NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

Division on Engineering and Physical Sciences
Board on Energy and Environmental Systems
Board on Physics and Astronomy

Proposal for an Assessment of

Prospects for Inertial Confinement Fusion Energy Systems

INTRODUCTION

Statement of Task
A committee will be convened to assess the prospects for inertial confinement fusion energy systems. The Committee will prepare a report that will:

- Assess the prospects for generating power using inertial confinement fusion;
- Identify scientific and engineering challenges, cost targets, and R&D objectives associated with developing an IFE demonstration plant; and
- Advise the U.S. Department of Energy on its development of an R&D roadmap aimed at creating a conceptual design for an inertial fusion energy demonstration plant.

The Committee will also prepare an interim report to inform FY 2012 budget deliberations. A Panel on Fusion Target Physics will serve as a technical resource to the committee..

This proposal requests $1,190,905 from the United States Department of Energy (DOE) to support the Committee for a 24-month study addressing the above Statement of Task. Preliminary plans for the proposed study are given below. A separate proposal describes the charge to the Panel and its work in more detail and requests funding from DOE to support the Panel's study.

BACKGROUND

The energy produced by nuclear fusion has the potential to provide a low-carbon, base-load source of electricity; however, significant scientific and engineering efforts are still required before the feasibility of a commercial fusion plant can be established. Concepts for initiating fusion based upon magnetic confinement and inertial confinement of the fusion plasma have been studied for decades. In inertial confinement fusion (ICF), a driver delivers energy to the outer surface of a pellet of fuel (typically containing a mixture of deuterium and tritium), heating and compressing it. If the target physics and driver performance are sufficiently controlled, and other characteristics are adequately understood and controlled, this process will create a fusion chain reaction that yields more energy than that incident on the fuel from the driver. This state is known as "ignition."

There are multiple concepts for delivering energy to the target pellet. Drivers can be in the form of lasers, particle beams, or x-rays. These concepts have very different operating conditions and characteristics. The construction of the target chamber is a significant materials problem and depends on the driver and pellet technologies used. Understanding the strengths and weaknesses of each approach is central to the effort to develop IFE as a power source.

Over the next several years, experiments will be ongoing at the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory that may achieve ICF ignition and propagation burn. This initial demonstration of ignition would be a critical milestone and demonstration of "proof of principle" of ICF. This milestone will need to be achieved for any serious consideration of how an inertial fusion energy (IFE) power plant could be designed based on the energy produced from ICF. At the same time, experiments such as those at the University of Rochester's Laboratory for Laser Energetics, the Naval Research Laboratory, and Sandia National Laboratory's Z Machine continue to advance our understanding and control of inertial confinement fusion using different technology and target physics approaches.

Given the current level of activity in ICF research, now is an appropriate time to consider how to proceed regarding inertial fusion as a potential power source. An NRC committee and panel will be formed to provide findings and recommendations to advise DOE on the development of an R&D roadmap for inertial fusion energy.

All the approaches to ICF will require much investigation and will need to be considered in any long-term R&D strategy. These include different concepts for the driver (e.g. heavy ions, lasers, z-pinch), the target chamber (e.g. dry wall, thin-liquid, thick-liquid), and the target (direct and indirect drive). At this time, it is not clear whether any of these approaches can lead to a successful IFE demonstration. Therefore, an assessment of ICF concepts is in order.

With this assessment of ICF concepts in-hand, a reasonable approach would be to define a suite of component technologies with the highest likelihood of success, develop them to a suitable level of maturity, and then select a mainline approach toward building and operating for several years a small-scale technology demonstrator based upon progress. Such a device should be the smallest device that incorporates all the major elements of a full-scale machine and is sufficiently large to serve as a basis for scaling up the technology and extrapolating the cost and performance to a machine that could attract commercial investment. Such a technology demonstration plant would need to prove inertial fusion's potential as a stable and reliable source of power and provide enough operating experience to build confidence in the ability to reach commercial scale. Further work would still be needed after this point to achieve a viable and economically attractive commercial IFE system.

PROPOSED STUDY

Scope & Process

The NRC study will have two components. The Committee on Inertial Confinement Energy Systems, composed of about 14 members, will be convened to assess the prospects for inertial confinement fusion energy systems. The Panel on Fusion Target Physics, composed of about 6 members and with access to classified information as well as controlled-restricted unclassified information, will serve as a technical resource to the Committee and will describe, in a report containing only publicly accessible information, the R&D challenges to providing suitable targets on the basis of parameters established and provided by the Committee.

The committee's first task would be to identify the key scientific and engineering challenges associated with achieving a viable IFE system capable of harnessing the energy released by the fusion reactions for power production. This task will include an assessment of the state of the current technology and its projected capabilities, what additional research or other work is required, and the major issues to be resolved. The committee will also identify and describe the most promising concepts for using inertial fusion as the energy source in a commercial power plant. This information will be used to develop, where practical, conceptual roadmaps for the most promising component technology paths leading from current capabilities to the achievement of a technology demonstrator. The roadmaps will have success criteria allowing periodic assessment of progress and exit ramps in the event progress is not achieved. The plans will be coordinated as a logical structure for making downselects as needed.

In the course of its work, the Committee on Inertial Confinement Energy Systems will specifically address the following issues and undertake the following tasks:

1. Key scientific challenges for achieving a viable IFE system and opportunities for using existing facilities to overcome them, as well as where new capabilities will be needed;
2. Key engineering and technology challenges for achieving a viable IFE system, including an assessment and comparison of component technology maturity and performance (e.g., driver, chamber, energy capture, and target technologies, and balance of plant), as well as technical uncertainties, and timescales associated with the development and demonstration of these components;
3. Where practical, conceptual roadmaps will be defined for the most promising concepts for using inertial fusion as the energy source, leading from current capabilities to the achievement of a technology demonstrator. The roadmaps will have success criteria allowing periodic assessment of progress and exit ramps in the event progress is not achieved. The plans will be coordinated as a logical structure for making downselects as needed.
4. Key cost targets for primary commercial plant components, and components that offer the greatest opportunities for cost reduction and pose the greatest cost uncertainties; and
5. Write an interim report that will provide initial guidance to DOE on:
    - Main issues and major component performance roadblocks that will need to be addressed;
    - Major milestones that would have to be achieved; and
    - The plausibility of scale-up for an IFE system.

   This report may or may not include a public annex from the Panel on Target Physics.
6. Write a final report that will address Tasks 1 to 4 above and include a public annex from the Panel on Target Physics.

The Committee on Inertial Confinement Energy Systems will meet approximately 8 times during the course of the study. It may also make visits to a number of facilities that are conducting work on inertial confinement fusion (ICF), including national laboratories, universities, and private industry. To assist the committee in understanding the current performance of fusion targets, an independent Panel on Fusion Target Physics will be appointed to serve as a technical resource to the Committee (detail on the Target Physics Panel is given in a separate proposal).

The first and second meetings of the Committee will be devoted to briefings from the agencies and other stakeholders, including initial planning of the report, development of an outline and content for the interim report, and development of guidance for the Target Physics Panel. The third meeting will be used to develop consensus on the interim report and prepare it for the review process. The fourth, fifth, and sixth meetings will be spent collecting and considering detailed data and information for the purpose of developing the basis for the final report, and in developing the final report's chapters and draft findings and recommendations. The seventh and eighth meetings will be devoted to tuning the committee's message and developing a consensus on recommendations after receiving the final report from the Target Physics Panel. Throughout the study process the Committee will receive and consider input from the Target Physics Panel in the form of periodic progress reports and the final panel report.

The Committee will collect all of its information from only public sources from the start of the study. If the Committee determines in the course of its deliberations that access to controlled-restricted unclassified information as noted above (e.g. International Traffic in Arms Regulations [ITAR] or

Unclassified Controlled Nuclear Information [UCNI]) is necessary to complete its task, then the NRC will implement Information Rights Management (IRM) software to handle all information from that point forward, which might include computing resources necessary to manage this information. These resources will be in place before the Committee begins its study.

To avoid contaminating the Committee's work with classified information generated by the Panel, direct interaction between the Committee and Target Physics Panel, with the exception of the Committee leadership (see “Membership”), will be avoided. Therefore, all communication from the Committee to the Target Physics Panel will go through NRC staff to ensure that the necessary procedures are followed. Communication from the Target Physics Panel to the Committee will go through an ADC before being distributed to the Committee by the NRC staff.

Membership

The Committee on Inertial Confinement Energy Systems will be composed of about 14 individuals with expertise in fields such as nuclear engineering, mechanical engineering, materials science, fusion energy, laser systems, heat transfer, radiation physics, plasma physics, electrical engineering, central station power plants, nonproliferation, electric utility industry, economics, and the construction of large energy systems. Members may have expertise in more than one area. With the exception of the Committee leadership, there will be no overlap in the membership of the Committee and Panel. Members of the National Academy of Engineering and the National Academy of Sciences will be sought for membership on the Committee and Panel. There will be a balance between physics expertise and engineering expertise. Individuals will also be sought to provide a balance of industrial, academic, national laboratory and other experience.

The Committee's chair may be appointed prior to the constitution of the entire committee in order to assist with composing the Committee and to provide any needed final guidance on the scope of work for the separate Target Physics Panel. The NRC intends to identify a Committee chair who can also serve as a member (not as chair) of the Target Physics Panel so that there is additional interaction between the two bodies.

REPORTS

The Committee on Inertial Confinement Energy Systems will write two reports. The first will be a public interim report to be delivered nine months after funds are received by the NRC to initiate the study, intended to inform budget deliberations for the 2012 fiscal year. The interim report will be no more than 10,000 words and provide conclusions addressing the first and second elements of the Committee's statement of task as they pertain to FY12. The final, public report will be delivered to the sponsor about 21 months after study initiation, with the published version available 3 months later. The Committee's interim and final reports will be public.

The interim and final reports of the Committee on Inertial Confinement Energy Systems may include an annex produced by the Panel of Target Physics consisting of only publicly accessible information. The Committee’s interim and final report will be subject to a classification review by an Authorized Derivative Classifier (ADC) to ensure they are unclassified. The Committee has no intention, a priori, of producing a classified document.

The report's primary audience is the Department of Energy. The secondary audience is Congressional staff; Congressional committees; the research community, the technical community, policy leaders, and the general public.

FEDERAL ADVISORY COMMITTEE ACT

The Academy has developed interim policies and procedures to implement Section 15 of the Federal Advisory Committee Act, 5 U.S.C. App. § 15. Section 15 includes certain requirements regarding public access and conflicts of interest that are applicable to agreements under which the Academy, using a committee, provides advice or recommendations to a Federal agency. In accordance with Section 15 of FACA, the Academy shall submit to the government sponsor(s) following delivery of each applicable report a certification that the policies and procedures of the Academy that implement Section 15 of FACA have been substantially complied with in the performance of the contract/grant/cooperative agreement with respect to the applicable report.

PUBLIC INFORMATION ABOUT THE PROJECT

In order to afford the public greater knowledge of Academy activities and an opportunity to provide comments on those activities, the Academy may post on its website (http://www.national-academies.org) the following information as appropriate under its procedures: (1) notices of meetings open to the public; (2) brief descriptions of projects; (3) committee appointments, if any (including biographies of committee members); (4) report information; and (5) any other pertinent information.

ESTIMATE OF COSTS

The estimated cost of supporting the effort described above during the period April 1, 2010 to March 31, 2012 is $1,190,905.

Attachment: Detailed Estimate of Costs