntary physics R&D of a continuing nature during construction.

Since the United States has decided not to offer to be host, typical on-site activities such as building design and construction, craft work, and project administrative functions have not been listed.

OAK RIDGE NATIONAL LABORATORY
MANAGED BY LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE U.S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2008
OAK RIDGE, TN 37831-8248

PHONE: (423) 574-5510
FAX: (423) 576-6118
INTERNET: ojl@ornl.gov

February 13, 1997

Dr. Martha A. Krebs
Director
Office of Energy Research
Department of Energy
1000 Independence Avenue, S. W.
Forrestal Building
ER-1, 7B-058
Washington, D.C. 20585

Martha

Dear Dr. ~~Krebs~~:

I have been working on setting up a panel to review your second charge to FESAC on ITER, relating to possible U.S. activities if the program goes into construction and operation. One of my difficulties is that I have a large number of people, particularly FESAC members, tied up in answering the first charge, and with this busy time of year I have not succeeded yet in assembling the review panel which I would like. In addition, it would help to have in hand the answer to the first charge. I have discussed this with Anne Davies, who suggested that I should write to you requesting a change in the schedule. Hermann Grunder has agreed to chair the review, and the period mid-June into July would be convenient for him. Therefore, I would appreciate it if you would agree to a change to give a response by August 1.

Sincerely,

John

John Sheffield
Chairman of the Fusion Energy
Sciences Advisory Committee

JS:djb

cc: N. Anne Davies

Department of Energy
Washington, DC 20585

February 25, 1997

Dr. John Sheffield, Chair
Fusion Energy Sciences Advisory Committee
Oak Ridge National Laboratory
Bethel Valley Road
Oak Ridge, Tennessee 37831

Dear Dr. Sheffield:

I have received your letter dated February 13, 1997, asking for an extension of the due date for a response to the second of the two charges pending before the Fusion Energy Sciences Advisory Committee concerning the International Thermonuclear Experimental Reactor (ITER). I understand that the large number of people involved in addressing the first charge has made it difficult to assemble a second review panel to address the second charge in parallel.

In reviewing the need for the Committee's response to the second charge, I find that it would cause no difficulty if that response were not available until August 1, 1997. In fact, I could accept the response to the second charge as late as October 31, 1997.

I look forward to meeting with the Committee at its April meeting in the Washington, D.C., area to discuss the results of its consideration of the first ITER charge. I heartily endorse your choice of Dr. Grunder to chair the panel considering the second ITER charge.

Sincerely,

Martha A. Krebs
Director
Office of Energy Research

Department of Energy
Washington, DC 20585

May 19, 1997

Dr. John Sheffield, Chair
Fusion Energy Sciences Advisory Committee
Energy Technology Programs
Oak Ridge National Laboratory
Bethel Valley Road
Oak Ridge, TN 37831

Dear Dr. Sheffield:

In my September 23, 1996, letter to you, I requested that FESAC address the topic of U.S. participation in an ITER construction phase, assuming the ITER Parties decide to proceed with construction. The situation has now changed, and we do not expect to begin construction at the end of the EDA. I would, therefore, like to expand this charge to the Committee to include the U.S. role in an interim period between the EDA and Construction.

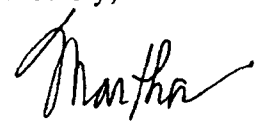
Currently, representatives of the ITER Parties are considering the need for a transition period between the end of the EDA and the beginning of construction. Time is needed to adapt the design to site-specific requirements and to begin the licensing discussions for each of the candidate sites, of which we expect there to be several. The ITER team would also use this time to complete the design, to complete the testing of prototypes built during the EDA, and to reconfigure the ITER team itself for construction. We would also, through our base programs, be consolidating the physics basis for ITER operations.

We expect this transition period to last three to five years, with an interim assessment of the readiness to proceed with construction around July 2000, and a construction decision in about July 2001.

Based upon the above circumstance, I request that FESAC address U.S. participation in an ITER transition phase as well as the construction phase. The draft criteria and list of typical activities included in my September 23, 1996, letter are still appropriate for FESAC consideration; however, they may not apply equally to both phases. FESAC should apply judgment in this regard.

I would like to receive a letter report from FESAC by the end of October 1997, with a final report by the middle of January 1998. I appreciate the Committee's willingness to take on this expanded charge.

Sincerely,



Martha A. Krebs
Director
Office of Energy Research

OAK RIDGE NATIONAL LABORATORY
MANAGED BY LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE U.S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2008
OAK RIDGE, TN 37831-6248

PHONE: (423) 574-5510
FAX: (423) 576-6118
INTERNET: oji@ornl.gov

May 30, 1997

Dr. Martha A. Krebs
Director
Office of Energy Research
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Dr. Martha Krebs:

Thank you for your letter of May 19, requesting an expansion of the charge to review U.S. participation in the ITER construction phase to include the U.S. role in an interim period between the EDA and construction. I am pleased that Dr. Hermann Grunder, the chairman of the FESAC Panel set up to undertake the original review, has agreed to the expansion of the charge to his panel. At his request, I have added four members to his panel to help him in handling the extra work. He understands the need for FESAC to submit a letter report by the end of October 1997, with a final report from FESAC by the middle of January.

I will set up a FESAC meeting, probably around the middle of October, to prepare the letter and do something which I liked in the BESAC format – hear about parts of the program without having to vote on them!

Sincerely,

John

John Sheffield
Chairman of the Fusion Energy Sciences Advisory Committee

cc: N. A. Davies, OFES
H. Grunder, CEBAF

Department of Energy
Washington, DC 20585

November 20, 1997

Dr. John Sheffield, Chair
Fusion Energy Sciences Advisory Committee
Energy Technology Programs
Oak Ridge National Laboratory
Bethel Valley Road
Oak Ridge, TN 37831

Dear Dr. Sheffield:

I have received the interim response of the Fusion Energy Sciences Advisory Committee (FESAC) to the charge regarding the level and nature of U.S. participation in possible future International Thermonuclear Experimental Reactor (ITER) activities. I want to thank you and the other members of FESAC for the excellent job that has been done thus far in dealing with this important and sensitive issue. I also want to express my appreciation to the members of the panel that you established to deal with this charge, and, in particular, Dr. Hermann Grunder, the panel Chair, for the diligent efforts that have resulted in such a thoughtful report.

The Office of Energy Research accepts the recommendations made by FESAC in its interim response letter and is taking the necessary actions to implement them within our budgetary constraints.

I understand that your deliberations regarding this charge have correctly been limited to the nearer term transition phase, and that the Committee has yet to deal with the ITER construction activities portion of the charge. In fact, the Department is also dealing with how we should proceed with respect to the proposed transition phase, making consideration of the parameters of the construction activities premature. Therefore, I would like the Committee to continue to concentrate on transition phase recommendations and defer any consideration of the level and nature of U.S. participation in the construction activities until the appropriate time, when I will restate the charge.

I look forward to receiving your final report on this charge at your meeting in Germantown on January 22-23, 1998.

Sincerely,

Martha

Martha A. Krebs
Director
Office of Energy Research