United States Government Accountability Office

Report to Congressional Committees

April 2014

NUCLEAR WEAPONS

Technology Development Efforts for the Uranium Processing Facility

GAO-14-295

GAO Highlights

Highlights of GAO-14-295, a report to congressional committees

April 2014

NUCLEAR WEAPONS

Technology Development Efforts for the Uranium Processing Facility

Why GAO Did This Study

NNSA conducts enriched uranium activities—including producing components for nuclear warheads and processing nuclear fuel for the U.S. Navy—at the Y-12 National Security Complex in Tennessee. NNSA has identified key shortcomings in the Y-12 plant's current uranium operations, including rising costs due to the facility's age. In 2004, NNSA decided to build a more modern facility—the UPF—which will use nine new technologies that may make enriched uranium activities safer and more efficient.

In November 2010, GAO reported on the UPF and identified risks associated with the use of new technologies (GAO-11-103). The Fiscal Year 2013 National Defense Authorization Act mandated that GAO assess the UPF quarterly. This is the third report, and it assesses (1) additional technology risks, if any, since GAO's November 2010 report and (2) NNSA's actions to address any risks. GAO reviewed NNSA and contractor documents and interviewed NNSA officials and contractor personnel.

GAO is not making any new recommendations. However, NNSA should continue actions to address the two recommendations—which NNSA generally agreed with—in GAO's November 2010 report related to ensuring that technologies reach optimal levels of maturity prior to critical project decisions. In commenting on a draft of this report, NNSA said its current technology maturation guidance is adequate.

View GAO-14-295. For more information, contact David C. Trimble at (202) 512-3841 or trimbled@gao.gov.

What GAO Found

GAO has identified five additional risks since its November 2010 report (GAO-11-103) associated with using new technologies in the National Nuclear Security Administration's (NNSA) Uranium Processing Facility (UPF), which is to be built in three interrelated phases. These risks and the steps that NNSA is taking to address them include the following:

- **Technology integration risks**. An August 2013 UPF independent peer review team concluded that the microwave casting technology—a process that uses microwave energy to melt and form uranium into various shapes—has not been demonstrated in a relevant environment, which is a requirement to reach a key technology maturity milestone. To address this risk, NNSA officials said they plan to accelerate the procurement and environmental testing of a microwave casting prototype.

- **Technology development risks**. A key insulation material planned as a nuclear safety control during uranium casting failed a series of performance tests in fiscal year 2013. According to UPF contractor representatives, this risk is now the project's most significant technological risk. To address this risk, these representatives said they are trying to identify a replacement insulation material and exploring the use of a different safety control.

- **Technology transition risks**. NNSA is currently evaluating an alternative technology to the UPF's baseline uranium purification technology, which has been under development since 2005. The alternative technology may generate less radioactive waste and may be more efficient to operate than the baseline technology. If NNSA switches technologies, NNSA officials said that the UPF contractor (1) will have to redesign the processing area and equipment; (2) may have to add utilities; and (3) will have to revise the UPF's nuclear safety analysis, creating the potential for further project risks.

- **Performance assurance risks**. NNSA stopped development efforts on a key machining technology, which is part of the UPF's second phase. As a result, NNSA may not have optimal assurance that the technology will work as intended before starting construction. However, in January 2014, NNSA began (1) reevaluating alternatives to the UPF that may not include machining operations and (2) developing a uranium infrastructure strategy, which is a framework for how NNSA will maintain all uranium capabilities into the future. It is too soon to determine if the draft uranium strategy, scheduled to be issued in April 2014, will outline actions to address this risk.

- **Funding risk**. Instead of using UPF project funds, NNSA has primarily funded UPF technology development activities from a limited research and development program. As a result of budget constraints in this program, for fiscal year 2014, 7 of the 19 technology projects the UPF contractor considered priority were not funded. Per a corrective action plan recently developed, the UPF Assistant Project Manager for Technology is responsible for determining which technology development activities should be funded directly with UPF project funds and is to prepare a cost estimate for those activities. This official said he expects to complete these estimates in March 2014.

Contents

Abbreviations

B&W	Babcock & Wilcox Technical Services Y-12, LLC
CD	critical decision
CNS	Consolidated Nuclear Security, LLC
DER/ER	direct electrolytic reduction and electrolytic refining
DOD	Department of Defense
DOE	Department of Energy
NASA	National Aeronautics and Space Administration
NNSA	National Nuclear Security Administration
PDRD	plant-directed research and development
TRL	Technology Readiness Level
UNH	uranyl nitrate hexahydrate
UPF	Uranium Processing Facility

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

April 18, 2014

Congressional Committees

The Y-12 National Security Complex in Oak Ridge, Tennessee, is the National Nuclear Security Administration's (NNSA) site for conducting enriched uranium activities, producing uranium-related components for nuclear warheads and bombs, and processing nuclear fuel for the U.S. Navy.[1] NNSA is a separately organized agency within the Department of Energy (DOE). According to NNSA documents, the Y-12 plant's current enriched uranium operations, which are conducted in four separate facilities, have key shortcomings including: (1) an inefficient work flow; (2) continually rising operations and maintenance costs due to facility age; and (3) hazardous processes that could expose workers to radiological contamination, among other things.

To address these shortcomings, in 2004, NNSA decided to construct a new Uranium Processing Facility (UPF).[2] According to NNSA documents, the UPF will consist of a single, consolidated facility less than half the size of existing facilities. As NNSA consolidates its facilities, the agency plans to develop several advanced technologies to make uranium processing and component production safer, more effective, and more efficient. Uranium processing uses chemicals and other means to recover enriched uranium from multiple sources in NNSA's inventory. Component production includes enriched uranium metalworking and other processes to assemble new or refurbished nuclear weapons components. In November 2010, we reported on the extent to which the UPF is to use

[1]NNSA owns the buildings, equipment, and the components produced at the Y-12 plant, but the site is operated under contract to NNSA by Babcock & Wilcox Technical Services Y-12, LLC (B&W), a partnership of the Babcock & Wilcox Company and Bechtel National, Inc. Beginning in July 2014, the Y-12 plant will be operated under contract to NNSA by Consolidated Nuclear Security, LLC, (CNS) which is comprised of member companies Bechtel National, Inc., Lockheed Martin Services, Inc., ATK Launch Systems Inc., and SOC LLC, with Booz Allen Hamilton, Inc., as a teaming subcontractor.

[2]B&W is the contractor managing the UPF design and has subcontracted portions of the design work to four other contractors. In July 2014, CNS will become the contractor managing the UPF design.

new, experimental technologies, and resultant risks.[3] Specifically, we found that

- NNSA is using a systematic approach to assess the maturity of its new technologies; and
- NNSA may not have assurance that all technologies will work as intended, and the UPF could have to revert to existing or alternative technologies, which could result in design changes, higher costs, and schedule delays.

At the request of the Senate Appropriations Committee, Subcommittee on Energy and Water Development and, in accordance with the Fiscal Year 2013 National Defense Authorization Act, GAO is mandated to submit quarterly reports on the UPF.[4] We issued our first report in July 2013, which found that key assumptions contained in multiple cost estimates proved to be inaccurate and were the primary factors that contributed to the UPF's cost increase from $1.1 billion in 2004 to $6.5 billion in 2012.[5] We issued our second report in October 2013, which found that the Defense Nuclear Facilities Safety Board—an independent executive branch agency created by Congress in 1988 to assess safety conditions at DOE's defense nuclear facilities—had identified safety concerns with the UPF's design, and that NNSA had taken actions to address most of these concerns.[6] The objectives for this third quarterly report are to identify (1) additional risks, if any, since our November 2010 report of using new technologies associated with the UPF and (2) NNSA's actions, if any, to address those risks.

To do this work, we reviewed DOE's key project management order that establishes project management requirements, including those for technology development, as well as the order's accompanying technology

[3]GAO, *Nuclear Weapons: National Nuclear Security Administration's Plans for Its Uranium Processing Facility Should Better Reflect Funding Estimates and Technology Readiness,* GAO-11-103 (Washington, D.C.: Nov. 19, 2010).

[4]The National Defense Authorization Act for Fiscal Year 2013 renamed UPF as the Uranium Capabilities Replacement Project. NNSA uses the new nomenclature in its fiscal year 2014 budget request.

[5]GAO, *Nuclear Weapons: Factors Leading to Cost Increases with the Uranium Processing Facility*, GAO-13-686R (Washington, D.C.: July 12, 2013).

[6]GAO, *Nuclear Weapons: Information on Safety Concerns with the Uranium Processing Facility*, GAO-14-79R (Washington, D.C.: Oct. 25, 2013).

development guidance. In addition, we reviewed UPF technology maturation plans, UPF technology risk assessments, and UPF technology risk reduction plans. We also reviewed an August 2013 report by an NNSA independent peer review team that examined various aspects of the UPF project, including technology development. The peer review report contained multiple technology development related findings and recommendations, and we also reviewed NNSA's corrective action plan for addressing these findings and recommendations. We interviewed UPF contractor representatives responsible for managing technology development efforts, as well as NNSA officials who oversee this process. We visited the Y-12 plant and received technology development related briefings from NNSA officials and UPF contractor representatives and visited the UPF's technology research and development facilities.

We conducted this performance audit from August 2013 to April 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.

Background

In 1990, we first designated DOE program and contract management as an area at high risk of fraud, waste, abuse, and mismanagement.[7] In January 2009, to recognize the progress made at DOE's Office of Science, we narrowed the focus of the high-risk designation to two DOE program elements, NNSA and the Office of Environmental Management.[8] In February 2013, our most recent high-risk update, we narrowed this focus to major projects (i.e., projects over $750 million) at NNSA and the Office of Environmental Management.[9] DOE has taken some steps to address our concerns, including developing an order in 2010 (Order 413.3B) that defines DOE's project management principles and process for executing a capital asset construction project, which can include

[7]GAO, *Government Financial Vulnerability: 14 Areas Needing Special Review,* GAO/OCG-90-1 (Washington, D.C.: Jan. 23, 1990). We update our high-risk list every 2 years.

[8]GAO, *High-Risk Series: An Update*, GAO-09-271 (Washington, D.C.: January 2009).

[9]GAO, *High-Risk Series: An Update*, GAO-13-283 (Washington, D.C.: February 2013).

building or demolishing facilities or constructing remediation systems.[10] NNSA is required by DOE to manage the UPF construction project in accordance with this order. The project management process defined in Order 413.3B requires DOE projects to go through five management reviews and approvals, called “critical decisions” (CD), as they move forward from project planning and design to construction to operation. The CDs are as follows:

- CD 0: Approve a mission-related need.
- CD 1: Approve an approach to meet a mission need and a preliminary cost estimate.
- CD 2: Approve the project’s cost, schedule and scope targets.
- CD 3: Approve the start of construction.
- CD 4: Approve the start of operations.

In August 2007, the Deputy Secretary of Energy originally approved CD 1 for the UPF with a cost range of $1.4 to $3.5 billion. In June 2012, the Deputy Secretary of Energy reaffirmed CD 1 for the UPF with a cost range of $4.2 to $6.5 billion and approved a phased approach to the project, which deferred significant portions of the facility’s original scope.[11] According to NNSA documents, this deferral was due, in part, to the project’s multibillion dollar increased cost estimate and to accelerate the completion of the highest priority scope. In July 2013, NNSA decided to combine CD 2 and CD 3 for the first phase of UPF.[12] Table 1 shows the UPF’s phases, scope of work, cost estimate, as of June 2012, and proposed start of operations.

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

[11]Order 413.3B requires reaffirmation if the original CD 1 cost range increases by more than 50 percent.

[12]According to the UPF Federal Project Director, there were two reasons for this decision: (1) NNSA’s delay in awarding the combined management and operating contract for the Y-12 plant and the Pantex plant in Texas and (2) NNSA needed to conduct further analysis to help ensure an optimized UPF project execution strategy.

Table 1: Uranium Processing Facility (UPF) Phases, Scope of Work, Cost Estimate, as of June 2012, and Proposed Start of Operations

Phase	Scope of work	Cost estimate as of June 2012	Proposed start of operations
Phase I	UPF building exterior, all support systems, and Building 9212 capabilities (uranium purification and casting)	$4.2 to $6.5 billion	2025
Phase II	Building 9215 capabilities (machining) and Building 9998 capabilities (product certification)	NNSA has not established a cost estimate.	from 2030 to 2036
Phase III	Building 9204-2E capabilities (assembly and dismantlement)	NNSA has not established a cost estimate.	from 2030 to 2036

Source: NNSA.

However, the future status of the UPF project and the process by which enriched uranium operations at the Y-12 plant will be modernized are unclear. NNSA has recently decided to: (1) delay later UPF phases, (2) assess options other than the UPF for enriched uranium operations at the Y-12 plant, (3) change a key technological requirement for the UPF, and (4) develop a strategy for how NNSA will maintain the Y-12 plant's uranium capabilities into the future. Specifically:

- **NNSA is delaying UPF Phase II and Phase III a minimum of 2 years.** In a December 2013 testimony before the Defense Nuclear Facilities Safety Board, the NNSA Acting Administrator said that the agency does not expect to move out the facilities that house machining operations (Building 9215) as well as assembly and dismantlement operations (Building 9204-2E) until 2038 due primarily to budget constraints. NNSA previously estimated that these capabilities would be operational in the UPF no later than 2036.
- **NNSA is currently evaluating alternatives to the UPF.** In early January 2014, NNSA began to consider options other than the UPF for enriched uranium operations at the Y-12 plant because, according to the UPF Federal Project Director, the project is facing budget constraints, rising costs, and competition from other high-priority projects within NNSA—such as the planned B61 bomb and W78/88 warhead nuclear weapon life extension projects. NNSA has initiated a formal analysis of UPF alternatives—an analytical comparison of the operational effectiveness, costs, and suitability of proposed solutions to address a mission need. According to the UPF Federal Project Director, the analysis of alternatives, which is scheduled to be completed by April 15, 2014, will include a potential solution for

replacing only uranium purification and casting capabilities (Building 9212) by July 2025 at a cost that does not exceed $6.5 billion.[13] According to the NNSA Acting Administrator, NNSA does not plan to continue full operations in Building 9212, which has been operational for over 60 years, past 2025 because the building does not meet modern safety standards, and increasing equipment failure rates present challenges to meeting required production targets. While NNSA is undertaking the analysis of alternatives, the UPF project team is currently (1) delaying the start of approximately $300 million in site preparation and long lead procurement activities and (2) will no longer complete engineering work to have the UPF's design reach the 90 percent complete milestone by August 2014, as previously planned.

- **NNSA is currently evaluating alternatives for a key uranium purification technology originally planned for UPF Phase I, which now may be part of UPF Phase II**. In late January 2014, NNSA decided to consider alternatives from its baseline uranium purification technology—which was to be part of UPF Phase I scope and had been under development since 2005—to a new technology, according to the UPF Federal Project Director. NNSA believes the new technology will require less space in the UPF and be more efficient to operate. In early February 2014, NNSA directed the UPF contractor to suspend design efforts in two UPF processing areas impacted by the potential technology change. Furthermore, NNSA is now considering installing this new technology as part of UPF Phase II scope, pending the results of further analysis.
- **NNSA is currently developing a Uranium Infrastructure Strategy for the Y-12 plant.** In early February 2014, the NNSA Deputy Administrator for Defense Programs directed his staff to develop a Uranium Infrastructure Strategy, which establishes the framework of how NNSA will maintain the Y-12 plant's uranium mission capabilities into the future. Key aspects that are to be considered during the strategy's development include, among other things: (1) an evaluation of the uranium purification capabilities and the throughput needed to support requirements for life extension programs and nuclear fuel for the U.S. Navy; (2) an evaluation of the alternatives to the UPF that prioritizes replacement capabilities by risk to nuclear safety, security, and mission continuity; (3) an identification of existing infrastructure as

[13] During the June 2012 CD 1 reaffirmation process, NNSA analyzed six alternatives to meet its enriched uranium processing mission need. NNSA ranked the alternative of a smaller building containing only Building 9212 capabilities fifth out of the six alternatives.

a bridging strategy until replacement capability is available in new infrastructure. A draft of the strategy is due to the Deputy Administrator by early April 2014.

To assess the maturity of new technologies, DOE and NNSA adopted the use of Technology Readiness Levels (TRL). DOE took this action in response to our March 2007 report[14] that recommended that DOE develop a consistent approach to assess the extent to which new technologies have been demonstrated to work as intended in a project before starting construction.[15] As shown in table 2, TRLs start with TRL 1, which is the least mature; through TRL 4, in which the technology is validated in a laboratory environment; to TRL 9—the highest maturity level, where the technology as a total system is fully developed, integrated, and functioning successfully in project operations.

Table 2: Definitions of Technology Readiness Levels (TRL)

TRL	Definition
TRL 1	Basic principles observed
TRL 2	Concept/applications formulated
TRL 3	Proof of concept
TRL 4	Validated in a laboratory environment
TRL 5	Validated in a relevant environment
TRL 6	Subsystem demonstrated in a relevant environment
TRL 7	Subsystem demonstrated in an operational environment
TRL 8	Total system tested and demonstrated
TRL 9	Total system used successfully in project operations

Sources: GAO analysis of DOD, NASA, and DOE data.

In 2009, DOE first issued guidance on the use of TRLs.[16] In our November 2010 report,[17] we found that DOE's TRL guidance was not

[14]GAO, *Department of Energy: Major Construction Projects Need a Consistent Approach for Assessing Technology Readiness to Help Avoid Cost Increases and Delays*, GAO-07-336 (Washington, D.C.: Mar. 27, 2007).

[15] TRLs were pioneered by the National Aeronautics and Space Administration (NASA) and have been used by the Department of Defense (DOD) and other agencies in their research and development efforts for several years.

[16]DOE, *Technology Readiness Assessment Guide*, DOE G 413.3—4A (Washington, D.C.: Oct. 12, 2009).

always consistent with best practices followed by other federal agencies, as well as with our prior recommendations. Specifically, DOE's TRL guidance recommended that new technologies reach TRL 6—the level where a prototype is demonstrated in a relevant or simulated environment and partially integrated into the system—at the start of construction (CD 3). However, best practices followed by other federal agencies and our prior recommendations state that new technologies should reach TRL 7—the level where a prototype is demonstrated in an operational environment, has been integrated with other key supporting subsystems, and is expected to have only minor design changes—at the start of construction. In our November 2010 report, we recommended that the Secretary of Energy evaluate where DOE's guidance for gauging the maturity of new technologies is inconsistent with best practices and, as appropriate, revise the guidance to be consistent with federal agency best practices.[18] In September 2011, DOE issued its revised TRL guidance, but the guidance does not incorporate federal agency best practices and is not fully responsive to our recommendation.[19] Specifically, DOE's revised TRL guidance continues to recommend that new technologies reach TRL 6 at the start of construction, while stating that reaching TRL 7 at the start of construction is a recognized best practice.

In November 2010, we reported that NNSA was developing 10 advanced uranium processing and nuclear weapon components production technologies for the UPF. [20] Since that time, NNSA eliminated 1 technology as the agency removed certain operations from the UPF. In April 2013, NNSA chartered an independent peer review team to examine various aspects of the UPF project, including assessing the current TRLs for new technologies. In an August 2013 report, the independent peer review team found that 6 of the 9 new technologies were not as mature as previously reported in the UPF contractor's May 2013 TRL assessment; the independent peer review report also stated that no fundamental technology show stoppers were identified. In addition, the independent peer review report contained multiple technology development related findings and recommendations, and NNSA and the

[17]GAO-11-103.

[18]GAO-11-103.

[19]DOE, *Technology Readiness Assessment Guide*, DOE G 413.3—4A (Washington, D.C.: Sept. 15, 2011).

[20] GAO-11-103.

UPF contractor developed a corrective action plan to address them. Table 3 provides a description of the new technologies, the phase in which each technology will be deployed, and the TRL assessment concluded by the UPF contractor in May 2013 and the UPF independent peer review in August 2013.

Table 3: Uranium Processing Facility (UPF) New Technologies and Technology Readiness Levels (TRL) Assessed by the UPF Contractor and UPF Independent Peer Review

New technology	Description	May 2013 TRL assigned by UPF contractor	August 2013 TRL assigned by UPF independent peer review report
Phase I			
Microwave casting	A process that uses microwave energy to melt and cast uranium metal into various shapes	6	Less than 6[a]
Special casting	A custom process for casting uranium into various shapes	3	3
Bulk metal oxidation	A process that converts bulk uranium metal to oxide	7	7
Uranyl nitrate hexahydrate (UNH) calcination	A process that converts impure solutions into a stable, storable condition	5	5[b]
Saltless direct oxide reduction[c]	A process that converts uranium dioxide into metal	6	4 or 5
Recovery extraction centrifugal contactors	A process that uses solvent to extract uranium for purposes of purification	7	Not above 6[d]
Phase II			
Agile machining	A system that combines multiple machining operations—for fabricating metal into various shapes—into a single process	5	4
Chip management	An automated process that reduces operator interactions with machining process and improves worker safety by minimizing exposure to radioactive metal chips. It is one of the multiple operations to be performed through agile machining	6	5
Alternate processing of pins	A process to form uranium metal into custom shapes	7	6

Source: GAO analysis of NNSA data.

Note: A TRL is assigned to each critical technology on a scale from a TRL 1, which is the least mature, through TRL 9—the highest maturity level where the technology as a total system is fully developed, integrated, and functioning successfully in project operations.

[a]According to the August 2013 independent peer review team's report, the microwave casting technology is assessed to be "less than TRL 6" because certain testing and planning activities were incomplete.

[b]The August 2013 independent peer review team concluded that pending the completion of a nuclear safety study for UNH calcination, this technology would be at TRL 6 as all other requirements were met. According to UPF contractor officials, the required study is complete, and the contractor has reassessed the TRL.

[c] Although saltless direct oxide reduction is the UPF's current baseline uranium purification technology, NNSA notified the UPF contractor in early February 2014 of its plans to update the

document that establishes UPF requirements to incorporate a new uranium purification technology called direct electrolytic reduction and electrolytic refining (DER/ER). According to NNSA officials, the agency currently (1) has not directed the UPF contractor to pursue the DER/ER technology as part of UPF Phase I and (2) is considering installing the DER/ER technology into UPF Phase II pending the results of further analysis. According to the August 2013 UPF independent peer review report, the DER/ER technology is less mature than the saltless direct oxide reduction technology. Specifically, the direct electrolytic reduction technology is at TRL 3 and the electrolytic refining technology is at TRL 4.

[d]According to the August 2013 peer review team's report, the recovery extraction centrifugal contactors technology is assessed to be "not above TRL 6" because the entire system has not been tested.

New Technologies Planned for the UPF Face Five Additional Risks

Since our November 2010 report, we identified five additional risks associated with using new technologies in the UPF. Specifically:

- **Integration risks for microwave casting technology.** The August 2013 independent peer review team report raised concerns with microwave casting—a process that uses microwave energy to melt and cast uranium metal into various shapes—as it is planned to be integrated in the UPF's casting system.[21] According to an NNSA official, the casting system planned for the UPF will employ uranium processing technology, equipment, and steps that are substantially different than the casting system currently used at the Y-12 plant. For example, microwave casting in the UPF will use glovebox enclosures—a containment system of secured gloves attached to a box that allows workers to process nuclear material inside the box without risk of contamination. The independent review team found that the UPF's planned casting glovebox enclosures are: (1) large and somewhat complex, (2) have not had their functionality tested, and (3) have not been demonstrated with microwave casting. As such, the independent review team concluded that microwave casting has not been demonstrated in a relevant environment—a key requirement to reach TRL 6.
- **Technology development risk for special casting technology.** In 2012, the UPF project team determined that a different nuclear safety control was needed for special casting—a custom process for casting uranium metal into various shapes—as this process uses more uranium than the regular casting process.[22] For special casting, the

[21]A casting system includes multiple processing steps and related equipment to handle, transfer, melt, cast, and cool uranium, as well as conduct quality assurance inspections.

[22]A nuclear criticality accident occurs when enough fissile material, such as uranium, is brought together to cause a sustained nuclear chain reaction. The immediate result of a nuclear criticality accident is the production of an uncontrolled and unpredictable radiation source that can be lethal to people who are nearby.

UPF contractor is developing a nuclear safety control called "entombment." [23] The entombment control—which uses multiple parts, such as cylinders and an insulation material—would occupy void volume where molten uranium metal could otherwise collect in the event of an improper casting (i.e., mis-pour). However, a key insulation material planned for use in the entombment control failed an important series of performance tests in fiscal year 2013. According to UPF contractor representatives, this failure and the need to identify and test an alternative insulation material is now the project's most significant technology development risk and the primary reason why the special casting technology is currently assessed to be at TRL 3.

- **Transition risks if NNSA switches to a new uranium purification technology**. In 2005, NNSA decided to deploy the saltless direct oxide reduction technology—a process that converts uranium dioxide into a useable metal form—into the UPF. The August 2013 UPF independent peer review report concluded that an alternate technology called direct electrolytic reduction and electrolytic refining (DER/ER; currently assessed to be at TRL 3 and 4, respectively) could potentially reduce the UPF's operating costs and produce less radioactive waste compared with the saltless direct oxide reduction technology. In a December 2013 testimony before the Defense Nuclear Facilities Safety Board, the Acting NNSA Administrator stated that early research and development investments in the DER/ER technology are promising and NNSA is actively seeking to mature and deploy the technology into UPF to minimize future waste streams. NNSA is now considering installing this new technology as part of UPF Phase II scope, pending the results of further analysis, and directed the UPF contractor in February 2014 to suspend design efforts in two UPF processing areas impacted by this potential technology change.

UPF contractor representatives told us that incorporating DER/ER into the UPF would require significant changes to the facility's design. For example, NNSA officials said that changing to DER/ER would require a complete redesign of the processing areas and their equipment and may require adding new support utilities and that the UPF facility would have

[23] According to the UPF Federal Project Director, special casting will account for 20 percent of UPF's casting operations while regular casting will account for the remaining 80 percent. He also said that currently the Y-12 plant is not able to conduct special casting operations due to nuclear safety concerns.

to revise its nuclear safety analysis. In addition, the August 2013 UPF independent peer review report found that the UPF project team has not conducted any nuclear criticality studies or developed any nuclear safety controls for the DER/ER technology because the technology was not planned for use in UPF at the time.

- **Assurance risks that the agile machining technology will work as intended before making key project decisions.** As stated earlier, NNSA plans to approve a combined CD 2 (approved cost, schedule, and scope targets) and CD 3 (approve start of construction) milestone in for UPF Phase I, which includes the building exterior, all UPF processing areas, and all UPF support systems. In short, UPF Phase I will create key parameters that subsequent UPF phases must work within. Agile machining—a system combining multiple machining operations into a single process that fabricates metal into various shapes—is the key technology planned for UPF Phase II. The August 2013 independent UPF peer review assessed agile machining to be at TRL 4. In December 2013, NNSA decided to no longer fund agile machining technology development efforts because (1) agile machining is not considered a baseline technology for UPF Phase I as it is part of the deferred scope and (2) NNSA is considering combining agile machining development efforts with other machining development efforts used in at the Y-12 plant. According to NNSA officials, the UPF contractor has completed the design for the agile machining prototype, but it will be the responsibility of the UPF Phase II project to mature this technology.[24]

According to best practices we identified in our 2007 report, a new technology should achieve at least TRL 6 by CD 2 and at least TRL 7 by CD 3.[25] Since NNSA cancelled agile machining development efforts, the technology will remain at TRL 4 when NNSA plans to approve the combined CD 2 and CD 3 milestone for UPF Phase I. As a result, NNSA will not have optimal assurance that agile machining will work as intended before making a key project decision, which could result in costly design changes and construction delays. In addition, NNSA plans to operate the UPF as an integrated system that incorporates all uranium capabilities,

[24]According to the UPF Federal Project Director, there are examples of other DOE construction projects that have provided space for future technologies, such as the Spallation Neutron Source constructed by DOE's Office of Science.

[25]GAO-07-336.

which requires the successful deployment of all new technologies planned for the UPF, including those scheduled for UPF Phase II.

- **Risk that funding mechanism for UPF technology development activities may not be adequate to develop all new technologies.** According to NNSA officials and UPF contractor representatives, NNSA has primarily funded UPF technology development activities from the Y-12 plant-directed research and development (PDRD) program, which requires projects from every part of the Y-12 plant to compete for funding.[26] From fiscal year 2005 to fiscal year 2013, the $73 million in UPF technology development costs have been funded by non-UPF project sources, such as the PDRD program, instead of from the $1 billion specifically allotted to the UPF project, according to the UPF contractor Project Manager. UPF contractor representatives told us that NNSA made the decision to fund technology development activities from non-UPF project sources because some UPF technologies could be used for other operations at the Y-12 plant or at other nuclear weapon stockpile programs. However, NNSA did not select some UPF technology development projects identified as being priority by the UPF project team for PDRD funding. For example, in fiscal year 2013, 19 projects were considered priority by the UPF project team, but NNSA did not fund 3 of these projects. For fiscal year 2014, 19 projects were considered priority by the UPF project team, but NNSA did not fund 7 of these projects. In addition, one of the five UPF technology development risk reduction plans developed by the UPF contractor is to “obtain additional PDRD funding,” but the effectiveness of this plan is unclear given that existing UPF technology development projects considered priority have not received funding.

NNSA Is Taking Some Actions to Address Identified Risks

NNSA is currently taking some actions to address three of the five UPF technology risks we have identified. NNSA is currently developing plans and making programmatic decisions about the UPF that could address the other two risks but, it is still too soon to determine if these actions will sufficiently address these two risks. Specifically:

[26]Similar to DOE’s Laboratory Directed Research and Development program, the PDRD program funds conceptual or preliminary designs of innovative technologies. PDRD funding may not exceed 4 percent of a plant’s budget. At the Y-12 plant in fiscal year 2012, for example, PDRD program funding was $23.9 million, or 3.1 percent of the plant’s budget.

- **Microwave casting technology.** To address the risks with integrating microwave casting—a process that uses microwave energy to melt and cast uranium metal into various shapes—into the UPF's casting system, the UPF contractor plans to issue a request for proposal in March 2014 for the development of a prototype microwave casting furnace. UPF contractor representatives said that they have had preliminary discussions with two vendors about building the prototype. According to NNSA officials, the UPF contractor will be required to test the prototype in an integrated UPF configuration that includes glovebox enclosures. If completed, we believe these planned actions will help NNSA reduce this risk and identify further mitigation measures that may need to be taken.
- **Special casting technology.** For the entombment nuclear criticality safety control planned for special casting—a custom process for casting uranium metal into various shapes—UPF contractor representatives told us that they would like to have a replacement insulation material identified and successfully tested by June 2014. However, NNSA officials said that this June 2014 date is optimistic and may not be met. In addition, UPF contractor officials said they are currently conducting a formal analysis of alternatives for the entombment control. The UPF contractor expects to finish its analysis by the end of January 2014 and brief the results and potential impacts to senior NNSA management. If NNSA completes these planned actions, we believe that the agency may have taken appropriate actions to address this risk.
- **DER/ER technology.** According to the UPF Federal Project Director, in February 2014, the NNSA Deputy Administrator for Defense Programs directed NNSA's Production Office—the field office responsible for contractor oversight and management of the Y-12 plant—to: (1) create a technology development plan for DER/ER, (2) develop a preliminary cost estimate for DER/ER technology development, (3) identify existing facilities at the Y-12 plant where DER/ER could be deployed, and (4) use DER/ER in actual uranium operations no later than 2021.

  However, as noted above, the design of the two UPF processing areas impacted by the potential switch to DER/ER has been suspended. According to the UPF Federal Project Director, these areas are considered part of UPF's deferred scope which means that (1) the UPF will reserve space for DER/ER capabilities and ensure that all needed support utilities are available in the two processing areas and (2) it will be the responsibility for the UPF Phase II project team to install the DER/ER equipment into the UPF. Given the early stages of NNSA's planning, we believe that it is too soon to determine if these actions will address this technology transition risk.

- **Agile machining technology.** The UPF is to modernize and consolidate all enriched uranium operations at the Y-12 plant in three phases. Agile machining—a system that combines multiple machining operations for fabricating metal into various shapes into a single process—is the key technology planned for UPF Phase II. As stated above, NNSA decided in December 2013 to no longer fund agile machining technology development efforts (currently assessed at TRL 4) for multiple reasons. UPF contractor representatives told us that (1) they have completed the design of an agile machining prototype; (2) by the end of 2014, they will outline the actions needed to mature the technology to TRL 6; and (3) the UPF Phase II project team will have the responsibility to mature the technology.

  NNSA is currently evaluating alternatives to the UPF, and the outcome of this evaluation may require different agency actions to address this risk. If NNSA decides to continue with a UPF that includes machining operations, the agency will need to take action to address a recommendation from the August 2013 UPF independent peer review team. Specifically, the peer review team recommended that the UPF project fabricate and test an agile machining prototype before starting construction on the UPF. According to the peer review team, implementing this recommendation is a high-priority action and will help ensure the confident integration of the agile machining technology into UPF at a later date. However, if NNSA decides to construct a facility with only uranium purification and casting capabilities—which do not include machining capabilities—the agency will have to develop alternate plans that detail how machining capabilities will be modernized and how the agile machining technology will be matured. It is too soon to determine if the Uranium Infrastructure Strategy that NNSA is currently developing and scheduled to issue in draft form in early April 2014 will address this issue. Given that NNSA is: (1) currently evaluating potential UPF alternatives; (2) currently developing its Uranium Infrastructure Strategy; and (3) planning to conduct machining operations in its current facility, until at least 2038, we believe it is too early to tell if NNSA is taking appropriate action to address this risk.

- **Technology development funding.** The August 2013 UPF independent peer review report recommended that the UPF project fund more technology development activities from project funds instead of PDRD funds. In October 2013, the UPF contractor issued a corrective action plan to address the recommendations from the

August 2013 UPF independent peer review. This corrective action plan: (1) lists planned and ongoing actions that the contractor and NNSA will take to address each recommendation, (2) provides an estimated date by which planned actions are to be completed, and (3) identifies which UPF contractor representative or NNSA official is responsible for completing the planned action. As part of this corrective action plan, the UPF Assistant Project Manager for Technology is responsible for determining which technology development activities should be funded directly with UPF project funds and is to prepare a cost estimate for those activities. The UPF Assistant Project Manager for Technology told us that he expects to complete the planned corrective action by the end of March 2014. Adding required technology development activities to the UPF's cost estimate may increase the project's cost estimate, but it may also improve the accuracy and comprehensiveness of the estimate. If NNSA completes these planned actions, we believe that the agency may have taken appropriate actions to address this risk.

Conclusions

Enriched uranium operations at the Y-12 plant play a vital role in the national security of the United States by producing critical components for the nuclear weapons stockpile and by supplying fuel for the Navy. There is a clear need for NNSA to replace the old, deteriorating, and high-maintenance facilities at the Y-12 plant. NNSA is currently reevaluating the UPF project and may decide to construct a facility that is smaller and contains only select enriched uranium processing capabilities. Whether NNSA continues with the UPF project or chooses to undertake a smaller project, the facility will likely cost billions of dollars, and its ability to meet critical national security needs will depend on the successful development and deployment of new technologies. It is encouraging that NNSA has taken some steps to manage the development of these technologies. However, as we have detailed in this and other reports, we are concerned that, nearly a decade after the project started, the UPF project continues to face key technology-related risks, including the potential transition risks associated with NNSA's recent decision to consider alternatives to a new uranium purification technology. NNSA is in the process of making key programmatic decisions with the UPF and has some ongoing efforts that may address identified risks if fully and successfully implemented. We will continue to monitor NNSA's progress in addressing these risks as part of our UPF critical decisions reviews as directed by the Fiscal Year 2013 National Defense Authorization Act.

In addition, NNSA has not taken action to address the two recommendations related to UPF technology development we made in our November 2010 report: (1) that NNSA ensure that new technologies reach the level of maturity called for by best practices prior to CDs being made on the UPF project and (2) that the agency report to Congress any decisions to approve cost and schedule performance baselines or to begin construction of UPF without first having ensured that project technologies are sufficiently mature. NNSA generally agreed with those recommendations, and we continue to believe that best practices followed by other federal agencies for managing technology development, particularly reaching TRL 7 at the start of construction, are important. By not fully incorporating these practices, NNSA may not be able to ensure that the UPF and its other projects can be completed on time and within budgets.

Agency Comments and Our Evaluation

We are not making any new recommendations in this report. We provided a draft of this report to NNSA for comment. In written comments (see Appendix I), the acting NNSA Administrator stated that NNSA's existing TRL guidance, which encourages the achievement of TRL 7 prior to the start of construction (CD 3), provides adequate protection against the premature commitment of resources while giving projects flexibility to make decisions between seeking TRL 6 and TRL 7. In addition, the acting NNSA Administrator stated the agency is closely overseeing and managing UPF's ongoing technology development efforts using on-site personnel and independent reviews to confirm reported progress while also keeping senior management informed of development efforts.

We continue to believe that DOE should fully adhere to best practices in its technology development activities. DOE's guidance recognizes that achieving a TRL 7 at the start of construction is a best practice and DOE encourages—but does not require—projects to achieve this level of readiness. Achieving TRL 7—the level where a prototype is demonstrated in an operational environment, has been integrated with other key supporting subsystems, and is expected to only have minor design changes—does require more time, effort, and money than achieving TRL 6. However, TRL 7 is seen as a best practice because it provides greater assurance the new technologies will work as intended before making very significant resource investments in construction activities, which for the UPF will total billions of dollars. Notably, DOD follows best practices in this area and recommends projects reach TRL 7 before production and deployment, or the equivalent of beginning construction on a DOE project.

Regarding NNSA's oversight of technology development efforts, it is clear that certain NNSA actions, such as the August 2013 UPF independent peer review, helped identify and respond to some technology development issues. However, since NNSA is currently considering alternatives to UPF and developing the Uranium Infrastructure Strategy for the Y-12 plant, it is too early to determine if the oversight and management actions cited by NNSA will be sufficient to fully address all the risks we identified.

NNSA also provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, the Administrator of NNSA, 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 on matters discussed in this report, please contact me at (202) 512-3841 or trimbled@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 major contributions to this report are listed in appendix II.

David C. Trimble

David C. Trimble
Director, Natural Resources and Environment

List of Committees

The Honorable Carl Levin
Chairman
The Honorable James M. Inhofe
Ranking Member
Committee on Armed Services
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 Howard P. "Buck" McKeon
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Mike Simpson
Chairman
The Honorable Marcy Kaptur
Ranking Member
Subcommittee on Energy and Water Development, and Related Agencies
Committee on Appropriations
House of Representatives

Appendix I: Comments from the National Nuclear Security Administration

Department of Energy
National Nuclear Security Administration
Washington DC 20585

April 11, 2014

OFFICE OF THE ADMINISTRATOR

MEMORANDUM FOR DAVID TRIMBLE
DIRECTOR
NATURAL RESOURCES AND ENVIRONMENT
GOVERNMENT ACCOUNTABILITY OFFICE

FROM: EDWARD BRUCE HELD
ACTING ADMINISTRATOR

SUBJECT: Comments on the Government Accountability Office Draft Report Titled "Nuclear Weapons: Technology Development Efforts for the Uranium Processing Facility" (Job Code: 500649/2012-03339)

Thank you for the opportunity to review and comment on the subject draft report, which is the third in a series of congressionally directed quarterly reports on the Uranium Processing Facility Project (UPF) at the Y-12 National Security Complex. The first report covered cost and schedule; the second report addressed safety; and, this report assesses the Project's technology development.

In performing this audit, the Government Accountability Office (GAO) team first identified new technology risks that may have emerged since the GAO's previous 2010 technology readiness report (GAO-11-103). They then assessed the steps that the National Nuclear Security Administration (NNSA) is taking to mitigate these new risks.

The draft report finds that the NNSA is using a systematic approach to assess the maturity of its new technologies. While the report does not make any specific recommendations, it does voice concern: 1) that technology uncertainties still exist at this point in the project's development; and, 2) that the Department of Energy (DOE) and NNSA had not acted on recommendations in the GAO's 2010 report relating to differences between DOE's technology readiness level policies and those issued by other organizations.

DOE and NNSA fully evaluated the recommended 2010 policy changes prior to issuing the 2011 revision of DOE's Technology Readiness Assessment Guide (DOE G 413.3-4A). It was concluded that the existing policy statements recommending that all Critical Technology Elements reach at least Technical Readiness Level (TRL) 6 prior to Critical Decision (CD) 2 and encouraging the achievement of TRL 7 prior to CD-3 provided adequate protection against the premature commitment of resources while also

Printed with soy ink on recycled paper

allowing projects needed flexibility to make cost benefit based decisions between seeking TRL 6 or TRL 7.

We appreciate the auditors' efforts and are fully committed to: 1) selecting the optimum technologies for UPF from a cost, safety, and operational standpoint; 2) verifying that these technologies are adequately mature prior to baselining the project at CD- 2; and, 3) ensuring that alternate or fallback technologies are available for insertion in the design should a preferred technology prove to be too immature for implementation. NNSA is closely overseeing and managing UPF's ongoing technology development efforts using our on-site federal and contractor staffs. Senior management is being kept informed of the status of development efforts and the independent reviews are being utilized to confirm reported progress. This high level of involvement allows us to promptly identify and respond to any emerging issues.

Our specific comments on the draft report are attached for your consideration. It should be noted that in several cases the audit team's statements have been overtaken by my decision to evaluate options to the UPF project to achieve 9212 scope capabilities by 2025 for not to exceed $6.5B. We have provided alternate wording or proposed sentence modifications where this has occurred.

I thank you again for your consideration of these comments and look forward to working with the GAO to improve NNSA project management.

Attachment

NNSA's attachment provided technical comments which we incorporated as appropriate in the final report.

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

David C. Trimble, (202) 512-3841 or trimbled@gao.gov.

Staff Acknowledgments

In addition to the individual named above, Jonathan Gill, Assistant Director; Patrick Bernard; Antoinette Capaccio; Will Horton; Katrina Pekar-Carpenter; Dr. Timothy Persons, and Ron Schwenn made key contributions to this report.

GAO's Mission

The Government Accountability Office, the audit, evaluation, and investigative arm of Congress, exists to support Congress in meeting its constitutional responsibilities and to help improve the performance and accountability of the federal government for the American people. GAO examines the use of public funds; evaluates federal programs and policies; and provides analyses, recommendations, and other assistance to help Congress make informed oversight, policy, and funding decisions. GAO's commitment to good government is reflected in its core values of accountability, integrity, and reliability.

Obtaining Copies of GAO Reports and Testimony

The fastest and easiest way to obtain copies of GAO documents at no cost is through GAO's website (http://www.gao.gov). Each weekday afternoon, GAO posts on its website newly released reports, testimony, and correspondence. To have GAO e-mail you a list of newly posted products, go to http://www.gao.gov and select "E-mail Updates."

Order by Phone

The price of each GAO publication reflects GAO's actual cost of production and distribution and depends on the number of pages in the publication and whether the publication is printed in color or black and white. Pricing and ordering information is posted on GAO's website, http://www.gao.gov/ordering.htm.

Place orders by calling (202) 512-6000, toll free (866) 801-7077, or TDD (202) 512-2537.

Orders may be paid for using American Express, Discover Card, MasterCard, Visa, check, or money order. Call for additional information.

Connect with GAO

Connect with GAO on Facebook, Flickr, Twitter, and YouTube.
Subscribe to our RSS Feeds or E-mail Updates. Listen to our Podcasts.
Visit GAO on the web at www.gao.gov.

To Report Fraud, Waste, and Abuse in Federal Programs

Contact:

Website: http://www.gao.gov/fraudnet/fraudnet.htm
E-mail: fraudnet@gao.gov
Automated answering system: (800) 424-5454 or (202) 512-7470

Congressional Relations

Katherine Siggerud, Managing Director, siggerudk@gao.gov, (202) 512-4400, U.S. Government Accountability Office, 441 G Street NW, Room 7125, Washington, DC 20548

Public Affairs

Chuck Young, Managing Director, youngc1@gao.gov, (202) 512-4800
U.S. Government Accountability Office, 441 G Street NW, Room 7149
Washington, DC 20548