参考資料２

米国核融合エネルギー科学諮問委員会（ＦＥＳＡＣ）の開催について

平成１０年２月１０日
事　　　務　　　局

１月２２日にＦＥＳＡＣが開催され、エネルギー省（ＤＯＥ）から提出された「核融合科学技術研究における国際協力戦略計画（案）」（別紙１参照）及びＩＴＥＲパネルから提出された「米国のＩＴＥＲ活動への参加レベルについての報告書」（別紙２参照）について、レビューが行われた。提出された報告書案の概要はそれぞれ以下のとおり。

１．核融合科学技術研究における国際協力戦略計画（案）の概要

○ 米国は１９５８年に磁場核融合エネルギー研究計画を機密からはずして　　以来、国際協力を主要な戦略要素として採用してきた。

○ 国際協力は我々に核融合計画のゴールに達するのに可能なうちで最も効　　果的な道具である。

○ 次の３年間の国際協力戦略は、
　国外の対応するパートナーと協力する機会を活かし、世界の核融合研究者と施設の特徴ある能力を活用して核融合計画のゴールを達成するように努めることである。

○ 次の３年～５年の間にこの戦略を支持する主要な要素は以下のとおり。

(1) 燃焼プラズマ物理とトカマク性能
　ＪＥＴ及びＪＴ－６０との協力の可能性の検討、並びにマシンの大きさとエネルギーの閉じ込め量との関係、パワーと粒子の制御及び長時間パルス運転等に係る国際協力の推進

(2) 革新的概念の開発
球型トーラスに係る国際協力計画の策定及び日や独の計画を通じてのステラレータに係る協力の可能性の追求。また、慣性核融合に関する二国間協力の拡大及び既存のＩＥＡ協力への慣性核融合の取り込み。

(3) 核融合工学と材料開発

世界の核融合実験に米国の技術を有効に活用していく方策の探索。また、世界の核融合施設を用いての中性子照射効果などの核融合技術と材料課題についての共同開発実施の追求。

○ これらに加え、エネルギー省（ＤＯＥ）は、広範な分野における人材交　流と幅広い分野での共同実験や理論研究への参加を支援するとともに、核融合が直面する重要な科学的、技術的な問題及びＩＴＥＲの建設に関する物理専門家グループや他の非公式な国際的グループへの専門家グループの利用を推進する。

２．米国のＩＴＥＲ活動への参加レベルについての報告書について

１９９８年以降のＩＴＥＲ活動に対する米国の取り組みについて、ＩＴＥＲパネルから最終報告書（昨年１０月の中間報告からの変更はほとんどない）が提出された。レビューにおいて、ＥＤＡの延長期間中に低コスト概念を他極と検討すべき必要性が指摘され、その旨も含めてＦＥＳＡＣからＤＯＥに最終的な報告がなされる見込み。

３．その他

本年１月１４日付けＤＯＥからＦＥＳＡＣに対して、５月１５日までに材料研究計画についてレビューするよう諮問がなされた。

Strategic Plan
for
International Collaborations*
in
Fusion Science and Technology Research

(DOE Logo)

Draft

*This plan includes all international collaborations with the exception of the International Thermonuclear Experimental Reactor activities. For a discussion of the U.S. Strategy for ITER please see the letter from John Sheffield to Martha Krebs dated October 21, 1997.

Rev 1
11/14/97

January 1998

U.S. Department of Energy
Office of Energy Research
Office of Fusion Energy Sciences

Introduction

Over the next three to five years, the Office of Fusion Energy Sciences will pursue collaborative fusion research worldwide. The approach to all of these collaborations except the International Thermonuclear Experimental Reactor activities, will be based on the Strategic Plan for International Collaborations in Fusion Science and Technology Research. The U.S. strategy for pursuing ITER is contained in the letter from John Sheffield to Martha Krebs dated October 21, 1997. Both of these strategies support the overall United States fusion program strategy described in the Strategic Plan for the Restructured Fusion Energy Sciences Program (DOE/ER-0684, August 1996).

The technical options considered in developing the Strategic Plan for International Collaborations in Fusion Science and Technology Research were generated by the ad hoc Working Group on International Collaborations, chaired by Dr. N. Sauthoff of the Princeton Plasma Physics Laboratory. These technical options are presented in the working group's report Technical Opportunities for International Collaborations by the U.S. Fusion Program (November 1997).

The Strategic Plan for International Collaborations in Fusion Science and Technology Research, the Strategic Plan for the Restructured Fusion Energy Sciences Program, and the Technical Opportunities for International Collaborations by the U.S. Fusion Program are available on the World Wide Web at the following address:

http://wwwofe.er.doe.gov/More_HTML/Fusion Docs.html

A draft version of this document was reviewed by the Fusion Energy Sciences Advisory Committee (FESAC) and the recommendations of the committee have been incorporated into this document. The report of the FESAC review and the Sheffield to Krebs letter mentioned above are available on the World Wide Web at the following address:

http://wwwofe.er.doe.gov/More_HTML/FESAC CHARGES_Reports.html

Executive Summary

The United States Government has employed international collaborations as a key strategic element in magnetic fusion energy research since the program was declassified in 1958. The United States has been a leader in establishing and fostering collaborations that have involved scientific and technological exchanges and joint work at fusion facilities in the U.S. and worldwide. International collaborations have played a similar role in inertial fusion energy research since its inception.

International collaborations are a tool that allows us to meet fusion program goals in the most effective way possible. The strategy for employing international collaborations during the next three years is to:

> ***Identify and make use of opportunities to have U.S. scientists and engineers join with their counterparts in other countries to carry out research that uses the unique worldwide capabilities of fusion researchers and fusion facilities to achieve fusion program goals.***

The key elements supporting this strategy for the next three to five years are shown below, grouped into three research areas.

(1) Burning plasma physics and tokamak performance

- seek to discuss with the Joint European Torus (JET) authorities the possibility that the U.S. could become a major collaborator on JET, the only existing fusion facility with advanced performance capabilities that can operate with prototypic fusion powerplant fuels, Deuterium and Tritium

- pursue development of an active collaboration on the physics of energy confinement and transport barrier formation on JT-60U, a flexible Japanese tokamak facility with equivalent break-even performance capability.

- promote international topical collaborations in the areas of size scaling, power and particle control and long pulse operation.

(2) **Innovative concept development**

- establish a program of international collaborations on spherical tori, including inviting international participation on the National Spherical Torus Experiment in the U.S.
- pursue opportunities for collaboration on stellarators through participation in the Large Helical Device program in Japan and the Wendelstein program in Germany .
- expand bilateral collaborations in Inertial Fusion Energy (IFE), and explore the incorporation of IFE issues into the fusion energy activities at the International Energy Agency.

(3) **Fusion technology and materials development:**

- seek to deploy U.S. technologies on worldwide fusion experiments to access test conditions unavailable domestically, particularly on scientific issues related to long pulse/steady state operation, high power densities, and reliability.
- pursue the conduct of joint development work on the key feasibility issues for fusion technologies and materials, such as neutron irradiation effects, using unique fusion facilities worldwide.

In addition to the collaborative efforts that will arise from the key strategic elements, the Department will continue to support personnel exchanges and participation in joint experimental and theoretical research in a wide range of areas. The Department will also seek to promote the use of expert groups on key scientific and technological issues facing fusion, building on the success of the International Thermonuclear Experimental Reactor (ITER) Physics Expert Groups and other less formal international groups.
The international collaborations strategy was initially developed

assuming that ITER will enter a three to five year long Transition Phase in July 1998. Once the key elements of the strategy were identified, the assumption was re-examined. Upon re-examination, it has been determined that, while the overall U.S. fusion program would be severely affected, the key technically-based strategic elements of international collaboration would be insensitive to the assumption about ITER.

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Mission

The international activities undertaken by the U.S. fusion energy sciences program support the overall program strategy as described in the Strategic Plan for the Restructured U.S. Fusion Energy Sciences Program, (DOE/ER-0684, August, 1996).

The mission of the fusion energy sciences program is to:

> *Advance plasma science, fusion science, and fusion technology — the knowledge base needed for an economically and environmentally attractive fusion energy source*

The policy goals that support this mission are:

- *understanding the physics of plasma, the fourth state of matter*
- *identifying and exploring innovative and cost-effective development paths to fusion energy*
- *exploring the science and technology of energy producing plasmas, the next frontier in fusion research, as a partner in an international effort*

Guiding Principles

The general principles that have guided the development of the international collaborations strategy are summarized below.

- **The perceived urgency of the energy goal differs among the countries funding fusion research.**
  However, the common goal of all of the worldwide fusion programs continues to be achieving practical fusion energy in the most effective way possible.

- **International considerations are a fundamental part of the overall rationale for fusion energy development.**
  The development of fusion as a practical energy source is motivated by global energy and environmental issues as well as national concerns regarding energy security and economic competitiveness.

- **International collaboration brings together the best worldwide intellectual and facility capabilities**
  The development of fusion energy is a complex scientific and technological challenge involving substantial commitments of resources, with the commercialization phase decades away.

- **International collaborative efforts are a necessary, integral part of and contribute directly to the program.**
  Such efforts have been a part of the U.S. program since its early days and they are a part of essentially every component of the program today.

- **International collaboration, taken as a whole, should allow each participant to fulfill its own objectives.**
  For the U.S., international activities should be supportive of the strategy of our science-focused Fusion Energy Sciences Program. We, in turn, should understand the needs of our partners and their energy-focused programs.

- **The most productive collaborations occur when all parties "bring something to the table".**
  Successful collaborations by U.S. scientists on devices worldwide often include contributions of hardware and people.

- **The development of effective and productive international collaborations is based on mutual understanding and trust.**
  Such relationships are facilitated by stable national commitments and funding.

- **Breadth in technical collaborations is an advantage and should be maintained.**
  International collaborative activities have covered many topical areas (plasma theory and experiments, technology development, materials research and design studies) using a wide variety of methods (personnel exchanges, workshops, joint experiments, common planning, etc.).

- **The U.S. strategy for international collaboration should give priority to those areas where such collaborations are judged essential to meet U.S. program goals.**
  With the present and projected resources, it is not possible to have a stand-alone U.S. fusion program, nor is it possible for the U.S. to be a major participant in every international collaborative effort. Those scientific and technological areas wherein the U.S. could make its strongest contributions, both in leading and supporting roles, should be identified and pursued.

- **The application of state-of-the-art information technologies will greatly facilitate future international collaborations.**
  International collaborations like fusion research will help drive as well as benefit from developments in information technology through expanded use of remote operations, data storage and transmission, telecommunications, etc.

Situation Analysis

Most of the world's fusion research is funded by the European Union (EU), and the governments of Japan (JA), the Russian Federation (RF), and the United States. Smaller, but increasingly significant fusion programs are funded by Canada, China, India, and the Republic of Korea. Other countries funding fusion research activities include Australia, Argentina, Brazil, the Czech Republic, Egypt, Ukraine, Kazakhstan, Mexico, Poland, South Africa, and Turkey.

The yearly funding for U.S. fusion program was reduced 40% between fiscal years 1995 and 1997. Between fiscal years 1977 and 1998, the U.S. fusion budget was reduced 70% in real terms. In contrast, funding for the European and the Japanese fusion programs has significantly increased during that same period. In fiscal year 1997, the EU spent nearly three times the amount spent by the United States for fusion research, while we estimate that the Japanese program spent about twice as much as the United States.

A consequence of the continuous reduction in the U.S. fusion budget has been the inability of the U.S. fusion program to make investments in major new experimental facilities. In contrast, the EU and Japan have continued to design and build such new fusion experiments.

In 1995, the Congress instructed the Department of Energy to restructure the U.S. fusion program to be consistent with the expectation that, with the reduced urgency for new energy sources in the U.S, budgets will remain flat for the foreseeable future. Thus, the U.S. is no longer pursuing fusion as a goal-oriented energy technology development program. A new strategic plan for the fusion energy sciences program has been developed with new program goals that support plasma science research, emphasize the importance of exploring innovative solutions to technical issues, reinvigorate the search for alternative concepts to the conventional tokamak, and recognize the need to pursue research on the scientific and technological foundations for economically and environmentally attractive fusion energy powerplants through international collaboration.

Taken together, the declining budget and the program restructuring have resulted in an increasing U.S. need to participate in international collaborations to achieve our fusion goals cost-effectively, help maintain technical breadth in the program, and provide access to existing capital facilities for which we do not have counterparts, and to future major capital facilities that we could not construct independently.

With energy situations perceived differently than in the United States, the EU and Japan are continuing their goal-oriented fusion energy development programs. The long term goal of these programs is to produce a prototype fusion power plant.

While both the European and the Japanese programs are pursuing the tokamak as the basis for an engineering test reactor, they are pursuing alternative concepts to the tokamak for possible use in their demonstration powerplants.

More information about the worldwide fusion programs is contained in the report of the Working Group on International Collaborations on the World Wide Web at the address shown on Page 2.

Strategy-Burning Plasma and Tokamak Performance

The tokamak is presently the most advanced energy containment configuration being pursued by the magnetic fusion energy sciences program. Worldwide there are a number of ongoing tokamak experiments with a wide variety of designs and capabilities. The largest facilities are JET, in Europe, which is now the only fusion device in the world that can operate with a deuterium/tritium (D-T) fuel mixture to produce energy, and JT-60U, in Japan, which has performance capabilities comparable to JET without tritium. With the shut down of the Tokamak Fusion Test Reactor facility, the U.S. has no fusion experiment that is comparable in size or performance to either JET or JT-60U.

International collaborations that make use of the unique capabilities of JET and JT-60U offer an avenue for achieving important scientific goals of the U.S. fusion program within the limited funding available.

A scientific goal of the JET and JT-60U collaborations would be to complement the ongoing experimental programs at the two U.S. tokamak facilities, DIII-D and C-MOD, in trying to understand and control plasmas. These collaborations will provide valuable scientific information critical to the design and projections of the performance of ITER, which is the principle rationale for these facilities.

The U.S. will seek to:

- discuss with JET authorities the possibility that the U.S. could build on our current cooperation to become a major collaborator in the JET experiment. These discussions will make clear that the U.S. would like not only to support scientists and engineers, both at the JET site and possibly at remote sites, but also to fabricate and deliver hardware to the experimental site, as appropriate. The U.S. could potentially contribute hardware in the areas of diagnostics, and auxiliary heating, in the form of additional neutral beams or more efficient antennas for radio frequency heating. Remote operation of JET from the U.S. would also be an objective of this collaboration. Such remote operation would demonstrate a capability for remote operation of ITER.

- implement on JT-60U diagnostic techniques that have played an important role in the development of theoretical models of energy containment. Their implementation on JT-60U would be a critical element in trying to establish the physics basis of confinement in JT-60U experiments.

- continue the active collaboration between DIII-D and JT-60U on the influence of plasma shape on confinement.

- propose to the international community the establishment of International Topical Collaborations on key scientific and technology issues. These topical collaborations would typically involve multiple experiments worldwide and would act as catalysts in the international fusion community for addressing key scientific issues. Examples of issues that could be addressed are the scaling of energy confinement with machine size, the design of divertors for suppression of impurities and the efficient removal of ash, and the control of plasma dynamics during steady-state operation.

Technical information supporting the recommendations above can be found in the report of the Working Group on International Collaborations on the World Wide Web at the address shown on Page 2.

Strategy-Innovative Concept Development

The development of innovative concepts has become an important part of the U.S. fusion program strategy. Several of the innovative concepts under investigation within the U.S. are also being pursued by parties that have invested in large facilities aimed at extending plasma performance beyond what can be achieved in U.S. facilities. Collaboration with these programs would allow us to assess the viability, influence the development, and test ideas for further improvement of these concepts.

The U.S. program does not, by itself, have the resources to bring any innovative concept from initial conception to its ultimate embodiment as a fusion powerplant. Hence, U.S. participation in the ultimate development of any innovative concept will depend both on positive results from that concept's development program, and on the formation of international partnerships to complete proof-of-performance and D-T burning experiments. Some innovative concepts already have broad international support (e.g., stellarators, spherical tori, and reverse field pinches). For these concepts, an important goal of the collaborations is to maximize the scientific benefit to the programs of the participants, and to begin building the scientific and technical partnerships that will be required for the U.S. program to participate in carrying these concepts toward their powerplant embodiment. For other concepts (e.g., spheromaks, field reversed configurations, and magnetic dipoles) the international effort is small. Positive technical results from U.S. efforts to develop these concepts will be used to interest prospective international partners in joining us in the further development of these concepts.

Innovative confinement concepts in which the U.S. will seek or continue international collaborations include spherical tori, stellarators, and inertial fusion energy. The department will seek to:

- establish a program of international collaborations on spherical tori, including inviting international participation on the National

Spherical Torus Experiment in the U.S.

- pursue opportunities for collaboration on stellarators through the Large Helical Device program in Japan and the Wendelstein program in Germany.

- expand bilateral collaborations in Inertial Fusion Energy (IFE), and explore the incorporation of IFE issues into the fusion energy activities at the International Energy Agency.

Technical information supporting the recommendations above can be found in the report of the Working Group on International Collaborations on the World Wide Web at the address shown on Page 2.

Strategy-Fusion Technology

International collaboration in the technology area provides opportunities to obtain access to experiments worldwide and test facilities with capabilities not available in the U.S., to stay abreast of world wide technology developments, and to share development costs.

In the U.S., most technology development is now carried out in support of the ITER Engineering Design Activities (EDA). The principal focus is on superconducting magnet development and R&D related to divertor and first wall issues. Other activities include safety research, plasma fueling and heating, tritium processing systems, remote welding and cutting, and metrology systems.

International collaborations on enabling technologies include: superconducting magnets, plasma facing materials and components, plasma material interactions, wall conditioning and particle control, plasma fueling and fuel process systems and plasma heating systems.

Development of fusion technologies and materials is critical to both the economic and the safety/environmental features of fusion. This will be even more important for advanced high power density machines envisioned with improved plasma physics. The identification and evaluation of high-performance concepts with high-neutron wall load capability, high-power density components, and attractive safety and environmental features is essential for progress on fusion energy. This involves performing research on innovative high performance concepts with large potential payoff. The development of low activation materials is an important part of this effort. Progress requires advancing the sciences necessary for understanding and evaluating the performance and interactions of an attractive and compatible combination of low activation structural, breeding, cooling and plasma facing materials. Effects of irradiation on materials or components must be conducted in the limited number of fission reactors available in the international community until a high flux 14-MeV neutron source is constructed.

For the longer term, international collaboration on fusion technologies and materials should include: Breeding Blanket and Shield Systems; Structural Materials and Radiation Effects; Remote Maintenance and Reliability; Systems Analysis and Safety Research; and Instrumentation in the Fusion Environment.

The Department will seek to:

- deploy U.S. technologies on experiments worldwide to access test conditions unavailable domestically, particularly on scientific issues related to long pulse/steady state operation, high power densities, and reliability.

- conduct joint development work on the key feasibility issues for fusion technologies and materials, such as neutron irradiation effects, using unique facilities.

- enlarge the scope of the existing bilateral technology exchanges with Europe, Japan, and Russia.

- continue to participate in the discussions on an international fusion neutron source.

- continue to participate in research on high-performance breeding blankets and joint fission reactor irradiations on advanced materials.

Technical information supporting the recommendations above can be found in the report of the Working Group on International Collaborations on the World Wide Web at the address shown on Page 2.

(別紙2)

THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

Jefferson Lab

Hermann A. Grunder
Director

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

letter.pas

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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.

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