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Strategic Plan for the Restructured U.S. Fusion Energy Sciences Program

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Executive Summary

This plan reflects a transition to a restructured fusion program, with a change in focus from an energy technology development program to a fusion energy sciences program.

Since the energy crisis of the early 1970s, the U.S. fusion program has presented itself as a goal-oriented fusion energy development program, with milestones that required rapidly increasing budgets. The Energy Policy Act of 1992 also called for a goal-oriented development program consistent with the Department's planning. Actual funding levels, however, have forced a premature narrowing of the program to the tokamak approach. By 1995, with no clear, immediate need driving the schedule for developing fusion energy and with enormous pressure to reduce discretionary spending, Congress cut fusion program funding for FY 1996 by one-third and called for a major restructuring of the program.

Based on the recommendations of the Fusion Energy Advisory Committee (FEAC), the Department has decided to pursue a program that concentrates on world-class fusion science, with innovation in all areas of fusion research, on world-class plasma science, and on maintaining an involvement in fusion energy science through international collaboration.

At the same time, the Japanese and Europeans, with energy situations different from ours, are continuing with their goal-oriented fusion programs. Collaboration with them provides a highly leveraged means of continued involvement in fusion energy science and technology, especially through participation in the engineering and design activities of the International Thermonuclear Experimental Reactor program, ITER.

This restructured fusion energy sciences program, with its focus on fundamental fusion science and technology, may well provide insights that lead to more attractive fusion power plants, and will make use of the scientific infrastructure that will allow the United States to launch a fusion energy development program at some future date.

The Conference Report accompanying the FY 1996 Energy and Water Development Appropriations Act provided guidance on the need for the fusion program to restructure its strategy, content, and near-to-medium term objectives. It instructed the Department of Energy (DOE), with the participation of the fusion community and FEAC, to prepare a strategic plan to implement such a restructured program at a constant level of effort for the next several years. This Strategic Plan responds to the congressional guidance. In this Plan, DOE endorses the new mission and policy

goals contained in the recent FEAC Report and outlines the specific steps that DOE is taking to implement the substantial restructuring of the Fusion Energy Sciences Program that was recommended by FEAC in response to congressional guidance.[1]

The new *MISSION* of the Fusion Energy Sciences Program is:

> ***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 the new mission are:

- ***Advance plasma science in pursuit of national science and technology goals;***

- ***Develop fusion science, technology, and plasma confinement innovations as the central theme of the domestic program; and***

- ***Pursue fusion energy science and technology as a partner in the international effort.***

The previous strategy was characterized as a schedule-driven development program to prove fusion to be a technically and economically credible energy source with the goal of an operating demonstration power plant by about 2025. However, in a climate of severe budgetary constraints, the previous strategy became highly unrealistic in terms of the funding increases that would have been required to attain such a goal. In the face of budgetary constraints, the fusion program concentrated almost all of its available resources on the conventional tokamak concept, virtually eliminating support for alternative concepts and plasma science.

The new strategy emphasizes advancing the scientific knowledge base, including basic plasma science, needed for an economically and environmentally attractive fusion energy source, with the United States playing an important supporting role as a partner in the international pursuit of fusion energy development. To be a credible partner in this long-term quest, the United States needs a vigorous domestic program in fusion science and technology. At a constant level of funding, the restructured U.S. program will focus on fusion's underlying scientific foundations and will enable the United States to exert leadership in selected areas of expertise in the international effort to develop fusion energy.

Highlights of the restructured Fusion Energy Sciences Program are:

> Advance Plasma Science - The fusion program will assume the responsibility to be the advocate for and to act as a steward for basic

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[1] ***A Restructured Fusion Energy Sciences Program*, Report of the Fusion Energy Advisory Committee, January 27, 1996.**

plasma science, which is the underlying core science of fusion energy and has significant impact on a wide range of national science and technology goals (e.g., national security, industrial processing, and astrophysics, as well as fusion energy).

Develop Fusion Science and Concept Innovation - The restructured program will pursue the underlying science and enabling technology of fusion, with increased emphasis on conventional tokamak fusion concept innovation, alternative concepts, theory and computation, materials and key enabling technologies, and inertial fusion energy. Although each of the three major experimental tokamak facilities has distinct capabilities and makes different contributions to fusion science, it will be necessary to terminate one of these facilities in the near-term in order to provide resources for the program initiatives. The DOE concurs with the FEAC recommendation that the Tokamak Fusion Test Reactor should be the first of the tokamaks to be retired, after a period of operation to extract the remaining scientific benefit.

Pursue Fusion Energy as an International Collaboration - Fusion energy offers the long-term potential to provide an environmentally attractive and economically viable energy option for a growing world population in the next century. Although the United States is unable to pursue an independent fusion energy development program, it is in the national interest to remain a credible partner in the international fusion program aimed at long-term energy development. The restructured program seeks to meet the U.S. commitment to the successful completion of the Engineering Design Activities (EDA) for ITER in July 1998, which will leave open the possibility of U.S. participation in ITER construction, as a modest cost but high-leveraged investment.

Resources - The FY 1996 budget of $244 million (a 32% reduction compared to FY 1995) required difficult choices among: meeting U.S. international commitments to the ITER EDA; conducting scientific programs at major world-class research facilities located within the United States (facilities that are in a period of unprecedented scientific productivity); and terminating valuable elements of the core U.S. scientific program. The Department's FY 1997 budget submission has restructured the fusion program as recommended by FEAC. This Strategic Plan assumes that the restructured program will be implemented at a constant level of effort of about $255 million per year. In FY 1997, funds for Program Direction and for computing are budgeted elsewhere in the Energy Research Energy Supply, Research, and Development program. The comparable FY 1996 funding level is $227.4 million. The comparable FEAC recommendation is $264 million.

Program Governance - The Office of Fusion Energy Sciences is being reorganized, and the number of people in the Office is being reduced to be consistent with its new science mission. A new decision-making process involving more fusion community input, more peer review, and the assistance of the FEAC Scientific Issues Subcommittee is being installed. The peer review process will be used as the primary mechanism for evaluating proposals, assessing progress and quality of work, and for initiating and terminating facilities, projects, research programs, and groups.

Strategic Plan for the Restructured U.S. Fusion Energy Sciences Program

Introduction

Since the energy crisis of the early 1970s, the U.S. fusion program has presented itself as a goal-oriented fusion energy development program, with milestones that required rapidly increasing budgets. Funding did increase from the mid-1970s until about 1980, when the urgency associated with new energy sources evaporated. Based on the Fusion Policy Advisory Committee review of 1990, the Department put forward specific, long-term energy goals for the program, goals that, again, required increasing funding. For years, in the face of flat or declining budgets, the program has maintained its long-term goals and its mission, planning for increased funding in the near future. Doing so has required an ever narrowing research program focused more and more on the tokamak concept. By 1994, the mismatch between the program's stated goals and the available funding had become clear, and Congress called for a review of the program by the President's Committee of Advisors on Science and Technology (PCAST).

In the summer of 1995, both the PCAST and the Congress made it clear that the mission and the goals of the fusion program should change. In particular, PCAST recommended a program without the energy specific milestones, such as the operation of a demonstration power plant or a commercial plant. With no clear, immediate need driving the schedule for developing fusion energy and with enormous pressure to reduce discretionary spending, Congress cut funding for the fusion program by one-third for FY 1996, and called for a major restructuring of the program.

With the involvement of the fusion community, the Fusion Energy Advisory Committee (FEAC) has recommended and the Department has adopted a new strategy for this program, a strategy that builds upon the PCAST report, but goes beyond it to focus on the science that underpins the fusion process. This new strategy, with a still substantial budget, will allow the program to explore alternative approaches to fusion, to pursue innovation in all areas of fusion research, and to maintain an involvement in fusion energy science. The program will now work toward identifying a more attractive end product and, perhaps, a more affordable development path, while conducting world-class fusion and plasma science.

At the same time, the Japanese and Europeans, with energy situations different from ours, are continuing with their goal-oriented fusion programs. Collaboration with our international partners provides a highly leveraged means of continued involvement in fusion energy science and technology. Although reduced in scale, the restructured U.S. program will continue to have much to offer our international partners and much to gain, especially through participation in the International Thermonuclear Experimental Reactor program, ITER, where the experimental exploration of the physics of burning plasmas, an essential element of fusion science, will occur.

This combination of fusion and plasma science, innovation, and the search for more attractive approaches, along with international collaboration on fusion energy science, will allow the United States to maintain the fusion infrastructure and many of the competencies that will provide the platform from which to launch a fusion energy development program at some future date. That time will come when the development path is judged to be affordable and the end product attractive enough to justify the cost.

The Conference Report accompanying the FY 1996 Energy and Water Development Appropriations Act[1] provided guidance on the need for the fusion program to restructure its strategy, content, and near-to-medium term objectives and instructed the Department of Energy (DOE), with the participation of the fusion community and FEAC, to prepare a strategic plan to implement such a restructured program at a constant level of effort for the next several years.

In response to the congressional guidance, the Director of the Department's Office of Energy Research requested FEAC to provide recommendations on how to restructure the fusion program. The Department also requested that, in its deliberations on the restructuring of the fusion program, FEAC consider the broader issue of plasma science that underpins fusion energy and has numerous applications in science, technology, and the commercial sector. In addition, DOE requested FEAC's help in planning the implementation of the strategy for restructuring the fusion program, including institutional considerations and the role of international collaboration in the program.

On January 27, 1996, FEAC transmitted its report, "A Restructured Fusion Energy Sciences Program" to DOE.[2] The FEAC Report provided recommendations on how to restructure the fusion program in light of congressional guidance and budgetary realities. The FEAC recommended a new mission and new policy goals for a renamed Fusion Energy Sciences Program. The FEAC pointed out that the fusion energy program outlined in the Energy Policy Act of 1992 with the goal of a technology demonstration by 2010 that would verify the practicability of commercial electric power production, cannot be realized at the budget levels now foreseen. As a result, FEAC recommended that the mission of the U.S. program be restated in a world context to reflect the reality that the leadership of the world's fusion energy development effort now lies outside the United States and to emphasize the program's science and technology goals.

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[1] ***H.R. Conference Report Number 293, 104th Congress, 1st Session, 62 (1995).***

[2] ***A Restructured Fusion Energy Sciences Program*, Report of the Fusion Energy Advisory Committee, January 27, 1996.**

The goals recommended by FEAC have the same major elements as the key priorities contained in the July 1995 Report[3] of PCAST, but emphasize more the science foundation of the program and take into account later congressional funding guidance to conduct the program within a reduced annual budget.

The FEAC recommended *MISSION* is:

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

In pursuit of the new mission, FEAC recommended the following *POLICY GOALS*:

- *Advance plasma science in pursuit of national science and technology goals;*

- *Develop fusion science, technology, and plasma confinement innovations as the central theme of the domestic program; and*

- *Pursue fusion energy science and technology as a partner in the international effort.*

The Department endorses the FEAC recommended Mission and Policy Goals.

This Strategic Plan discusses these policy goals and outlines the specific steps that DOE is taking to implement the substantial restructuring of the Fusion Energy Sciences Program that was recommended by FEAC in response to congressional guidance.

Overall Change in Strategy

The previous strategy was characterized as a schedule-driven development program to prove fusion to be a technically and economically credible energy source, with the goal of an operating demonstration power plant by about 2025. However, in a climate of severe budgetary constraints, the previous strategy became highly unrealistic in terms of the funding increases that would have been required to attain such a goal. In an attempt to stay as close as possible to this goal-oriented schedule in the face of budgetary constraints, the fusion program concentrated almost all of its available resources on the tokamak concept, virtually eliminating support for

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[3] ***The U.S. Program of Fusion Energy Research and Development, Report of the Fusion Review Panel*, President's Committee of Advisors on 'Science and Technology, July 1995.**

alternative concepts and restricting funding for concept improvement and plasma science. Despite impressive scientific progress, the program has continued to receive insufficient resources to accomplish its mission.

The new strategy emphasizes advancing the scientific knowledge base, including basic plasma science, needed for an economically and environmentally attractive fusion energy source, with the United States playing an important supporting role as a partner in the international pursuit of fusion energy development. To be a credible partner in this long-term quest, the United States needs a vigorous domestic program in fusion science and technology. At a constant level of funding, the restructured U.S. program will focus on fusion's underlying scientific foundations and will enable the United States to exert leadership in selected areas of expertise in the international effort to develop fusion energy.

Advance Plasma Science

The underlying core science of fusion energy is plasma science, which is the study of the ionized states of matter and is central to the development of fusion as an energy source. As documented in the recent National Research Council (NRC) Plasma Science Report, plasma science is a fundamental scientific discipline that has significant impact on a wide range of national science and technology goals (e.g., national security, industrial processing, and astrophysics, as well as fusion energy).[4] Citing the many important future contributions to our society that can be expected from a healthy plasma science program, the NRC Report expressed a central concern about the need to address effectively the current lack of support for fundamental plasma science. The NRC Report recommended that DOE's Office of Basic Energy Sciences, with the cooperation of the Office of Fusion Energy, "... provide increased support for basic experimental plasma science."

The containment of high temperature plasmas required for the production of fusion energy is the primary reason for the fusion program to support plasma science. According to the NRC Report, fusion energy is "the largest driver for the intellectual development of plasma science." However, under the prior strategy of schedule-driven development, when faced with budget constraints the fusion program narrowed support for plasma science, funding only that science directly applicable to fusion technology (i.e., high temperature magnetized plasma physics).

A key policy goal of the restructured fusion program is to advance plasma science in pursuit of national science and technology goals. To achieve this policy goal, the fusion program will assume the responsibility to advocate and act as a steward for basic plasma science. The fusion program plans to expand its support to include fundamental plasma science, regardless of potential future application, in partnership with other DOE offices and other agencies. The expected benefits to the fusion programs, both magnetic and inertial, from this new responsibility include

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[4] ***Plasma Science From Fundamental Research to Technological Applications***, **National Academy Press, Washington, D.C., 1995.**

aiding the development of fusion energy through advances in fundamental understanding of plasmas, and an improved interaction with related disciplines in the scientific community. Benefits should also accrue to other DOE energy programs, as this basic research may well lead to improved materials and processes with broad applications.

Develop Fusion Science and Concept Innovation

The restructured fusion program will pursue the underlying science and enabling technology of fusion, with increased emphasis on conventional tokamak concept innovation, alternative fusion concepts, theory and computation, materials and key enabling technologies, and inertial fusion energy. Tokamak research will continue to be a major element in the science program because tokamaks provide a superb vehicle for experiments in fusion science and because innovative conventional tokamak research offers the potential for significant improvements in the concept.

Conventional Tokamak Concept Innovation:

The fusion program's major tokamak research facilities are DIII-D at General Atomics in San Diego, Alcator C-MOD at the Massachusetts Institute of Technology, and the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory (PPPL). These are world-class research facilities with outstanding records of scientific accomplishment. Their research programs contribute greatly to the goal of tokamak concept improvement by establishing the scientific foundations for steady-state operation, low frequency of disruption, improved confinement, and higher power density. These programs also contribute stimulating ideas and results to the world fusion program. Each facility has distinct capabilities that enable it to make different contributions to fusion science. However, restructuring the fusion program within greatly reduced budget levels will make it necessary to terminate one of these facilities in the near-term to provide resources for new initiatives. The Department concurs with the FEAC recommendation that "TFTR should be the first of the three tokamaks to be retired, after a period of operation to extract the remaining scientific benefit from this facility."

Alternative Fusion Concepts:

This refers to magnetic confinement approaches other than the conventional tokamak. Under the prior strategy, in response to budgetary pressure, in 1990 U.S. support for alternative concepts was drastically reduced in favor of schedule-driven development of the tokamak reactor concept. The restructured program will place renewed emphasis on broadening the scope of research to include studies of alternative concepts. The principal reason for investigating

alternative concepts is to advance fusion science in ways not possible with the tokamak concept alone. Understanding the scientific issues involved may also lead to improved concepts for energy applications.

Theory and Computation:

The United States is still a world leader in theory and computational modeling, which, in conjunction with experiment, provide the predictive capability needed for the conduct of scientific research. The restructured fusion program will increasingly build upon U.S. strengths in theory and modeling to achieve scientific and technological goals in a cost-effective way. At low cost, theory and modeling, which have made great strides in recent years, can have enormous impact on the program by influencing the direction of large, costly experimental facilities.

Materials and Key Enabling Technology:

Fusion science includes research on materials and key enabling technologies (e.g., radiation resistant, low-activation materials essential to achieve the safety and environmental potential of fusion; blanket system technologies that meet safety and performance requirements; and enabling technologies required to support advances in plasma physics). The science associated with fusion materials and technology research and development has a wide range of applications far beyond the fusion program (e.g., superconducting magnet technology, high temperature and radiation resistant materials, and cryogenic materials). The restructured U.S. fusion program will focus on those materials and technology issues that are critical to the safety and environmental goals of fusion and will strive for extensive use of international cooperation.

Inertial Fusion Energy (IFE):

In inertial confinement fusion, the fusion energy is released by imploding a small pellet of deuterium and tritium using energetic lasers or particle beams as drivers. Inertial confinement fusion is primarily supported by Defense Programs (DP) in DOE to provide the scientific base for national security applications. The Office of Fusion Energy Sciences (OFES) has been funding a relatively small research effort (about $8 million per year) on energy-specific efforts, primarily heavy ion beam development for inertial fusion energy. The FEAC Report did not assess the IFE effort in detail, but acknowledged its potential as a fusion energy source and the major role of DP in addressing key scientific and plasma issues. The DOE asked FEAC to review the IFE program in the context of the restructured fusion energy sciences mission. This review has been completed and will assist the OFES in planning the future direction of the IFE program.

Pursue Fusion Energy as an International Collaboration

Fusion energy offers the long-term potential to provide an environmentally attractive and economically viable energy option for a growing world population in the next century. As discussed in the PCAST and FEAC reports, energy availability will be a critical need for the economic growth of the less developed countries in the next century, and it could become a major determinant of global political stability. Because the development cost of fusion energy is high and the scientific challenge is great, fusion energy can most effectively be pursued through international collaboration.

Although the United States is unable to pursue an independent fusion energy development program, it is in the national interest to remain a credible partner in the international fusion program aimed at energy development. Because Europe and Japan have energy situations different from the United States, fusion energy research has a higher priority in those countries. Europe's fusion program is about 2 1/2 times the size of the U.S. fusion program and Japan's program is about 1 1/2 times the size of the U.S. program. Benefits for the United States from collaboration in the international pursuit of fusion energy include: ensuring energy availability for a growing world population, enabling U.S. scientific and technological leadership in selected areas, positioning U.S. industry as a participant in the provision of energy technology, demonstrating U.S. reliability as a partner, and potentially alleviating the environmental problems of fossil fuels. To be a strong partner in the long-term pursuit of fusion energy, the United States needs a vigorous domestic program in fusion science and technology.

International collaboration involving the United States, the European Union, Japan, and the Russian Federation is now focused on the scientific base, technology development, and engineering design necessary to construct a long-pulse burning plasma experiment, ITER. A primary goal of the ITER program is to demonstrate the scientific and technological feasibility of fusion by achieving controlled ignition and extended burn of the fusion fuel. The broad physics and engineering challenges that ITER addresses are largely generic to any next step toward the goal of fusion energy.

The ITER program is now engaged in the conduct of the Engineering Design Activities (EDA) to produce a comprehensive engineering design of ITER and all technical data necessary for future decisions on the construction of ITER. The scientific research conducted in support of the ITER program is valuable and is consistent with the fusion energy science mission of the U.S. program. The United States will seek to meet its commitment to the successful completion of the ITER EDA in July 1998. Doing so will leave open the possibility of U.S. participation in ITER construction and other international collaborations to advance fusion energy science and technology. Such collaborations would be a modest cost, but high-leveraged investment for the United States.

The restructured U.S. program will make every effort to remain a credible partner in the international fusion program that includes both ITER and many smaller activities in all areas of fusion science and technology. Given the high projected cost of a burning physics experiment and the fact that the United States now funds only about one-sixth of the world effort, a strategy based on international collaboration on fusion energy research and development can be highly cost-effective.

Resource Requirements

The FY 1996 budget of $244 million (a 32% reduction compared to FY 1995) required difficult choices among: meeting U.S. international commitments to the ITER EDA; conducting scientific programs at major world-class research facilities located within the United States (facilities that are in a period of unprecedented scientific productivity); and terminating valuable elements of the core U.S. scientific program. The reduced budget has resulted in:

- a restructured, reduced U.S. contribution to the ITER EDA (the reduction was done in such a way as to minimize the effects on the project plan and on the other Parties);

- the foregoing of any significant new U.S. scientific research facilities (including termination of the Tokamak Physics Experiment just as it was ready to enter construction);

- severe cutbacks in the scientific programs conducted at the major U.S. tokamak research facilities;

- curtailment of university research programs in experimental plasma physics;

- termination of some critical enabling technologies programs; and

- a major loss of scientific and technical personnel from universities, national laboratories, and industry.

Implementation Actions (FY 1997 and Beyond)

The Department's FY 1997 budget submission has restructured the fusion program as recommended by FEAC. In response to congressional guidance, this Strategic Plan assumes that the restructured program will be implemented at a constant level of effort and will avoid future mortgages for large construction projects. At a constant funding level of about $255 million per year (about 4% below the level recommended by FEAC)[5], the following key actions will be initiated in FY 1997 and carried forward in later years to implement a restructured Fusion Energy Sciences Program:

[5] About $9 million for program administration costs has been moved to another account.

Advance Plasma Science

- *Establish significant plasma science research efforts at U.S. universities, building over the next five years to a sustained level of about $10 million per year.*

This will initiate action to support the new policy goal of advancing plasma science in pursuit of national science and technology goals, as recommended by both the NRC and FEAC. Success in the form of significant and enduring contributions to the advancement of plasma science will require a sustained effort by the Fusion Energy Sciences Program, as well as close coordination with other agencies funding plasma science (e.g., the National Aeronautics and Space Administration and the National Science Foundation) and with the Department's Office of Basic Energy Sciences and DP.

Develop Fusion Science and Concept Innovation

- *Complete the most important remaining experiments on TFTR to allow it to be shut down during FY 1997 or FY 1998, after running for at least half of FY 1997.*

This will carry out the FEAC recommendation to retire TFTR "after a period of operation to extract the remaining scientific benefit from it," no later than 1998. Operation will focus on unique scientific experiments to be carried out to resolve several important physics research issues aimed at improved performance regimes and profile control in a deuterium-tritium plasma. Priorities for these experiments will be established by FEAC through its Scientific Issues Subcommittee (SciCom). This Subcommittee will also review the scientific progress on TFTR in mid-FY 1997 and recommend whether to continue with the program for up to one more year or to stop operations and begin to prepare for decommissioning. As pointed out in the FEAC Report, premature termination of TFTR would forego unique scientific opportunities and "it is unclear when these lost scientific opportunities would return."

Resources made available from the shutdown of TFTR after the completion of these experiments will enable other fusion research programs to be pursued more effectively, as also recommended by FEAC. After TFTR shutdown, PPPL will continue to be a center of excellence in fusion and plasma science, with renewed emphasis on theory and modeling, diagnostics and instrumentation, and innovative fusion experimental science.

- *Exploit the scientific potential of DIII-D and Alcator C-MOD and the leading smaller research facilities more fully. Continue exploitation of the scientific potential of DIII-D and Alcator C-MOD at least through 2001, including some upgrades, as user facilities.*

This will enable the scientific research programs at these facilities to be carried out on a highly productive and cost-effective basis. In addition to the contributions expected for the study of tokamak improvement, it is anticipated that the scientific output and emphasis on innovation will broaden in the restructured program. The FEAC SciCom, through FEAC, will recommend priorities among the research efforts conducted at these facilities.

The keys to conventional tokamak concept improvement are plasma control and particle and power exhaust. Both DIII-D and Alcator C-MOD are modern tokamaks with flexible control of the plasma shape, profile, transport, and boundary conditions. The DIII-D program is particularly well-suited to tokamak concept improvement research with outstanding shaping flexibility, multiple external heating sources, and detailed diagnostics that permit careful scientific investigation of plasma characteristics. Alcator C-MOD is the only shaped, high magnetic field tokamak in the world. Its compact design allows the investigation of numerous science issues at a much reduced cost in comparison to more conventional tokamaks. At lower fields, Alcator C-MOD is also capable of concept improvement experiments at relatively long pulses.

- *Increase support for research on alternative concepts physics.*

This will begin the implementation of the FEAC call for increased attention to alternative approaches to fusion, as well as the FEAC support for new experiments "including one or two smaller but scientifically aggressive new facilities, at least one taking advantage of the PPPL infrastructure."

Funding is planned for completing the design and initiating fabrication of components for the National Spherical Tokamak Experiment (NSTX) at PPPL. This project will be used as a national facility for studying concept innovations at a moderate cost (a total of about $20 million over three years). Funding increases are anticipated for several ongoing small but world-class alternative concept facilities that at present are significantly underfunded. Other actions to enhance the alternative programs may include an innovations initiative and new university scale experiments. In addition, a just completed FEAC review of alternative concepts provides strategic guidance for developing an enhanced alternative concepts program.

- *Provide increased support for theory and modeling.*

This will start to implement the FEAC call for a robust theory and modeling program, which can be a very cost-effective approach to scientific research. The development and use of improved theoretical and computational tools will provide and verify scientific understanding of high temperature plasmas. Emphasis will be placed on use of the Numerical Tokamak Project to simulate plasma physics behavior and on the development of mathematical models and other advanced computer techniques.

- *Provide modest increases in the materials and in the technology budgets.*

Research on radiation resistant, low-activation materials is central to fusion's ultimate environmental and economic attractiveness and will continue. In early 1997, the European Union, Japan, the Russian Federation, and the United States will complete a joint conceptual design of a fusion materials testing facility. At that point, the United States will have to decide whether to participate, at a modest financial level, in follow-on design and construction activities. In addition, enabling technology research in support of current and next generation fusion experimental devices will continue in order to ensure optimal advancement of plasma science. However, development of hardware components for energy applications (e.g., demonstration of critical fusion nuclear processes) will be deferred.

Pursue Fusion Energy as an International Collaboration

- *Maintain the ITER EDA commitment constant in as-spent dollars at the revised lower level.*

This will enable the U.S. program to complete work on the high priority tasks assigned to it (e.g., fabrication of the Central Solenoid Model Magnet and completion of testing of a high-heat flux ITER divertor). The United States will thereby meet its commitment to the successful completion of the ITER EDA in July 1998, obtain important scientific and technical information, and preserve the option for further cooperation internationally.

- *In FY 1997, decide whether to enter into negotiations with the European Union, Japan, and the Russian Federation concerning the possibility of U.S. participation at a modest financial level in the construction and operation of ITER.*

At current funding levels, the United States can only pursue fusion energy science and technology as an international collaboration. As recommended by FEAC, a decision to enter into formal negotiations on ITER construction would follow a U.S. Government review of the results of the ITER EDA, as represented by the Detailed Design Report to be completed in December 1996, and be made in consultation with our international partners. Possible U.S. contributions to ITER construction in areas where the United States has expertise include system integration, engineering and component production, diagnostics and control systems, as well as physics design. Any increase over the current ITER EDA funding level would require overall budget growth for the U.S. program. Nevertheless, the United States should be able to play an important role with a modest financial commitment, with annual contributions comparable to the present EDA annual funding amount.

Program Governance

Changes are being made at DOE to reflect the new mission and the changes in the policy goals. The Office of Fusion Energy, which is responsible for fusion program management within the Office of Energy Research, is being reorganized and has been renamed as the Office of Fusion Energy Sciences to reflect the restructured program. The number of people in the Office is being reduced to be consistent with its new science mission. The structure of the fusion budget has also been changed to reflect the program changes.

Along with the structural changes, a new decision-making process involving more fusion community input, more peer review, and the assistance of the FEAC SciCom is being installed. The peer review process will be used as the primary mechanism for evaluating proposals, assessing progress and quality of work, and for initiating and terminating facilities, projects, research programs, and groups. The FEAC Report provided a number of specific recommendations for guiding and implementing the major programmatic changes inherent in the restructuring in a smooth and effective manner. In accordance with the FEAC Report, the following specific actions are being taken:

- Fusion Energy Sciences Advisory Committee (FESAC) - The FEAC has been renamed as the FESAC to reflect its new focus and will be reconfigured to broaden representation from the scientific community and stakeholders. The FESAC will advise the Department on policy, goals, priorities, budget, direction, and program balance, including fulfillment of the changes involved in the restructuring.

- Scientific Issues Subcommittee - This is a continuing FESAC subcommittee composed of experts from the fusion community and selected other fields of science and engineering. SciCom provided the critical scientific assessments that underpin the restructuring recommendations contained in the FEAC Report of January 27, 1996, and will continue to provide the best possible scientific information to FESAC to aid in priority setting.

- User Access Working Group - This working group, composed of facility managers and user representatives, will be established to work with the Office of Fusion Energy Sciences to develop mechanisms for encouraging and funding the highest quality proposals from the broad fusion community for experiments on the major facilities.

Conclusions

The new mission and policy goals of the restructured Fusion Energy Sciences Program contained in this Strategic Plan are responsive to congressional programmatic and funding guidance. In addition to revising the program's mission and goals, the Department has set priorities and made hard choices to implement

the restructured program with substantially reduced funding. The new strategy represents a shift away from a schedule-driven energy development program to a program that emphasizes the scientific knowledge foundations of fusion. The restructured program will foster progress and innovation in fusion science and will advance basic plasma science.

A key element of the new strategy is the use of international cooperation for the pursuit of fusion energy science and technology. Under the new strategy, the United States will play an important supporting role in the international pursuit of fusion energy development and will be able to exert leadership in selected areas of expertise. This includes fulfilling the U.S. commitment to the ITER EDA and leaving open the possibility of U.S. participation in ITER construction, as a modest cost but high-leveraged investment.

A new decision-making process will ensure the close involvement of the fusion science community in priority setting, and follow-on reviews will assist in guiding the implementation of the major programmatic restructuring of the Fusion Energy Sciences Program.

To carry out the new strategy successfully and thereby realize the significant scientific benefits and future opportunities possible from the program's restructuring, the Fusion Energy Sciences Program requires annual funding in the range of the $255 million level included in the FY 1997 President's Budget Request.