ＦＥＳＡＣ（核融合エネルギー科学諮問委員会）が１９９８年以降の ＩＴＥＲ活動に対する米国の取り組みについての報告書を提出

（背景）

○ １９９６年9月及び１９９７年5月にエネルギー省（ＤＯＥ）から核融合エネルギー科学諮問委員会(ＦＥＳＡＣ)に対して、１９９８年7月以降のＩＴＥＲ活動への取り組み方等について検討するよう指示されていたもの

○ ＦＥＳＡＣにおいては、専門家からなるパネルを設置して検討を実施。このパネルからの中間報告に基づき、１０月２３日(米国時間)にＦＥＳＡＣとしての中間報告書がとりまとめられ、ＤＯＥに報告された。

○ 今後、この中間報告書も踏まえながら、ＤＯＥにおいて、今後のＩＴＥＲ活動への取り組み方を踏まえ、１９９９年度予算案についての検討がなされていくことになる。

（報告書の主な概要）

○ ＦＥＳＡＣは、「国際協力のパートナーと協力して、可能な限り早い時期に燃焼プラズマ実験施設を建設すべきである」というパネルの主要勧告を支持。この主要勧告を実施する場合の１９９９年度の活動資金としては、核融合エネルギー科学予算（総額２５０百万ドル）のおおよそ２０％を割り当てることが適当。

○ ＦＥＳＡＣは、この内数として、「延長期間中のＩＴＥＲ基準設計に関する共同作業について、より低いレベルで参加すべきとする」パネルの提言を承認。 ○ＦＥＳＡＣは、「ＩＴＥＲの使命を満たす装置の建設の確約が得られない状況を踏まえ、コストとリスクと使命との兼ね合いを見つつオプションの検討をすべき」とするパネルの結論を承認。

○ ＦＥＳＡＣは、「核融合エネルギー技術開発活動は核融合計画の目標をより広範に支えるよう再構築すべき」とするパネルの勧告と同意見。

○ ＦＥＳＡＣは、「ＪＥＴやＪＴ－６０Ｕにおける協力の増大の可能性を国際的な関係者と探るべきとする」パネルの提言を踏まえ、ＦＥＳＡＣは、プラズマの最適化による可能な限りのコスト低減を図るための物理的基礎や燃焼プラズマ物理の課題にねらいを定めた実験計画の活性化を勧告する

ＦＥＳＡＣ(核融合エネルギー科学諮問委員会)
の中間報告（概要）

１．背景

平成８年１月、ＦＥＡＣ（現ＦＥＳＡＣ）がＤＯＥに、１９９６会計年度の大幅な予算削減を踏まえ、米国エネルギー省核融合計画の再構築に係る報告書を提出。

平成８年９月、ＤＯＥがＦＥＳＡＣに、ＩＴＥＲ建設に対する米国の参加について諮問を行う。

平成９年５月、ＤＯＥがＦＥＳＡＣに、現行工学設計活動と建設の間の移行期間における米国の役割について追加諮問を行う。

２．勧告の概要

○ **米国のＩＴＥＲに対する勧告の柱は、以下の通り**
「国際協力により可及的速やかに燃焼プラズマ施設を建設すべき」

○ **この勧告を実施するために、延長期間の３年間の活動として、以下の４要素を米国核融合戦略として提案**

① 他国に現存する大規模装置を用いて、エネルギーを産出する核融合プラズマ科学を支援する研究の機会を短期的に追求する
② 核融合エネルギー計画の目標を幅広く支援するために、核融合エネルギー技術開発活動を再構築する
③ 現在進行中のＩＴＥＲの設計活動に、米国の支援レベルを下げて引き続き参加する
④ 低コスト化を図った核融合エネルギーを産出するプラズマ概念の設計を行う

○ なお本報告書は、平成９年９月の大統領科学技術諮問委員会（ＰＣＡＳＴ）の報告書と平成８年のＦＥＡＣの報告書の内容と資金規模を支持する。

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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

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 FESAC 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.

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 RECOMMENDATION

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, 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.

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

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

Dr. John Sheffield, Chair
(Dr. Ira B. Bernstein)
Dr. Richard J. Briggs
Dr. James D. Callen
Dr. Robert W. Conn (present first day)
Ms. Melissa Cray
Dr. Katharine B. Gebbie
Dr. Samuel D. Harkness
Dr. Richard D. Hazeltine
Dr. Joseph A. Johnson, III
(Dr. Charles F. Kennel)
Dr. Michael L. Knotek (present first day)
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. William Hogan
Dr. Ned Sauthoff

*Absent members in ()