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Fusion Energy: The World's Most Complex Energy Project

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Thank you Chairman Lummis, Ranking Member Swalwell, and distinguished members of the Committee. I am pleased to come before you today to discuss the status of the Department of Energy's (DOE) Fusion Energy Sciences (FES) program within the Office of Science.

The Fusion Energy Sciences Program and ITER in the Office of Science

The Fusion Energy Sciences (FES) program is one of six science program areas in DOE's Office of Science. Among the goals of the FES program are to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation needed to develop a fusion energy source. This is accomplished through the study of plasma, the fourth state of matter, and how it interacts with its surroundings. Understanding the scientific character of the burning plasma state, as well as establishing the science for maintaining this state for long durations, is a major objective of FES research. To achieve these research goals, FES invests in U.S. experimental facilities of various scales, international partnerships that leverage U.S. expertise, large-scale numerical simulations based on experimentally validated theoretical models, the development of advanced fusion-relevant materials, and the invention of new measurement techniques.

The knowledge established through FES research supports U.S. goals for future scientific exploration on ITER, an international partnership, under an agreement among the U.S, China, India, Japan, Russia, South Korea, and the European Union, to produce net fusion energy. . If successful, ITER will be the world's first magnetic-confinement burning plasma experiment to demonstrate the scientific and technical feasibility of fusion as a future energy source.

The idea to cooperatively design and build a burning plasma device through an international agreement originated from a Geneva superpower summit in November 1985, at which Premier Gorbachev proposed

to President Reagan that an international project be established to develop fusion energy for peaceful purposes. The ITER Agreement thus began as a four-party collaboration among the former Soviet Union, the U.S, the European Community (which has since become the European Union, or EU), and Japan. As a technical basis for the ITER project, the four parties agreed that the tokamak configuration would be the logical choice, given its superior performance (both then and now) in plasma energy confinement. The ITER Conceptual Design Activities began in 1988. This was followed in 1992 by the Engineering Design Activities (EDA), which involved a great deal of research and development and concluded in 1998. At that point, Congress directed DOE not to participate in a 3-year extension of the EDA primarily because of concerns over the size of ITER's construction cost estimate. The remaining three Parties continued to work on the ITER design, with an emphasis on de-scoping to cut its construction cost by roughly half. The result was the 2001 ITER Final Design Report (FDR).

As the result of an initiative by President Bush in 2003, the U.S. initiated negotiations to rejoin the ITER project through entering into an international agreement with the countries involved, including the EU. Later in 2003, South Korea and China joined, followed by India in 2005. In addition to determining a construction site, the negotiations produced the *Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project (JIA)*, which was signed by the seven Members in November 2006. It entered into force on October 24, 2007, for a period of 35 years, consisting nominally of 10 years for construction, 20 years for operation, and 5 years for deactivation.

U.S. participation in ITER, and its execution of the ITER international agreement, was specifically authorized by the Energy Policy Act of 2005 (EPAct 2005), Section 972(c)(5)(C). The EPAct 2005 also required that any final ITER agreement be submitted to Congress for its review prior to its execution by the U.S. To comply with EPAct 2005, DOE provided Congress with the following reports: (1) a document entitled *Plan for U.S. Scientific Participation in ITER*; (2) a report describing the management structure of the ITER and an estimate of the cost of U.S. participation (although the ITER Agreement requires principally in-kind contributions, rather than fixed, dollar contributions); and (3) a report describing how U.S. participation in the ITER would be funded without a funding reduction in other Office of Science programs. In 2008, the National Research Council (NRC) reviewed and endorsed the *Plan for U.S. Scientific Participation in ITER*; such a review was another requirement of EPAct 2005. Currently, the ITER project is the only planned burning plasma experiment in the world, and it is therefore an important component of the FES program. The U.S. domestic fusion program and facilities are currently aligned to support research relevant towards a burning plasma experiment at ITER. For our agreed 9% share of the ITER project under the ITER Agreement, the U.S. would have access to all the

science. Given the projected costs it is unlikely that any single country would build the ITER machine on its own.

ITER is an extremely large and complex construction project, with additional challenges coming from its international governance and distributed workload. As mentioned, each ITER partner is obligated to build and deliver specified components or systems for the ITER machine and complex. These completed components are shipped to the ITER site in France and are to be assembled and integrated by the ITER Organization.

An important aspect of the FES program is the completion of a strategic plan for the entire domestic program. In April of this year, I charged the Fusion Energy Sciences Advisory Committee with providing advice on priorities among continuing and potential new Fusion Energy Sciences program investments. The charge requests advice and priorities in areas relevant to burning plasmas and discovery plasma science, and the charge explicitly assumes continued U.S. participation in ITER. The Office of Science will use this input to develop a congressionally directed strategic plan for fusion by the end of this calendar year.

FES and ITER in Context: The Office of Science and its Broad Mandate

The Office of Science is the nation's largest Federal sponsor of basic research in the physical sciences and the lead Federal agency supporting fundamental scientific research for energy, supporting discovery science in high energy, nuclear, and plasma physics; materials and chemistry; biological systems and earth system components; and mathematics, computer, and computational sciences. Much of this research underpins advances in clean energy. The Office of Science supports about 22,000 investigators at over 300 U.S. academic institutions and at all of the DOE laboratories. The Office of Science user facilities – the finest collection of such facilities anywhere in the world – support about 28,000 users annually. Our research investments are vital to advancing U.S. leadership in science and strengthening our national competiveness.

Within the Office of Science, a priority is the pursuit of leadership in areas judged to be critical for the U.S. and for DOE's missions, especially the energy mission in the midterm time frame. Examples include high performance computing with the development of a capable exascale machine over the next decade; the characterization of materials—including biomaterials—to enable predictive design using facilities such as the upgraded Linac Coherent Light Source and the upgraded Advanced Photon Source; and research to address some of the most important fundamental research problems facing DOE, including solar energy conversion, bio-energy, catalysis, and energy transduction and storage.

Investments in FES and ITER are part of this balanced portfolio within the Office of Science, a balance made increasingly more difficult each year by a host of new scientific discoveries and new technology developments that have created scientific imperatives in virtually every sector of science supported by the Office of Science. We now are in world-wide competitions for the most capable scientific computers and for revolutionary x-ray laser light sources that probe matter at the atomic level and thus help us create designer materials. Increased urgency has been placed on research to develop new materials, new chemistries, and new biological processes for clean and efficient energy. Furthermore, within the past two years, discoveries in subatomic physics—such as the characterization of the neutrino and the discovery of the Higgs Boson—have redefined and clarified the future of high energy physics, which we steward, and have made progress toward that future more urgent.

Considerations of the Future for the Office of Science Programs and FES Activities in a Constrained Budget Environment

At the time of U.S. re-entry into ITER, the U.S. planned contribution to ITER was estimated at $1.1 billion, a tractable amount in an era of projected strong budget growth. Indeed, in 2007, President Bush signed the America COMPETES Act, which authorized appropriations initiating a trajectory for the doubling of funding for the Office of Science—and other federal basic science programs—over a period of a decade. However, since that time, the estimated cost of U.S. contributions to ITER has grown to more than $4 billion. While the actual components the U.S. is obligated to contribute under the ITER Agreement have remained unchanged, the growth in the dollar cost of U.S. contributions to ITER from the initial 2005 estimate arise from several factors, captured in the recent GAO report on ITER. The initial estimates for the cost of U.S. hardware components were low due to incomplete design and requirements for the project. Changes to the U.S. hardware component requirements and the international project schedule also added additional cost. In contrast to the sharply increased estimate for the cost of the U.S. obligations under the ITER Agreement, funding for the Office of Science has grown slowly, particularly in the past few years.

In addition to costs, other factors impacting ITER have recently emerged. In late 2013, the third biennial Management Assessment (MA) of the ITER Organization identified significant management issues, which threaten the success of the project; the Management Assessment produced eleven recommendations for the ITER Organization and the ITER Council. The Administration agreed with the MA's findings that the management of the international ITER Project must be improved for ITER to succeed. Subsequently, U.S. delegations to ITER Council meetings have consistently and strongly argued that the recommendations be adopted and implemented. These management problems do not relieve the U.S. of any of its obligations under the ITER Agreement.

In the FY 2014 President's Budget request to Congress, the Administration made the decision to support an annual funding level [for ITER] of no more than $225,000,000 per year, while also maintaining funding for an impactful domestic fusion program. In FY 2015, the Administration requested $150M for ITER, as the U.S. believed the project could not meet the most recent schedule put forward by the ITER Organization. Our best estimate of the international schedule is that it is currently delayed approximately three years due to the delay in the civil construction of the tokamak building that will house the ITER machine. Through FY 2014, Congress has appropriated $667.2 million for hardware and $130.7 million for cash contributions for a total of $797.9 million for support of ITER.

Success of the global ITER project requires changes and improvements that go beyond the required U.S. contributions. In order to improve the operations of the ITER Organization and the Council, and in accordance with the procedures of the ITER Council, chairmanship of the Council has changed; it was assumed by Dr. Robert Iotti (recommended for the post by the U.S.), who has the broad respect of the partners and of the ITER Organization and who is working tirelessly to improve the project.

We believe that, at present, the success of ITER will require that all Members support the necessary changes in the ITER Organization and the ITER Council; acknowledge the true global schedule of the ITER project and plan to that schedule; improve performance and cooperation by the ITER Organization and the EU domestic agency, which is a 45% partner of the project; and execute the storage, assembly, and integration of the components of ITER by the ITER Organization.

The U.S. obligation under the ITER Agreement is only 9% of the total obligations—unlike most Office of Science construction projects—and therefore many aspects of ITER are outside U.S. control. This includes, for example, the current delay in the civil construction of the Tokamak Building. At the most recent ITER Council meeting, it was determined that this is the critical path item currently limiting the ITER schedule.

It will not be possible to baseline the U.S. contributions to ITER until a realistic schedule is developed by the ITER Organization. This updated schedule is to be completed by the ITER Organization by June 2015. The best U.S. estimate is that the ITER first-plasma milestone would be achieved no earlier than late 2023 and that full fusion operations would begin in the 2030s. We continue to apply the principles of DOE's Project Management Order 413.3 to the U.S. contributions, reassessing annually.

The U.S. has spent significant time and energy to help ITER succeed: we have sent U.S. personnel to work at the ITER Organization; we have recommended Dr. Robert Iotti as ITER Council Chair; and we have insisted that all the Management Assessment recommendations be adopted and implemented. At

ITER council meetings and in bilateral meeting with our partners, we have emphasized the need for improved project management and leadership, and we have repeatedly noted the urgency of righting the project.

If the U.S. were to abandon the ITER project, the U.S. could be liable for significant fiscal obligations, because the ITER Agreement allows for withdrawal from the project only after 10 years and requires the withdrawing party to fully perform its obligations, even after withdrawal. Modification of this requirement, or withdrawal from ITER earlier than 10 years from entry into force of the ITER Agreement would require negotiation with and consent of the other ITER members. An unconsented withdrawal might trigger responses from our international partners.

Finally, the Department agrees with the four recommendations for Executive Action that the GAO identified in its recent report on ITER. We have already taken action to advocate for a credible international project schedule; once completed in June of 2015, we will use that schedule to establish a baseline and funding plan for the U.S. contributions. We have set a date for completing a strategic plan for U.S. fusion, using FESAC in the development of the plan.

Thank you for providing me with the opportunity to testify before your Committee today. I look forward to continuing to work with the Committee on the complex domestic and international challenges in fusion research.