DOE/SC-0060

Fusion Energy Sciences Advisory Committee

A BURNING PLASMA PROGRAM STRATEGY TO ADVANCE FUSION ENERGY

Executive Summary

September, 2002

U. S. Department of Energy
Office of Science

Left Blank Intentionally

Department of Energy
Washington, DC 20585

February 22, 2002

Professor Richard D. Hazeltine, Chair
Fusion Energy Sciences Advisory Committee
Institute for Fusion Studies
University of Texas at Austin
Austin, TX 78712

Dear Professor Hazeltine:

In response to our earlier request, FESAC has provided me with clear advice on the scientific status of burning plasma physics. FESAC has recommended that the Department proceed apace toward decisions that would enable the U.S. fusion energy sciences community to address experimentally the important scientific issues involved in burning plasma physics.

In accordance with the FESAC recommendations, we are supporting the Fusion Summer Study later this year, with its focus on a detailed examination and assessment of the benefits to be achieved in the various possible approaches to an experimental program in this field.

The next step in this process is for FESAC to establish a high-level panel that would use the results of the Summer Study to recommend a strategy for burning plasma experiments. This panel's report should show how ITER would fit into the U.S. fusion program, if it were to go forward with our participation. The panel should also indicate how a FIRE or Ignitor type of device would fit in our program, if ITER were not to go forward. The panel's proposed strategy should provide flexibility for us to join ITER, should the Administration decide to enter negotiations, and if we are able to negotiate acceptable terms, and that allows us to decline to join if the terms are not acceptable to both the community and the Administration.

Given the importance of a timely decision process, I ask FESAC to have the panel complete its report as quickly as possible after the Summer Study in July. It is important that FESAC itself review the panel report and send me the full Committee's recommendation by the end of the summer, in September 2002.

In parallel, we will ask the National Research Council to prepare to review FESAC's recommendations and report to us with their assessment by the end of 2002.

This set of actions will provide the Department with the essential fusion community view, as well as an external review, on the critical question of how to pursue burning plasma physics.

Thank you in advance for your efforts to provide your report to us on a timely basis.

Sincerely,

James F. Decker
Acting Director
Office of Science

September 13, 2002

Dr. Ray Orbach
Director, Office of Science
United States Department of Energy
1000 Independence Avenue, S.W.
Washington, DC 20585

Dear Dr. Orbach:

The Fusion Energy Sciences Advisory Committee (FESAC) endorses the conclusions of the Burning Plasma Strategy Panel. This endorsement is unanimous and enthusiastic.

On February 22, Acting Director James Decker charged FESAC "to establish a high-level panel …to recommend a strategy for burning plasma experiments." The panel, chaired by Professor Stewart Prager, met in Austin on August 6 – 8 and submitted its strategy recommendation to the FESAC on September 5. FESAC has now formally reviewed the panel's report, "A Burning Plasma Program Strategy to Advance Fusion Energy," and, with this letter, submits the panel's report to you.

The report notes that "The world effort to develop fusion energy is at the threshold of a new state in its research: the investigation of burning plasmas. This investigation, at the frontier of the physics of complex systems, would be a huge step in establishing the potential of magnetic fusion energy to contribute to the world's energy security." It then outlines a consistent, aggressive strategy, taking advantage of US and international efforts, to develop the science and technology of plasmas heated primarily by thermonuclear reactions. The FESAC finds the outlined strategy to be sensible, coherent and convincing. We thank Professor Prager and the panel for their carefully reasoned plan.

Submission of this report is the latest step in a process that began in October of 2000, with the charge from Dr.Mildred Dresselhaus, for the FESAC to "address the scientific issues of burning plasma physics..." The panel responding to this charge, chaired by Professor Jeffrey Freidberg, issued its report in September of 2001, stating that "NOW is the time for the US Fusion Energy Sciences Program to take the steps leading to the expeditious construction of a burning plasma experiment," and laying out a plan for finding the best burning-plasma strategy. The second step in the process, recommended by the Freidberg panel, occurred in July of 2002: a 2-week Summer Study of burning plasma physics, involving a large part of the fusion research community. The most important product of the Summer Study, aside from the community unanimity it revealed on the need for burning plasma research, was a uniform technical assessment of the three leading proposals for burning-plasma experimental devices. This assessment provided crucial input to the deliberations of the Prager panel, and hence to the attached report.

I will remark that both the Freidberg panel report (DOE/SC-0041) and the report of the Snowmass Summer Study contain a wealth of technical material that provide helpful background to the present report.

As you know, the need for a burning plasma experiment was recognized in fusion community planning long before the Dresselhaus charge. For example the report of the FESAC Panel on Priorities and Balance, issued in September of 1999, includes participation in a burning plasma experiment as part of one of its four key goals. However, the present report is more than a restatement of long-felt ambitions: it offers a proactive plan to realize those ambitions. For there has been a change in our community: a firmer confidence that burning plasma physics is well within our reach, and a reinforced conviction that studying the behavior of a burning plasma will bring truly enormous scientific and technical gains for fusion energy. This community sees itself on the threshold of a giant step forward.

Yours truly,

Richard Hazeltine
Chair, FESAC

RDH/lh

Enclosure

cc: N. A. Davies
Michael Roberts
John Willis

A BURNING PLASMA PROGRAM STRATEGY TO ADVANCE FUSION ENERGY

EXECUTIVE SUMMARY

Fusion energy shows great promise to contribute to securing the energy future of humanity. The risk of conflicts arising from energy shortages and supply cutoffs, as well as the risk of severe environmental impacts from existing methods of energy production, are strong reasons to pursue fusion energy now.

The world effort to develop fusion energy is at the threshold of a new stage in its research: the investigation of burning plasmas. This investigation, at the frontier of the physics of complex systems, would be a huge step in establishing the potential of magnetic fusion energy to contribute to the world's energy security.

The defining feature of a burning plasma is that it is self-heated: the 100 million degree temperature of the plasma is maintained mainly by the heat generated by the fusion reactions themselves, as occurs in burning stars. The fusion-generated alpha particles produce new physical phenomena that are strongly coupled together as a nonlinear complex system. Understanding all elements of this system poses a major challenge to fundamental plasma physics. The technology needed to produce and control a burning plasma presents challenges in engineering science similarly essential to the development of fusion energy.

Experimental study of a burning plasma has long been a goal of the U.S. science-based fusion energy program. There is an overwhelming consensus among fusion scientists that we are now ready scientifically, and have the full technical capability, to embark on this step. The fusion community is prepared to construct a facility that will allow us to produce this new plasma state in the laboratory, uncover the new physics associated with the fusion burn, and develop and test new technology essential for fusion power.

Three options are presently under consideration as burning plasma experimental facilities: the international ITER project, the U.S.-based FIRE project, and the Italian IGNITOR project. All three are tokamaks, the most extensively studied magnetic configuration. The projects are at different stages of development, and have different mission scopes, time schedules, and costs. ITER is a power-plant scale facility with a comprehensive science and technology program. It has a well-developed engineering design and negotiations for construction are underway. U.S. participation in ITER would have substantial domestic benefits. FIRE is a smaller scale facility with a broad science program. It has an advanced pre-conceptual design. International participation in FIRE would provide substantial benefits. IGNITOR has a well-developed design and is moving forward in Italy. Its operation would provide valuable insight into burning plasma science, although it is not designed to be the sole burning plasma facility in the world.

Recognizing the opportunity before us, the Fusion Energy Sciences Advisory Committee was charged by the Department of Energy to "recommend a strategy for burning plasma experiments." A FESAC panel was convened for this purpose. The recommendations of the Panel are based, in large part, on an extensive scientific

assessment of the three options by the 2002 fusion summer study, a two-week meeting of 280 fusion scientists, preceded by eight months of preparatory activity.

Given this background, the Panel has produced a strategy to enable the U.S. to proceed with this crucial next step in fusion energy science. The strategy was constructed with awareness that the burning plasma program is only one major component in a comprehensive development plan for fusion energy. A strong core science and technology program focused on fundamental understanding, confinement configuration optimization, and the development of plasma and fusion technologies is essential to the realization of fusion energy. The core program will also be essential to the successful guidance and exploitation of the burning plasma program, providing the necessary knowledge base and scientific work force.

The Panel recommendations are guided by the design options and considerations presented above and by two primary findings:

ITER and FIRE are each attractive options for the study of burning plasma science. Each could serve as the primary burning plasma facility, although they lead to different fusion energy development paths.

Because additional steps are needed for the approval of construction of ITER or FIRE, a strategy that allows for the possibility of either burning plasma option is appropriate.

With this background, the Panel puts forth the following major strategy recommendations.

Since ITER is at an advanced stage, has the most comprehensive science and technology program, and is supported internationally, we should now seek to join the ITER negotiations with the aim of becoming a partner in the undertaking, with technical, programmatic and timing considerations as follows:

> ***The desired role is that the U.S. participates as a partner in the full range of activities, including full participation in the governance of the project and the program. We anticipate that this level of effort will likely require additional funding of approximately $100M/yr.***
>
> ***The minimum acceptable role for the U.S. is at a level of effort that would allow the U.S. to propose and implement science experiments, to make contributions to the activities during the construction phase of the device, and to have access to experimental and engineering data equal to that of all partners.***
>
> ***The U.S. performs a cost analysis of U.S. participation and reviews the overall cost of the ITER project.***

The Department of Energy concludes, by July, 2004, that ITER is highly likely to proceed to construction and terms have been negotiated that are acceptable to the U.S. Demonstrations of likelihood could include submission to the partner governments of an agreement on cost-sharing, selection of the site, and a plan for the ITER Legal Entity.

Since FIRE is at an advanced pre-conceptual design stage, and offers a broad scientific program, we should proceed to a physics validation review, as planned, and be prepared to initiate a conceptual design by the time of the U.S. decision on participation in ITER construction.

If ITER negotiations succeed and the project moves forward under terms acceptable to the U.S., then the U.S. should participate. The FIRE activity should then be terminated.

If ITER does not move forward, then FIRE should be advanced as a U.S.-based burning plasma experiment with strong encouragement of international participation.

If IGNITOR is constructed in Italy, then the U.S. should collaborate in the program by research participation and contributions of related equipment, as it does with other major international facilities.

A strong core science and technology program is essential to the success of the burning plasma effort, as well as the overall development of fusion energy. Hence, this core program should be increased in parallel with the burning plasma initiative.

A burning plasma science program should be initiated by the OFES with additional funding in FY 04 sufficient to support this strategy.

FESAC Panel on the Strategy for a Burning Plasma Program

Charles Baker, *University of California, San Diego*
David Baldwin, *General Atomics*
Herbert Berk, *University of Texas at Austin*
Riccardo Betti, *University of Rochester*
James Callen, *University of Wisconsin – Madison*
Vincent Chan, *General Atomics*
Bruno Coppi, *Massachussetts Institute of Technology*
Jill Dahlburg, *General Atomics*
Steven Dean, *Fusion Power Associates*
William Dorland,* *University of Maryland*
James Drake, *University of Maryland*
Jeffrey Freidberg, *Massachussetts Institute of Technology*
Robert Goldston, *Princeton Plasma Physics Laboratory*
Richard Hawryluk, *Princeton Plasma Physics Laboratory*
Richard Hazeltine, *University of Texas at Austin*
E. Bickford Hooper, *Lawrence Livermore National Laboratory*
Amanda Hubbard, *Massachussetts Institute of Technology*
Thomas Jarboe, *University of Washington*
Joseph Johnson, *Florida A & M University*
Martin Lampe,* *Naval Research Laboratory*
John Lindl, *Lawrence Livermore National Laboratory*
Grant Logan, *Lawrence Livermore National Laboratory*
Earl Marmar, *Massachussetts Institute of Technology*
Michael Mauel, *Columbia University*
Kathryn McCarthy, *Idaho National Engineering and Environmental Laboratory*
William McCurdy,* *Lawrence Berkeley National Laboratory*
Dale Meade, *Princeton Plasma Physics Laboratory*
Wayne Meier, *Lawrence Livermore National Laboratory*
Stanley Milora, *Oak Ridge National Laboratory*
George Morales, *University of California at Los Angeles*
Farrokh Najmabadi, *University of California, San Diego*
Gerald Navratil, *Columbia University*
William Nevins, *Lawrence Livermore National Laboratory*
David Newman, *University of Alaska at Fairbanks*
Ronald Parker, *Massachussetts Institute of Technology*
Francis Perkins, *General Atomics*
Cynthia Phillips, *Princeton Plasma Physics Laboratory*
Miklos Porkolab, *Massachussetts Institute of Technology*
Stewart Prager (Chair), *University of Wisconsin – Madison*
Marshall Rosenbluth,* *University of California, San Diego*
Ned Sauthoff, *Princeton Plasma Physics Laboratory*
Kurt Schoenberg,* *Los Alamos National Laboratory*
John Sheffield, *Oak Ridge National Laboratory*
Ronald Stambaugh, *General Atomics*
Edward Synakowski, *Princeton Plasma Physics Laboratory*
George Tynan, *University of California, San Diego*
Nermin Uckan, *Oak Ridge National Laboratory*

*Not present at panel meeting in Austin, Texas