Report of the FESAC Panel on

A BURNING PLASMA PROGRAM STRATEGY TO ADVANCE FUSION ENERGY

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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.***
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> ***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.***
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> ***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.