

**Statement of Thomas E. Mason
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**Before the
Subcommittee on Energy and Environment
Committee on Science and Technology
U.S. House of Representatives
October 29, 2009**

Hearing on the Next Generation of Fusion Research

Mr. Chairman, Ranking Member Inglis, and members of the Committee: Thank you for the opportunity to appear before you today. My name is Thomas E. Mason, and I am Director of the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee. It is an honor to provide this testimony on the status of the ITER international fusion project, the role of ORNL as the headquarters of the U.S. ITER Project Office, and the way that fusion research fits into the overall portfolio of research and development (R&D) at ORNL.

INTRODUCTION

ORNL is the Department of Energy's largest science and energy laboratory. From my position as director of a national laboratory with research encompassing fundamental science of relevance to energy through an extensive suite of energy programs—including energy efficiency; energy from renewable, fossil, and fission sources; and energy transmission and distribution—I view fusion as an essential part of the nation's R&D portfolio. Fusion is a promising long-term source of energy whose fuel is widely available and whose emissions would include neither CO₂ nor long-lived radioactive waste. Its scientific and technological basis is maturing and warrants a significant federal investment, with the aim of advancing the underlying science and gaining understanding of the technology sufficient to enable future decisions on advancing to the level of a prototype reactor.

ORNL has been engaged in research on fusion energy since the early 1950s, when the Atomic Energy Commission launched Project Sherwood with the goal of developing a fusion analog to the fission reactor. From its earliest days, the Oak Ridge fusion program has drawn on the diverse resources afforded by ORNL's standing as a multiprogram laboratory, and it has leveraged substantial investments by the Department of Energy in materials science, nuclear technology, and high-performance computing to deliver advances in plasma theory and simulation, magnetic confinement experiments, plasma heating and fueling, atomic physics, and materials development.

As soon as magnetic fusion research was declassified in 1958, the ORNL program initiated extensive collaborations with the international fusion community, which continue today. In particular, ORNL has been a key contributor to ITER since the inception of this activity in 1985.

The promise of fusion as a clean and abundant source of energy has driven extensive programs of R&D, at ORNL and other institutions throughout the world, for more than six decades. Impressive progress has been made in overcoming the challenges of harnessing fusion energy. From experiments in the United States and other nations, we have established the scientific and technical knowledge base for fusion, and we have reached a point at which the next step is to create a burning plasma: that is, an ionized gas in which the alpha particles produced by the fusion of hydrogen isotopes provide enough heat to keep the fusion reaction going.

With the potential to provide clean baseload electrical energy without a fuel resource constraint, fusion can be an important component of a long-term shift away from fossil fuels with the attendant environmental, economic, and national security benefits. The main cost lies in the intellectual content and high-end manufacturing, both of which are hallmarks of American industrial strength, so in addition to providing an attractive solution to our energy needs, fusion offers the potential to drive the development of a new industry.

THE ITER INTERNATIONAL FUSION PROJECT

The ITER international fusion project has been established to construct an experimental device that will demonstrate the scientific and technological feasibility of fusion energy and achieve sustained fusion power generation. The long-range goal is for ITER to produce at least ten times as much power as is needed to heat the plasma. It will test many of the key technologies needed to use fusion as a practical energy source, and it will provide industry with the opportunity to validate production techniques for components needed for future fusion power plants.

ITER will be constructed at Cadarache in southeastern France from components fabricated in the countries of the ITER Members: the United States, the Russian Federation, the European Union, Japan, the People's Republic of China, South Korea, and India. A Joint Implementation Agreement, finalized in 2007, governs the details of construction, operation, and decommissioning, as well as financing, organization, and staffing. Each ITER Member is responsible for supplying a share of hardware (including supporting R&D and design); personnel assigned to the ITER site; and cash contributions toward common expenses. The international ITER Organization established by the Joint Implementation Agreement is the legal entity responsible for project execution. It is governed by a Council that includes senior U.S. Department of Energy officials.

Each ITER Member was tasked with creating a Domestic Agency to fulfill the Member's obligations under the ITER Joint Implementation Agreement. The Domestic Agencies' role is to perform R&D and design and to procure each Member's in-kind (i.e., noncash) contributions to ITER. The Domestic Agencies employ their own staff, have their own budget, and place contracts with suppliers. The United States was the first ITER Member to establish its Domestic Agency under the auspices of the Office of Fusion Energy

Sciences within DOE's Office of Science. This is the U.S. ITER Project Office, about which I will speak further in a moment.

Under the terms of the Joint Implementation Agreement, the United States is a full Member of the ITER project. Our 9.09% share of the total cost gives us access to all scientific data and the right to propose and carry out experiments. It also creates opportunities for U.S. industry to manufacture the high-technology components that make up roughly 80% of our contribution.

The ITER project presents an extraordinary number of technical and management challenges. Although the design of ITER is not yet complete, it is expected to be twice the size of the largest existing fusion experiment. It is a "first-of-a-kind" experimental facility comprising a large number of systems, some of which require innovative technologies. These systems, to be constructed by suppliers selected by the seven Domestic Agencies, must be integrated to produce a system that can perform under extremely demanding conditions.

The ITER Organization has also faced the challenge of standing up and staffing a new organization to provide coordination, project management, technical integration, and engineering while overseeing efforts to finalize the ITER design and supervising early-stage civil construction in Cadarache. A host of issues relating to finances, communication, intellectual property rights, conflicting national safety and import/export regulations, and other areas unique to this large-scale, high-visibility multinational scientific collaboration have had to be resolved to the satisfaction of all parties.

Given these challenges, it is not surprising that the project has experienced some "teething pains." We have not been immune to those teething pains in the United States as we struggled to secure funding during some very tough budget years; however, with the support provided by Congress in FY 2009 we are now on a sound footing and able to fully engage our international partners. The most urgent tasks facing the international ITER Organization today are completing the overall ITER design and systems engineering and establishing realistic schedule and cost baselines. The U.S. fusion community is supporting these tasks, while continuing to carry out an extensive program of work that is enhancing the physics basis and technology support for ITER.

THE ROLE OF ORNL AS HEADQUARTERS OF THE U.S. ITER PROJECT OFFICE

Since 2006, ORNL has hosted and led the U.S. ITER Project Office, which is responsible for project management of all U.S. activities to support construction of ITER. The U.S. share of the international ITER project construction has an estimated range of \$1.4 billion to \$2.2 billion, so this is a heavy responsibility and one that we at ORNL take very seriously.

All U.S. ITER activities are managed by the Department of Energy's Office of Science as a Major Item of Equipment (MIE) project and are subject to rigorous review. The project

team under ORNL includes Princeton Plasma Physics Laboratory and Savannah River National Laboratory as partner laboratories.

The U.S. ITER Project Office was located at Oak Ridge to take advantage of the project management expertise developed during the construction of the Spallation Neutron Source. This \$1.4 billion neutron scattering facility was designed and constructed by a partnership of six Department of Energy national laboratories, which I had the privilege of leading from 2001 to 2006. The project was completed ahead of schedule and within budget in 2006, and many members of the project team are now applying their expertise to the needs of the U.S. ITER Project Office.

The U.S. ITER team is engaging other national laboratories and industry and university partners across the United States in R&D, engineering, manufacturing, and fabrication of the U.S. contributions to ITER. Earlier this month, the U.S. ITER Project Office awarded two contracts totaling \$33.6 million, one to a company in Waterbury, Connecticut, and the other to a company in Carteret, New Jersey, for components of the superconducting magnets that will confine the ITER plasma. It is noteworthy that in addition to these U.S.-funded contracts, a similar award has been made to the New Jersey supplier by the European Union's ITER Domestic Agency, which speaks well of the ability of U.S. industry to compete in this area on the world stage. To date, more than 160 companies and universities in 33 states have worked directly on the project, and some 140 have expressed interest in future procurements.

The U.S. ITER team is also providing substantial support to the international ITER Organization. Staff have contributed to the development of systems engineering procedures and technical baseline documents, assisted in the development of project management processes and procurement arrangements, and evaluated project risks and assisted with development and implementation of risk mitigation plans.

FUSION ENERGY RESEARCH AT ORNL OVER THE NEXT 20 YEARS

As the ITER project moves through construction and operation, ORNL will continue to play a substantial role, both through the U.S. ITER Project Office and through an extensive and well-integrated program of science, technology, and engineering aimed at supporting ITER and developing the understanding required for an attractive fusion energy source.

In particular, we will take advantage of ORNL's distinctive capabilities in materials R&D, nuclear technology, and high-performance computing to deliver the science and technology needed to realize the full potential of ITER and to exploit the knowledge gained from it in advancing toward a fusion power plant. Expertise in nuclear design and operations, nuclear materials science, ITER, fusion engineering, and project management positions ORNL to lead U.S. technical and programmatic planning for a next-generation fusion nuclear science facility. Such a facility and associated R&D programs could establish the scientific basis for fusion fuel self-sufficiency and reliable and efficient power extraction under realistic fusion power reactor conditions.

CLOSING REMARKS

The international ITER project represents an opportunity for the Department of Energy's national laboratories, U.S. universities, and U.S. industry to play a key role in a very challenging technical development and build a scientific and technical base for moving the fusion program from a science experiment to an engineering demonstration. The United States is positioned to make substantial contributions to the international ITER project and to reap the rewards that it will provide: increased scientific knowledge, high-technology jobs that can contribute to the restoration of U.S. manufacturing capacity, and training of fusion scientists and engineers who have the opportunity to work on this experiment with their colleagues from other nations and to apply the findings to the next generation of fusion systems. Sustaining the U.S. investment in ITER is essential to realizing the benefits of this extraordinary effort.

Our investment in ITER should be complemented by a vibrant domestic fusion program to ensure that the United States is positioned to exploit ITER for research, capitalize on the knowledge gained from ITER, and move forward along the way to commercial fusion power. While ITER represents a pathbreaking advance toward the goal of practical magnetic fusion energy, it cannot address all of the questions that must be answered before we can proceed with a fusion power plant. For example, ITER is based on a magnetic confinement concept known as the tokamak, which was invented in Russia in the 1960s. This configuration was selected for ITER because of its maturity, but other configurations have properties that may make them attractive candidates for commercial power plants. Other challenges that lie outside ITER's scope include the development of materials and components that can withstand the intense conditions at the edge of a burning plasma and handle prolonged exposure to neutrons.

Legislation introduced by Congresswoman Zoe Lofgren, the Fusion Engineering Science and Fusion Energy Planning Act of 2009 (H.R. 3177), calls for the development of a comprehensive plan to identify what the U.S. fusion community must do to ensure the realization of practical fusion energy. This is a vital step in determining the direction of the U.S. fusion program, and it has the full support of the program's leadership.

Congresswoman Lofgren's bill also calls for a targeted investment of \$165 million over the next 3 years to enhance U.S. capability in fusion engineering science, in addition to the funding provided to the Department of Energy's Office of Fusion Energy Sciences for current programs. This would provide the U.S. fusion community with resources for developing the materials and enabling technology needed to realize the full benefit of the ITER project and to prepare for the experiments, such as a fusion nuclear science facility, needed to move beyond ITER to a successful fusion demonstration facility.

Some might argue that the investment of substantial sums in fusion R&D over the past six decades should have enabled us to reach the goal of fusion energy by now. In response to such an argument, I would make two points. First, controlled fusion has turned out to be a much more challenging scientific and technological problem than was originally thought. Optimistic predictions based on an incomplete understanding of the

difficulties involved have haunted the program in the past. Today, however, we have attained a level of understanding that provides a solid foundation for ITER and for continuing efforts to find ways of meeting our energy needs with fusion.

Second, in 1972, federal funding for magnetic fusion energy was \$33.3 million (about \$172 million in today's dollars); it rose dramatically in response to the energy crisis, peaking in 1977 at roughly \$1 billion in today's dollars, and then declined precipitously, to \$230 million in 1997 (about \$300 million in today's dollars) and has remained close to that level. The FY 2010 Energy and Water Appropriations bill passed by the Congress allocates \$426 million for fusion energy sciences, which includes \$135 million for the U.S. contribution to ITER. While much useful science and engineering has been accomplished at these funding levels, it is unlikely that we will be able to make the final leap to practical fusion power without sustained support for fusion engineering science and facilities for answering the questions that lie outside ITER's scope.

Ambassador Kaname Ikeda, ITER Director General, has pointed out that the current world energy market is about \$3 trillion and growing. The amount invested in energy R&D generally (not just in fusion) is very modest when compared with the economic value of the market; this is in sharp contrast to the situation in industries such as information technology or health sciences, despite the fact that the benefits to society and the scientific and technical challenges are no less significant.

Perhaps even more important, most of the world's energy needs are now being met with nonrenewable fossil fuels that represent the primary source of the greenhouse gases that are contributing to climate change. As a safe and essentially inexhaustible source of baseload power that emits no greenhouse gases, fusion would be a sustainable energy solution for the long term.

This is not to say that improvements in energy efficiency, renewables, and fission, combined with electrification of our transportation sector, are not key near-term to medium-term challenges that we must address. But given that there is no single element of energy R&D that will yield supplies sufficient to meet our overall objectives of reducing the environmental consequences of CO₂ and other emissions and the national security and economic consequences of a growing reliance on imported petroleum, fusion needs to be an element of a balanced energy R&D portfolio. Answering the remaining key science questions about the feasibility of fusion, which is a central focus of ITER, will enable us to shift our focus to the technological and engineering challenges of fusion as a power source.

Thank you again for the opportunity to testify. I welcome your questions on this important topic.

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Thomas Mason is a native of Dartmouth, Nova Scotia, in Canada. He graduated from Dalhousie University in Halifax, Nova Scotia, with a Bachelor of Science degree in physics and completed his postgraduate study at McMaster University in Hamilton, Ontario, Canada, receiving a Doctor of Philosophy degree in experimental condensed matter physics.

After completing his Ph.D., he held a postdoctoral fellowship at AT&T Bell Laboratories in Murray Hill, New Jersey, and then became a Senior Scientist at Risø National Laboratory in Denmark. In 1993 he joined the faculty of the Department of Physics at the University of Toronto.

Thom joined Oak Ridge National Laboratory (ORNL) in 1998 as Scientific Director for the Department of Energy's Spallation Neutron Source (SNS) project. In April 2001 he was named Associate Laboratory Director for SNS and Vice President of UT-Battelle, LLC, which manages ORNL for the Department. In 2006 he became Associate Laboratory Director for Neutron Sciences, leading a new organization charged with delivering safe and productive scientific facilities for studying of structure and dynamics of materials. In May 2007, Thom was named Director of Oak Ridge National Laboratory.

Thom's research background is in the application of neutron scattering techniques to novel magnetic materials and superconductors using a variety of facilities in North America and Europe. He is coauthor of more than 100 refereed publications and an Associate of the Quantum Materials Program of the Canadian Institute for Advanced Research. In 1997, he was awarded an Alfred P. Sloan Foundation Research Fellowship. Thom was named a Fellow of the American Association for the Advancement of Science in 2001 and a Fellow of the American Physical Society in 2007. He received the Distinguished Alumni Award for the Sciences from McMaster University in 2008.

Thom and his wife, Jennifer MacGillivray, also a native of Nova Scotia, live in Oak Ridge with their two sons, William and Simon.

