A US Strategy to Explore the Science and Technology of Energy-Producing Plasmas

Discussion Draft
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Introduction

Last year, the Department of Energy redirected the fusion program from an energy technology development program to a program focused on the scientific foundations that underpin the fusion process. The specific objectives of the fusion program are to: (1) advance plasma science in pursuit of national science and technology goals, (2) identify and study fusion science, technology, and plasma confinement innovations, and (3) explore the science and technology of energy producing plasmas, as an international partner. This strategy provides a basis for the relative size and emphasis of various US fusion research activities by charging the Fusion Energy Sciences Program with stewardship of a vital element of our nation's scientific infrastructure and with a mission to develop the knowledge base for an environmentally-attractive fusion power source.

The major element supporting the third objective of the program is participation in the International Thermonuclear Experimental Reactor (ITER) Engineering Design Activity (EDA), consisting of physics analysis, engineering design, and supporting technology R&D activities. By working collaboratively, the ITER Partners benefit through cost-sharing. Additionally, the ITER collaboration increases 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 the physics and technology of long-pulse burning plasmas.

The presently agreed EDA is approaching its end, and a construction decision has been delayed. These events necessitate an assessment of the proper form and scale of the activities which support the program's third objective, in relation to the overall Fusion Energy Sciences program. This assessment must be made in light of the rapid recent progress in fusion science, such as the increased understanding and control of transport processes in high temperature tokamak plasmas, and the experimental and theoretical advance of non-tokamak fusion concepts.

This document presents a draft proposal for internationally collaborative research and design activities motivated by our assessment of the opportunities present in today's world fusion program. Our proposal would directly advance our understanding of plasmas capable of fusion energy production and also provide key information contributing to the international decision to construct a next-step burning plasma experiment. Our proposal maximizes the benefit to the long-term interests of the US and sustains our credibility as an international partner in large-scale science projects.

An Assessment

Our assessment, shared by many of our colleagues, is that the US strategy to explore the science and technology of energy-producing plasmas must change in the post-ITER-EDA period. The need for this change results from the appearance of three opportunities:

1. The scientific demonstration and theoretical understanding of improved control of transport processes in a tokamak.

2. The possibility that, if our techniques to control plasma transport can be applied during higher-power operation of the JET device, the world fusion community might be able to conduct significant but limited investigations of energy producing plasmas within a currently operating facility.

3. The delay in an ITER construction decision which we view, not as a setback or dilemma, but as an opportunity for the world fusion program to strengthen the science and technology bases for fusion and to explore opportunities for possibly significant cost reductions in a next-step burning plasma experiment.

These three opportunities guide our proposed changed strategic plan for the third fusion program objective, in particular:

1. **The US should pursue near-term opportunities for research on energy-producing plasmas, using existing large-scale facilities abroad.**

2. **The US should make use of international collaboration in fusion technology development to realize the full potential of fusion as an environmentally and economically attractive energy source.**

3. **The ITER process has been very successful, and the US should continue to participate at a level appropriate to the benefits which will accrue to its program.**

The Proposed Strategic Plan

In consonance with the above findings, we recommend three areas of collaborative international activity in support of the third Fusion Energy Sciences objective.

1. **Increased scientific research on the physics of energy-producing plasmas, in direct support of the third objective of the Fusion Energy Sciences program.**

   Recent experimental and theoretical results point to new approaches to achieving high levels of energy production in tokamak plasmas, and the interest of Europe and Japan in US collaboration provides opportunities for the US to pursue these new approaches internationally.

   In experimental research, we recommend strongly increased US participation in the large foreign experiments, JET and JT-60U. We recommend that the US DOE

negotiate with Euratom for partnership status in JET, a device capable of deuterium-tritium operation for fusion energy production. US participation in JT-60U should be enhanced as well. As part of these collaborations, the US should develop and test techniques for remote experimentation on international fusion devices.

We also recommend a significant new initiative of broad-based US theoretical and computational effort to understand high-temperature confined plasmas in the energy-producing regime, in support of the international effort in this area.

2. **Continuation of key collaborative international programs to develop the technologies necessary for fusion science experiments and for environmentally and economically attractive fusion power.**

Much of the US 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 which would be carried out under our normal technology R&D activities. The US 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 and they also help complete the R&D required for the ITER design. Non-ITER-specific technology R&D should also be continued, and, over time, international collaboration in fusion technology R&D should be encouraged outside of the ITER context.

3. **Support of ongoing ITER design and analysis activities, at a reduced level.**

To date the ITER design concept has been developed as an international collaboration. Two of the partners, the European Union and Japan, now have much larger fusion programs than the US. Driven by greater perceived need for environmentally and economically attractive new domestic energy sources, they have more aggressive plans for the development of fusion. Even in the strategic context of the US science-focused fusion program, however, construction and operation of ITER would be beneficial.

The US should focus its efforts on opportunities for cost reduction and for enhanced scientific flexibility. These efforts should be carried out in conjunction with the physics research and technology R&D discussed above, so as to motivate and guide these activities and to shorten the time for adoption of fruitful results into the international machine design.

Finally, the funding level for activities directed towards the third Fusion Energy Science program objective must be considered in the context of resource constraints and scientific opportunities within the overall US fusion program. We expect these resource levels will evolve in time.

Conclusion

We reaffirm the importance to the US Fusion Energy Sciences program of continuing in a collaborative international effort to pursue energy-producing plasmas and fusion technology. In

reaching the conclusion of the EDA, the US fusion community acknowledges the success of the ITER process in focusing the world fusion effort toward a common goal. The ITER process has significantly increased the integration and effectiveness of the world fusion effort and has led to important insights into fusion-reactor science and design. By adopting and supporting the plan outlined in this document, the US will be able to continue to pursue a balanced Fusion Energy Sciences program, which will address all three of its program objectives.

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