United States Government Accountability Office

Report to Congressional Requesters

June 2014

FUSION ENERGY

Actions Needed to Finalize Cost and Schedule Estimates for U.S. Contributions to an International Experimental Reactor

GAO-14-499

GAO Highlights

Highlights of GAO-14-499, a report to congressional requesters

June 2014

FUSION ENERGY

Actions Needed to Finalize Cost and Schedule Estimates for U.S. Contributions to an International Experimental Reactor

Why GAO Did This Study

ITER is an international research facility being built in France to demonstrate the feasibility of fusion energy. Fusion occurs when the nuclei of two light atoms collide and fuse together at high temperatures, which results in the release of large amounts of energy. The United States has committed to providing about 9 percent of ITER's construction costs through contributions of hardware, personnel, and cash, and DOE is responsible for managing those contributions, as well as the overall U.S. fusion program. In fiscal year 2014, the U.S. ITER Project received $199.5 million, or about 40 percent of the overall U.S. fusion program budget.

GAO was asked to review DOE's cost and schedule estimates for the U.S. ITER Project. This report examines (1) how and why the estimated costs and schedule of the U.S. ITER Project have changed since 2006, (2) the reliability of DOE's current cost and schedule estimates, and (3) actions DOE has taken to reduce U.S. ITER Project costs and plan for their impact on the overall U.S. fusion program. GAO reviewed documents; assessed DOE's current estimates against best practices; and obtained the perspectives of 10 experts in fusion energy and project management.

What GAO Recommends

GAO recommends, among other things, that DOE formally propose the actions needed to set a reliable international project schedule and set a date to complete the U.S. fusion program's strategic plan. DOE agreed with GAO's recommendations.

View GAO-14-499. For more information, contact Frank Rusco at (202) 512-3841 or ruscof@gao.gov.

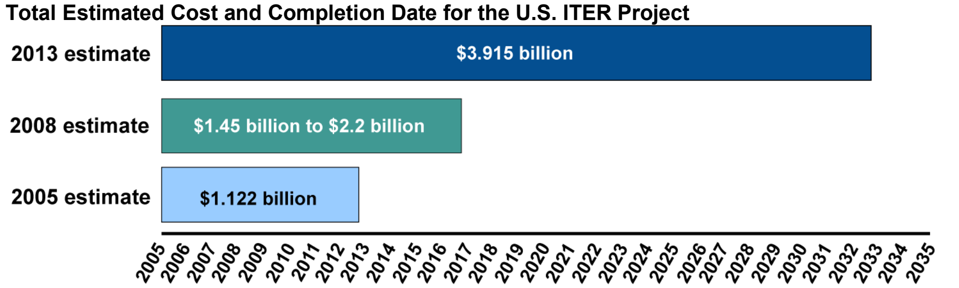
What GAO Found

Since the International Thermonuclear Experimental Reactor (ITER) Agreement was signed in 2006, the Department of Energy's (DOE) estimated cost for the U.S. portion of ITER has grown by almost $3 billion, and its estimated completion date has slipped by 20 years (see fig.). DOE has identified several reasons for the changes, such as increases in hardware cost estimates as designs and requirements have been more fully developed over time.

DOE's current cost and schedule estimates for the U.S. ITER Project reflect most characteristics of reliable estimates, but the estimates cannot be used to set a performance baseline because they are linked to factors that DOE can only partially influence. A performance baseline would commit DOE to delivering the U.S. ITER Project at a specific cost and date and provide a way to measure the project's progress. According to DOE documents and officials, the agency has been unable to finalize its cost and schedule estimates in part because the international project schedule the estimates are linked to is not reliable. DOE has taken some steps to help push for a more reliable international project schedule, such as providing position papers and suggested actions to the ITER Organization. However, DOE has not taken additional actions such as preparing formal proposals that could help resolve these issues. Unless such formal actions are taken to resolve the reliability concerns of the international project schedule, DOE will remain hampered in its efforts to create and set a performance baseline for the U.S. ITER Project.

DOE has taken several actions that have reduced U.S. ITER Project costs by about $388 million as of February 2014, but DOE has not adequately planned for the potential impact of those costs on the overall U.S. fusion program. The House and Senate Appropriations Committees have directed DOE to complete a strategic plan for the U.S. fusion program. GAO has previously reported that strategic planning is a leading practice that can help clarify priorities, and DOE has begun work on such a plan but has not committed to a specific completion date. Without a strategic plan for the U.S. fusion program, DOE does not have information to create an understanding among stakeholders about its plans for balancing the competing demands the program faces with the limited available resources or to help improve Congress' ability to weigh the trade-offs of different funding decisions for the U.S. ITER Project and overall U.S. fusion program.

Total Estimated Cost and Completion Date for the U.S. ITER Project



Source: GAO analysis of DOE data. | GAO-14-499

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Abbreviations

DOE	Department of Energy
ITER	International Thermonuclear Experimental Reactor
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
State	Department of State

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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June 5, 2014

The Honorable Mary Landrieu
Chair
The Honorable Lisa Murkowski
Ranking Member
Committee on Energy and Natural Resources
United States Senate

The Honorable Dianne Feinstein
Chairwoman
The Honorable Lamar Alexander
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Ron Wyden
United States Senate

In 2006, the United States signed an agreement with the European Union and five other countries[1] to help build and operate the International Thermonuclear Experimental Reactor (ITER),[2] a first-of-its-kind research facility currently being built in Cadarache, France, to demonstrate the feasibility of fusion energy. Fusion occurs when the nuclei of two light atoms—typically hydrogen isotopes—collide and fuse together when heated at high temperatures and placed under tremendous pressure. The result is the release of a large amount of energy that, it is hoped, someday may be captured to produce electricity. Fusion has the potential to be an abundant source of energy to help meet future energy needs, and it also offers many other benefits. Among those benefits would be no emissions of greenhouse gases, no risk of the type of severe accidents that could occur at existing nuclear power plants, and no long-lived radioactive waste. Over the last 50 years, scientists around the world

[1]The five countries are India, Japan, the People's Republic of China, the Republic of Korea, and the Russian Federation.

[2]The term "International Thermonuclear Experimental Reactor" is no longer used for the project. Instead, the project is simply referred to as "ITER."

have made progress in understanding how to create the conditions for fusion, but many outstanding scientific and technical questions must still be addressed before fusion can be used as an energy source. As a result, the United States and the six other parties to the ITER Agreement identified ITER as a critical experiment that, if successful, could finally produce more power from fusion reactions than is needed to start the fusion reaction—the first step toward producing electricity from fusion energy and developing the first demonstration fusion power plant. By participating in ITER, the United States will share the cost of building this complex and expensive fusion device, benefit from the scientific and technological expertise of the six other ITER members, and have full access to ITER research results. However, since the ITER Agreement was signed in 2006, the expected total cost of building ITER has grown by billions of dollars from its original estimate of about $5 billion,[3] and its construction schedule has slipped by years, as have the cost and schedule estimates for the U.S. portion of the construction project.

The ITER Agreement established the management framework for ITER. Under the agreement, the international ITER Organization is responsible for managing the overall project, including specifying final hardware designs and performance parameters; managing the international project schedule; and assembling, installing, and commissioning the ITER facilities.[4] The ITER Organization is led by a Director-General, who serves as its Chief Executive Officer and is responsible for the execution of the organization's activities. The ITER Organization is governed by the ITER Council, which is composed of high-level government officials from each of the seven ITER members.[5] During ITER's construction phase, each of the seven ITER members is responsible for procuring and delivering an assigned set of hardware components and making cash and personnel contributions to the ITER Organization. Each member also is responsible for managing the cost and schedule of its assigned

[3]According to a Department of Energy (DOE) document, the original estimate of about $5 billion for ITER's construction was in 2002 dollars and based on the 2001 ITER design. The estimate was developed for the purpose of establishing relative contributions of the ITER members toward ITER's construction and was not comparable to a DOE construction project cost estimate.

[4]The ITER Organization will also be responsible for managing the operation and deactivation of the ITER facilities.

[5]The ITER Council meets at least twice a year. ITER members have the ability to raise issues for consideration and decision by the council.

contributions within the milestones set by the international project schedule. The United States has committed to providing about 9 percent of the cost of building ITER,[6] and those construction contributions are managed by the Department of Energy (DOE) through the U.S. ITER Project Office at Oak Ridge National Laboratory in Oak Ridge, Tennessee, in partnership with Princeton Plasma Physics Laboratory and Savannah River National Laboratory.[7] DOE's Office of Fusion Energy Sciences, which is responsible for managing the overall U.S. fusion program within the Office of Science, provides program-level oversight of the U.S. ITER Project. Through March 2014, DOE had spent about $692 million on the project. In fiscal year 2014, the U.S. ITER Project received $199.5 million, which represented about 40 percent of that year's overall U.S. fusion program budget and continued a pattern of substantial funding increases for the project that began in fiscal year 2011 after several years of fluctuating funding levels.

In 2007, when the U.S. ITER Project was just beginning, we reported on the importance of DOE assessing the full costs of U.S. participation in ITER and setting a definitive cost estimate for the project.[8] We noted at the time that DOE had made a commitment to provide hardware components to ITER without a definitive cost and schedule estimate and a complete project design and, as a result, DOE's preliminary cost estimate of $1.122 billion for U.S. contributions to ITER's construction might be subject to significant change. We also noted the risk that management challenges facing the ITER Organization could result in ITER construction delays and further increase costs for the United States. Today, significant questions remain about how much the U.S. ITER Project will cost, when it will be completed, and how DOE plans to manage the impact of U.S. ITER Project costs on the overall U.S. fusion

[6]Of the seven ITER members, the United States and five other countries—the People's Republic of China, Japan, India, the Republic of Korea, and the Russian Federation—are each providing 9.09 percent of the total construction cost. The European Union is the largest contributor—45.46 percent—because ITER is being built on a European Union country's soil, and the European Union has agreed to pay for infrastructure costs.

[7]The U.S. ITER Project covers only U.S. contributions to ITER's construction phase. U.S. contributions for ITER's operation, deactivation, and decommissioning phases are not part of the U.S. ITER Project.

[8]GAO, *Fusion Energy: Definitive Cost Estimates for U.S. Contributions to an International Experimental Reactor and Better Coordinated DOE Research Are Needed*, GAO-08-30 (Washington, D.C.: Oct. 26, 2007).

program in a constrained federal budget environment. The House and Senate Appropriations Committees, in particular, have expressed concern that DOE will fund the U.S. ITER Project at the expense of the rest of the U.S. fusion program, and they have directed DOE to provide detailed cost and schedule estimates for the project.

In this context, you asked us to review DOE's cost and schedule estimates for U.S. contributions to ITER's construction. This report examines (1) how and why the estimated cost and schedule for the U.S. ITER Project have changed since 2006; (2) the reliability of DOE's current cost and schedule estimates for the U.S. ITER Project and the factors, if any, that have affected their reliability; and (3) the actions DOE has taken, if any, to reduce U.S. ITER Project costs and plan for their potential impact on the overall U.S. fusion program.

To conduct this work, we reviewed the ITER Agreement, relevant laws, and DOE guidance. To determine how and why the estimated costs and schedule for the U.S. ITER Project have changed since 2006, we reviewed DOE and U.S. ITER Project Office documents. We assessed the reliability of the data on the changes in the cost estimates by interviewing DOE officials and U.S. ITER Project Office representatives who had knowledge of the data and by other means, and we determined that the data were sufficiently reliable for reporting on the reasons for the changes in the cost estimates. To evaluate the reliability of DOE's current cost and schedule estimates and the factors, if any, that have affected their reliability, we reviewed DOE's most recent cost and schedule estimates for the U.S. ITER Project—as developed by the U.S. ITER Project Office in August 2013—and DOE's internal peer review of those estimates. We also reviewed DOE's project management order and related guidance, as well as an October 2013 report to the ITER Council on the results of a management assessment of the ITER Organization. We assessed the reliability of DOE's current cost and schedule estimates by analyzing those estimates against best practices identified in GAO's *Cost Estimating and Assessment Guide* and *Schedule Assessment Guide*.[9] Specifically, we reviewed documentation, interviewed the U.S. ITER Project Office representatives who prepared the estimates,

[9]GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: Mar. 2, 2009) and *GAO Schedule Assessment Guide: Best Practices for Project Schedules—Exposure Draft*, GAO-12-120G (Washington, D.C.: May 30, 2012).

reviewed relevant sources, and compared the information collected with the best practices. For DOE's current schedule estimate, we assessed the characteristics of two selected subordinate schedules—the central solenoid modules schedule and the tokamak cooling water system schedule—that are used as inputs to the integrated U.S. ITER Project master schedule.[10] We were able to use the results of the two subordinate schedules to provide insight into the integrated master schedule since the same strengths and weaknesses of the subordinate schedules would transfer to the master schedule. We determined that the schedules were sufficiently reliable for our reporting purposes, and our report notes the instances where reliability concerns affect the quality of the schedules. To examine the actions DOE has taken, if any, to reduce U.S. ITER Project costs and plan for their potential impact on the overall U.S. fusion program, we reviewed DOE and U.S. ITER Project Office documents on actions taken to reduce and plan for U.S. ITER Project costs and reviewed our prior work on leading practices in federal strategic planning for agency divisions, programs, or initiatives.[11] We also interviewed 10 experts in fusion energy and the management of large scientific research projects. We selected these experts through a multistep process to ensure coverage and a range of perspectives from industry, DOE's national laboratories, and universities. We analyzed the experts' responses across a standard set of questions and summarized the results. Appendix I presents a more detailed description of our objectives, scope, and methodology, and appendix II lists the names and affiliations of the 10 experts we interviewed.

We conducted this performance audit from June 2013 to June 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that

[10]We selected these two subordinate schedules because they are the largest two hardware items, in terms of value, that the United States is responsible for contributing to ITER. By examining the two subordinate schedules against our guidance, we conducted a reliability assessment on each of the schedules and incorporated our findings on reliability limitations in the analysis of each subordinate schedule.

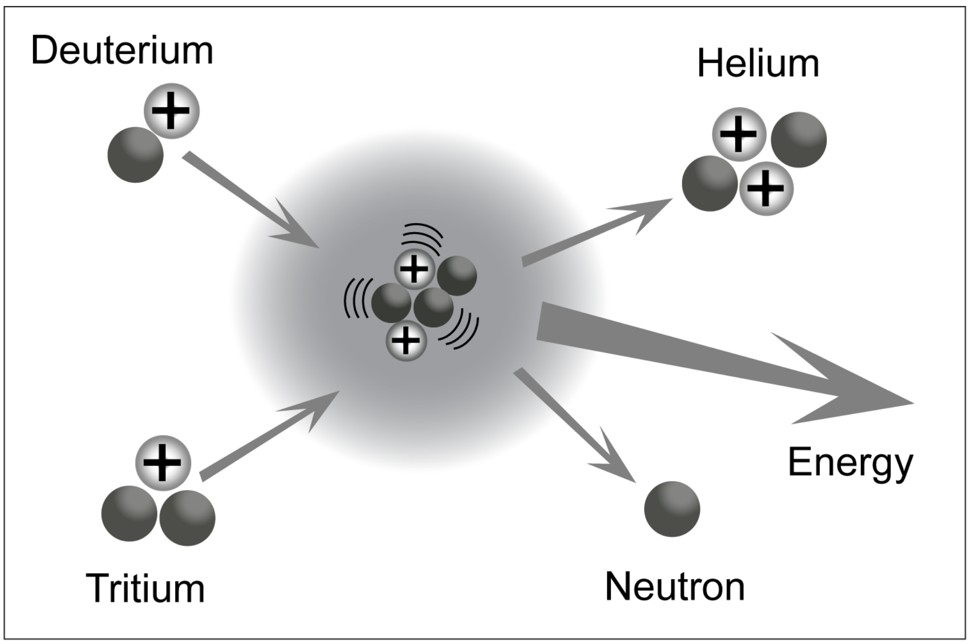
[11]For example, see GAO, *Environmental Protection: EPA Should Develop a Strategic Plan for Its New Compliance Initiative*, GAO-13-115 (Washington, D.C.: Dec. 10, 2012) and *Environmental Justice: EPA Needs to Take Additional Actions to Help Ensure Effective Implementation*, GAO-12-77 (Washington, D.C.: Oct. 6, 2011).

the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Fusion is the energy source that powers the sun and stars. Fusion occurs when the nuclei of two light atoms collide with sufficient energy to overcome their natural repulsive forces and fuse together. Scientists are currently using deuterium and tritium—two hydrogen isotopes—for this reaction. When the nuclei of the two atoms collide, the collision produces helium and a large quantity of energy (see fig. 1). For the fusion reaction to take place, the atoms must be heated to very high temperatures—about 100 million degrees centigrade, or 10 times the temperature of the surface of the sun—and placed under tremendous pressure.

Figure 1: The Fusion Reaction



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For more than 50 years, the United States has been trying to control fusion to produce electricity. The United States is pursuing two paths to achieve controlled fusion—magnetic and inertial. The goal for both approaches is to generate more energy than is needed to begin and sustain the fusion reaction. The world's first controlled release of fusion power was achieved in 1991, but no fusion device has succeeded in generating more power than it consumes. Magnetic fusion uses magnetic devices to confine a plasma, consisting of electrically charged atoms, and sustain a fusion reaction.[12] ITER will be a magnetic fusion device known as a "tokamak."[13] To reduce the risk of investing in only one device, DOE's Office of Fusion Energy Sciences also funds scientific research on alternative types of magnetic devices. Inertial fusion relies on intense lasers or particle beams to heat and compress a small, frozen pellet of deuterium and tritium—a few millimeters in size—that would yield a burst of energy. The lasers or particle beams would continuously heat and compress the pellets, which would simulate, on a very small scale, the actions of a hydrogen bomb. The National Nuclear Security Administration, a separately organized agency within DOE, is leading efforts in inertial fusion because it can be used for defense needs, such as validating the integrity and reliability of the U.S. nuclear weapons stockpile.

ITER is considered to be the next step in magnetic fusion. It is an experiment to study fusion reactions in conditions similar to those expected in a future electricity-generating power plant. The goal is to be the first fusion device in the world to produce a substantial amount of net power—that is, produce more power than it consumes. Specifically, the objective is to produce 10 times more power than is needed to start the fusion reaction in pulses of 5 or more minutes. ITER also will test a number of key technologies, including the heating, control, and remote maintenance systems that will be needed for a fusion power station. ITER has been planned to consist of four phases: (1) construction, (2) operation, (3) deactivation, and (4) decommissioning. The construction phase, which is the sole focus of the U.S. ITER Project, began in 2007 (see fig.2 for an aerial view of construction progress at the ITER site as of June 2013). The international project schedule, as of April 2014, anticipates that the ITER fusion device will be built by 2019 and achieve

[12]Current magnetic devices have not been able to sustain this fusion reaction for more than a few seconds, not the long period of time that the reaction would need to be sustained to produce electricity.

[13]The term "tokamak" comes from a Russian acronym for a fusion device that was developed in the former Soviet Union during the 1950s and 1960s. A tokamak has been the most successful magnetic fusion device, but there is still uncertainty that it will lead to a commercially viable fusion energy device.

its “first plasma” in 2020.[14] After ITER has achieved its first plasma, the next several years are expected to be devoted to a preliminary period of operation in pure hydrogen during which physics testing will be done, followed by operation in deuterium with a small amount of tritium to test ITER’s wall shielding. This will then be followed by the start of full ITER operations in an equal mixture of deuterium and tritium, at which point ITER will be used to try to produce 10 times more power than it consumes. As of April 2014, the international project schedule anticipates the start of deuterium-tritium operations in 2027. ITER’s operation phase is expected to last 20 years followed by a 5-year deactivation phase and then a decommissioning phase. If ITER is successful, it will lead to power plant design and testing.

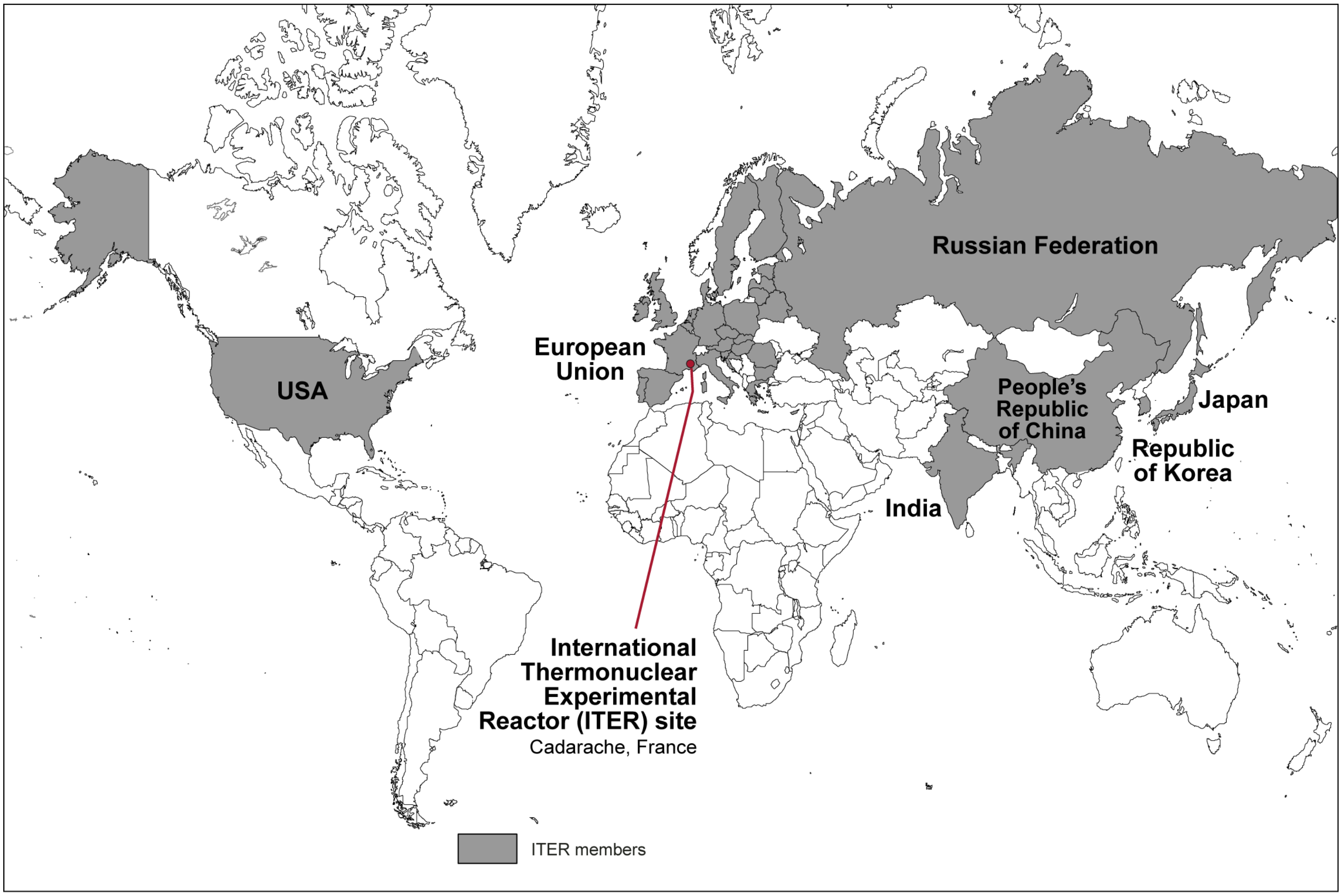
[14]“First plasma” refers to the first time the ITER device is able to successfully produce a plasma. Construction will continue after this to prepare ITER to use deuterium-tritium fuel. The introduction of deuterium-tritium fuel marks the start of full ITER operations.

Figure 2: Aerial View of Construction Progress at the ITER Site as of June 2013

Note: The ITER construction site sits on a total of 180 hectares (or about 450 acres) of land in southern France.

ITER was first proposed at the Geneva Summit in November 1985, when President Reagan and Soviet Premier Gorbachev recognized that joint activities were needed to diffuse the tension of the arms race during the cold war and begin the then Soviet Union's economic integration into the world economy. The goal was to share scientific and technical information in a program where both sides had a comparable level of knowledge and could jointly realize commercial gains from the development of fusion technology. Following the Geneva Summit, the United States, the Soviet Union, Japan, and several European countries entered into an agreement to develop ITER's design. The United States stopped participating in the project in 1999 after Congress raised concerns that the technical basis for the proposed project was not sound, the cost was too high, and the facility was too large. In response to the U.S. withdrawal, the countries participating in ITER reduced the size of the facility and the estimated cost of building ITER to about $5 billion. Subsequently, a number of scientific advances increased U.S. confidence that the new ITER design would meet its scientific and technological goals and, in January 2003, President Bush announced that the United States would rejoin ITER. In 2003, the People's Republic of China and the Republic of Korea also joined the project; in December 2005, India became the seventh and most recent member to join. In November 2006, all six countries and the European Union signed the ITER Agreement. Figure 3 shows the countries participating in ITER and the location of the ITER site.

Figure 3: Countries Participating in ITER and ITER Site Location



Sources: GAO; Map Resources (map). | GAO-14-499

Under the ITER Agreement, the United States is responsible for 9.09 percent of ITER's total construction cost.[15] DOE fulfills this obligation by supplying personnel to work for the ITER Organization; by making cash contributions to the ITER Organization to cover common expenses; and

[15]The United States will also be responsible in the future for 13 percent of the costs of operating, deactivating, and decommissioning ITER. These costs—which DOE estimated would be about $1.5 billion when the ITER Agreement was signed in 2006—are not included in U.S. ITER Project cost estimates because the U.S. ITER Project only covers U.S. contributions to ITER's construction phase.

by procuring and delivering the 12 assigned U.S. hardware components to the ITER Organization (see table 1 for a list of the 12 U.S. hardware components).[16] The ITER Agreement includes a provision that allows any ITER member except the European Union to withdraw from the project after the agreement has been in force for 10 years, which would be in October 2017.[17] However, withdrawing members still have responsibility for providing the entire cost of their assigned hardware components and cash contributions to the construction phase, and they could be responsible for other costs as well if they withdraw during ITER's operation phase.

Table 1: U.S. Hardware Components to Be Delivered to the ITER Organization

U.S. hardware component	Purpose
Central solenoid magnet system	Confines, shapes, and controls the plasma inside ITER's vacuum vessel.
Diagnostics (15% of ITER diagnostics)	Provides the measurements necessary to control, evaluate, and optimize plasma performance and to further the understanding of plasma physics.
Disruption mitigation systems (up to a capped value)	Limits the impact of plasma current disruptions to the tokamak vacuum vessel and other components.
Electron cyclotron heating transmission lines	Brings additional heat to the plasma and deposits heat in specific areas of the plasma to minimize instabilities.
Ion cyclotron heating transmission lines	Brings additional heat to the plasma.
Pellet injection system	Provides efficient fueling and delivers hydrogen, deuterium, or a deuterium/tritium mixture as required by plasma operations.
Roughing pump system	Exhausts certain parts of the ITER machine.
Steady state electrical network (75% of total network)	Supplies the electricity needed to operate the entire ITER plant, including offices and the operational facilities.
Tokamak cooling water system	Manages temperatures generated during the operation of the tokamak.
Tokamak exhaust processing system	Separates tokamak exhaust gases into a stream containing only hydrogen isotopes and a stream containing only nonhydrogen gases.
Toroidal field conductor (8% of total conductor)	Part of the toroidal field magnet that confines, shapes, and controls the plasma inside the ITER vacuum vessel.
Vacuum auxiliary systems	Creates low density in ITER's vacuum vessel and connected vacuum components.

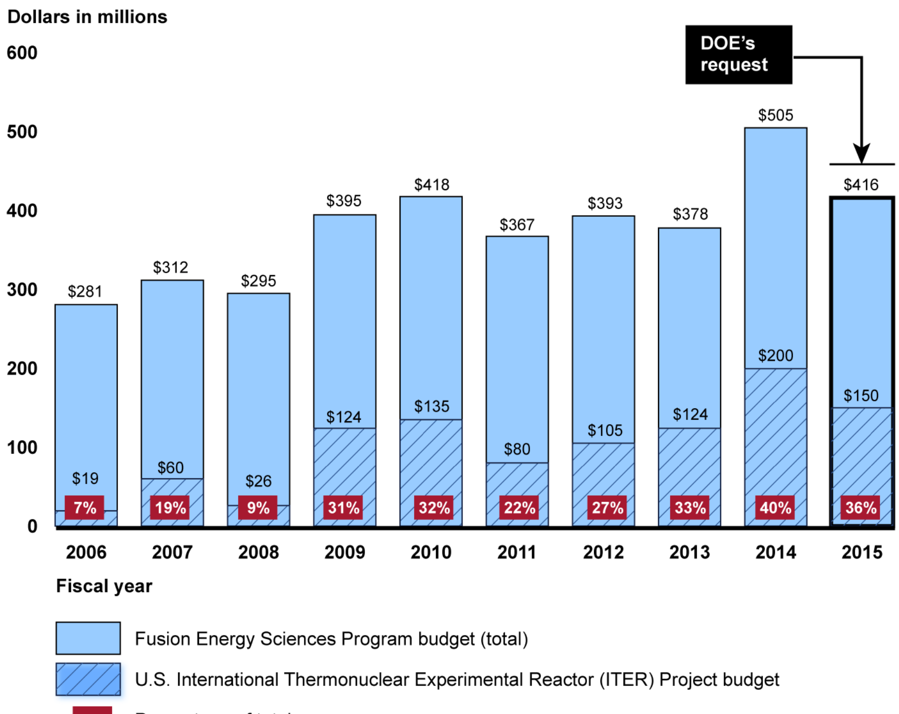
Source: GAO analysis of DOE documents. / GAO-14-499

[16] See appendix III for additional information on the status of each U.S. hardware component as of August 2013.

[17] The European Union, as the host of the ITER site, is not permitted to withdraw from the project under the ITER Agreement.

The percentage of the overall U.S. fusion program budget going toward the U.S. ITER Project has grown since fiscal year 2011 after fluctuating in previous years (see fig. 4). In fiscal year 2011, the U.S. ITER Project received $80 million, or about 22 percent, of the U.S. fusion program budget of roughly $367 million. In fiscal year 2012, the U.S. ITER Project received $105 million, or about 27 percent, of the U.S. fusion program budget of approximately $393 million. In fiscal year 2013, the project received about $124 million, or roughly 33 percent, of the U.S. fusion program budget of approximately $378 million and, in fiscal year 2014, it received just under $200 million, or about 40 percent, of the U.S. fusion program budget of approximately $505 million. DOE has requested that $150 million, or about 36 percent, of its fiscal year 2015 proposed budget for the U.S. fusion program ($416 million) go toward the U.S. ITER Project.

Figure 4: U.S. ITER Project Share of the U.S. Fusion Program Budget, Fiscal Years 2006-2015



Source: GAO analysis of DOE data. | GAO-14-499

Note: This figure reports dollar values rounded to millions of dollars and percentages rounded to the nearest whole percentage point.

DOE's project management order[18] establishes, among other things, a process for planning and executing large construction projects.[19] The order establishes several major milestones—or "critical decision points"—that span the life of the project and includes DOE's review and approval of a project's cost and schedule estimates at the major milestones. The order emphasizes that cost estimates should be provided at each major milestone, but the degree of rigor and uncertainty of the estimates will depend on the stage of the project. Specifically, it provides that cost and schedule estimates are not considered to be final until DOE has approved a "performance baseline" for a project.[20] A performance baseline captures a project's key performance, scope, cost, and schedule parameters, and it represents a commitment from DOE to Congress to deliver a project within those parameters. DOE's project management order explains that a performance baseline sets the bar against which a project's progress will be measured, and that cost and schedule estimates developed prior to DOE approval of a performance baseline are only preliminary estimates. According to DOE guidance,[21] developing a performance baseline for a project

- fosters effective coordination and integration of planning and decision making among the different DOE parties involved in a project;
- enables routine monitoring and reporting on all aspects of a project's performance;
- helps define a project and ensure that project requirements are rigorously refined; and

[18]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Washington, D.C.: Nov. 29, 2010).

[19]In December 2012, the Deputy Secretary of Energy authorized the removal of the U.S. ITER Project's designation as a "capital asset project" as defined by DOE's project management order because he determined that the U.S. ITER Project did not fit the definition of such a project. However, the Deputy Secretary directed the Office of Science to continue to apply DOE's project management policies, principles, and processes to the extent practical. According to DOE documents, DOE is following the process described in DOE's project management order, including its major milestones.

[20]For the purposes of this report, we refer to the definitive cost and schedule estimates that DOE sets when it approves a project's performance baseline as "final" estimates. The estimates set at the time DOE approves a performance baseline can change, but DOE's project management order states that such a change would represent an irregular event that should be avoided to the maximum extent possible.

[21]Department of Energy, *U.S. Department of Energy Performance Baseline Guide*, DOE Guide 413.3-5A (Washington, D.C.: Sept. 23, 2011).

- facilitates the delivery of first-of-a-kind projects that typically have a high degree of uncertainty, high cost, high impact on stakeholders, and high visibility.

The Estimated Cost and Schedule of the U.S. ITER Project Has Grown Substantially Since 2006

The estimated cost and schedule of the U.S. ITER Project has grown substantially since the ITER Agreement was signed in 2006 (see fig. 5), and DOE has identified several reasons for these changes. At the time the ITER Agreement was signed, DOE planned on spending $1.122 billion on the U.S. ITER Project and expected to complete the project in 2013[22] based on preliminary estimates it approved in 2005.[23] In 2008, DOE formally increased its preliminary cost estimate to a cost range of from $1.45 billion to $2.2 billion.[24] This was the most recent time DOE approved a cost estimate for the U.S. ITER Project.[25] Also, in 2008, DOE said it expected ITER to achieve first plasma in 2016 and expected the U.S. ITER Project to be completed in 2017. DOE now estimates that the U.S. ITER Project will cost $3.915 billion, that ITER will achieve first plasma in 2023, and that the U.S. ITER Project will be completed in 2033. These estimates were developed based on a set of key assumptions that were not used by DOE in its 2008 estimates. The current estimates include an assumption of annual funding for the U.S. ITER Project of $225 million, starting in fiscal year 2015 and continuing until the project is

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[22]According to DOE documents, the U.S. ITER Project will be considered to be complete when DOE has made the last delivery of hardware components and the final cash contribution for the U.S. share of ITER's construction budget. DOE will still be responsible for making cash contributions to the ITER Organization for the operation, deactivation, and decommissioning phases of the ITER project.

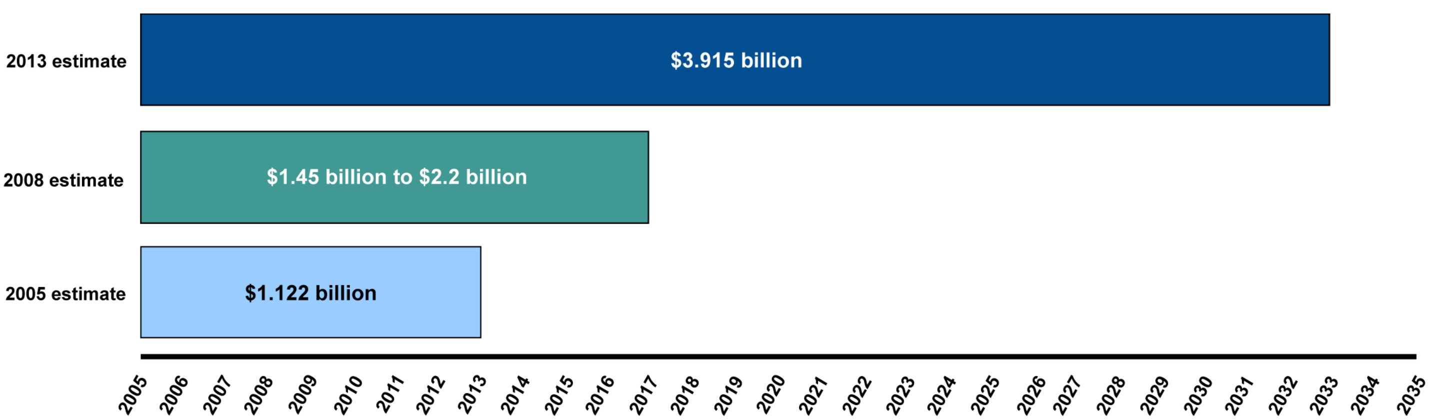
[23]Under DOE's program management order, projects are organized by phases and major milestones, starting with the initiation phase and approval of broadly-stated mission needs, known as "CD-0." In 2005, DOE estimated that the U.S. ITER Project would cost $1.122 billion as part of the project's CD-0 milestone. The $1.122 billion cost estimate was a rough-order-of-magnitude estimate, which means it was preliminary and based on high-level project objectives. It remained DOE's cost estimate for the U.S. ITER Project when the ITER Agreement was signed in 2006.

[24]In 2008, DOE approved the start of the U.S. ITER Project's execution phase at the project's second major milestone, known as "CD-1." This milestone included DOE's approval of a preliminary cost range for the U.S. ITER Project of from $1.45 billion to $2.2 billion.

[25]According to DOE officials, the U.S. ITER Project estimate was capped at $2.2 billion until April 2011. They explained that, from January 2011 through August 2013, DOE directed the U.S. ITER Project Office to include various funding profiles in its detailed planning.

completed, with no adjustment for inflation; limited U.S. cash contributions to the ITER Organization from 2014 to 2016; future U.S. contributions to the ITER Organization for ITER's operation, deactivation, and decommissioning phases coming out of the $225 million annual funding level; and a hardware delivery schedule not tied to the ITER Organization's schedule. DOE also instructed the U.S. ITER Project Office to use its estimate of ITER achieving first plasma in 2023 rather than the 2020 date in the ITER Organization's schedule, and to use its best estimate for ITER Organization construction costs rather than the budget most recently approved by the ITER Council.[26] Nonetheless, these current estimates remain preliminary, according to DOE officials, because DOE has not approved a performance baseline for the U.S. ITER Project. A performance baseline captures a project's key performance, scope, cost, and schedule parameters, and represents a commitment from DOE to Congress to deliver a project within those parameters.

Figure 5: Total Estimated Cost and Completion Date for the U.S. ITER Project



Source: GAO analysis of DOE data. | GAO-14-499

[26]As of March 2014, the official ITER Organization schedule anticipates ITER achieving first plasma in 2020, but DOE officials told us this date is unrealistic. Instead, the U.S. ITER Project Office developed the August 2013 estimates based on its best estimate that ITER will achieve first plasma in 2023, with contingency for another year delay to 2024. DOE officials told us that the August 2013 estimates also assumed an increase in the ITER Organization construction budget of 1 billion euros, and the U.S. share of this value was included in the estimates.

According to DOE documents, the current $3.915 billion cost estimate for the U.S. ITER Project includes the following:

- $1.469 billion (38 percent)[27] to complete the remaining work to procure and deliver U.S. hardware components for ITER;
- $928 million (24 percent) in contingency to address potential schedule delays or increases in costs for manufacturing components, including $852 million in contingency for the remaining work to procure and deliver U.S. hardware components, and $76 million in contingency for U.S. cash contributions to the ITER Organization;[28]
- $541 million (14 percent) to account for project costs through June 2013;
- $519 million (13 percent) for remaining cash contributions to the ITER Organization to pay for scientists, engineers, and support personnel working at the ITER Organization; the assembly and installation of the components in France to build the reactor; quality assurance testing of all ITER member-supplied components; and contingencies; and
- $458 million (12 percent) for escalation costs, such as changes in currency exchange rates and commodity prices, which are driven by the extended length of the project due to the funding assumptions used to develop the cost estimate.

DOE documents and officials identified several key reasons for the growth of the cost and schedule estimates for the U.S. ITER Project. DOE officials identified a number of reasons that led to the change in the project's initial 2005 cost estimate of $1.122 billion to its 2008 cost range of from $1.45 billion to $2.2 billion. These included (1) higher estimates for the cost of U.S. hardware components as their designs and requirements were more fully developed; (2) updated estimates for external factors such as currency exchange rates and commodity prices; (3) changes to U.S. hardware component requirements and the international project schedule due to a 2007 design review of the overall ITER project; and (4) additions for contingency and recognized risks. According to DOE documents and officials, the primary reasons the U.S.

[27]The percentages in this list do not sum to 100 percent because of rounding.

[28]According to DOE, the current cost estimate includes 47 percent in contingency for the remaining work to procure and deliver U.S. hardware components, and 12 percent in contingency for U.S. cash contributions to the ITER Organization.

ITER Project's cost estimate grew from the upper range of $2.2 billion in 2008 to the current $3.915 billion estimate included the following:[29]

- *Higher estimates for U.S. hardware components as designs and requirements have been more fully developed over time:* The design and requirements for U.S. hardware components have evolved over time, and the cost estimates for these components have changed as a result, according to DOE documents and officials. Specifically, the current U.S. ITER Project cost estimate includes about $770 million more than the 2008 figures due to greater understanding of what U.S. hardware components are likely to cost. According to DOE officials, expected hardware costs now reflect more fully developed designs, better industry estimates of the cost of producing those designs, and greater understanding of project risks, among other things. DOE documents noted that, as of February 2014, about two-thirds of U.S. hardware components by value were in final design or beyond, although there were some smaller components that were still in earlier stages of design.[30] According to DOE officials, because of the progress in developing hardware component designs, the project team has a greater understanding of what those components are likely to cost and has reflected that understanding in the current $3.915 billion cost estimate.
- *Higher contingency amounts added to address risks:* The U.S. ITER Project Office has increased the amount of contingency in the current cost estimate to address the risks from the project's significantly longer schedule and to increase confidence in the estimate, according to DOE documents and officials. Specifically, the current estimate includes about $681 million more in contingency than was in the U.S. ITER Project cost estimate in 2008. According to DOE officials, the amount of contingency is based on detailed risk analyses as well as a management assessment of key assumptions. DOE officials told us

[29]The current $3.915 billion estimate does not include $667 million that was included in the $2.2 billion upper range estimate in 2008 to cover potential future cost growth from risks that were not fully understood at that time or difficult to quantify, according to DOE documents and officials.

[30]See appendix III for the status of U.S. hardware components as of August 2013. Overall, U.S. hardware component designs were about 52 percent complete as of February 2014, with the level of completion varying by hardware component from as low as 40 percent complete to as high as 100 percent complete. At that time, DOE officials expected to finish delivering the first of the 12 U.S. hardware components in 2015 and to finish delivering the last of the U.S. hardware components in 2030.

that, to develop contingency amounts for the current estimate, the U.S. ITER Project Office identified and evaluated program-level risks, such as changes in currency exchange rates and growth in ITER Organization cash contribution requirements. They also considered project-level risks, such as the U.S. ITER Project's dependence on other ITER members or the ITER Organization for inputs needed to complete U.S. hardware components and potential procurement and manufacturing difficulties. Further, they added contingency amounts if U.S. ITER Project Office management representatives thought initial contingency amounts were too low for the risks associated with the project's longer schedule or based on their past experience with large science projects.

- *Schedule delays:* U.S. schedule delays due to international project schedule delays and U.S. funding constraints accounted for about $544 million of the increase in the U.S. ITER Project's cost estimate since DOE last approved the estimate in 2008, according to DOE documents and officials. First, international project schedule delays have lengthened the U.S. ITER Project schedule and have also led to increases in the cost estimate. For example, in 2007, an international review identified extensive changes that were needed in ITER's design, and that significantly delayed the ITER Organization from defining requirements for U.S. hardware components.[31] This in turn created delays in the U.S. ITER Project schedule for procuring and delivering those components, which led to higher cost estimates for those components. Second, U.S. funding constraints resulting from the project's most recent $225 million per year funding plan and lower-than-requested funding levels in some years have lengthened the U.S. ITER Project schedule, according to DOE documents and officials. This in turn has made it necessary for the U.S. ITER Project Office to build additional amounts into the project's cost estimate to account for higher escalation costs and the longer period of time the U.S. ITER Project workforce will be needed. For example, DOE officials told us that the project's most recent $225 million per year funding plan reflected discussions between DOE, the Department of State (State), the Office of Management and Budget (OMB), and the Office of Science and Technology Policy (OSTP) to provide enough

[31]DOE officials told us that ITER's design was less developed than the United States understood it to be when the ITER Agreement was signed in 2006. At that time, the United States understood that ITER's design was about 80 to 90 percent complete. However, DOE officials said it was later determined that ITER's design was only about 40 percent complete and that extensive changes would be needed to the design.

funding to meet U.S. obligations to ITER and reduce the amount of the U.S. fusion program budget and the overall DOE budget that had to be devoted to the U.S. ITER Project on an annual basis.[32] However, this lengthened the U.S. ITER Project's schedule and created procurement inefficiencies, resulting in increases in the project's overall cost estimate.

- *Higher cash contributions to the ITER Organization due to growth in ITER construction costs:* The U.S. ITER Project Office built an additional $348 million into the current cost estimate to reflect the increase in U.S. cash contributions it expects to have to make to the ITER Organization, according to DOE documents and officials. DOE officials explained this increase includes $169 million for the U.S. share of a previously approved increase in the ITER Organization's construction budget, as well as $179 million for the U.S. share of a potential future billion euro increase in the ITER Organization construction budget and the anticipated cost increases for the ITER Organization staff based on a 2023 first plasma date.
- *The United States has taken on additional hardware responsibilities:* DOE agreed to take on additional hardware responsibilities, accounting for $39 million of the increase in the U.S. ITER Project cost estimates since 2008, according to DOE documents and officials.[33] DOE officials told us that there is a cost cap for each of these additional hardware responsibilities, and that the ITER Organization will be responsible for paying any amounts that exceed the caps. As a result, they view taking on these additional hardware responsibilities as a way to reduce uncertainty about future U.S. ITER Project costs because DOE will not have to spend more than the amounts specified in the cost caps for each item.

[32]State had a role in the negotiation of the ITER Agreement and has a continuing role interpreting U.S. obligations under the agreement. OMB, as the implementation and enforcement arm of presidential policy, is responsible for, among other things, the development and execution of the federal budget. Under the National Science and Technology Policy, Organization, and Priorities Act of 1976 (Pub. L. No. 94-282), the primary function of the OSTP Director is to provide, within the Executive Office of the President, advice on the scientific, engineering, and technological aspects of issues that require attention at the highest level of government. Further, the office serves as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the federal government.

[33]The additional hardware responsibilities DOE agreed to take on were the disruption mitigation systems and the design, fabrication, and testing of insert coils for the central solenoid magnet system and the toroidal field conductor.

Despite Reflecting Most Characteristics of Reliable Cost and Schedule Estimates, DOE's Estimates Cannot Be Used to Set a Baseline in Part Because They Are Linked to an Unreliable International Schedule

DOE's current cost estimate for the U.S. ITER Project reflects most of the characteristics of a reliable cost estimate, and its schedule estimates reflect all characteristics of a reliable schedule.[34] However, DOE's estimates cannot be used to set a performance baseline that would commit DOE to delivering the project at a specific cost and date primarily because of some factors that DOE can only partially influence. The factors DOE can only partially influence include an unreliable international project schedule to which the U.S. schedule is linked and an uncertain U.S. funding plan. DOE has taken some action to address the factors that have prevented it from setting a performance baseline and finalizing its estimates, but significant challenges remain.

DOE's Current Cost Estimate for the U.S. ITER Project Reflects Most Characteristics of a Reliable Estimate, and Its Schedule Estimates Reflect All These Characteristics

DOE's current cost estimate for the U.S. ITER Project reflects most of the characteristics of high-quality, reliable cost estimates as established by best practices documented in the *GAO Cost Estimating and Assessment Guide*.[35] In addition, DOE's current schedule estimates fully reflect the characteristics of high-quality, reliable schedule estimates as established by best practices documented in the *GAO Schedule Assessment Guide*.[36] According to the guides, four characteristics make up reliable cost estimates—they are comprehensive, well-documented, accurate, and credible (see table 2). Similarly, four characteristics make up reliable schedule estimates—they are comprehensive, well-constructed, credible, and controlled. Cost and schedule estimates are considered reliable if each of the four characteristics is substantially or fully met. If any of the characteristics is not met, minimally met, or partially met, then the estimates do not fully reflect the characteristics of a high-quality estimate and cannot be considered reliable.

[34] GAO-09-3SP and GAO-12-120G.

[35] GAO-09-3SP.

[36] GAO-12-120G.

Table 2: Four Characteristics of High-Quality, Reliable Cost and Schedule Estimates

Characteristics of reliable cost estimates	
Comprehensive	A comprehensive cost estimate has enough detail to ensure that cost elements are neither omitted nor double counted.
Well-documented	A well-documented cost estimate allows for data it contains to be traced to source documents.
Accurate	An accurate cost estimate is based on an assessment of most likely costs and has been adjusted properly for inflation.
Credible	A credible cost estimate discusses any limitations because of uncertainty or bias surrounding data or assumptions.
Characteristics of reliable schedule estimates	
Comprehensive	A comprehensive schedule includes all government and contractor activities necessary to accomplish a project's objectives.
Well-constructed	A well-constructed schedule sequences all activities using the most straightforward logic possible.
Credible	A credible schedule uses data about risks and opportunities to predict a level of confidence in meeting the completion date.
Controlled	A controlled schedule is updated periodically to realistically forecast dates for activities.

Source: GAO. / GAO-14-499

DOE's current cost estimate for the U.S. ITER Project—as developed by the U.S. ITER Project Office in August 2013—substantially met best practices for comprehensive, well-documented, and accurate estimates, but only partially met best practices for credible estimates. For example, DOE's cost estimate substantially met best practices for documenting all assumptions that will influence costs (comprehensive), describing step by step how the estimate was developed (well-documented), and adjusting properly for inflation (accurate). However, the U.S. ITER Project Office did not conduct a complete sensitivity analysis on the cost estimate, and an independent cost estimate has not been conducted (credible).[37] The U.S. ITER Project Office did identify four key assumptions from the estimate for sensitivity testing. However, the analysis did not include some cost elements that represent high percentages of the overall estimate, including some of the most expensive hardware components being built by the United States. For example, the sensitivity analysis did not include the tokamak cooling water system, which is the most expensive U.S.

[37]A sensitivity analysis describes how much costs can change by varying major assumptions, parameters, and data inputs.

hardware component. Without a comprehensive sensitivity analysis that identifies how the cost estimate is affected by changes to its assumptions, DOE will not fully understand how certain risks can affect the cost estimate and potentially result in decisions based on incomplete information. In addition, DOE did not conduct an independent cost estimate to determine whether other estimating methods produce similar results. DOE policy does not require an independent cost estimate until it approves a performance baseline, which the agency does not expect to occur until late 2015. However, including an independent estimate is a best practice associated with credible cost estimates. Independent cost estimates are less likely to reflect organizational bias. They also incorporate adequate risk, which generally results in more conservative estimates due to higher estimated costs. Without such an independent cost estimate, DOE faces a greater risk of underfunding the project, which can lead to overall cost growth and schedule slippage. (See app. IV for the individual ratings of each cost estimating practice.)

DOE's current schedule estimates for the two most expensive U.S. hardware items[38]—the central solenoid modules and the tokamak cooling water system—fully met best practices for comprehensive schedules and substantially met best practices for well-constructed, credible, and controlled schedules. For example, DOE's schedule estimate fully met best practices for capturing and establishing the duration of all activities (comprehensive), and substantially met best practices for sequencing all activities (well-constructed), conducting a schedule risk analysis (credible), and updating the schedule with actual progress (controlled). However, the schedule estimate partially met best practices for horizontal and vertical traceability,[39] maintaining a baseline schedule, and ensuring reasonable total float, which is the amount of time an activity can be delayed before the dates of the program's completion milestones are affected. U.S. ITER Project Office representatives acknowledged these

[38]We chose to analyze the schedule for the central solenoid modules, which are the largest part of the central solenoid magnet system that will help control the shape of the ITER plasma, and the tokamak cooling water system, which is designed to cool ITER's systems, because they are the largest two hardware items, in terms of value, that the United States is responsible for contributing to ITER. The U.S. ITER Project Office developed the current estimates for these schedules in August 2013.

[39]Horizontal traceability verifies that activities are arranged in the right order for achieving aggregated products or outcomes. Vertical traceability means that varying levels of activities and supporting subactivities can be traced to each other enabling different groups to work to the same master schedule.

issues with the schedule and attributed them to problems with the international project schedule. For example, according to project representatives, DOE's schedule does not align with the international project schedule (i.e.: is not vertically traceable) because the international project schedule does not account for delays in ITER Organization delivery milestones, including a 30-month delay in ITER construction site preparations. Without up-to-date reliable international milestones, DOE cannot develop realistic U.S. milestones that align with the international project schedule and set a baseline that can provide a reliable, specific cost and completion date for the project. (See app. V for the individual ratings of each scheduling best practice).

DOE's Cost and Schedule Estimates Cannot Be Used to Set a Baseline Due to Factors That DOE Can Only Partially Influence

DOE considers its current cost and schedule estimates for the U.S. ITER Project to be preliminary, and these estimates cannot be used to set a performance baseline that would represent a commitment from DOE to Congress to deliver the project at a specific cost and date. DOE policy says that cost and schedule estimates are considered final only after a performance baseline has been approved for a project, and DOE has not approved a performance baseline for the U.S. ITER Project. According to DOE's project management order, a performance baseline sets a bar against which a project's progress can be measured. DOE's target date for setting a performance baseline finalizing its cost and schedule estimates for the U.S. ITER Project has continually slipped from an original expected date of fiscal year 2007 to the current target of late in fiscal year 2015. That is when DOE expects the international project schedule to be updated, according to DOE documents and officials.

According to DOE documents and officials, DOE's current estimates for the U.S. ITER Project cannot be used to set a performance baseline because of three factors, two of which DOE can only partially influence as follows:

- First, the overall international project schedule that DOE uses as a basis for the U.S. schedule is not reliable. In July 2010, the ITER Council approved an official schedule for the overall ITER project. However, an October 2013 management assessment of the ITER Organization determined that the international project schedule established in 2010 was not reliable. The assessment attributed the unreliable schedule, in part, to management deficiencies within the ITER Organization. For example, the assessment found that the ITER Organization's senior management had insisted that the international project schedule not be changed even when staff had developed what they thought were more realistic schedules, and that staff had not been allowed to openly challenge the schedule. According to DOE officials, the ITER Organization plans to spend the next year reassessing the international project schedule and taking actions to address the identified management deficiencies, and it hopes to complete its schedule reassessment by June 2015.[40]

- Second, DOE has not proposed a final, stable funding plan for the U.S. ITER Project. DOE's most recent plan had been to provide a flat $225 million per year for the project, and that figure was the basis for its current cost and schedule estimates. However, DOE officials told us that this funding plan could potentially change depending on the outcome of the ITER Organization's reassessment of the international project schedule. In March 2014, DOE requested $150 million for the U.S. ITER Project in fiscal year 2015, $75 million less than the $225 million per year funding plan. According to DOE documents, the $150 million request would allow the U.S. ITER Project to meet its fiscal year 2015 commitments to ITER but would not be enough for the project to meet the milestones set in the official international project schedule. Officials noted that if Congress provided less than DOE's requested funding, the U.S. ITER Project schedule will slip further. Six of the 10 fusion energy and project management experts we interviewed said that identifying sufficient funding to execute the U.S. ITER Project poses a significant management challenge for DOE.

The third factor that has kept DOE from setting a performance baseline finalizing its estimates is within the agency's direct control. Specifically, an August 2013 internal peer review found that the methodologies used to develop DOE's current cost and schedule estimates were appropriate, but that the estimates do not sufficiently consider all project risks and uncertainties.[41] For example, the review found that the U.S. ITER Project Office did not identify and quantify all risks, that its view of potential risk mitigation was too optimistic, and that the range of possible cost outcomes due to each individual risk factor was too narrow. Further, the review identified potential cost increases related to changing technical

[40]DOE officials told us the U.S. ITER Project Office used its best estimate of a realistic international project schedule to develop the August 2013 cost and schedule estimates for the U.S. ITER Project and included a contingency for 1 year of additional potential delay.

[41]At the request of the Office of Fusion Energy Sciences, the Office of Project Assessment within DOE's Office of Science conducted an internal peer review of the U.S. ITER Project in August 2013. The review evaluated, among other things, the project's cost and schedule estimates and the supporting documentation.

requirements, uncertainty about the ITER Organization's performance, and the dependence on other ITER members for production of items that are used in U.S. hardware components. To better account for these risks and uncertainties, the review added additional amounts to DOE's current cost estimate of $3.915 billion and found that the U.S. ITER Project was more likely to cost from $4 billion to $6.5 billion.[42] The reviewers recommended, among other things, that the U.S. ITER Project Office update its risk estimates to be more comprehensive and reevaluate its risk mitigation assessments before DOE approves a performance baseline for the U.S. ITER Project.

In the absence of a performance baseline, DOE has developed a 2-year plan for the U.S. ITER Project that sets near-term cost and schedule targets to guide the project's performance in fiscal years 2013 and 2014.[43] However, this 2-year plan is an interim measure and does not represent DOE's commitment to a specific cost and schedule for the U.S. ITER Project as a performance baseline would. Most of the fusion energy and project management experts we interviewed emphasized the importance of DOE approving a performance baseline for the U.S. ITER Project, with some experts noting that a performance baseline would provide a goal for all project stakeholders to work toward and might ease concerns about the uncertainty of the funding levels needed to complete the project. Several experts also told us that, until DOE approves a performance baseline for the U.S. ITER Project, there will continue to be uncertainty about the project's direction.

[42]DOE, in its fiscal year 2015 budget request, identified the internal peer review's suggested cost range of $4 billion to $6.5 billion as the best estimate for the U.S. ITER Project's potential cost. According to DOE officials, the internal peer review's cost range was not a detailed cost estimate like the U.S. ITER Project Office's $3.915 billion estimate. Rather, the range reflected amounts added to the $3.915 billion estimate by peer review officials to address their assessment that the U.S. ITER Project Office estimate did not sufficiently consider all project risks and uncertainties. Four of the 10 fusion energy and project management experts we interviewed said they thought the internal peer review's cost range was overstated and unrealistic, with 2 of the experts stating that the review committee used a worst case scenario, which they do not view as likely, to develop the higher end of the cost range.

[43]DOE officials told us that the interim 2-year plan also allows the agency to formally monitor project progress.

DOE Has Taken Some Actions to Address the Factors Preventing It from Setting a Baseline, but Challenges Remain

DOE has taken some actions to address the factors preventing it from setting a performance baseline that would allow the agency to finalize its cost and schedule estimates for the U.S. ITER Project. However, project management and schedule deficiencies in the ITER Organization and uncertainty in the U.S. ITER Project funding plan continue to pose management challenges for the agency and delay its efforts to set a performance baseline.

According to DOE officials, DOE has taken several actions to try to get the ITER Organization to address international project management and scheduling deficiencies. For example, DOE officials told us that their aggressive participation in early ITER Agreement negotiations led to the adoption of a biannual management assessment requirement. This has focused attention on international management deficiencies, resulting in several recommendations for improving the project. Further, DOE officials told us they have used ITER Council Management Advisory Committee meetings to introduce, communicate, and advance project management principles, such as competitive procurement actions, in an effort to improve ITER Organization project management.[44] Additionally, DOE has developed position papers describing the agency's concerns with ineffective ITER Organization scheduling and management and suggesting actions the ITER Organization could take to develop a reliable international project schedule and improve international management. For example, in a position paper on scheduling issues, DOE recommended the ITER Council direct the ITER Organization to focus on developing a short-term schedule, and defer long-term schedule development until lessons are learned from the short-term effort. DOE has provided the position papers to other ITER members and achieved some unofficial support, but the agency has not submitted a formal proposal on the suggested actions to the ITER Council, which could vote on and ultimately require the implementation of these actions. According to DOE officials, DOE has not submitted formal proposals because previous ITER Council Chairs delayed substantive discussions of issues such as schedule slippages and conducted meetings with a primary goal of obtaining consensus among ITER members. However, DOE officials said the ITER Council and other ITER members are aware of DOE's position,

[44]The ITER Council Management Advisory Committee, at the request of the ITER Council, reviews and evaluates matters of strategic management importance to the ITER project and makes recommendations to the ITER Council to facilitate the successful development of the ITER Organization and the successful execution of the ITER construction project.

and they hope the new ITER Council Chair, who took over in January 2014,[45] will change the way the ITER Council operates. DOE officials also said the ITER Council approved at the November 2013 ITER Council meeting the initiative for the ITER Organization to develop a short-term annual work plan for 2014, the results of which will inform long-term schedule development, and that all milestones had been met by all seven ITER members for the first three months.

Even so, challenges remain that will continue to hamper DOE's ability to develop a baseline for the U.S. ITER Project. Eight out of the 10 fusion energy and project management experts we interviewed said DOE does not have enough information from the ITER Organization and other ITER members to effectively plan the U.S. ITER Project, and 7 of the 10 experts said the international structure and management issues contribute to DOE's management challenges. In this context, DOE's efforts may have helped improve ITER Organization project management and helped jump-start efforts to develop a reliable international project schedule, but a reliable international project schedule is not expected until June 2015, as previously noted. Further, the previous international project schedule developed by the ITER Organization and approved by the ITER Council in 2010 has not proved reliable, and management issues that were identified in previous years continue to pose challenges at the international level. For example, the October 2013 management assessment of the ITER Organization found that the ITER Council had not acted on many recommendations for project management improvements from a previous management assessment in 2009 and that the problems identified in that assessment continue. The most recent management assessment attributed the inaction to the ITER Council's reliance on consensus decision making, which caused it to avoid or delay difficult decisions. The 2013 assessment stated that the ITER members needed to openly discuss and then make decisions on difficult issues at ITER Council meetings, even if there is no consensus, and all members should be held accountable for results. The management assessment contained 11 recommendations that were designed to be taken together. The assessment further said that the international project would not achieve significant improvement if the ITER Council only adopted a few recommendations, as has been the case with recommendations in

[45]Robert Iotti, a U.S. representative, became the ITER Council Chair in January 2014 and will serve a term of up to 4 years.

previous management assessments. DOE officials told us that the ITER Council had approved proposals to address the recommendations from the October 2013 management assessment and that the ITER Council Chair was actively monitoring the implementation of the recommendations.

To address the uncertainty of the U.S. funding plan for the U.S. ITER Project, DOE has evaluated a range of funding scenarios for executing the project. As previously noted, DOE most recently developed a $225 million per year flat funding plan with State, OMB, and OSTP, but DOE officials acknowledged that the plan constrained funding for the project to allow DOE to meet U.S. obligations to ITER and reduce the amount of the U.S. fusion program and overall DOE budgets devoted to the project annually. DOE officials told us the flat funding plan created a long and inefficient schedule and has created gaps between the design and fabrication stages of some systems, which has led to cost growth. DOE officials said that they will not be able to meet the most recent international project schedule under this funding plan, and delivery of some U.S. components will likely be late under the plan. DOE officials told us they plan to develop a final, stable funding plan for the U.S. ITER Project, but that plan can only be developed if the international project schedule is reliable.

To ensure that all risks and uncertainties are sufficiently incorporated into its estimates, DOE officials told us the U.S. ITER Project Office held a series of risk workshops. According to DOE officials, as of March 2014, the U.S. ITER Project Office had held risk workshops on U.S. hardware components and associated risks, as well as a workshop on external risks. U.S. ITER Project Office representatives told us that they are currently analyzing the results of the workshops and that the workshops will ultimately lead to updated risk estimates and an update to the current cost estimate of $3.915 billion for the U.S. ITER Project.

DOE Has Taken Actions to Reduce U.S. ITER Project Costs but Has Not Adequately Planned for Their Impact on the U.S. Fusion Program

DOE has taken several actions to reduce the cost of the U.S. ITER Project. Some fusion energy and project management experts we interviewed suggested additional strategies DOE could pursue that might further reduce U.S. ITER Project costs or improve project management. DOE has not adequately planned for the potential impact of U.S. ITER Project costs on the overall U.S. fusion program because it has not completed a strategic plan that would clarify the program's priorities given those costs.

DOE Has Taken Several Actions to Reduce U.S. ITER Project Costs

According to DOE documents and officials, DOE has taken several actions to reduce the cost of the U.S. ITER Project by about $388 million as of February 2014,[46] including the following:

- *Value engineering:* The U.S. ITER Project Office has identified ways to design U.S. hardware components that lower costs but maintain the component's essential functions. According to DOE officials, this strategy—known as "value engineering"—has been an integral part of the U.S. design effort.[47] For example, the U.S. ITER Project Office has been able to reduce the cost of the central solenoid magnet system by more than $18 million by eliminating, simplifying, or reducing the number of some parts. It also has reduced the cost of the vacuum auxiliary systems by almost $34 million by, among other things, revising test equipment items and quantities and reducing the number of system connections and pumps. According to DOE officials, these and other value engineering efforts have resulted in about $225 million in savings as of February 2014. DOE documents

[46]This includes amounts identified by DOE as "cost avoidance" or "cost savings." According to OMB, "cost avoidance" is an action taken in the immediate time frame that will decrease costs in the future, and "cost savings" are a reduction in actual expenditures below the projected level of costs to achieve a specific objective. For purposes of this report, we are using the term "cost savings" to encompass both types of actions.

[47]According to DOE's project management order, value engineering is a structured technique commonly used in project management to optimize the overall value of the project. Often, creative strategies will be employed in an attempt to achieve the lowest life-cycle cost available for the project. Value engineering is a planned, detailed review and evaluation of a project to identify alternative approaches to providing the needed assets.

indicated that about half of the savings come from value engineering the design of the tokamak cooling water system.

- *Centralized and consolidated procurement for certain items:* The U.S. ITER Project Office has agreed to have the ITER Organization centrally procure piping for the tokamak cooling water and vacuum systems for which the United States is responsible. It has also reached agreement with other ITER members to consolidate procurement of certain common parts rather than having each ITER member procure those parts for their assigned hardware components. For example, the U.S. ITER Project Office has agreed to have the European Union procure all cable trays needed for U.S. hardware components. According to DOE officials, centralized and consolidated procurement for certain items has saved the U.S. ITER Project about $120 million as of February 2014.
- *Scope transfers and reallocations:* The U.S. ITER Project Office has reached agreements to transfer some U.S. hardware responsibilities to the ITER Organization and to reallocate some hardware responsibilities among ITER members to improve procurement efficiency and reduce U.S. costs. For example, project officials told us that they reached an agreement to shift the U.S. responsibility for procurement of one system to other ITER members, with the United States taking on more engineering work for that system in return. DOE officials estimated that this resulted in $20 million in savings. According to DOE officials, scope transfers and reallocations have saved about $43 million as of February 2014.
- *Other strategies:* According to DOE documents and officials, the U.S. ITER Project Office has used several other strategies to reduce U.S. ITER Project costs. These strategies have included implementing lessons learned and leading practices from other large projects; working with the ITER Organization on cost reduction initiatives to improve ITER Organization processes and requirements; and minimizing costs associated with project execution by, for example, providing incentives in contract provisions. DOE officials said that it was too soon to quantify the cost savings resulting from these actions.

According to DOE documents and officials, these cost savings are reflected in the current $3.915 billion cost estimate for the U.S. ITER Project. DOE officials told us that cost containment will continue to be a high priority for the project. They told us that the most significant opportunity to further reduce U.S. ITER Project costs would be the adoption of an optimal funding plan for the project. Officials explained that $458 million of the current $3.915 billion cost estimate is included to cover escalation costs, and an optimal funding plan could potentially reduce those and other costs by allowing the U.S. ITER Project to be completed in a shorter period of time.

Some Experts Suggested Strategies to Further Reduce U.S. ITER Project Costs or Improve Management

Some of the 10 fusion energy and project management experts that we interviewed identified strategies DOE could pursue to further reduce the cost of the U.S. ITER Project. The following two strategies were suggested by several of these experts:

- Six experts suggested that DOE could reduce U.S. ITER Project costs by adopting an optimal funding plan for the project. The optimal funding plan being suggested would involve different dollar figures year to year rather than DOE's most recent strategy of funding the U.S. ITER Project at a flat $225 million per year starting in fiscal year 2015. Some experts noted that a funding plan that scaled up in the near-term and then scaled down in later years could potentially reduce overall U.S. ITER Project costs by hundreds of millions of dollars. Specifically, three experts said that an optimal funding plan could shorten the current U.S. ITER Project schedule, and that doing so would reduce overall project costs. Two experts noted that one issue with this strategy would be that the U.S. ITER Project would need to receive more funding in some years, and that could lead to funding cuts for other DOE projects and programs. To address that issue, one expert suggested DOE not propose an optimal funding plan for the U.S. ITER Project until the agency determines that there is a reliable international project schedule and that the ITER Organization has made significant progress improving its management of the overall ITER project. Another expert suggested that DOE first communicate its plans for managing the impact on the overall U.S. fusion program of higher U.S. ITER Project funding in certain years before proposing an optimal funding plan. When we discussed this strategy with DOE program officials, they agreed that an optimal funding plan for the project could shorten the U.S. ITER Project schedule and potentially reduce costs significantly. However, they emphasized that the most recent $225 million annual funding plan was an attempt to balance the funding needs of the U.S. ITER Project and the rest of the U.S. fusion program.
- Three experts suggested that DOE could reduce U.S. ITER Project costs by working with its international partners to develop a reliable international project schedule and aligning U.S. ITER Project efforts with that schedule. One expert noted that this would help make DOE's cost estimate for the U.S. ITER Project more certain. Another expert told us that a reliable international project schedule was necessary for DOE to set an optimal funding plan, which in turn could help minimize

U.S. ITER Project costs. The expert said that aligning the U.S. ITER Project with a reliable international project schedule was necessary to ensure that the United States was not producing its hardware components too early or too late, either of which could result in cost growth. When we discussed this strategy with DOE program officials, they said that the United States has actively presented its views to its international partners on what would be a realistic schedule for the overall ITER project. Further, the officials told us that they do try to align U.S. ITER Project efforts with the international project schedule in spite of imperfect knowledge due to the current international project schedule not being reliable.

Some of the 10 experts we interviewed also suggested strategies that DOE could pursue to improve its management of the U.S. ITER Project. The following two strategies were mentioned by several experts:

- Six experts suggested DOE establish a separate office that would report directly to top DOE management officials to provide oversight of the U.S. ITER Project. Two of these experts said that having a separate office would give the U.S. ITER Project greater visibility at the highest levels of DOE. Another expert said a benefit would be to enhance the project's interaction with stakeholders, including Congress and the U.S. fusion community. Further, two experts told us that a separate office for the U.S. ITER Project would enhance DOE's ability to oversee the project's complexity and complications given the international structure the project operates within. When we discussed this strategy with DOE program officials, they said that a separate DOE office to oversee the U.S. ITER Project would not provide many benefits and could have unintended consequences. Specifically, they said that the project already has high visibility with top DOE management officials and that creating a separate office could result in a greater degree of funding competition between the U.S. ITER Project and the rest of the U.S. fusion program.
- Four of the 10 experts we interviewed said DOE should make more information on the U.S. ITER Project available to stakeholders in the U.S. fusion community. One expert said DOE should be more forthcoming about what the agency expects the U.S. ITER Project to cost and how they plan to pay for it. Two other experts suggested that DOE should disclose its internal peer reviews of the U.S. ITER Project. Several of the experts we interviewed also identified a number of negative effects of DOE not being sufficiently transparent about the U.S. ITER Project. These included the erosion of stakeholder commitment to the project and a diminished ability for stakeholders to effectively plan research efforts and make informed

funding decisions related to the impact of project costs on the overall U.S. fusion program. When we discussed this strategy with DOE program officials, they said they have shared a substantial amount of information on the U.S. ITER Project with stakeholders and were trying to share more. For example, they noted that DOE included a detailed section on the U.S. ITER Project in its fiscal year 2015 budget request. In some cases, however, officials said they were limited in the information they could share with stakeholders by the international sensitivities of the overall ITER project, by procurement sensitivities, and by the nature of the budget process.

DOE Has Not Adequately Planned for the Impacts of U.S. ITER Project Costs on the U.S. Fusion Program

DOE has not adequately planned for the potential impact of U.S. ITER Project costs on the overall U.S. fusion program, although it has taken some steps. For example, as previously mentioned, the project's most recent $225 million per year funding plan was an attempt by DOE and other parts of the administration to meet U.S. obligations to ITER and reduce the project's impact on the U.S. fusion program and DOE's overall budget. However, according to agency officials, DOE has not completed a strategic plan for the U.S. fusion program to clarify the program's goals and priorities and its proposed approach for meeting them in light of the potential impact of U.S. ITER Project costs.[48]

The House and Senate Appropriations Committees directed DOE to submit a 10-year strategic plan for the U.S. fusion program in the explanatory statements that accompanied both the fiscal year 2012 and fiscal year 2014 energy and water development appropriation acts.[49] In addition, DOE's Fusion Energy Sciences Advisory Committee recommended in 2013 that DOE develop a strategic plan for the U.S.

[48]A DOE official told us that, in the absence of a completed strategic plan, the agency believes it has clearly stated the values that are driving U.S. fusion program priorities through DOE's annual budget requests and presentations to stakeholders. Those presentations have provided some information on the program's direction and the challenges it faces, but they are broad in nature and are not equivalent to a completed strategic plan.

[49]See Explanatory Statement, 160 Cong. Rec. H 878 (daily ed., Jan.15, 2014), to the Energy and Water Development and Related Agencies Appropriations Act, 2014, contained in Division D of the Consolidated Appropriations Act, 2014, Pub. L. No. 113-76; and H.R. Rep. No. 112-331, at 855 (Dec.15, 2011) (Conf. Rep.). The fiscal year 2014 explanatory statement further directed that the strategic plan DOE submitted should assume U.S. participation in ITER and assess its priorities for the domestic fusion program based on three funding scenarios.

fusion program using the advisory committee process and with broad U.S. fusion community input.[50] Further, 9 of the 10 fusion energy and project management experts we interviewed agreed that it would be useful for DOE to develop such a plan.

DOE officials told us they have not completed a strategic plan for the U.S. fusion program to date, for three reasons. First, they said an effort in 2012 to obtain the Fusion Energy Sciences Advisory Committee's input on U.S. fusion program priorities had been unsuccessful because the committee did not address program priorities under a constrained budget scenario due to conflict of interest issues. Second, DOE officials said there had been too much budget uncertainty in fiscal year 2013 regarding the U.S. ITER Project and the overall U.S. fusion program to complete a plan. They explained that the House and Senate Appropriations Committees proposed different direction and funding levels for the U.S. fusion program in fiscal year 2013, and these differences were not resolved until the passage of the fiscal year 2014 appropriations act in January 2014. Third, DOE officials said an effort in 2012 and 2013 to develop a high-level strategic document for the U.S. fusion program was unsuccessful because OMB did not concur with the document developed by DOE. DOE officials said they are in the early stages of developing a strategic plan in response to the House and Senate appropriations committees' direction in the explanatory statement that accompanied the fiscal year 2014 appropriations act. These officials said they would ask the Fusion Energy Sciences Advisory Committee in April 2014 to provide input on U.S. fusion program priorities by October 2014. According to the officials, DOE will consider the committee's input in developing a strategic plan for the U.S. fusion program, and it hopes to finalize a plan no later than the January 2015 deadline set by the House and Senate Appropriations Committees. However, DOE officials could not provide a specific date when they expect to complete the strategic plan.

We have previously reported that strategic planning is a leading management practice organizations can employ to define their mission and goals; help clarify priorities; address management and other

[50]The Fusion Energy Sciences Advisory Committee provides independent advice to the Director of DOE's Office of Science on complex scientific and technological issues that arise in the planning, implementation, and management of the fusion energy sciences program. Committee members are drawn from universities, national laboratories, and industrial companies.

challenges that threaten an agency's ability to meet its long-term strategic goals; align activities, core processes, and resources to accomplish those goals; and foster informed communication between an agency and its stakeholders.[51] Without a strategic plan for the overall U.S. fusion program that addresses DOE's plans for managing the impacts of U.S. ITER Project costs, the agency does not have information to

- involve and help create a basic understanding among stakeholders—including Congress and the U.S. fusion community—about its plans for balancing the competing demands that confront the program with the limited resources available;
- better ensure that the U.S. ITER Project and other U.S. fusion program activities are aligned to effectively and efficiently achieve the program's goals; and
- improve Congress's ability to weigh the potential trade-offs of different funding decisions for the U.S. ITER Project and the overall U.S. fusion program within a constrained budget environment.

Conclusions

DOE has taken some actions to address the factors that affect the reliability of its cost and schedule estimates for the U.S. ITER Project. However, more than 7 years and nearly $700 million after the ITER Agreement was signed, significant uncertainty remains about how much the U.S. ITER Project will cost, when it will be completed, and how DOE plans to manage the impact of the project's costs on the overall U.S. fusion program. DOE's current preliminary cost and schedule estimates met most characteristics of high-quality, reliable cost and schedule estimates, but the cost estimate was not fully credible. Specifically, the U.S. ITER Project Office did not include the most expensive U.S. hardware component in its sensitivity analysis and an independent cost estimate has not been conducted, which could result in DOE making decisions based on incomplete information and increase the risk of more cost growth.

It is important for DOE to set a performance baseline for the U.S. ITER Project in order to finalize its cost and schedule estimates, provide a bar against which the project's progress can be measured, and allow Congress to make well-informed funding decisions about the project within a constrained budget environment. However, DOE has not yet set

[51]For example, see GAO-13-115 and GAO-12-77.

a performance baseline for the U.S. ITER Project in part because the international project schedule is not reliable, a key factor that DOE can only partially influence. To its credit, DOE has taken several actions to push for a reliable international project schedule and improvements to ITER Organization project management. Nonetheless, the agency could do more to ensure the ITER Organization develops a reliable international project schedule and that ITER Organization project management deficiencies are addressed by making formal proposals to the ITER Council that address these issues and remaining vigilant about the timely implementation of the proposed improvements. Without a reliable international project schedule, DOE neither can propose a final, stable funding plan for the U.S. ITER Project, nor can it reasonably assure Congress that the project's cost will not continue to grow and the schedule will not continue to slip.

DOE has taken some steps to reduce the cost of the U.S. ITER Project and plan for the impact of the project's cost on the overall U.S. fusion program. However, even though there has been repeated direction from the House and Senate Appropriations Committees going back more than 2 years and a recommendation from its own advisory committee to do so, DOE has not yet completed a strategic plan for the overall U.S. fusion program. Strategic planning is a leading practice that can help organizations clarify priorities and address challenges that threaten their ability to meet long-term strategic goals. Completing a strategic plan for the overall U.S. fusion program would reduce uncertainty by addressing DOE's priorities for the program in light of U.S. ITER Project costs. Moreover, involving stakeholders, such as the Fusion Energy Sciences Advisory Committee, in the plan's development would increase stakeholder understanding of DOE's plans for balancing the competing demands that face the U.S. fusion program with the limited resources available. DOE is beginning the initial work on such a plan, but a similar effort that was started in 2012 did not result in a completed strategic plan for the U.S. fusion program, and the agency has not provided a specific date when it will complete its current effort. Without committing to a specific date, DOE may not complete a strategic plan for the U.S. fusion program in a timely manner and, without a completed strategic plan, DOE may face challenges ensuring that it has effectively aligned U.S. fusion program activities to achieve program goals. Further, Congress and the U.S. fusion community are likely to remain uncertain about DOE's plans for balancing the competing funding demands of the U.S. ITER Project and the rest of the U.S. fusion program.

Recommendations for Executive Action

To reduce uncertainty about the expected cost and schedule of the U.S. ITER Project and its potential impact on the U.S. fusion program, the Secretary of Energy should direct the Associate Director of the Office of Fusion Energy Sciences to take the following four actions:

- Direct the U.S. ITER Project Office to revise and update the project's cost estimate to meet all characteristics of high-quality, reliable cost estimates. Specifically, the U.S. ITER Project Office should revise the project's cost estimate to ensure it is credible by including a comprehensive sensitivity analysis that includes all significant cost elements and conducting an independent cost estimate;
- Develop and present at the next ITER Council meeting a formal proposal describing the actions DOE believes need to be taken to set a reliable international project schedule and improve ITER Organization project management. Continue to formally advocate for the timely implementation of those actions at each future ITER Council meeting until the ITER Council approves an updated international project schedule;
- Once the ITER Organization completes its reassessment of the international project schedule, use that schedule, if reliable, to propose a final, stable funding plan for the U.S. ITER Project, approve a performance baseline with finalized cost and schedule estimates, and communicate this information to Congress; and
- Set a specific date for completing, in a timely manner, a strategic plan for the U.S. fusion program that addresses DOE's priorities for the overall U.S. fusion program in light of U.S. ITER Project costs, and involve the Fusion Energy Sciences Advisory Committee in the development of the plan.

Agency Comments and Our Evaluation

We provided a draft copy of this report to DOE for review and comment. DOE provided written comments on the draft report on May 27, 2014, which are reproduced in appendix VI, and also provided technical and clarifying comments, which we incorporated as appropriate. DOE agreed with each of the report's recommendations and said it has taken steps or plans to take additional steps to fully implement them.

We are sending copies of this report to the Secretary of Energy, the appropriate congressional committees, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have any questions about this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our

Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix VII.

Frank Rusco
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

Our review assessed: (1) how and why the estimated cost and schedule for the U.S. International Thermonuclear Experimental Reactor (ITER) Project have changed since 2006; (2) the reliability of the Department of Energy's (DOE) current cost and schedule estimates for the U.S. ITER Project and the factors, if any, that have affected their reliability; and (3) the actions DOE has taken, if any, to reduce U.S. ITER Project costs and plan for their potential impact on the overall U.S. fusion program. To address these objectives and better understand the U.S. ITER Project, we reviewed the ITER Agreement, relevant laws, and DOE guidance and met with DOE and Department of State officials, representatives from the U.S. ITER Project Office, and fusion energy and project management experts from industry, DOE's national laboratories, and universities.

To determine how and why the estimated cost and schedule for the U.S. ITER Project have changed since 2006, we reviewed DOE and U.S. ITER Project Office documents. We assessed the reliability of the data on changes in the cost estimates by checking for obvious errors in accuracy and completeness; comparing the data with other sources of information; and interviewing DOE officials and U.S. ITER Project Office representatives who had knowledge of the data. We determined that DOE and the U.S. ITER Project Office's data on changes in the cost estimates for the U.S. ITER Project were sufficiently reliable for reporting on the reasons for the changes in the estimates. We also contacted the national audit offices of each of the six other ITER members to identify any audit reports they had issued on ITER, and we reviewed each report that was identified.

To evaluate the reliability of DOE's current cost and schedule estimates and the factors, if any, that have affected their reliability, we reviewed DOE's most recent cost and schedule estimates for the U.S. ITER Project—as developed by the U.S. ITER Project Office in August 2013—and DOE's internal peer review of those estimates. We also reviewed DOE's project management order and related guidance, as well as an October 2013 report to the ITER Council on the results of a management assessment of the ITER Organization. We assessed the reliability of DOE's current cost and schedule estimates by analyzing the August 2013 estimates against the best practices identified in GAO's *Cost Estimating* *and Assessment Guide (Cost Guide)* and *Schedule Assessment Guide (Schedule Guide)*.[1]

Specifically, we determined the reliability of the cost estimate by reviewing documentation DOE submitted for the cost estimate, interviewing U.S. ITER Project Office representatives who prepared the estimate, reviewing relevant sources, and comparing the information collected with the best practices identified in the *Cost Guide* to determine whether the cost estimate was (1) comprehensive, (2) accurate, (3) well-documented, and (4) credible.[2] After a review of all source data, we assessed the extent to which the cost estimate met these best practices by calculating the assessment rating of each criteria within the four characteristics on a five-point scale: not met = 1, minimally met = 2, partially met = 3, substantially met = 4, and fully met = 5.[3] Then, we took the average of the individual assessment ratings for the criteria to determine the overall rating for each of the four characteristics. The resulting average became the overall assessment as follows: not met = 0 to 1.4; minimally met = 1.5 to 2.4; partially met = 2.5 to 3.4; substantially met = 3.5 to 4.4; and fully met = 4.5 to 5.0. After conducting our initial analysis, we shared it with DOE officials and representatives from the U.S. ITER Project Office who developed the cost estimate to provide an opportunity for them to comment and identify reasons for observed shortfalls in cost estimating best practices. We took their comments and any additional information they provided and incorporated it into the assessments to finalize the scores for each characteristic and best practice.

We determined the reliability of the current schedule estimate for the U.S. ITER Project by assessing the characteristics of two selected subordinate

[1]GAO-09-3SP and GAO-12-120G.

[2]GAO designed the *Cost Guide* to be used by federal agencies to assist them in developing reliable cost estimates and also as an evaluation tool for existing cost estimates. To develop the *Cost Guide*, GAO cost experts assessed measures applied by cost-estimating organizations throughout the federal government and industry and considered best-practices for the development of reliable cost-estimates.

[3]Not met– DOE provided no evidence that satisfies any of the criterion; minimally met– DOE provided evidence that satisfies a small portion of the criterion; partially met– DOE provided evidence that satisfies about half of the criterion; substantially met– DOE provided evidence that satisfies a large portion of the criterion; and fully met– DOE provided complete evidence that satisfies the entire criterion.

schedules—the central solenoid modules schedule and the tokamak cooling water system schedule—that are used as inputs to the integrated master schedule. We selected these two schedules because they are the largest two hardware items, in terms of value, that the United States is responsible for contributing to ITER. We determined whether the schedules were (1) comprehensive, (2) well-constructed, (3) credible, and (4) controlled by reviewing documentation DOE submitted for the U.S. ITER Project schedule estimate, interviewing U.S. ITER Project Office representatives who developed the estimate, reviewing relevant sources, and comparing the information collected against the criteria for each of these characteristics identified in the *Schedule Guide*.[4] We also analyzed schedule metrics as a part of that analysis to highlight potential areas of strengths and weaknesses against each of our four characteristics of a reliable schedule. In order to assess each schedule against the four characteristics and their accompanying 10 best practices, we traced and verified underlying support and determined whether the U.S. ITER Project Office provided sufficient evidence to satisfy the criterion and assigned a score based on the same five-point scale we used in our analysis of the cost estimate. Then, we took the average of the individual assessment ratings to determine the overall rating for each of the characteristics, also using the same scale we used in our analysis of the cost estimate. After conducting our initial analysis, we shared it with DOE officials and representatives from the U.S. ITER Project Office who developed the schedule estimate to provide an opportunity for them to comment and identify reasons for observed shortfalls in schedule management best practices. We took their comments and any additional information they provided and incorporated it into the assessments to finalize the scores for each characteristic and best practice. By examining the two subordinate schedules against our guidance, we conducted a reliability assessment on each of the schedules and incorporated our findings on reliability limitations in the analysis of each subordinate schedule. We were also able to use the results of the two subordinate schedules to provide insight into the health of the integrated master schedule since the same strengths and weaknesses of the subordinate schedules would transfer to the master schedule. We determined that the schedules were

[4]The *Schedule Guide* is intended to expand on the scheduling concepts introduced in the *Cost Guide* by providing 10 best practices to help managers and auditors ensure that the program schedule is reliable. The reliability of the schedule determines the credibility of the program's forecasted dates for decision making.

sufficiently reliable for our reporting purposes, and our report notes the instances where reliability concerns affect the quality of the schedules.

To examine the actions DOE has taken, if any, to reduce U.S. ITER Project costs and plan for their potential impact on the overall U.S. fusion program, we reviewed DOE and U.S. ITER Project Office documents on actions taken to reduce U.S. ITER Project costs, interviewed DOE program officials about the status of their efforts to complete a strategic plan for the U.S. fusion program, and reviewed meeting records of DOE's Fusion Energy Sciences Advisory Committee.[5] We also reviewed our prior work on leading practices in federal strategic planning for agency divisions, programs, or initiatives,[6] as well as the House and Senate Appropriations Committees' direction to DOE in the explanatory statements for the fiscal year 2012 and fiscal year 2014 energy and water development appropriation acts to submit a 10-year strategic plan for the U.S. fusion program. Further, we summarized the results of semistructured interviews with 10 experts in fusion energy and the management of large scientific research projects. To select these experts, we first identified 105 experts by reviewing the results of a literature search; congressional hearings; National Academies of Science publications; membership lists for the Fusion Energy Sciences Advisory Committee, the ITER Council Management Advisory Committee,[7] the ITER Council Science and Technology Advisory Committee,[8] and DOE's internal peer reviews of the U.S. ITER Project; and recommendations from other fusion energy experts we interviewed. From this list, we then

[5]The Fusion Energy Sciences Advisory Committee provides independent advice to the Director of DOE's Office of Science on complex scientific and technological issues that arise in the planning, implementation, and management of the fusion energy sciences program. Committee members are drawn from universities, national laboratories, and industrial companies.

[6]For example, see GAO-13-115 and GAO-12-77.

[7]The ITER Council Management Advisory Committee, at the request of the ITER Council, reviews and evaluates matters of strategic management importance to the ITER project and makes recommendations to the ITER Council to facilitate the successful development of the ITER Organization and the successful execution of the ITER construction project.

[8]The ITER Council Science and Technology Advisory Committee, at the request of the ITER Council, reviews and advises the ITER Council on science and technology issues concerning the implementation of the ITER project.

used a multistep process to select 10 experts.[9] To ensure coverage and a range of perspectives, we selected fusion energy and large scientific project management experts from industry, DOE's national laboratories, and universities. We conducted semistructured interviews with the 10 selected experts using a standard set of questions and analyzed their responses, grouping them into overall themes. We summarized the results of our analysis and then asked DOE program officials for their views on actions suggested by multiple stakeholders to potentially reduce U.S. ITER Project costs or improve U.S. ITER Project management. Not all 10 of the experts answered all of our questions. The views expressed by experts do not represent the views of GAO. Appendix II lists the names and affiliations of the 10 experts we interviewed.

We conducted this performance audit from June 2013 to June 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[9]We initially selected 15 experts using this multistep process. We eliminated 3 of the initially selected experts because they were working directly on the U.S. ITER Project, either for DOE or the U.S. ITER Project Office. Another expert we initially selected told us she did not have sufficient knowledge of the U.S. ITER Project to participate in our review, and we were unable to get in contact with one other expert we initially selected, so we eliminated both experts and ended up with our final list of 10 experts. We determined that the remaining 10 experts still ensured sufficient coverage and a range of perspectives.

Appendix II: List of Experts

- Dr. Riccardo Betti, University of Rochester
- Dr. Aesook Byon, Brookhaven National Laboratory (retired)
- Dr. Richard W. Callis, General Atomics
- Dr. Adam Cohen, Princeton Plasma Physics Laboratory
- Dr. Ray Fonck, University of Wisconsin—Madison
- Dr. Charles M. Greenfield, General Atomics
- Dr. Martin Greenwald, Massachusetts Institute of Technology
- Dr. Richard Hawryluk, Princeton Plasma Physics Laboratory
- Dr. Robert Iotti, CH2M Hill (retired)
- Dr. Dale Meade, Princeton Plasma Physics Laboratory (retired)

Appendix III: Status of U.S. Hardware Components for the International Thermonuclear Experimental Reactor (ITER) as of August 2013

Dollars in millions

U.S. hardware component	Purpose	Design status	Estimate to complete[a]	Estimated final delivery date	Procurement arrangement[b] reached
Central solenoid magnet system	Confines, shapes, and controls the plasma inside ITER's vacuum vessel.	Final design[c, f]	$252.1	April 2019	Yes
Diagnostics (15% of ITER diagnostics)	Provides the measurements necessary to control, evaluate, and optimize plasma performance and to further the understanding of plasma physics.	Preliminary design[d]	$112.2	September 2024	Yes
Disruption mitigation systems (up to a capped value)	Limits the effect of plasma current disruptions to the tokamak vacuum vessel and other components.	Preliminary design	$19.4	June 2019	No
Electron cyclotron heating transmission lines	Brings additional heat to the plasma and deposits heat in specific areas of the plasma to minimize instabilities.	Final design	$90.4	November 2024	Yes
Ion cyclotron heating transmission lines	Brings additional heat to the plasma.	Preliminary design	$98.1	August 2026	Yes
Pellet injection system	Provides efficient fueling and delivers hydrogen, deuterium, or a deuterium/tritium mixture as required by plasma operations.	Preliminary design	$39.0	July 2026	No
Roughing pump system	Exhausts certain parts of the ITER machine.	Conceptual design[e]	$36.0	September 2021	No
Steady state electrical network (75% of total network)	Supplies the electricity needed to operate the entire ITER plant, including offices and the operational facilities.	Design complete[f]	$39.2	March 2016	Yes
Tokamak cooling water system	Manages temperatures generated during the operation of the tokamak.	Final design[f]	$463.4	September 2029	Yes
Tokamak exhaust processing system	Separates tokamak exhaust gases into a stream containing only hydrogen isotopes and a stream containing only non-hydrogen gases.	Preliminary design	$107.0	April 2030	No
Toroidal field conductor (8% of total conductor)	Part of toroidal field magnet that confines, shapes, and controls the plasma inside the ITER vacuum vessel.	Design complete[f]	$10.3	July 2015	Yes
Vacuum auxiliary systems	Creates low density in ITER's vacuum vessel and connected vacuum components.	Preliminary design[f]	$58.7	September 2023	Yes

Source: GAO analysis of DOE documents.

[a]The "Estimate to complete" refers to the latest estimate of budget required to finish the work remaining. The estimates listed in this column are burdened, meaning they include direct and indirect costs, and unescalated, meaning they represent current year dollar values.

[b]"Procurement arrangements" govern the procurement of plant systems, components, or site construction, detailing all the necessary technical specifications and management requirements.

[c]"Final design" is the last stage of design development prior to implementation. At the final design stage, the project scope should be finalized and changes should be permitted only for compelling reasons.

[d]The "Preliminary design" stage initiates the process of converting concepts to a more detailed design whereby more detailed and reliable cost and schedule estimates are developed. This stage of the design is complete when it provides sufficient information to support development of the performance baseline.

[e]The "Conceptual design" process must ensure that a solution or alternatives are responsive to an approved need, and also technically achievable, affordable, and will provide the best value to the agency.

[f]Certain parts of these components are already being fabricated or being prepared for fabrication.

Appendix IV: GAO Assessment of DOE's Current (August 2013) Cost Estimate for the U.S. International Thermonuclear Experimental Reactor (ITER) Project Compared with Best Practices

Characteristic	Overall assessment[a]	Best practice	Individual assessment
Comprehensive	*Substantially met*	The cost estimate includes all life-cycle costs.	*Partially met*
		The cost estimate completely defines the program, reflects the current schedule, and is technically reasonable.	*Substantially met*
		The cost estimate work breakdown structure is product-oriented, traceable to the statement of work/objective, and at an appropriate level of detail to ensure that cost elements are neither omitted nor double-counted.	*Substantially met*
		The estimate documents all cost-influencing ground rules and assumptions.	*Substantially met*
Well-documented	*Substantially met*	The documentation should capture the source data used, the reliability of the data, and how the data were normalized.	*Substantially met*
		The documentation describes in sufficient detail the calculations performed and the estimating methodology used to derive each element's cost.	*Substantially met*
		The documentation describes step by step how the estimate was developed so that a cost analyst unfamiliar with the program could understand what was done and replicate it.	*Substantially met*
		The documentation discusses the technical baseline description and the data in the baseline is consistent with the estimate.	*Fully met*
		The documentation provides evidence that the cost estimate was reviewed and accepted by management.	*Substantially met*
Accurate	*Substantially met*	The cost estimate results are unbiased, not overly conservative or optimistic and based on an assessment of most likely costs.	*Partially met*
		The estimate has been adjusted properly for inflation.	*Substantially met*
		The estimate contains few, if any, minor mistakes.	*Fully met*
		The cost estimate is regularly updated to reflect significant changes in the program so that it is always reflecting current status.	*Substantially met*
		Variances between planned and actual costs are documented, explained, and reviewed.	*Substantially met*
		The estimate is based on a historical record of cost estimating and actual experiences from other comparable programs.	*Substantially met*
		The estimating technique for each cost element was used appropriately.	*Partially met*
Credible	*Partially met*	The cost estimate includes a sensitivity analysis that identifies a range of possible costs based on varying major assumptions, parameters, and data inputs.	*Partially met*
		A risk and uncertainty analysis was conducted that quantified the imperfectly understood risks and identified the effects of changing key cost driver assumptions and factors.	*Partially met*
		Major cost elements were cross-checked to see whether results were similar.	*Partially met*

Characteristic	Overall assessment[a]	Best practice	Individual assessment
		An independent cost estimate was conducted by a group outside the acquiring organization to determine whether other estimating methods produce similar results.	*Partially met*

Source: GAO analysis of DOE data.

[a]Not met– DOE provided no evidence that satisfies any of the criterion; minimally met– DOE provided evidence that satisfies a small portion of the criterion; partially met– DOE provided evidence that satisfies about half of the criterion; substantially met– DOE provided evidence that satisfies a large portion of the criterion; and fully met– DOE provided complete evidence that satisfies the entire criterion.

Appendix V: GAO Assessment of DOE's Current (August 2013) Schedule Estimates for the Two Largest Hardware Items of the U.S. International Thermonuclear Experimental Reactor (ITER) Project Compared with Best Practices

	Overall assessment[a]			Individual assessment	
Characteristic	**Central solenoid modules**	**Tokamak cooling water system**	**Best practice**	**Central solenoid modules**	**Tokamak cooling water system**
Comprehensive	*Fully met*	*Fully met*	Capturing all activities.	*Fully met*	*Fully met*
			Assigning resources to all activities.	*Substantially met*	*Substantially met*
			Establishing the durations of all activities.	*Fully met*	*Fully met*
Well-constructed	*Substantially met*	*Substantially met*	Sequencing all activities.	*Substantially met*	*Substantially met*
			Confirming that the critical path is valid.	*Substantially met*	*Substantially met*
			Ensuring reasonable total float.	*Partially met*	*Partially met*
Credible	*Substantially met*	*Substantially met*	Verifying that the schedule is traceable horizontally and vertically.	*Partially met*	*Partially met*
			Conducting a schedule risk analysis.	*Substantially met*	*Substantially met*
Controlled	*Substantially met*	*Substantially met*	Updating the schedule with actual progress and logic.	*Substantially met*	*Fully met*
			Maintaining a baseline schedule.	*Partially met*	*Partially met*

Source: GAO analysis of DOE data.

[a]Not met– DOE provided no evidence that satisfies any of the criterion; minimally met– DOE provided evidence that satisfies a small portion of the criterion; partially met– DOE provided evidence that satisfies about half of the criterion; substantially met – DOE provided evidence that satisfies a large portion of the criterion; and fully met– DOE provided complete evidence that satisfies the entire criterion.

Appendix VI: Comments from the Department of Energy

Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

May 27, 2014

Mr. Frank Rusco
Director, Natural Resources and Environment
Government Accountability Office
441 G Street
Washington, DC 20548

Dear Mr. Rusco:

Thank you for the opportunity to comment on the Government Accountability Office (GAO) draft report entitled, "Fusion Energy: Actions Needed to Finalize Cost and Schedule Estimates for U.S. Contributions to an International Experimental Reactor" (GAO-14-499). We found the report balanced in its discussions of the status of the U.S. and international parts of ITER, the efforts of the Office of Science (SC) and the U.S. ITER Project Office to manage the U.S Contributions to ITER Project, and the current managerial and technical challenges. We appreciate GAO's thoroughness and effective coordination of its assessment.

The Department agrees with the four recommendations for Executive Action that the GAO identified in its draft report and provides comments on each below. In addition, an Enclosure provides detailed comments on specific points throughout the report.

Recommendation 1: "Direct the U.S. ITER Project Office to revise and update the project's cost estimate to meet all characteristics of high quality, reliable cost estimates. Specifically, the U.S. ITER Project Office should revise its cost estimate to ensure they are credible by including a comprehensive sensitivity analysis that includes all significant cost elements and conducting an independent cost estimate."

We agree. Conducting a sensitivity analysis and an independent cost estimate/review is consistent with the requirements set forth in DOE Order 413.3B, "Program and Project Management for the Acquisition of Capital Assets," for the establishment of the scope, cost, and schedule performance baseline as part of Critical Decision 2 for the U.S. Contributions to ITER Project.

Recommendation 2: "Develop and present at the next ITER Council Meeting a formal proposal describing the actions DOE believes need to be taken to set a reliable international project schedule and improve ITER Organization project management. Continue to formally advocate for the timely implementation of those actions at each future ITER Council meeting until the ITER Council approves an updated international project schedule."

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We believe that this recommendation has essentially been accomplished. The U.S. has advocated using two ITER forums—the ITER Management Advisory Committee (MAC) and the ITER Council (IC)—for improving the ITER Organization's (IO) project management capabilities. During two MAC meetings in 2013, the U.S. senior MAC member (now the ITER Council Chair) led discussions resulting in clear guidance to the IO that set in motion efforts to prepare a credible international project schedule. This action was recorded in the IC-13 Record of Decisions. The U.S. will continue to be an advocate of improving the IO's project management capabilities and of working with the IO and the other ITER Members in the development of a project schedule that is credible. It is anticipated that the IO will present its proposed schedule to the ITER Council in June 2015.

Recommendation 3: "Once the ITER Organization completes its reassessment of the international project schedule, use that schedule, if reliable, to propose a final, stable funding plan for the U.S. ITER Project, approve a performance baseline with finalized cost and schedule estimates, and communicate this information to Congress."

We agree. We are awaiting the completion of the international project schedule.

Recommendation 4: "Set a specific date for completing, in a timely manner, a strategic plan for the U.S. fusion program that addresses DOE's priorities for the overall U.S. fusion program in light of U.S. ITER Project costs, and involve the Fusion Energy Sciences Advisory Committee in the development of the plan."

We agree. On April 8, 2014, the Acting Director of the Office of Science issued a charge to the Fusion Energy Sciences Advisory Committee to advise the Office of Science on a portfolio that will ensure that the U.S. is in a position to exert long-term leadership in fusion energy sciences research. This report, due October 1, 2014, is responsive to congressional direction in the FY 2014 Omnibus Appropriations Act.

Again, we very much appreciate the opportunity to provide comments on the draft report. If you have any questions, please contact Dr. Edmund Synakowski, Associate Director of the Office of Science for Fusion Energy Sciences, at (301) 903-4941.

Sincerely,

Patricia M. Dehmer
Acting Director
Office of Science

Enclosure

Appendix VII: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco, (202) 512-3841 or ruscof@gao.gov

Staff Acknowledgments

In addition to the individual named above, other key contributors to this report were Dan Haas, Assistant Director; David Marroni; Andrew Moore; and Jacqueline Wade. Important contributions were also made by Cheryl Arvidson, Brian Bothwell, Nikki Clowers, Elizabeth Curda, R. Scott Fletcher, Cindy Gilbert, Jason Lee, Karen Richey, and Barbara Timmerman.

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