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Report to the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate

September 2017

PLUTONIUM DISPOSITION

Proposed Dilute and Dispose Approach Highlights Need for More Work at the Waste Isolation Pilot Plant

Accessible Version

GAO-17-390

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GAO Highlights

Highlights of GAO-17-390, a report to the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate

Why GAO Did This Study

The United States has pledged to dispose of 34 metric tons of surplus, weapons-grade plutonium. The current U.S. approach relies on disposing of the plutonium by irradiating it as MOX fuel—a mixture of plutonium and uranium oxides—in modified commercial nuclear reactors. Due to a significant rise in cost, DOE recently proposed terminating the MOX approach in favor of the dilute and dispose approach, which DOE stated may be less expensive. Under this approach, plutonium would be diluted with inert material and then disposed of in a geologic repository.

GAO was asked to review DOE's planning for both the MOX and dilute and dispose approaches. This report examines: (1) the extent to which DOE's revised cost estimates for completing the construction of the MOX facility and for completing the overall Plutonium Disposition Program met best practices, (2) the status of NNSA's development of a life-cycle cost estimate for the dilute and dispose approach, and (3) the extent to which DOE has sufficient disposal space and statutory capacity at WIPP to dispose of all defense TRU waste, including waste from the dilute and dispose approach. GAO reviewed documents and interviewed DOE and NNSA officials, including officials from five major waste-generating sites.

What GAO Recommends

GAO is making four recommendations, including that DOE develop a plan for expanding WIPP's disposal space that includes a schedule for completing the expansion before existing space is full. DOE concurs with the recommendations.

View GAO-17-390. For more information, contact David C. Trimble at (202) 512-3841 or TrimbleD@gao.gov.

What GAO Found

In August 2016, the Department of Energy's (DOE) revised cost estimate for completing construction of the Mixed-Oxide (MOX) Fuel Fabrication Facility was approximately $17.2 billion and assumed annual funding of $350 million. This estimate substantially met best practices and can be considered reliable as it substantially met all four characteristics of a high-quality cost estimate: comprehensive, well-documented, accurate, and credible. In contrast, DOE's National Nuclear Security Administration (NNSA) has not yet applied best practices when revising its life-cycle cost estimate of $56 billion for the Plutonium Disposition Program using the MOX approach, as GAO previously recommended. This is because NNSA officials developed the revised life-cycle cost estimate to satisfy an annual requirement to record the plutonium environmental liability on departmental financial statements that were due in September 2016.

NNSA is developing a life-cycle cost estimate for completing the Plutonium Disposition Program using the dilute and dispose approach, which would dispose of diluted plutonium at DOE's Waste Isolation Pilot Plant (WIPP). WIPP is an underground repository for the disposal of transuranic (TRU) nuclear waste, which is waste contaminated by nuclear elements heavier than uranium, such as diluted plutonium. NNSA is currently assessing the extent to which any new equipment and facilities would be needed to pursue this approach, and it expects to develop an independently validated life-cycle cost estimate for the program by late 2018. NNSA has outlined an initial set of milestones for the program using the dilute and dispose approach; these milestones include program elements such as preparing the plutonium for dilution, diluting the plutonium into waste and securely storing it, and disposing of it at WIPP.

DOE does not have sufficient space at WIPP to dispose of all defense TRU waste. DOE's current plan is to fill the existing disposal space in WIPP by 2026, and additional space will need to be excavated to dispose of all the waste included in DOE's current TRU waste inventory report. While DOE officials recognize that expansion of WIPP's disposal space may be necessary in the future, they have not analyzed or planned for the facility's expansion because their focus has been on resuming operations at WIPP, which had been suspended in 2014 after two separate accidents at the facility. Specifically, GAO found the following:

- DOE's TRU waste management plan, which includes planning for WIPP, covers a 5-year period and does not address possible expansion. Moreover, DOE's TRU waste management plan does not include a schedule for expanding DOE's disposal space before existing space is full.
- Expanding WIPP's disposal space will require regulatory approval that is expected to take several years. However, DOE modeling that is needed to begin the regulatory approval process is not expected to be ready until 2024.

Without developing a plan for WIPP that includes an integrated schedule for completing the regulatory approval process and constructing new space before WIPP's existing space is full, DOE does not have reasonable assurance that it will be able to expand the repository in a timely manner

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Abbreviations

ARIES	Advanced Recovery and Integrated Extraction System
Corps	U.S. Army Corps of Engineers
CD	critical decision
DOE	Department of Energy
EM	Office of Environmental Management
EPA	Environmental Protection Agency
GTCC	greater-than-Class C
LLW	low-level radioactive waste
m^3	cubic meters
MT	metric ton
MOX	mixed-oxide
MOX facility	Mixed-Oxide Fuel Fabrication Facility
NNSA	National Nuclear Security Administration
TRU	transuranic
WIPP	Waste Isolation Pilot Plant

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September 5, 2017

The Honorable Deb Fischer
Chairman
The Honorable Joe Donnelly
Ranking Member
Subcommittee on Strategic Forces
Committee on Armed Services
United States Senate

As a key step for nuclear nonproliferation, the United States and Russia pledged under the Plutonium Management and Disposition Agreement, signed in 2000, to each dispose of at least 34 metric tons (MT) of weapons-grade plutonium that is no longer needed for defense purposes.[1] Russia suspended its implementation of the agreement in October 2016, citing delays in the United States' implementation of the agreement, among other reasons, but Department of Energy (DOE) officials stated that they plan to continue to seek safe disposition of surplus U.S. plutonium. According to the National Nuclear Security Administration (NNSA), the amount of plutonium that the United States and Russia pledged to dispose of under the agreement is sufficient to manufacture 17,000 nuclear weapons.[2] Plutonium poses a proliferation risk and a risk to human health and the environment if not managed safely. The agreement, as modified, provides that disposition shall be by irradiation as fuel in nuclear reactors or any other methods that both countries may agree to in writing. Under the agreement, the United States would dispose of its plutonium as mixed-oxide (MOX) fuel—a mixture of plutonium and uranium oxides—in modified commercial nuclear reactors. If MOX fuel is used in a reactor, the plutonium in the fuel is transformed into radioactive spent fuel similar to the spent fuel produced in commercial reactors, which prevents it from being reused in a nuclear weapon. This effort is managed by NNSA through its Plutonium Disposition Program, which was established in 1997 to address the

[1]Plutonium is a man-made, radioactive element produced by irradiating uranium in nuclear reactors.

[2]NNSA is a separately organized agency within DOE that is responsible for the management and security of the nation's nuclear weapons programs.

disposition of surplus weapons-grade plutonium at the end of the Cold War.

As part of its Plutonium Disposition Program, NNSA began constructing the MOX Fuel Fabrication Facility (MOX facility) in 2007 at DOE's Savannah River Site in South Carolina. In 1997, DOE originally estimated the MOX facility would cost approximately $1.4 billion and be completed in 2004; however, by 2012, NNSA had spent about $3.4 billion and estimated that it needed approximately $4 billion more to complete construction by 2019. We reported in February 2014 that NNSA's cost estimate for completing construction of the MOX facility and its overall life-cycle cost estimate for the Plutonium Disposition Program were unreliable and that the program could be at risk for further cost increases.[3] In its fiscal year 2014 budget justification, DOE stated that pursuing the MOX approach may be unaffordable due to the growth in costs for completing the program, and it proposed a slowdown of program activities while it assesses other alternative plutonium disposition approaches.

In April 2014, DOE completed an analysis of plutonium disposition options that identified an alternative disposition approach that could significantly reduce the life-cycle cost of the Plutonium Disposition Program.[4] This alternative would involve diluting the plutonium and disposing of it in a geologic repository.[5] Two DOE-contracted reviews of this analysis—one by the Aerospace Corporation's Federally Funded Research and Development Center and one by Oak Ridge National Laboratory—estimated that the dilute and dispose approach could significantly reduce the life-cycle cost of the Plutonium Disposition Program, compared with continuing the program using the MOX

[3]GAO, *Plutonium Disposition Program: DOE Needs to Analyze the Root Causes of Cost Increases and Develop Better Cost Estimates*, GAO-14-231 (Washington, D.C.: Feb. 13, 2014).

[4]Department of Energy, *Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon-Grade Plutonium Disposition Options* (April 2014).

[5]According to an official from the Department of State, the United States sent a letter to start discussions with the Russian government on whether dilute and dispose could be added as a disposition method under the PMDA. This official indicated that this letter was sent in June 2016, which is prior to Russia's suspension of the agreement.

approach.[6] Given the conclusions from these reviews, DOE's fiscal year 2017 budget request proposed to terminate construction of the MOX facility and pursue the dilute and dispose approach. Under this proposal, plutonium would be diluted with inert material to inhibit its future use in weapons. It would then be packaged and shipped to a repository for permanent disposal, most likely DOE's Waste Isolation Pilot Plant (WIPP), an underground repository located near Carlsbad, New Mexico, that is used for disposing of defense transuranic (TRU) waste.[7] According to DOE officials, the diluted plutonium meets DOE's criteria for TRU waste. However, WIPP's current design includes a finite amount of disposal space, and the statute that established the repository also placed a limit on its TRU waste disposal capacity. WIPP is managed by DOE's Office of Environmental Management (EM) and is the only disposal site for TRU waste in the United States. Complicating matters, disposal operations at WIPP were suspended in 2014 as a result of two separate accidents at the facility involving a fire and a radioactive release. According to DOE officials, while the majority of the underground radioactive release was directed through the repository's ventilation system filters, a small portion bypassed filters and was released into the atmosphere. We reported in August 2016 that DOE missed its initial estimated date of March 2016 for reopening WIPP, in part because it did not develop the estimates using all cost and schedule estimating best practices. [8] DOE resumed disposing of TRU waste at WIPP in January 2017.

[6]Aerospace Corporation, *Plutonium Disposition Study Options Independent Assessment Phase 1 Report,* TOR-2015-01848 (Washington, D.C.: Apr. 13, 2015), and Oak Ridge National Laboratory, *Final Report of the Plutonium Disposition Red Team* (Oak Ridge, TN: Aug. 13, 2015).

[7]"Transuranic" is used to describe elements that have atomic numbers greater than that of uranium. Transuranic waste is defined in the Waste Isolation Pilot Plant Land Withdrawal Act of 1992 as waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for (A) high-level radioactive waste; (B) waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the disposal regulations; or (C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations. Pub L. No. 102-579, § 2 (1992).

[8]GAO, *Nuclear Waste: Waste Isolation Pilot Plant Recovery Demonstrates Cost and Schedule Requirements Needed for DOE Cleanup Operations*, GAO-16-608 (Washington, D.C.: Aug. 4, 2016).

In August 2016, in response to a provision in the National Defense Authorization Act for fiscal year 2016,[9] DOE's Office of Project Management Oversight and Assessments developed a revised cost estimate of approximately $17.2 billion to complete construction of the MOX facility by 2048.[10] According to NNSA officials, NNSA included this new estimate in revising the overall life-cycle cost estimate for the program using the MOX approach, which NNSA now estimates to be approximately $56 billion. In addition to these estimates, a provision in the Explanatory Statement for the Consolidated Appropriations Act of 2016 calls for DOE to provide to Congress a life-cycle cost and schedule estimate if the program were to instead use the dilute and dispose approach. While NNSA examines the activities needed to implement the dilute and dispose approach, Congress continues to authorize and fund the ongoing construction of the MOX facility.

You asked us to review DOE's planning for the Plutonium Disposition Program under both the MOX and dilute and dispose approaches. This report examines (1) the extent to which DOE's revised cost estimate for completing construction of the MOX facility, and the revised life-cycle estimate for completing the Plutonium Disposition Program using the MOX approach met cost estimating best practices, (2) the status of NNSA's development of a life-cycle cost estimate for completing the Plutonium Disposition Program using the dilute and dispose approach, and (3) the extent to which DOE has sufficient disposal space and statutory capacity at WIPP to dispose of all defense TRU waste, including the diluted plutonium resulting from the dilute and dispose approach.

To determine the extent to which DOE's revised cost estimate for completing construction of the MOX facility and the revised life-cycle estimate for completing the overall program using the MOX approach met best practices, we reviewed DOE and contractor documents and interviewed DOE and NNSA officials who were involved in developing DOE's revised estimates. We compared the steps DOE followed in developing the construction cost estimate to the 12 best practice steps outlined in our cost estimating guide that, when followed correctly, should

[9]Pub. L. No. 114-92, § 3119 (2015).

[10]This estimate for completing construction of the MOX facility was developed with assumed annual funding of $350 million. This estimate includes the approximately $5 billion that DOE has already spent in constructing the MOX facility.

result in a high-quality, reliable cost estimate.[11] We provided a draft of our assessment to DOE and revised the draft, as appropriate, after discussing our assessment with DOE officials and receiving additional information from them.

To determine the status of NNSA's development of a life-cycle cost estimate for completing the Plutonium Disposition Program using the dilute and dispose approach, we reviewed the planning documents that had been completed to date, including documents that outlined the scope of the program relying on the dilute and dispose approach and included dates for completing key program milestones.[12] We also interviewed NNSA officials to determine the extent of planning they had completed and the schedule for completing the remaining plans. We visited DOE's Savannah River Site to interview NNSA officials responsible for evaluating the dilute and dispose approach and officials from EM's project to dilute the 6 MT of non-pit plutonium. During this visit, we also reviewed a demonstration mock-up of the plutonium dilution equipment that EM already had in operation.

To determine the extent to which DOE has sufficient disposal space and statutory capacity at WIPP to dispose of all defense TRU waste, including the diluted plutonium resulting from the dilute and dispose approach, we reviewed relevant legislation relating to WIPP's statutory capacity, as well as DOE's WIPP annual TRU waste inventory report and data from the Waste Data System, which tracks the waste already disposed of in the repository. To assess the reliability of the DOE's inventory, we reviewed documents on its development and interviewed officials responsible for maintaining it. Based on our review, we determined that the data it contains are sufficiently reliable for our purposes. We also conducted a site visit to WIPP to interview DOE officials responsible for managing WIPP operations to understand how the waste disposal space is managed and how they plan for DOE's future disposal needs. To understand what efforts were ongoing to study the impact of disposing of

[11]GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: March 2009). This guide includes a compilation of cost estimating best practices drawn from across industry and the federal government.

[12]National Nuclear Security Administration, *Mission Need Statement: Surplus Plutonium Disposition Project Dilute and Dispose Approach* (Aug. 25, 2016), and *Surplus Plutonium Disposition Program Requirements Document for the Proposed Dilute and Dispose Approach* (Aug. 30, 2016).

diluted plutonium at WIPP, we interviewed officials from Sandia National Laboratories who are responsible for analyzing potential changes at WIPP. To evaluate potential sources of TRU waste from generator sites that may not be included in DOE's inventory report, to understand how such sites estimate the amount of TRU waste they will need to ship to WIPP, and to get these sites' perspectives on potential disposal space availability and capacity issues, we reviewed documents from and interviewed officials at DOE's five major waste-generating sites. Specifically, we conducted interviews with officials from the Hanford Site in Washington state, Idaho National Laboratory, Los Alamos National Laboratory in New Mexico, Oak Ridge National Laboratory in Tennessee, and Savannah River Site in South Carolina. These interviews included a site visit to Idaho National Laboratory. In addition, to understand the regulatory process through which DOE must work to operate WIPP, we spoke to officials from agencies that have regulatory authority over the WIPP facility—the U.S. Environmental Protection Agency (EPA) and the State of New Mexico Environment Department.

We conducted this performance audit from December 2015 to September 2017 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

This section provides information on NNSA's Plutonium Disposition Program, DOE's WIPP, and GAO cost estimating best practices.

NNSA's Plutonium Disposition Program

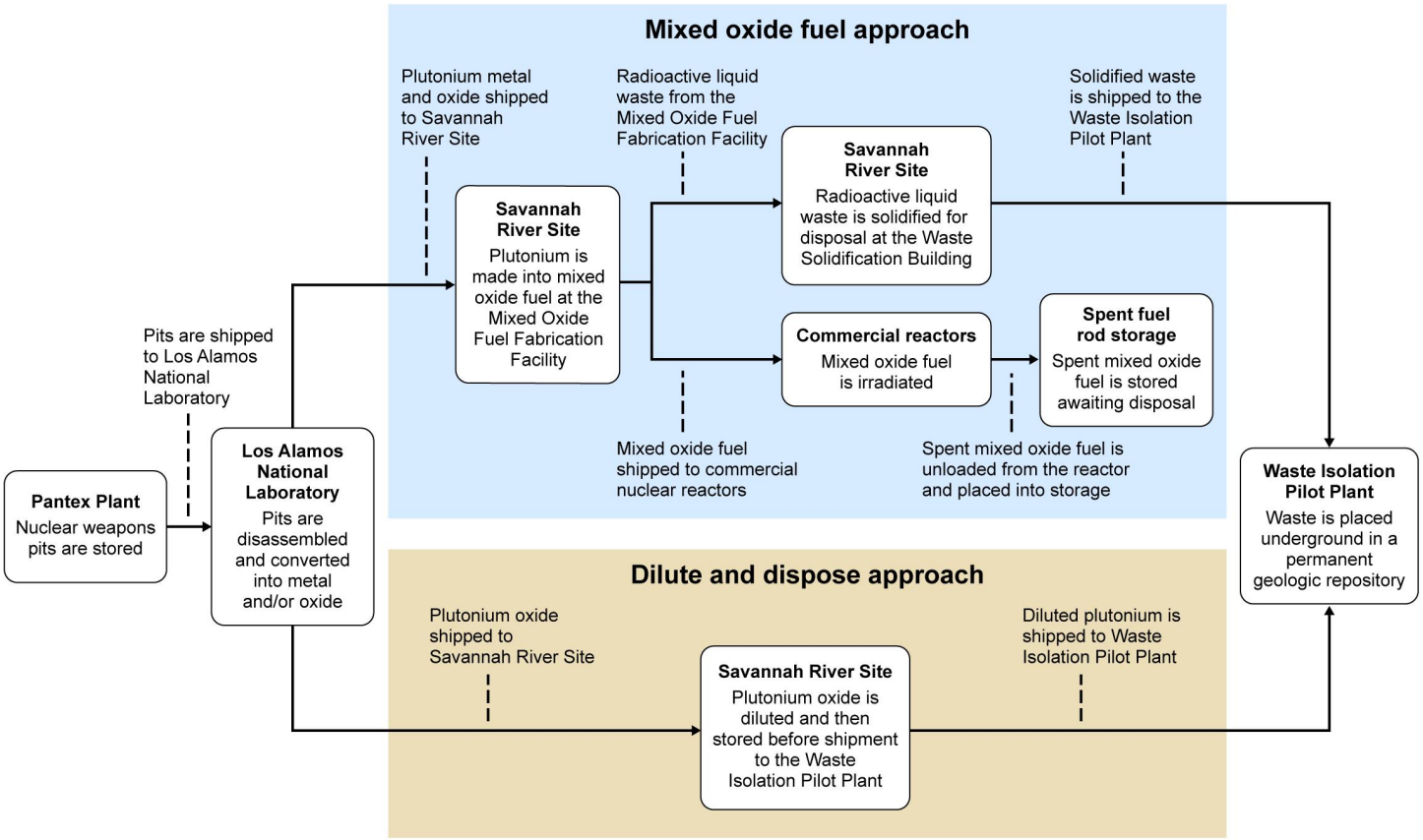
NNSA established the Plutonium Disposition Program in 1997 to address the disposition of weapons-grade plutonium at the end of the Cold War. To date, the United States has declared a total of 61.5 MT of plutonium as excess to defense needs. This quantity includes the 34 MT that is subject to the Plutonium Management and Disposition Agreement. The majority of the 34 MT is in the form of pits, which are nuclear weapons' central cores and are commonly produced using plutonium. The remainder of the 34 MT is in non-pit forms, such as metal and oxides. In addition to the 34 MT, DOE officials told us that EM is in the early stages

of diluting approximately 6 MT of non-pit plutonium at the Savannah River Site, some of which has already been sent to WIPP for disposal.[13]

NNSA's Plutonium Disposition Program manages the multiple projects and facility operations that comprise the effort to dispose of U.S. surplus, weapons-grade plutonium. For both the MOX and dilute and dispose approaches, NNSA plans to store pits at the Pantex Plant in Texas, and to disassemble some of the pits and convert some of the plutonium into oxide at Los Alamos National Laboratory. At the Savannah River Site, NNSA plans to fabricate the plutonium oxide into MOX fuel for the MOX approach or dilute the plutonium for disposal as TRU waste. In addition, NNSA estimates that both approaches will produce TRU waste that will need disposal at WIPP. Figure 1 illustrates the MOX approach and the dilute and dispose approach for disposing of surplus plutonium.

[13]According to a DOE document, the other approximately 22 MT of excess plutonium include plutonium scraps and residues that have already been disposed of at WIPP, plutonium that will be processed at the Savannah River Site and will be disposed of at WIPP or as high-level waste, plutonium contained in nuclear reactor fuel stored at Idaho National Laboratory, and plutonium contained in other spent nuclear fuel.

Figure 1: Proposed Approaches for Disposing of U.S. Surplus Plutonium from Nuclear Weapons Pits



Sources: GAO; National Nuclear Security Administration. | GAO-17-390

Note: The approaches outlined above only apply to plutonium currently contained in the pit (core) of nuclear weapons. The disposal process for non-pit plutonium would follow a modified version of the above for both the mixed-oxide approach and the dilute and dispose approach.

The MOX facility is designed to remove impurities from plutonium feedstock obtained from pits, form the plutonium into MOX fuel pellets, and fabricate these pellets into fuel assemblies for use in a reactor. The facility is designed to be a reinforced concrete structure measuring about 600,000 square feet (including support buildings) and, when complete, would include about 300 separate process systems using approximately 23,000 instruments; 85 miles of process piping; 500,000 linear feet of conduit; 3,600,000 linear feet of power and control cable; and 1,000 tons of heating, ventilation, and air conditioning duct work. As part of the Plutonium Disposition Program, NNSA in 2015 completed construction of the Waste Solidification Building, which is located near the MOX facility and is designed to process and dispose of liquid waste from the MOX

facility. The building is a 33,000-square-foot reinforced concrete structure and includes tanks, evaporators, and solidification equipment to process radioactive liquid waste streams from the MOX facility into solid waste forms suitable for disposal at WIPP.

According to NNSA officials, the dilute and dispose approach is based on a process first used by DOE in 1999 to remove excess plutonium stored at its former site at Rocky Flats near Denver, Colorado; this process is currently being used at the Savannah River Site. Approximately 5 MT of plutonium material from Rocky Flats and other DOE sites were diluted and shipped to WIPP for disposal. In addition, as a result of plutonium consolidation activities across the DOE complex, non-pit plutonium is stored at the Savannah River Site. In 2011, EM approved the dilution of some of this non-pit plutonium at the site and disposal of this material at WIPP.[14] In 2016, DOE made a formal decision to continue the dilute and dispose process for 6 MT of non-pit plutonium.[15] As of March 2017, according to a DOE official, EM had diluted approximately 67.2 kilograms of this plutonium.

Recent Cost Estimates for the MOX and Dilute and Dispose Approaches

In April 2014, DOE completed an analysis of alternative disposition options in its 2014 Plutonium Disposition Working Group Report.[16] This report found that the dilute and dispose approach would be significantly less expensive than the MOX approach and would face fewer technical risks. After DOE published this report, three other groups also estimated the life-cycle costs of the program using the MOX approach or the dilute and dispose approach, producing a range of estimated costs for both. Specifically:

[14]This plutonium came from surveillance activities at the Savannah River Site which, according to DOE officials, required DOE to annually open a certain number of plutonium storage containers. DOE officials explained that once they opened the containers, they examined the physical properties of the storage containers and the plutonium inside for any defects that might indicate a problem with the stored plutonium.

[15]Department of Energy, *Surplus Plutonium Disposition Record of Decision* (Mar. 29, 2016).

[16]*Department of Energy, Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon-Grade Plutonium Disposition Options (April 2014).*

- The Plutonium Disposition Working Group estimated in its report that the life-cycle cost of the program using the dilute and dispose approach would be approximately $8.8 billion and that the life-cycle cost of the program using the MOX approach would be approximately $25.1 billion—each of these estimates assumed annual funding of $500 million for construction activities. The report, however, reached this conclusion based on a life-cycle cost estimate for the dilute and dispose approach that had a high level of uncertainty and a life-cycle cost estimate for the MOX approach that we found to be unreliable in a prior report.[17]
- In response to congressional direction, DOE contracted with the Aerospace Corporation to assess the validity of the Plutonium Working Group's analysis and findings. In April 2015, Aerospace issued a report that also found that the dilute and dispose approach would be less costly than the MOX approach.[18] The report estimated that, not including any prior costs for the Plutonium Disposition Program through fiscal year 2013, the life-cycle cost of the program using the dilute and dispose approach would be approximately $17.2 billion.[19] In comparison, the report estimated that the remaining costs to complete the program using the MOX approach would be approximately $110.4 billion.[20]
- To further evaluate the MOX and dilute and dispose approaches, the Secretary of Energy requested that a team at Oak Ridge National Laboratory assess what the preferred approach for the Plutonium Disposition Program should be. In August 2015, the resulting report, known as the Red Team report, concluded that the dilute and dispose approach has lower technical risks and lower costs.[21] Specifically, the report concluded that the dilute and dispose approach would require

[17]GAO-14-231.

[18]Aerospace, *Plutonium Disposition Study Options Phase 1*.

[19]This estimate did not include the costs already incurred by the program as of fiscal year 2014. In addition, the estimate was developed using an assumed annual funding level of $100 million to $200 million for constructing and operating plutonium dilution equipment and facilities and $400 million to $500 million for constructing and operating plutonium preparation equipment and facilities.

[20]This estimate did not include the costs already incurred by the program as of fiscal year 2014. In addition, the estimate was developed using an assumed annual funding level of $375 million for construction activities.

[21]Oak Ridge National Laboratory, *Final Report of the Plutonium Disposition Red Team* (Oak Ridge, TN: Aug. 13, 2015).

approximately $400 million annually for the duration of the program, compared to approximately $700 million to $800 million annually using the MOX approach for approximately the same duration of time.

- In 2015, CB&I AREVA MOX Services LLC, the contractor constructing the MOX facility, commissioned High Bridge Associates to develop a series of reports that assessed the MOX approach and the dilute and dispose approach.[22] In contrast to the other three reports, High Bridge concluded that using the dilute and dispose approach would introduce significant risks and thus could be the more costly approach. High Bridge's report estimated that the life-cycle cost of the program using the dilute and dispose approach would be from $21.9 billion to $41.5 billion and that the life-cycle cost of the program using the MOX approach would be $19.4 billion.[23] The higher costs for the dilute and dispose approach were primarily driven by High Bridge's conclusion that placing the 34 MT of diluted plutonium in WIPP would increase the potential for an uncontrolled nuclear chain reaction in the WIPP underground and that DOE would need to undertake costly compensatory steps to avoid such risks.[24] However, according to DOE officials, High Bridge staff did not consult with DOE officials in developing its reports. Officials at Sandia National Laboratories who are responsible for evaluating the impact of any changes to WIPP on the facility's long-term performance explained that they had reviewed the findings of the High Bridge study and found that the study used unrealistic assumptions regarding the conditions at WIPP and overstated the potential for an uncontrolled nuclear chain reaction as a result. Nonetheless, the officials explained that an analysis that Sandia has under way looking at the disposal of diluted plutonium will include an analysis of the potential for an uncontrolled nuclear chain

[22]Reports issued by High Bridge Associates include: High Bridge Associates, Inc., *High Level Independent Review of Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Plutonium Disposition Study Options Independent Assessment* (June 29, 2015); High Bridge Associates, Inc., *Comparative Economic Analysis of the MOX Fuel Program and WIPP Dilute and Dispose Options for Surplus Weapons Plutonium Disposition* (May 5, 2016); and High Bridge Associates, Inc., *Independent Verification of Criticality Potential at WIPP for Disposal of Surplus Weapons Grade Plutonium* (July 29, 2016).

[23]These life-cycle cost estimates are presented in fiscal year 2014 dollars, meaning that they do not account for inflation.

[24]According to the analysis by High Bridge Associates, introducing the 34 MT of diluted plutonium to WIPP would increase the potential for a sufficient quantity, or critical mass, of plutonium to move together in the repository over time so that an uncontrolled nuclear chain reaction could take place.

reaction and will determine whether DOE would need to take any compensatory steps to decrease the potential for such an event.

WIPP and TRU Waste Volumes

If DOE were to pursue the dilute and dispose option, the 34 MT of diluted plutonium would likely be disposed at WIPP near Carlsbad, New Mexico. WIPP was established by the WIPP Land Withdrawal Act, which places a limit on the amount of TRU waste that can be disposed of in WIPP—the act caps the amount of TRU waste at 175,565 cubic meters (m^3) and specifies that WIPP is intended only for the disposal of radioactive waste generated from atomic energy defense activities.[25]

TRU waste at WIPP is divided into "contact-handled" and "remote-handled," based on the amount of radiation dose measured at the surface of the waste container.[26] Contact-handled waste comprises the vast majority of the TRU waste planned for disposal at WIPP. WIPP was designed to safely dispose of TRU waste in deep underground rooms excavated out of an ancient salt formation more than 2,000 feet below the earth's surface. DOE analysis has shown that, over a period of decades, the salt will shift and collapse to encapsulate the waste, permanently sealing it underground. The original design plan of the underground portions of WIPP comprised 10 waste disposal units, or panels, for placement of waste containers for final disposal.[27]

[25]Pub. L. No. 102-579 (1992), as amended. Section 7 of the act limits WIPP to the disposal of 6.2 million cubic feet (175,565 m^3) of TRU waste. For the purposes of consistency, we converted this volume to cubic meters.

[26]Contact-handled TRU waste has a radioactive surface dose rate of less than 200 millirem per hour. Such waste typically emits relatively little gamma (penetrating) radiation and waste containers can be handled directly by workers. Remote-handled TRU waste has a radioactive surface dose rate of 200 millirem or more per hour but may not exceed 1,000 millirem per hour. Remote-handled TRU waste emits relatively high levels of gamma radiation, which represents the primary radiological health hazard for workers handling such waste, and the waste containers should not be handled directly by workers and require heavy container shielding and/or remote-handling equipment. For the purposes of this report, when we refer to waste or TRU waste, we are referring to the total of contact-handled and remote-handled wastes, unless otherwise specified.

[27]WIPP was designed to accommodate the 175,565 m^3 of TRU waste in 10 disposal panels—8 of these panels were designed as individual disposal units, and the other 2 panels (panels 9 and 10) consist of access hallways running north to south through the repository. Specifically, panel 9 is to the south and provides access to panels 3, 4, 5 and 6, and panel 10 to the north provides access to panels 1, 2, 7, and 8.

WIPP is subject to regulation by EPA and the New Mexico Environment Department. EPA manages the radiological safety aspects of WIPP. As directed in the WIPP Land Withdrawal Act, EPA developed and issued regulations regarding the disposal of spent nuclear fuel, high-level radioactive waste, and TRU waste; these regulations include radioactive waste disposal standards for WIPP.[28] Under these standards, EPA conducts a recertification every 5 years of WIPP's compliance with these standards. To support the recertification, DOE prepares a performance assessment, which uses mathematical models and computer calculations to assess cumulative releases under specified scenarios relative to release limits established by EPA. If DOE needs to make significant changes to activities or conditions at WIPP that are different than what has been approved by EPA, DOE must obtain approval from EPA. According to EPA officials, this is generally done through a planned change request. For example, DOE submitted a planned change request for adjusting the required quantity of certain chemical barriers included with the waste to ensure favorable and consistent chemical conditions.[29] According to EPA officials, these planned change requests are generally for significant changes to the original design of the repository or the types of waste it can accept, and they require significant review, a recalculation of the performance assessment, and—in some cases—a federal rulemaking process that includes public comment. EPA officials told us that for less significant changes, DOE can notify EPA through a planned change notice, which does not require the same level of review. However, according to EPA officials, once DOE submits a notice, EPA can require that DOE resubmit the change as a planned change request if EPA judges the change to be significant enough to potentially impact WIPP's long-term performance.[30] EPA also determines whether WIPP complies with other federal environmental and public health and safety regulations, including the Clean Air Act and the Solid Waste Disposal Act.

[28]40 C.F.R. Part 191.

[29]DOE includes magnesium oxide (MgO) with disposed waste as an engineered barrier. When the MgO interacts with carbon dioxide (CO_2), it ensures that consistent chemical conditions are maintained, resulting in lower predicted radiological releases from the repository. In 2006, DOE determined that less MgO was required to ensure these favorable chemical conditions, and it submitted a planned change request to EPA to allow for a reduction in the required MgO.

[30]According to EPA officials, there is no guidance that outlines which types of changes to WIPP require a planned change request versus a planned change notice.

The New Mexico Environment Department also has regulatory authority over WIPP through the WIPP hazardous waste facility permit. This permit is issued under the New Mexico Hazardous Waste Act and New Mexico regulations as authorized by EPA under the Resource Conservation and Recovery Act.[31] Changes or modifications to the WIPP permit must be approved by the New Mexico Environment Department. There are three classes of permit modifications (classes 1, 2, and 3) that vary in terms of the level of review and the amount of supporting documentation required. The type of permit change required depends on the type of change requested, and New Mexico follows the guidelines outlined in federal regulations for modifying hazardous waste facility permits.[32] In general, class 3 modifications require the most significant level of review.

DOE's TRU Waste Planning

DOE has developed two documents to plan for how to handle the department's TRU waste—a TRU waste management plan, which outlines how DOE will conduct TRU waste disposal operations over a 5-year time frame, and the annual TRU waste inventory report. According to DOE officials, the TRU waste management plan is an operational planning document and not a strategic plan that focuses on near-term issues such as the number of shipments expected from waste generator sites over the next 5 years. DOE's annual TRU waste inventory report, however, is used for strategic planning. This report is intended to keep track of the TRU waste disposed of at WIPP and to estimate the volumes of TRU waste planned for disposal at WIPP until the facility's closure. On an annual basis, DOE officials at WIPP send guidance to all DOE TRU waste-generating sites on how each site should develop an updated estimate of the amount of TRU waste it has stored at the site and the amount it anticipates will be generated in the future. According to the 2015 guidance document, waste generators were asked to report stored waste and waste they anticipated will be generated through 2050, when WIPP is scheduled to stop accepting waste for disposal and begin the

[31] 42 U.S.C. § 6926.

[32] 40 C.F.R. § 270.42.

process of closing the facility.[33] DOE officials at WIPP take this data from the waste generators and compile it into the annual inventory report. According to the inventory report, these estimates of future TRU waste planned for disposal at WIPP are to be used for, among other things, strategic planning purposes, to support any requests to change the design of the facility, and as a basis for WIPP's performance assessment as part of EPA's 5-year recertification process. Since WIPP began accepting waste in 1999, DOE has depended on the facility to support its cleanup and national security missions. As of December 2015, DOE had disposed of approximately 91,129 m^3 of TRU waste in WIPP, including approximately 90,772 m^3 of contact-handled TRU waste and approximately 357 m^3 of remote-handled TRU waste.

February 2014 Accidents at WIPP

In February 2014, waste disposal operations at WIPP were suspended after two accidents underground: a fire on a salt-hauling truck and an unrelated radiological release from a waste container that contaminated portions of the facility underground and released a small amount of radiation into the environment above ground. The salt truck fire, which occurred on February 5, 2014, created substantial smoke and soot that damaged key equipment and facilities underground. The radiological release occurred less than 2 weeks later, on February 14, 2014, when a TRU waste container was breached. The breach was caused by a chemical reaction inside the container between materials that DOE later determined should not have been packaged together. The reaction generated enough heat to increase pressure in the container, which forced open the container's lid and propelled its radioactive contents, hot gases, and other materials into the air and onto adjacent waste containers. The radioactive contents, gases, and other materials ignited and triggered a fire in the disposal room, igniting other materials in the room. WIPP's ventilation system failed to contain all of the airborne radiological material underground and allowed a small amount of this material to enter the environment. As a result of the release, portions of the WIPP underground and the existing ventilation system were

[33]According to a 2015 document from the DOE officials that develop the TRU waste inventory report, waste generator sites were to begin reporting waste volume estimates assuming a closure date of 2050 rather than the assumed 2033 date used in earlier guidance. According to DOE officials, they adjusted this assumed closure date based on an improved understanding by the TRU waste generator sites of how long they will continue to have TRU waste in need of disposal.

radiologically contaminated. The suspension of WIPP's operations as a result of the accidents has impaired DOE's ability to meet its cleanup and national security missions as well as regulatory cleanup milestones agreed to with states that host DOE sites. WIPP reopened and DOE began limited waste disposal in January 2017. DOE plans to conduct limited waste disposal until a new ventilation system and exhaust shaft are installed in WIPP, which DOE officials stated is tentatively scheduled for fiscal year 2021 (pending independent assessment validation).[34]

DOE Capital Asset Acquisition Process

DOE is required to manage projects over a certain cost threshold in accordance with DOE Order 413.3B.[35] This order provides project management requirements for managing the acquisition of capital assets,[36] with the stated goal of delivering fully capable projects within the original performance baseline for cost and schedule and that meet mission performance and other requirements. The order establishes five critical decision processes for project development over the life of a project, with each process ending with a major approval milestone—or critical decision (CD) point. These CD points are as follows:

- CD-0: Approve mission need.
- CD-1: Approve alternative selection and cost range.
- CD-2: Approve project performance baseline.
- CD-3: Approve start of construction.
- CD-4: Approve start of operations or project completion.

The order specifies the requirements that must be met—including for developing and managing project cost and schedule estimates—to move a project past each CD milestone. In addition, the order requires senior

[34]According to DOE, the current cost estimate for the installation of the new ventilation system and exhaust shaft is $375.6 million.

[35]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Washington, D.C.: Dec. 20, 2016).

[36]DOE defines capital assets as land, structures, equipment and intellectual property that are used by the federal government and that have an estimated useful life of 2 years or more. The department defines a capital asset project as a project with defined start and end points that is required in the acquisition of capital assets.

management to review the supporting documentation and decide whether to approve the project moving forward at each CD.

While DOE Order 413.3B establishes requirements for estimating the cost of a capital asset project, these requirements do not apply to programs, such as the Plutonium Disposition Program. In November 2014, we found that DOE programs were not required to meet any cost estimating best practices and concluded that because DOE does not require the use of best practices for its programs, it is unlikely to consistently develop reliable cost estimates. We recommended that DOE revise its program and project management order to require that life-cycle cost estimates be developed in accordance with our best practices. DOE agreed with our recommendation and updated the order to require best practices for cost and schedule estimate for projects, however, these requirements still are not required for programs, such as the Plutonium Disposition Program.[37]

GAO Cost-Estimating Best Practices

Drawing from federal cost-estimating organizations and industry, our cost estimating guide provides best practices about the processes, procedures, and practices needed for ensuring development of high-quality—that is, reliable—cost estimates.[38] A high-quality cost estimate helps ensure that management is given the information it needs to make informed decisions. The guide identifies the following four characteristics of a high-quality cost estimate. Specifically, such an estimate is:

- **comprehensive** when it accounts for all possible costs associated with a project and contains a cost estimating structure in sufficient detail to ensure that costs are neither omitted nor double-counted, and the estimating teams' composition is commensurate with the assignment;
- **well-documented** when supporting documentation is accompanied by a narrative explaining the process, sources, and methods used to create the estimate and contains the underlying data used to develop the estimate;

[37]See GAO, *Project and Program Management: DOE Needs to Revise Requirements and Guidance for Cost Estimating and Related Reviews,* GAO-15-29 (Washington, D.C.: Nov. 25, 2014).

[38]GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: March 2009).

- **accurate** when it is not overly conservative or too optimistic and is based on an assessment of the costs most likely to be incurred; and
- **credible** when it has been cross-checked with an independent cost estimate,[39] the level of confidence associated with the estimate has been identified through the use of risk and uncertainty analysis, and a sensitivity analysis has been conducted.[40]

To develop a cost estimate that embodies these four characteristics, our cost estimating guide lays out 12 best practice steps. For example, one step—determining the estimating structure—includes the need to develop a "product-oriented" work breakdown structure that reflects the requirements and basis for identifying resources and tasks necessary to accomplish the project's objectives. A product-oriented work breakdown structure is organized to reflect the cost, schedule, and technical performance of project components.[41] Such a work breakdown structure allows a project to track cost by defined deliverables, promotes accountability by identifying work products that are independent of one another, and provides a basis for identifying resources and tasks for developing a cost estimate. Table 1 includes a listing of each of the 12 steps and the four corresponding characteristics.

[39]According to DOE's project management order, an independent cost estimate is a cost estimate prepared by an organization independent of the project sponsor, using the same detailed technical and procurement information to make the project estimate. It is used to validate the project estimate to determine whether it is accurate and reasonable.

[40]A risk and uncertainty analysis assesses the variability in the cost estimate from such effects as schedules slipping, missions changing, and proposed solutions not meeting users' needs. A sensitivity analysis examines the effect of changing one assumption related to each project activity while holding all other variables constant in order to identify which variable most affects the cost estimate.

[41]The work breakdown structure, among other things, provides a clear picture of what needs to be accomplished, how the work will be done, and a basis for identifying resources and tasks for developing a cost estimate.

Table 1: Four Characteristics of a High-Quality Cost Estimate with Corresponding Best Practices

Characteristic	12 Best Practice Steps
Comprehensive	• Develop the estimating plan • Determine the estimating structure
Well-documented	• Define the estimate's purpose, scope, and schedule • Define the program's characteristics • Identify ground rules and assumptions • Obtain the data • Document the estimate • Present the estimate to management for approval
Accurate	• Develop the point estimate[a] • Update the estimate to reflect actual costs and changes
Credible	• Compare the point estimate to an independent cost estimate[a] • Conduct sensitivity analysis • Conduct risk and uncertainty analysis

Source: GAO. | GAO-17-390

[a]As described in the GAO Cost Estimating and Assessment Guide, while we have separated these tasks in the bullets above, developing the point estimate and comparing it with an independent cost estimate are separate parts of the same step. For purposes of assessing the extent to which a cost estimate achieves the characteristics of a high-quality cost estimate, developing the point estimate contributes to accuracy, and comparing the point estimate with an independent cost estimate contributes to credibility.

DOE's Revised Cost Estimate for Constructing the MOX Facility Substantially Met Best Practices, but NNSA Has Not Yet Applied Best Practices to the Revised Life-cycle Cost Estimate for Completing the Overall Program

DOE's revised cost estimate for completing construction of the MOX facility substantially met best practices and, therefore, we believe it can be considered reliable because it substantially met all four characteristics of a high-quality estimate. In contrast, NNSA has not yet applied best practices when revising its life-cycle cost estimate for the Plutonium

Disposition Program using the MOX approach, as we previously recommended.[42]

DOE's Revised Cost Estimate for Constructing the MOX Facility Substantially Met Best Practices and Can Be Considered Reliable

DOE's revised cost estimate for constructing the MOX facility substantially met best practices. DOE developed the revised cost estimate in 2016 using two different funding scenarios reflecting the expected appropriation for the project.[43] DOE estimated the MOX facility construction would cost $17.2 billion assuming $350 million in funding per year until project completion, which is consistent with recent appropriations for the project, or $14.3 billion assuming $500 million per year until project completion. These two estimates were developed to illustrate the effect of varying funding levels on the project cost and duration. DOE's 2016 revised cost estimate for MOX construction substantially met all four characteristics of a high-quality, reliable cost estimate: comprehensive, well-documented, accurate, and credible. Therefore, we believe it can be considered reliable.[44] Table 2 summarizes our assessment of DOE's cost estimate by characteristic.

Table 2: Department of Energy's (DOE) 2016 Cost Estimate for Construction of the Mixed-oxide (MOX) Fuel Fabrication Facility Substantially Met All Characteristics for Reliability

The facility would produce MOX fuel—a mixture of plutonium and uranium oxides—for use in modified commercial nuclear reactors.

Characteristics of reliable cost estimates		GAO assessment of DOE's estimate
Comprehensive	A comprehensive cost estimate has enough detail to ensure that cost elements are neither omitted nor double counted.	**Substantially met.** The estimate included all actual and estimated future costs to construct the MOX facility, including the government's and contractor's costs.
Well-documented	A well-documented cost estimate allows for the data it contains to be traced to source documents.	**Substantially met.** DOE's documentation captured the data sources used for this update. The estimate was based on the same program and technical description as the 2013 Independent Cost Estimate.

[42]GAO-14-231.

[43]DOE also developed a cost estimate of $11.8 billion for an unconstrained funding scenario.

[44]A cost estimate is considered reliable if the overall assessment ratings for each of the four characteristics are substantially or fully met.

Characteristics of reliable cost estimates		GAO assessment of DOE's estimate
Accurate	An accurate cost estimate is based on an assessment of most likely costs; contains few, if any, mathematical errors; and has been adjusted properly for inflation.	**Substantially met.** GAO independently verified a sample of the estimate's output and found no mathematical errors. The estimate was developed using a 4 percent escalation rate to account for inflation.
Credible	A credible cost estimate discusses any limitations because of uncertainty or bias surrounding data or assumptions.	**Substantially met.** DOE conducted sensitivity and risk and uncertainty analyses. DOE consulted several prior independent studies that included construction costs for the MOX facility. DOE also followed the best practice of conducting schedule risk analysis as specified in our schedule guide.

Source: GAO analysis of Department of Energy data. | GAO-17-390

Note: A sensitivity analysis examines the effects of changing ground rules and assumptions, and a risk and uncertainty analysis assesses the variability in point estimates due to factors, such as errors and cost estimators' inexperience or biases.

Our assessment noted the following for each of the four characteristics:

- **Comprehensive:** DOE's revised estimate was substantially comprehensive because, among other things, it followed the best practices of including all costs incurred and estimated future costs to complete construction of the MOX facility, including the government's and contractor's costs. According to DOE officials responsible for revising this cost estimate, the estimate was based on the methodology and costs in a 2013 Independent Cost Estimate for constructing the MOX facility that was developed by the U.S. Army Corps of Engineers (Corps). For the revised estimate, DOE updated the costs of the work completed as of 2016 by adding to the costs for the work completed in the 2013 Independent Cost Estimate, the cost of materials that had actually been installed and inspected and that did not require rework as of 2016, the cost of different management accounts, escalation, and the costs to account for equipment and technology that had been or would be acquired and installed but that DOE officials expected to become obsolete and would need to be replaced before the facility construction was completed.
- **Well-documented:** DOE's revised estimate was substantially well-documented, in part because DOE's documentation captures the data sources the department used for this estimate. For example, the estimate included sources of data from the 2013 Independent Cost Estimate and from the contractor's performance data. In addition, the revised estimate was based on the work breakdown structure used in the 2013 Independent Cost Estimate, which described in detail the methodology for each element of work. We also found that DOE's revised cost estimate was based on the same program and technical description as the 2013 Independent Cost Estimate. According to DOE officials, the revised estimate has a range of minus 10 percent to

plus 10 percent.[45] In addition, in developing its revised estimate, DOE followed the best practice of presenting the estimate to DOE management for approval.

- **Accurate:** DOE's revised estimate was substantially accurate. Among other things, we independently verified a selection of the cost output and found no mathematical errors. We also found that DOE properly adjusted this estimate for inflation, applying a 4 percent escalation rate to account for inflation, which is the same factor that the Corps used in developing the 2013 Independent Cost Estimate and is consistent with NNSA's escalation rate used for this type of project, according to DOE. We assessed this characteristic as substantially accurate but not fully accurate, in part because it did not fully meet the best practice of basing the estimate on a historical record of costs from previous efforts and actual experiences from other comparable projects. This was because a portion of the estimate was not based on historical experience of other projects. For example, DOE added costs to the estimate to account for equipment and technology that had been or would be acquired and installed but that DOE officials expected to become obsolete and would need to be replaced before the facility construction was completed. According to DOE officials, this added cost was not based on a historical record because the MOX project is the first project for which this cost was added.
- **Credible:** DOE's revised estimate was substantially credible, in part because DOE followed the best practices of conducting sensitivity, and risk and uncertainty analyses. For example, DOE conducted statistical sensitivity analysis to understand the biggest cost drivers for the funds held by the government and the contractor that might be needed to cover risks. In addition, DOE's revised estimate also followed the best practice of conducting a schedule risk analysis as specified in our schedule guide.[46] DOE officials conducted schedule risk analysis to include the costs of possible schedule slippage in the estimate. Based on this analysis, DOE added a total of approximately 49 months, and this schedule addition increased the cost estimate by $744 million plus escalation, according to DOE officials. We assessed this characteristic as substantially credible and not fully credible, in part because it did not fully meet the best practice of conducting an independent cost estimate. While DOE's 2016 revised estimate was

[45]For example, the range for the $17.2 billion cost estimate is $15.5 billion to $18.9 billion.

[46]GAO, *GAO Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: Dec. 22, 2015).

itself not an independent cost estimate, it was based on the 2013 Independent Cost Estimate. In addition, according to DOE officials, DOE also compared its revised estimate to the estimates in the 2014 Plutonium Disposition Working Group Report and the 2015 Aerospace and Red Team reports and concluded that its estimate was in line with the results of these other reviews.[47] Appendix II provides more detail on our assessment of how well DOE's 2016 cost estimate for completing MOX facility construction met each best practice for developing a high-quality estimate.

NNSA Has Not Yet Applied Best Practices When Revising Its Life-Cycle Cost Estimate for the Plutonium Disposition Program Using the MOX Approach

NNSA has not yet applied best practices when revising its life-cycle cost estimate for the Plutonium Disposition Program using the MOX approach, as we previously recommended.[48] This is because, according to NNSA officials, they developed the $56 billion cost estimate to satisfy an annual requirement to record the plutonium environmental liability on departmental financial statements that were due in September 2016.

Specifically, NNSA revised the life-cycle cost estimate for the Plutonium Disposition Program using the MOX approach, increasing it from $24.2 billion in 2013 to $56 billion in 2016. In revising the life-cycle cost estimate, NNSA included DOE's revised MOX facility construction cost estimate of $17.2 billion. NNSA then extended the completion date for the program from the previous estimated completion date of 2036 to a new estimated completion date of 2065 to account for the 29 years DOE now estimates it will take to complete the construction of the MOX facility. NNSA officials explained that a significant part of the increase in the 2016 life-cycle cost estimate from the 2013 estimate was from applying escalation rates to account for inflation over the new, longer time period. Table 3 shows the difference between the two estimates for each

[47]According to DOE officials, they compared the revised estimate to the estimates in these reports because these reports were either congressionally mandated or directed by the Secretary of Energy. They did not compare the revised estimate to the estimates in the High Bridge reports because DOE officials did not view these reports to be sufficiently independent to use as basis for comparison because they were prepared for the contractor.

[48]GAO-14-231.

program component, while appendix III provides more information on the amounts spent to date and the estimated future costs.

NNSA officials told us that they did not develop a life-cycle cost estimate following best practices for the MOX approach because they only had sufficient funding to develop the life-cycle cost estimate for the dilute and dispose approach that Congress requested in 2016. NNSA officials explained that if the Plutonium Disposition Program was not authorized to move forward with the dilute and dispose approach, NNSA would need approximately $30 million and about 3 to 4 years to revise both the MOX facility cost estimate and the program's life-cycle cost estimate using the MOX approach.

Table 3: Differences between the National Nuclear Security Administration's (NNSA) Life-cycle Cost Estimates from April 2013 and September 2016 for Completing the Plutonium Disposition Program using the Mixed-oxide (MOX) Approach

Dollars in millions

Facility or program component	Type of cost	April 2013 Plutonium Disposition Program Life-cycle Cost Estimate Total	September 2016 Plutonium Disposition Program Life-cycle Cost Estimate Total	Differences between 2013 and 2016
MOX Fuel Fabrication Facility[a]	Construction	$7,424.2	$17,128.2[f]	$9,704.0
	Operations and maintenance	$8,258.8	$16,007.8	$7,749.0
Waste Solidification Building[b]	Construction	$397.9	$392.0	$(5.9)
	Operations and maintenance	$1,910.2	$6,540.9	$4,630.7
Pit Disassembly and Conversion Facility[c]	Construction	$730.1	$730.2	$0.1
MOX Irradiation, Feedstock, and Transportation[d]	Operations and maintenance	4,940.6	$14,040.2	$9,099.6
Program Management and Integration[e]	Operations and maintenance	$492.8	$1,173.3	$680.5
Total		**$24,154.7**	**$56,012.6**	**$31,858.0**

Source: GAO analysis of NNSA estimates. | GAO-17-390

Notes: Dollar amounts may not add up to totals due to rounding.

[a]The MOX Fuel Fabrication Facility will produce MOX fuel for nuclear reactors.

[b]The Waste Solidification Building is designed to dispose of liquid waste from the MOX Fuel Fabrication Facility.

[c]The Pit Disassembly and Conversion Facility was a stand-alone facility for producing feedstock for the MOX Fuel Fabrication Facility. NNSA canceled it in 2012 and is considering alternatives for pit disassembly and conversion.

[d]MOX Irradiation, Feedstock, and Transportation is the program component that, includes: (1) production of plutonium feedstock for the MOX Fuel Fabrication Facility, (2) qualification of MOX fuel for use in commercial nuclear reactors, and (3) procurement and maintenance of shipping containers for plutonium feedstock and MOX fuel.

[e]Program Management and Integration is the program component, that includes overall management and integration of the MOX Fuel Fabrication Facility and the Waste Solidification Building projects, and integration of the projects with activities that fall under the MOX Irradiation, Feedstock, and Transportation component. The Program Management and Integration component used to be called the Plutonium Disposition and Infrastructure Program.

[f]According to NNSA officials, this figure represents the Department of Energy's updated $17.2 billion cost estimate for the construction of the MOX Fuel Fabrication Facility using a $350 million per year funding profile. NNSA's documentation does not provide an explanation for this difference.

In our February 2014 report, we recommended that NNSA revise and update the Plutonium Disposition Program's life-cycle cost estimate using the MOX approach following our cost estimating best practices, such as

conducting an independent cost estimate.[49] NNSA generally agreed with our recommendation, but has not yet implemented it. While, as mentioned previously, there have been several other recent estimates for the life-cycle cost of the program using the MOX approach, these estimates concluded a wide range of potential life-cycle costs and used different methodologies. Based on the findings of our review of NNSA's revised life-cycle cost estimate, we continue to believe that our recommendation remains valid and that, should DOE choose to pursue the MOX approach, NNSA should revise this estimate consistent with our cost and schedule estimating best practices. NNSA officials in charge of revising this estimate stated that they will apply cost and schedule best practices to revise this estimate, including conducting an independent cost estimate, should there be a decision to continue with the MOX approach.

NNSA Is Developing a Life-cycle Cost Estimate for Completing the Plutonium Disposition Program Using the Dilute and Dispose Approach

NNSA is currently in the process of developing a life-cycle cost estimate for completing the Plutonium Disposition Program using the dilute and dispose approach. NNSA is currently assessing the extent to which any new equipment and facilities would be needed to pursue this approach and, according to NNSA officials, will complete a life-cycle cost estimate that will follow GAO's cost estimating best practices, including having the estimate independently validated. NNSA officials also told us that while they originally expected to have an independently validated life-cycle cost estimate completed in mid-2018, they had to suspend almost all estimating work because they were initially limited to $5 million in fiscal year 2017 for this work.[50] According to these officials, the soonest they will have the program life-cycle cost estimate ready to be submitted for independent validation will be in the second quarter of fiscal year 2018.[51]

[49]GAO-14-231.

[50]The $5 million limitation was included in the explanatory statement accompanying the fiscal year 2016 appropriation act. This amount was raised to $15 million in the explanatory statement for the fiscal year 2017 appropriations act passed in May, 2017.

[51]This time frame was based on the assumption that Congress would increase the amount of funding available in fiscal year 2017 for estimating work for the Plutonium Disposition Program using the dilute and dispose approach.

Based on this schedule, officials stated that the program life-cycle cost estimate could be independently validated by the end of 2018.

According to the program requirements document that NNSA created to outline its plans for conducting the dilute and dispose approach and NNSA officials, NNSA's life-cycle cost estimate for the program using this approach will include several program elements: preparing the plutonium for dilution, diluting the plutonium into waste, and disposing of it at WIPP.[52] NNSA identified in the program requirements document that it will need to expand its existing capabilities for preparing plutonium and diluting it, and according to NNSA officials, its life-cycle cost estimate will define the extent of these expansions and the overall cost for each element. To assist with the development of the cost estimates for each of the program elements, NNSA included an initial set of milestones for completing the program in the program requirements document. According to an NNSA official, program estimators can use these milestones to determine the rates at which each program element needs to process the plutonium in order to complete the program by the established date. These milestones are outlined in appendix IV.

NNSA Has Determined It Will Need to Expand Its Plutonium Preparation Capabilities for Dilute and Dispose

NNSA has determined that in order to complete the program using the dilute and dispose approach, it will need to expand its plutonium preparation capabilities. NNSA is currently assessing the extent of this expansion and how much it will cost. Currently, NNSA operates the Advanced Recovery and Integrated Extraction System (ARIES) project at Los Alamos National Laboratory, which has equipment for disassembling nuclear weapons pits and converting the plutonium in these pits into plutonium oxide. DOE developed this capability as a technology development project. According to NNSA officials, the ARIES project has operated sporadically since 1998 and has thus far produced approximately 667 kilograms of plutonium oxide, which NNSA had planned to use as feedstock for the MOX Facility. NNSA determined that,

[52]According to NNSA officials, other program elements whose costs will be part of the program's life-cycle estimate include: managing the surplus nuclear weapons pit inventory at Pantex, supporting the close-out and disposition of the MOX Fuel Fabrication Facility and Waste Solidification Building, and managing the overall program. See National Nuclear Security Administration, *Surplus Plutonium Disposition Program Requirements Document for the Proposed Dilute and Dispose Approach* (Aug. 30, 2016).

should the Plutonium Disposition Program continue forward with the MOX approach, NNSA would need to expand the capabilities of ARIES to produce sufficient plutonium oxide for operating the MOX facility. According to NNSA officials, the existing capabilities of ARIES are also insufficient for meeting the plutonium oxide production rates that NNSA has established for the dilute and dispose approach over the estimated lifetime of the program.[53] According to NNSA officials, additional equipment is needed, such as gloveboxes and tools for both disassembling nuclear weapons pits and converting the plutonium into plutonium oxide, so that ARIES can achieve the production rates outlined in the program requirements for the dilute and dispose approach. To estimate the life-cycle costs associated with expanding and operating the ARIES project, NNSA currently is assessing the quantities of equipment it would need to install and the floor space it would need to achieve specified production rates. NNSA officials in the Plutonium Disposition Program told us they consulted with the NNSA officials responsible for managing the relevant space at Los Alamos, who told them that current plans for the space would allow for an expansion of the ARIES project.[54] NNSA officials also told us they suspended their assessment of the costs to expand ARIES for dilute and dispose in January 2017 as they had reached the initial fiscal year 2017 funding limit for analyzing the dilute and dispose approach. These officials stated that the completion of the analysis would be delayed by at least 6 months past the original June 2017 completion date and acknowledged that this estimate must be completed prior to developing the life-cycle cost estimate for the dilute and dispose approach.

According to NNSA officials, NNSA has not initiated the capital asset acquisition process to expand its plutonium preparation capabilities because the extent of this expansion will differ depending on whether NNSA pursues the MOX approach or the dilute and dispose approach. NNSA officials explained that if NNSA started the acquisition process

[53]The production rate for plutonium oxide is included in a classified document NNSA has developed for the dilute and dispose approach.

[54]The ARIES project is located in what NNSA refers to as the "Plutonium Facility 4" at Los Alamos National Laboratory. As we reported in 2016, the scope of NNSA's ongoing Chemistry and Metallurgy Research Replacement project does not include the need for plutonium analysis capabilities for programs outside of NNSA's Office of Defense programs, including the need for these capabilities for the ARIES project. See GAO, *DOE Project Management: NNSA Needs to Clarify Requirements for Its Plutonium Analysis Project at Los Alamos,* GAO-16-585 (Washington, D.C.: Aug. 9, 2016).

using the requirements of the dilute and dispose approach and then this approach was rejected, NNSA would have to restart the process using the MOX requirements. These officials stated that if NNSA receives congressional authorization to pursue the dilute and dispose approach, it will initiate DOE's capital asset acquisition process for the expansion of ARIES to obtain the needed equipment. If this authorization is received, NNSA would use the ARIES expansion analysis it is currently conducting to develop the documentation needed for reaching the CD-0 milestone. The information provided by this analysis would support an assessment of the gap in capabilities in the existing ARIES project and a rough order-of-magnitude cost estimate to procure the equipment needed to close this gap.[55] However, if NNSA does not receive authorization to pursue the dilute and dispose approach, NNSA will need to update its assessment of ARIES expansion requirements under the MOX approach, according to NNSA officials. In 2013, NNSA assessed the costs of expanding ARIES to support the MOX approach and estimated that it would need approximately $438 million for new equipment and that this expansion would take approximately 12 years to complete.[56] This estimate was based on a plutonium oxide production rate that, according to NNSA officials, was significantly higher than the rate being used in the estimate for the dilute and dispose approach. NNSA officials told us that the ARIES requirements for the program using the MOX approach could be significantly different if operations begin in 2048, as DOE's revised MOX cost estimate concluded.

[55]Our Cost Guide defines a rough order-of-magnitude cost estimate as an estimate developed from limited data in a short amount of time and that is not considered to be a budget-quality estimate.

[56]In 2010, we found that NNSA had a limited supply of plutonium oxide on hand to supply the MOX facility prior to the start of pit disassembly and that it was unrealistic that NNSA would meet its MOX production schedule without obtaining additional sources of plutonium oxide. We recommended that NNSA develop a plan to mitigate the likely shortfall in plutonium oxide by, among other things, determining the actions needed for ARIES to meet its production goals and the cost and schedule for expansion, if needed. See GAO, *Nuclear Nonproliferation: DOE Needs to Address Uncertainties with and Strengthen Independent Safety Oversight of Its Plutonium Disposition Program*, GAO-10-378 (Washington, D.C.: Mar. 26, 2010).

NNSA Has Determined It Needs Additional Equipment and Facilities to Dilute Plutonium and Is Estimating the Cost to Acquire It

NNSA has determined it will need additional equipment and facilities to dilute the 34 MT of plutonium subject to the Plutonium Management and Disposition Agreement and is estimating the cost to acquire these using DOE's capital asset acquisition process. In September 2016, NNSA approved a revised mission need statement that identified the need for additional equipment and facilities to dilute plutonium and securely store it prior to disposal.[57] This document also included a rough order-of-magnitude cost estimate for the capital asset construction project needed to install the dilution and storage capabilities with a range of $200 million to $500 million. NNSA is in the process of further refining this cost estimate as part of its work towards the CD-1 milestone, which NNSA estimates will occur in the third quarter of fiscal year 2018. According to NNSA officials, NNSA is moving forward with CD-1 for the dilution portion of the program because, unlike for the ARIES expansion portion of the program, the need for the dilution capability only applies to the dilute and dispose approach. NNSA officials told us that they could stop the acquisition process for the dilution capabilities if the dilute and dispose approach does not move forward.

In order to reach CD-1 approval, NNSA is required, among other things, to conduct an analysis of alternatives to select a preferred alternative. The contractor NNSA hired to conduct this analysis identified dilution operations at the Savannah River Site—requiring $330 million in construction, including the installation of three gloveboxes and waste storage—as the highest scoring alternative. NNSA approved the analysis of alternatives in May 2017.[58] To identify the preferred alternative, the analysis began with nine potential alternatives that were put through an initial screening to determine whether each of the alternatives was sufficiently different from one another and whether each alternative could meet all the necessary requirements established in the dilute and dispose program requirements document and other documents. This screening

[57]DOE approved CD-0 for the Plutonium Disposition Program using the MOX approach in October 1997. The Department confirmed that this existing CD-0 document would apply to the program using the dilute and dispose approach.

[58]National Nuclear Security Administration, *Surplus Plutonium Disposition Project: Analysis of Alternatives*, (April 2017).

identified four alternatives that were judged as viable for providing the necessary dilution and waste storage capabilities to meet the program's requirements; NNSA then fully analyzed each of these four alternatives. These alternatives and their estimated costs are outlined in table 4 below.

Table 4: Alternatives for Providing Dilution and Waste Storage Capabilities for the Plutonium Disposition Program Using the Dilute and Dispose Approach

Dollars in millions

Alternative	Dilution Capabilities at Los Alamos National Laboratory	Dilution Capabilities at Savannah River Site	Cost Estimate for Capital Asset Acquisition Projects to Begin Operations	Life-cycle Cost Estimate
1	Three gloveboxes and waste storage for diluting pit plutonium	Two gloveboxes and waste storage for diluting non-pit plutonium	600	2,214
2	None	Three gloveboxes and waste storage for diluting pit and non-pit plutonium	330	2,854
3	Three gloveboxes and waste storage for diluting pit plutonium	None	373	2,817
4	Three gloveboxes and waste storage for diluting pit and non-pit plutonium	None	384	2,421

Source: GAO analysis of the National Nuclear Security Administration's analysis of alternatives report for the dilute and dispose approach. | GAO-17-390

Note: The National Nuclear Security Administration's analysis states that due to uncertainty regarding several assumptions and key parameters, the range for the capital asset acquisition project cost estimates listed above would be between -50% and +100%.

Among the four alternatives, the contractor's analysis ranked alternative 2, in the table above, as the highest scoring; this alternative proposes to dilute the 34 MT of both pit and non-pit plutonium at the Savannah River Site. This alternative was the highest scoring alternative for several reasons, including that (1) it was judged to have the lowest risk of any of the four based on the analysis of potential threats and opportunities for each alternative, (2) diluting the pit and non-pit plutonium at the Savannah River Site would make the most extensive use of existing facilities and capabilities and would have a lower impact on other ongoing site operations during construction and operations than would occur if dilution capabilities were installed at Los Alamos National Laboratory, and (3) it would provide easier access to a third party, such as the International Atomic Energy Agency to monitor and inspect the plutonium disposition process as required by the Plutonium Management and Disposition Agreement.

According to NNSA officials, they will use the results of the analysis of alternatives process to develop the conceptual design and estimated cost of the preferred alternative. NNSA officials told us that they were planning for NNSA management to approve CD-1 in September 2017. However, according to NNSA officials, they had suspended additional work towards CD-1 because of the initial restriction in fiscal year 2017 on their use of

additional funds for dilute and dispose planning. As a result, completion and approval of CD-1 is expected to be delayed by at least six months or more.

NNSA Is Assessing Potential Costs Associated with Disposing of Diluted Plutonium at WIPP

NNSA has been assessing what upgrades would be necessary and the costs for disposing of the 34 MT of diluted plutonium at WIPP. NNSA officials stated that any upgrades that are needed will likely be completed as part of normal operations and maintenance work at WIPP and will not require the initiation of a capital asset project. These officials also said they have identified some upgrades that will be needed at WIPP to accept the diluted plutonium. For example, security upgrades in the aboveground storage area of WIPP will be required so that the diluted plutonium can be monitored and protected in the case of an unplanned outage of the WIPP facility that prevents the diluted plutonium from being placed underground. Additionally, NNSA will need to pay for a system that allows a third party, such as the International Atomic Energy Agency, to monitor the diluted plutonium as it goes through the dilution process and is disposed of at WIPP. According to NNSA officials, the Plutonium Disposition Program will pay for the costs of the identified upgrades at WIPP associated with the disposal of diluted plutonium at WIPP. However, according to NNSA officials, their analysis for the costs of disposing of the diluted plutonium assumes that DOE will provide sufficient disposal space for this waste. These officials also said that if DOE needs to expand the disposal space at WIPP in order to accept all of the plutonium from the dilute and dispose approach, the costs for such an expansion would not be part of the life-cycle cost estimate currently under development for the program using the dilute and dispose approach. NNSA officials told us they do not have a current estimate of the costs for the upgrades at WIPP and have suspended the work assessing the costs for disposing of the plutonium at WIPP due to budget constraints.

WIPP Does Not Have Sufficient Space to Meet Current TRU Waste Disposal Needs, and Future Volumes May Exceed Statutory Capacity Even Without Diluted Plutonium

DOE does not have sufficient disposal space at WIPP to dispose of all defense TRU waste already planned for disposal, and future sources of waste could exceed WIPP's statutory capacity. To accommodate the waste identified in DOE's 2016 annual TRU waste inventory report as going to WIPP, DOE will need to further excavate the repository. To address WIPP's statutory capacity issue, DOE is considering changing its method of counting the volumes of waste disposed of at WIPP, which could allow it to dispose of the waste included in the inventory and much of the possible future volumes without exceeding the statutory capacity. However, DOE has not developed plans to obtain the requisite regulatory approvals to excavate more disposal space or plans for changing its method of counting waste volumes, which risks delaying the dilute and dispose approach if selected.

WIPP Will Need to Be Expanded to Dispose of Defense TRU Waste Already Planned for WIPP

DOE does not have sufficient disposal space available in WIPP for the TRU waste planned for disposal identified in its 2016 annual TRU waste inventory report, and DOE will need to expand the repository to accommodate this waste. DOE's inventory report includes the amount of TRU waste that DOE estimates will require disposal at WIPP or another geologic repository through 2050, the planned closure date for WIPP.[59] The 2016 inventory report includes 68,350 m^3 of contact-handled waste and 3,160 m^3 of remote-handled waste planned for disposal at WIPP.[60] These inventory totals do not include the 34 MT of diluted plutonium from the dilute and dispose approach. The inventory also has a separate section for "potential waste," which is waste that may be disposed of at

[59]In DOE's annual TRU waste inventory report, this is referred to as, "anticipated waste."

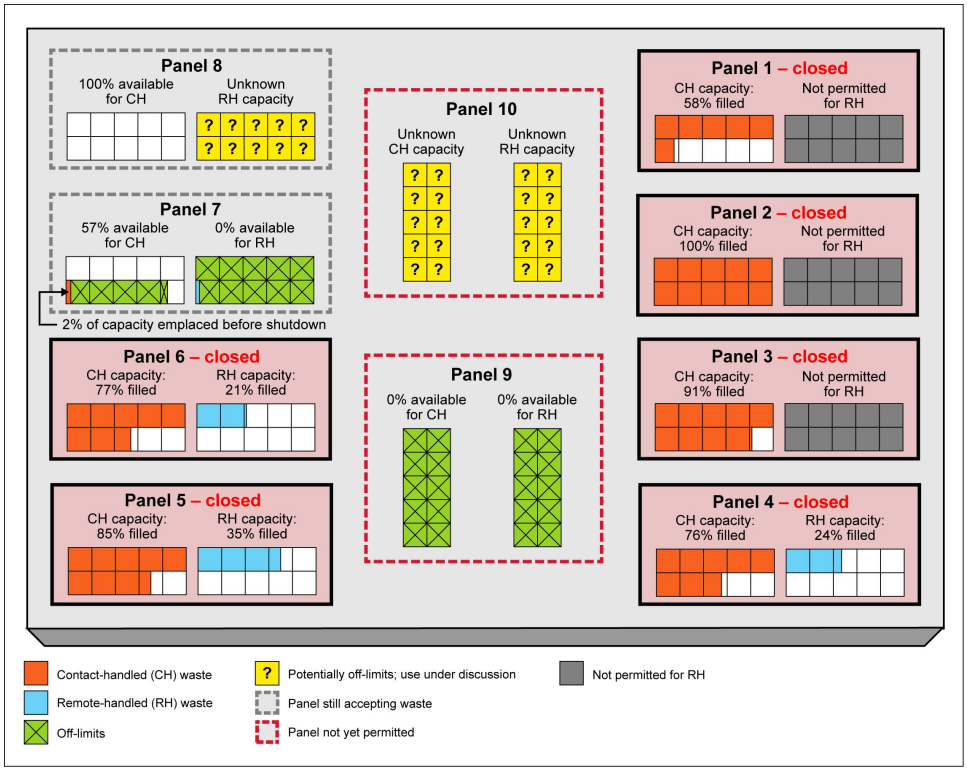
[60]This volume of contact-handled waste planned for disposal includes 385 m^3 of waste in temporary storage at Waste Control Specialists in Texas, but does not include 8,035m^3 of anticipated waste that is estimated to result from the Plutonium Disposition Program using the MOX approach.

WIPP but that, because of issues such as regulatory or physical restrictions, DOE has not yet determined meets all of WIPP's waste acceptance criteria.

DOE will be unable to dispose of all of the TRU waste planned for disposal identified in its inventory, in part because of problems with the remaining disposal space at WIPP. According to a recent DOE document, portions of the remaining disposal space outlined in WIPP's original 10-panel design are no longer suitable for waste disposal due to the accidents that took place at WIPP in February 2014. For instance, a portion of the panel where the radiological release took place will no longer be used for waste disposal. Additionally, according to DOE officials, they were unable to conduct sufficient maintenance of the entire WIPP underground while working to recover from the 2014 accidents, and as a result, additional portions of the facility's space are no longer suitable for waste disposal. In particular, these officials told us that they are not likely to dispose of waste in panel 9 due to the instability in the ceiling in that area. Figure 2 provides an illustration of the remaining disposal space available at WIPP and the extent to which prior panels were filled to their permitted capacity. For more information on the difficulties DOE faced in filling panels 1 through 6 to their permitted capacity, see appendix V.

Figure 2: Filled and Remaining Transuranic (TRU) Waste Disposal Space at the Waste Isolation Pilot Plant (WIPP), as of December 2016

TRU waste at WIPP is divided into "contact-handled" and "remote-handled," based on the radiation dose measured at the surface of the waste container. Remote-handled waste cannot be handled directly by workers.



Sources: GAO (analysis); Department of Energy (information). | GAO-17-390

Note: DOE has not finalized its determinations of the extent to which panels 9 and 10 can be safely used for all TRU waste and the extent to which panel 8 can be used for remote-handled waste. The future capacity of these panels is unknown as of May 2017.

WIPP's capability to accommodate the TRU waste planned for disposal is complicated by special requirements for disposing of the relatively small portion of remote-handled waste. Specifically, DOE may not be able to dispose of the 3,160 m^3 of remote-handled waste planned for disposal at WIPP in any of the remaining planned space at WIPP because of the additional requirements for remote-handled waste. Currently, remote-handled waste is disposed of in WIPP either in boreholes drilled into the walls or in specially designed shielded containers. DOE officials told us that it is possible that none of the remaining space at WIPP may be available for disposing of remote-handled waste using boreholes in the panels due to two factors. First, contamination from the February 2014 radioactive release accident is now contained in some of the facility's

walls, making them potentially unsuitable for borehole disposal. Second, officials told us panels 9 and 10 were not designed for borehole disposal. However, these officials also explained that DOE is still evaluating the suitability of WIPP's planned space for borehole disposal, and it has not yet made a final decision. DOE officials have approved the use of a shielded container that allows remote-handled waste to be disposed of alongside contact-handled waste in panels instead of in boreholes, but this container has not been widely used at WIPP. The department also issued an analysis of alternatives that suggests DOE expand its use of shielded containers for remote-handled waste.

Current DOE plans for WIPP do not include an analysis of whether the facility will need to be expanded to accommodate the TRU waste planned for disposal identified in its inventory, even though the department's current plan is to fill the remaining disposal space by 2026 and the facility is not expected to close until 2050. While DOE officials stated that they recognize expansion of WIPP's disposal space may be necessary in the future, they have not analyzed or planned for expanding the facility because their focus has been on resuming waste emplacement operations at WIPP. According to our analysis of DOE's 2016 annual TRU waste inventory report and the constraints on the remaining planned disposal space at WIPP, WIPP will not be able to accommodate all the waste planned for disposal without expansion. Using DOE's plans for filling WIPP's remaining disposal space, we estimate that DOE has space for approximately 25,350 m^3 of contact-handled TRU waste.[61] The extent to which any space remains for disposal of remote-handled waste is unknown because DOE officials told us the suitability of this space is still under evaluation. As shown in table 5, the waste planned for disposal at WIPP that is identified in DOE's 2016 inventory report exceeds the facility's disposal space.

[61]The amount of disposal space available at WIPP was calculated using the current 10-panel configuration for the facility and projections DOE provided on how much waste will be disposed of in the remaining panels. Officials provided an assumptions document listing the plans for filling the remaining space in panel 7, panel 8, and a small portion of panel 10. Officials were unable to determine whether additional waste would be disposed of beyond what was noted in this document

Table 5: Amount of Waste Planned for Disposal at the Waste Isolation Pilot Plant (WIPP) Compared to Available Disposal Space at WIPP

Type of Transuranic (TRU) Waste	Amount of Waste Planned for Disposal In 2016 annual TRU waste inventory report[a]	Projected Amount of Disposal Space Available at WIPP[b]	Disposal Space Shortfall
Contact-handled Waste	68,350 m^3	25,350 m^3	-43,000 m^3
Remote-handled Waste	3,160 m^3	Unknown[c]	Unknown

Source: DOE's 2016 annual TRU waste inventory report and GAO analysis. | GAO-17-390

[a]The quantities of TRU waste planned for disposal at WIPP are based on the anticipated waste identified in the 2016 annual TRU waste inventory report. The contact-handled waste planned for disposal includes 385 m^3 of waste in temporary storage at Waste Control Specialists in Texas but does not include 8,035 m^3 of anticipated waste estimated to result from the Plutonium Disposition Program using the mixed-oxide (MOX) approach. We removed this waste from our estimates because MOX waste will not be generated if DOE pursues the dilute and dispose approach. According to DOE officials, there is uncertainty in the estimates of the total volume of anticipated waste identified in the inventory report. Variances in the final volume of TRU waste requiring disposal at WIPP would result in changes to WIPP's need for additional disposal space in the future.

[b]The amount of disposal space available at WIPP was calculated using the current 10-panel configuration for the facility and projections DOE provided on how much waste will be disposed of in the remaining panels. Officials provided an assumptions document listing the plans for filling the remaining space in panel 7, panel 8, and a small portion of panel 10. Officials were unable to determine whether additional waste would be disposed of beyond what was noted in this document

[c]According to DOE officials, it is possible that none of the space at WIPP where remote-handled waste would be disposed of in the remaining panels will be available due to the 2014 radioactive release accident and facility design limitations. DOE is evaluating whether remote-handled waste will be disposed of in this space using a variety of methods.

To address the disposal space shortfall identified by our analysis, we estimate that DOE will need to further excavate the repository to develop two or more additional panels.[62] These additional panels could also be used to accommodate some of the remote-handled TRU waste identified in the inventory report, although not all of it. Our estimate of the additional panels that DOE will need to accommodate the contact-handled waste planned for disposal identified in the 2016 inventory report does not account for the 34 MT of diluted plutonium. If DOE were to move forward with the dilute and dispose approach, the 34 MT of diluted plutonium would require space equivalent to approximately one and a half additional panels. If new panels were permitted for a quantity of remote-handled waste similar to that permitted for as existing panels, two new panels could only accommodate 1,300 m^3 of the 3,160 m^3 of remote-handled

[62]This estimate is based on the quantity of waste DOE estimates would fit in a full panel based on their operational experience filling the prior panels.

TRU waste, or approximately 41 percent. With expanded use of shielded containers to dispose of remote-handled waste, DOE may be able to dispose of additional volumes, but officials told us that using additional shielded containers would only partially solve this issue. Additionally, any new shielded containers for remote-handled waste would need to be approved for use by EPA and the New Mexico Environment Department. According to DOE officials, the area set aside for WIPP in the Land Withdrawal Act is sufficient for the additional panels discussed above and could allow for further expansion if necessary.

DOE's Inventory of TRU Waste Planned for WIPP Is Not Comprehensive, and Additional Waste Could Exceed WIPP's Statutory Capacity

DOE's inventory of TRU waste planned for disposal at WIPP does not include all possible sources of TRU waste. We identified three sources of waste for which DOE has estimated volumes but that are not included in the inventory report as waste planned for disposal at WIPP. The first source, potential waste, is waste that DOE's waste generator sites have identified but that is not planned for disposal at WIPP because of regulatory constraints, physical constraints, or other reasons. For the other two sources—greater-than-Class C (GTCC) low-level radioactive waste (LLW) and GTCC-like waste, and diluted plutonium from the dilute and dispose approach—DOE is waiting on decisions by Congress and NNSA, respectively, before including this waste in the inventory as planned for disposal.[63] DOE officials stated that because there are pending determinations on whether the 34 MT of diluted plutonium or GTCC LLW waste will be disposed of at WIPP, they are not included in DOE's calculations regarding whether WIPP may exceed its statutory capacity in the future. According to our analysis of DOE's 2016 annual TRU waste inventory report and DOE documents relating to these three sources of waste, if some or all of these sources of waste are disposed of at WIPP, under DOE's current method for counting waste volume, the facility could exceed its statutory disposal capacity. Specifically:

[63]GTCC LLW is low level radioactive waste in which the concentrations of radionuclides exceed the limits for Class C waste established by the Nuclear Regulatory Commission (NRC). This waste is generated by activities licensed by the NRC or Agreement States. According to DOE officials, GTCC LLW may contain relatively high levels of radioactivity and certain longer-lived radionuclides, requiring rigorous disposal requirements. GTCC-like waste is DOE-owned or -generated low-level waste or TRU waste with characteristics similar to GTCC LLW and for which there is no identified disposal path.

- **Potential waste:** DOE's waste generator sites identified approximately 3,094 m^3 of waste in DOE's 2016 annual TRU waste inventory report that it characterized as "potential" TRU waste.[64] This potential waste is not counted in waste totals planned for disposal at WIPP. DOE relies on its TRU waste generator sites to estimate the amounts of this waste and determine if and when it can be considered waste planned for disposal at WIPP and thus be counted toward the total volume of waste planned for disposal.[65] Neither the TRU waste management plan nor the annual TRU waste inventory report includes a schedule for when waste generator sites are to make the necessary determinations on whether this potential waste can be disposed of at WIPP. Furthermore, DOE officials acknowledged that there is no requirement for the TRU waste generator sites to develop timetables for making these determinations. Federal standards for internal control state that management should use quality information to achieve the entity's objectives.[66] Among other characteristics, quality information is provided on a timely basis.[67] Without developing a schedule for making the determinations on whether the potential

[64]This amount does not include certain volumes of GTCC LLW and GTCC-like waste that are counted as potential waste but are part of a larger estimated volume for this waste that we are including separately. DOE's 2016 annual TRU waste inventory report lists a total of 7,950 m^3 of potential waste; however, we subtracted 4,856 m^3 of potential waste estimated from the West Valley Demonstration Project because it is included in DOE's estimate of 12,000 m^3 of GTCC LLW and GTCC-like waste which we included separately. Additionally, DOE officials responsible for estimating quantities of GTCC LLW and GTCC-like waste told us the amount of potential GTCC LLW and GTCC-like waste from the West Valley Demonstration Project that was reported in the 2016 inventory report differs from the totals estimated in the environmental impact statement. These officials told us that a more complete estimate of GTCC LLW and GTCC-like waste from West Valley is approximately 6,540 m^3. According to these officials, the difference between the estimates is caused by several factors, including that estimates in the Environmental Impact Statement were developed as conservative, lower-bound estimates, and uncertainty regarding quantities of GTCC LLW and GTCC-like waste that may be generated at the West Valley Demonstration Project in the future that were not reported to the inventory. Department of Energy, *Final Environmental Impact Statement for the Disposal of Greater-Than-Class-C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste*, DOE/EIS-0375 (January 2016).

[65]According to DOE officials, once a site determines that waste should be disposed of at WIPP, it works through a WIPP-certified characterization program to ensure the waste meets the criteria for disposal at WIPP.

[66]GAO, *Standards for Internal Control in the Federal Government,* GAO-14-704G (Washington, D.C.: September 2014).

[67]Quality information is appropriate, current, complete, accurate, accessible, and provided on a timely basis.

waste identified in its inventory report can be disposed of at WIPP, DOE cannot be assured that it has timely information on whether this waste needs to be included as part of DOE's planning for WIPP's future space and capacity needs.

- **Other Estimated Waste That May Go to WIPP:** Two other sources of waste could significantly impact the available capacity at WIPP. For the first source—GTCC LLW and GTCC-like waste—DOE issued a final environmental impact statement in 2016 that identified 12,000 m^3 of waste for which there is no current disposal capability. The environmental impact statement identifies WIPP and/or commercial disposal sites as the preferred alternatives for disposal of this waste; however, this waste was not generated from defense activities and therefore, according to the environmental impact statement, legislation would be required to allow for disposal of this waste at WIPP. In addition, DOE is required under the Energy Policy Act of 2005 to submit a report to Congress on disposal alternatives under consideration for GTCC LLW waste and await action by Congress before making a final decision on which disposal alternative to implement.[68] As of May 2017, DOE has not submitted the report to Congress. For the second source, DOE estimates that the diluted plutonium from the dilute and dispose approach would generate 23,800 m^3 of waste. In its current planning documents, NNSA assumes that WIPP will be the geologic repository for this waste if the decision is made to move forward with this approach for the Plutonium Disposition Program. As seen in table 6, if DOE were to dispose of all potential waste and GTCC LLW and GTCC-like waste at WIPP, it could exceed the statutory capacity established in the Land Withdrawal Act even without the 34 MT of diluted plutonium.

[68] Pub. L. No, 109-58, § 631 (2005).

Table 6: Statutory Disposal Capacity of the Waste Isolation Pilot Plant (WIPP) When Including Wastes Not Currently Planned for Disposal at WIPP

Statutory capacity remaining is a cumulative total of the preceding rows to indicate how the addition of each waste source would affect the remaining capacity under the statutory limit.

WIPP Statutory Disposal Capacity (figures in cubic meters) 175,565		
Waste source	**Volume of waste**	**Cumulative statutory capacity remaining after including waste source volume**
Waste already disposed of at WIPP	91,100	84,465
Waste planned for WIPP in 2016 TRU waste inventory report	71,510[a]	12,955
Potential waste	3,094[b]	9,861
Greater-than-Class C (GTCC) low-level and GTCC-like waste	12,000[c]	-2,139
34 metric tons of diluted plutonium	23,800	-25,939

Source: Department of Energy and GAO analysis. | GAO-17-390

[a]The volume of waste planned for disposal at WIPP is based on the anticipated waste in the Department of Energy's (DOE) 2016 annual TRU waste inventory report. According to DOE officials, this volume is based on estimates from DOE waste generator sites with varying levels of uncertainty, and the final volume of this waste could vary. The quantities of waste planned for disposal at WIPP shown above include 385 m^3 of waste in temporary storage at Waste Control Specialists in Texas but do not include 8,035 m^3 of anticipated waste that is estimated to result from the Plutonium Disposition Program using the mixed-oxide (MOX) approach. We removed this waste from our estimates because MOX waste will not be generated if DOE pursues the dilute and dispose approach. According to DOE officials, there is uncertainty in the estimates of the total volume of anticipated waste identified in the inventory report. Variances in the final volume of TRU waste requiring disposal at WIPP would result in changes to DOE's need for additional disposal space in the future.

[b]The estimated total volume of potential waste shown here does not reflect 4,856 m^3 of potential waste reported by the West Valley Demonstration Project because that waste is also included in DOE's estimates of GTCC low-level waste and GTCC-like waste.

[c]This quantity includes both GTCC low-level waste and GTCC-like waste. GTCC low-level waste is low-level radioactive waste in which the concentrations of radionuclides exceed the limits for Class C waste established by the Nuclear Regulatory Commission. GTCC-like waste is DOE-owned or -generated low-level waste or TRU waste with characteristics similar to GTCC low-level waste.

In addition to these estimated sources of waste that may be disposed of at WIPP in the future, there are other possible sources of TRU waste that DOE may need to dispose of at WIPP that have been identified but not yet estimated and are not reflected in the inventory. Specifically, DOE officials acknowledged that the possible TRU waste that could result from decontamination and decommissioning of facilities and exhumation of buried waste may represent a significant quantity of waste. Officials we interviewed at the five major DOE waste-generating sites told us of at least 44 facilities that could generate TRU waste during decontamination and decommissioning or that have buried TRU waste for which no volume

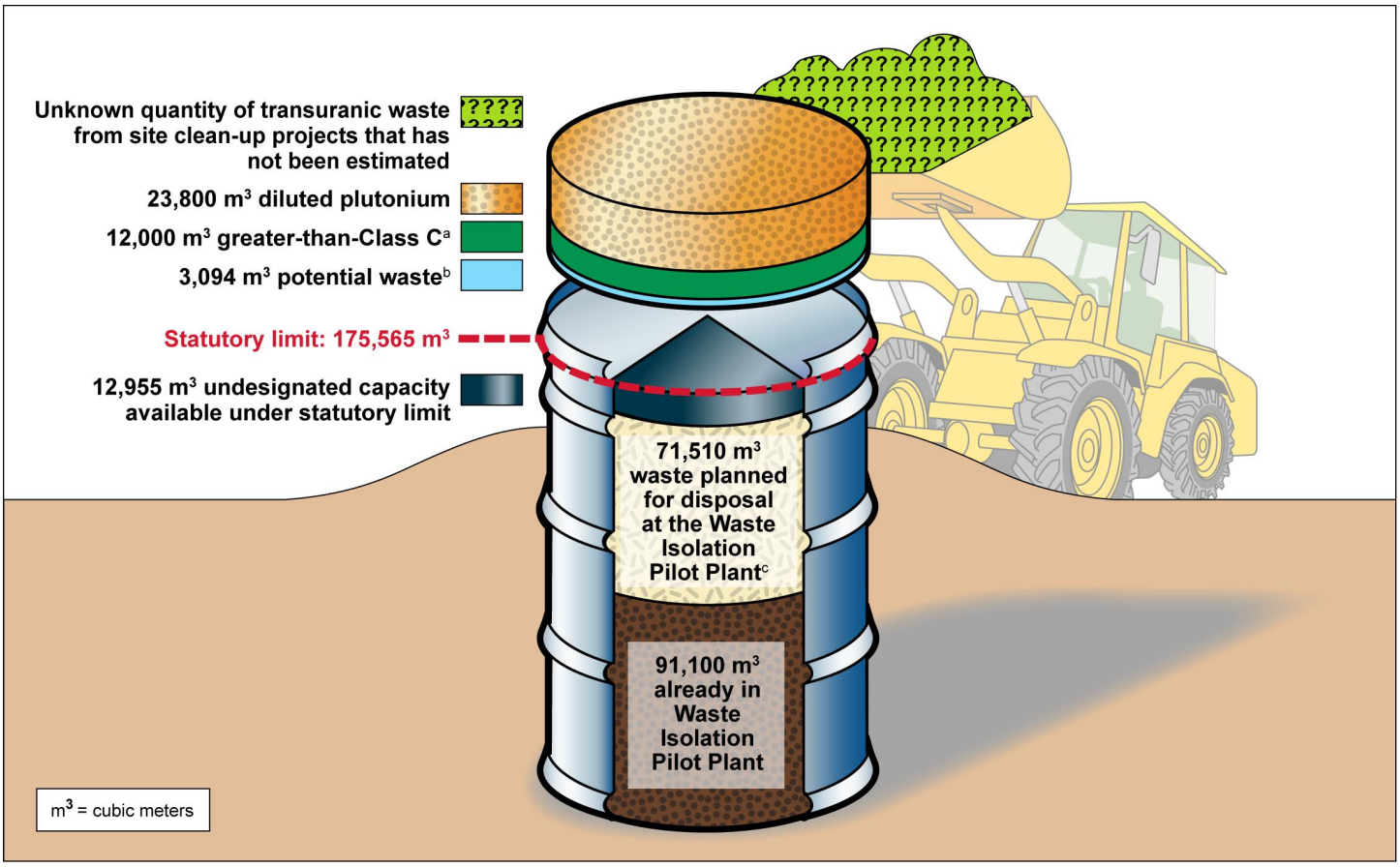
estimates have been reported to DOE.[69] Site officials told us that, in general, they do not estimate the volume of TRU waste that may result from these cleanup operations until they have agreements with state regulators on proposed methods for cleanup and plans to execute these agreements. Moreover, according to these officials, the amount of TRU waste that could be generated can vary greatly based on which cleanup methods are chosen. For a few of these facilities, site officials were able to make general estimates of the possible quantities of TRU waste. For example, officials at one site told us about a facility that did not yet have a cleanup plan and that could generate anywhere from 300 m^3 to 2,600 m^3 of TRU waste depending on the decontamination and decommissioning method. Officials at another site noted that they anticipate 2,500 m^3 to 3,000 m^3 of TRU waste from exhuming buried waste to satisfy the site's hazardous waste cleanup responsibilities, but that they had not yet reported this waste to DOE's inventory database. DOE sends guidance annually to TRU waste generator sites directing them to submit their anticipated TRU waste volume estimates through 2050 so these estimates can be included in the annual inventory report; however, this guidance does not specify how to report possible future waste for which an estimate has not yet been developed. DOE officials who manage the compilation of the inventory report told us that there is no requirement for sites to develop estimates for facilities or areas of buried waste that do not yet have established cleanup plans. Instead, officials told us that they leave this to the discretion of the sites.

Additionally, there are facilities at DOE sites that could produce TRU waste after 2050, WIPP's expected closure date, from facility operations or decontamination and decommissioning. Because DOE guidance requests that sites report future waste estimates through 2050, any estimates that sites have for waste that may be generated beyond that point are not included in DOE's annual TRU waste inventory report. DOE officials at each of the five sites we reviewed told us there are facilities that could produce TRU waste after 2050—either through eventual decontamination and decommissioning or through operations—for which TRU waste totals from cleanup have not yet been estimated. The potentially significant volumes of waste resulting from decontamination

[69]One site told us that TRU waste could be generated from "legacy waste removal" but that no waste would be generated from decontamination and decommissioning. Because removal of legacy waste is a component of decontamination and decommissioning, and any legacy waste designated as TRU waste will be sent to WIPP, we also included facilities that will generate TRU waste from legacy waste removal.

and decommissioning of facilities and exhumation of buried waste that have not yet been estimated increase the potential for WIPP to exceed its statutory disposal capacity in the future. Figure 3 shows how the addition of this possible future waste that has not yet been estimated, along with waste for which there is an estimate, could result in DOE exceeding WIPP's statutory disposal capacity.

Figure 3: Statutory Capacity Filled and Possible Future Waste Requiring Disposal at the Waste Isolation Pilot Plant (WIPP)



Sources: GAO analysis of Department of Energy data. | GAO-17-390

[a]This quantity of greater-than-Class C (GTCC) waste includes both GTCC low-level waste and GTCC-like waste. GTCC LLW is low-level radioactive waste in which the concentrations of radionuclides exceed the limits for Class C waste established by the Nuclear Regulatory Commission. GTCC-like waste is DOE-owned or -generated low-level waste or TRU waste with characteristics similar to GTCC low-level waste.

[b]The estimated total volume of potential waste shown here does not reflect 4,856 m^3 of potential waste reported by the West Valley Demonstration Project because that waste is included in DOE's estimates of GTCC low-level waste and GTCC-like waste.

[c]The volume of waste planned for disposal at WIPP is based on the anticipated waste in the Department of Energy's (DOE) 2016 annual TRU waste inventory report. According to DOE officials, this volume is based on estimates from DOE waste generator sites with varying levels of uncertainty, and the final volume of this waste could vary. The quantities of waste planned for disposal at WIPP shown above include 385 m^3 of waste in temporary storage at Waste Control Specialists in Texas but do not include 8,035 m^3 of anticipated waste that is estimated to result from the Plutonium Disposition Program using the mixed-oxide (MOX) approach. We removed this waste from our estimates because MOX waste will not be generated if DOE pursues the dilute and dispose approach. According to DOE officials, there is uncertainty in the estimates of the total volume of anticipated waste identified in the inventory report. Variances in the final volume of TRU waste requiring disposal at WIPP would result in changes to DOE's need for additional disposal space in the future.

As noted above, while DOE cannot plan for the disposal of GTCC waste and waste from the dilute and dispose approach until key decisions are made, its current planning mechanisms do not account for all waste it may need to dispose of in WIPP in the future. Federal standards for internal control state that management should use quality information to achieve the entity's objectives.[70] Among other characteristics, quality information is to be complete.[71] While DOE has developed guidance to instruct TRU waste generator sites on what information to include for the annual update to the TRU waste inventory report, this guidance does not explain how or whether sites should develop estimates of the volumes of TRU waste that may be generated in the future. Without developing guidance that helps sites produce more comprehensive estimates of the volumes of TRU waste that may be generated in the future from cleanup operations—including estimates of buried waste, waste that may be generated from decontamination and decommissioning of nuclear facilities, waste that may be generated past WIPP's expected closure date of 2050, and other possible future sources of TRU waste not currently reflected in the annual TRU waste inventory report—DOE will not have the information needed to effectively estimate the need for future space for TRU waste disposal and ensure that its plans are in compliance with WIPP's statutory capacity.

DOE Is Reviewing Alternative Waste Counting Methods That Would Allow It to Dispose of More Waste, including Diluted Plutonium, at WIPP without Exceeding the Statutory Capacity

DOE officials told us that they recognize that additional volumes of waste could result in WIPP exceeding its statutory capacity, and they are reviewing alternative methods for counting the volumes of TRU waste disposed of at WIPP that could increase the volume of waste DOE could dispose of there before reaching the facility's statutory capacity. Specifically, as identified in our analysis above, DOE will need to take steps in order to be able to confirm that waste volumes that could result in WIPP exceeding its statutory capacity, such as the 34 MT of diluted plutonium, can be disposed of at WIPP. DOE currently counts the volume

[70]GAO-14-704G.

[71]Quality information is appropriate, current, complete, accurate, accessible, and provided on a timely basis.

of waste disposed of at WIPP using the volume of the outermost container rather than the inner containers holding the waste or the volume of the waste itself. Most of the TRU waste disposed of at WIPP is packaged initially in 55-gallon drums, but some of these drums are subsequently packed inside larger containers, called overpacks, that hold multiple drums. DOE relies on several types of overpacks for the disposal of TRU waste. For the dilute and dispose approach, NNSA plans to package the waste inside small cylinders, which are then placed within 55-gallon drums. According to DOE officials, if the method for counting waste volumes changes for all TRU waste so that DOE counts the inner containers or the waste itself, this change would likely provide sufficient additional disposal capacity at WIPP for the waste planned for disposal identified in the 2016 inventory, potential waste, and the 34 MT of diluted plutonium.

In September 2016, DOE completed an analysis of alternative methods for counting the volume of TRU waste already at WIPP and the waste expected in the future. The report evaluated 13 prospective alternative calculation methods and recommended 2 preferred alternatives to present for final selection to DOE officials responsible for managing WIPP operations.[72]

- One of the preferred alternatives proposed to recalculate the volume of waste already disposed of in the repository using only the volume of the innermost waste container, and proposed that the volume of waste disposed of at WIPP in the future be determined by the volume of TRU waste in each container.
- The other preferred alternative proposed to recalculate the volume of waste already disposed of in the repository and future volumes of TRU waste using the volume of the innermost container, regardless of the amount of TRU waste in the container.

While either of the above methods would provide additional disposal capacity at WIPP, according to DOE officials, the department is still considering its options. DOE officials responsible for managing WIPP operations have previously estimated that revising the method for counting the amount of waste already disposed of could free up more

[72]Department of Energy, *Analysis of Alternatives for the Disposed Transuranic Waste Volume of Record at the Waste Isolation Pilot Plant (WIPP)* (Sept. 30, 2016).

than 30,000 m^3 of waste disposal capacity.[73] Additionally, while the volume of the 34 MT of diluted plutonium would be 23,800 m^3 using DOE's current counting method, this volume would decrease to 1,417 m^3 of waste counted towards the statutory capacity if DOE counted the volume of the inner containers instead of the 55-gallon drums. DOE officials also noted that, in addition to changing the method for counting waste, Congress could amend the WIPP Land Withdrawal Act to raise WIPP's statutory capacity to allow for more waste to be disposed of at the facility in the future.

DOE Has Not Developed Plans for Expanding WIPP's Disposal Space and Changing the Waste Counting Method

DOE officials stated that any efforts to expand the disposal space at WIPP or change the method by which they count waste volumes will require changes to DOE planning and approvals from federal or state regulators. To expand WIPP's disposal space or change the method of counting waste volumes, DOE will need to take several steps, including assessing the environmental impact of disposing of additional diluted plutonium at WIPP and seeking regulatory approval from the New Mexico Environment Department and, in some cases, EPA. According to EPA and New Mexico Environment Department officials, the effort needed for DOE to prepare the documentation and obtain regulatory approval for each of these issues is significant, and DOE has not yet begun these efforts. However, DOE officials told us that they have been focused on efforts related to reopening WIPP and will consider addressing these issues once WIPP resumes was disposal operations, which it did in January 2017.

Expansion of WIPP Disposal Space

According to DOE and EPA officials, to ensure that additional disposal space is available in time to prevent a possible disruption in waste shipments, DOE will need to: (1) complete the development of a new

[73]This estimate is based on the space savings for three container types: pipe overpacks, 10-drum overpacks, and standard waste boxes. DOE officials provided these estimates to GAO in June 2016 in a slide presentation, and the estimates are corroborated in a paper presented by a DOE official at the 2016 Waste Management Conference. Roger Nelson, "What's in WIPP? Packaging TRU Waste to Enhance WIPP's Capacity" (paper presented at the 2016 Waste Management Conference, Phoenix, AZ, March 2016).

mathematical model for assessing WIPP's regulatory performance that is necessary for designing the expansion, (2) complete an environmental impact assessment for disposing of 34 MT of diluted plutonium at WIPP if NNSA proceeds with the dilute and dispose approach, (3) secure the necessary regulatory approvals for expanding WIPP's disposal space, and (4) excavate new panels by 2026. While DOE has initiated the first two steps, it does not have a plan that outlines how it will complete all four steps by 2026, which is when it expects all existing disposal space at WIPP to be filled. DOE officials told us that before they can seek regulatory approval for expanding the facility or beginning excavation, they will first need a new mathematical model that can simulate the performance of an expanded WIPP and assess whether the facility still remains within regulatory standards. The performance assessment model is a simulation that DOE uses to demonstrate to EPA that WIPP will not exceed the EPA regulatory thresholds for the potential of a radiological release over a 10,000-year period. According to Sandia National Laboratories officials, the new model they are developing is required for expanding WIPP's disposal space in the areas DOE is currently considering, and they estimate that this model will be completed and validated by 2024.

If NNSA proceeds with the dilute and dispose approach and the 34 MT of diluted plutonium is sent to WIPP, DOE will need to include in its expansion planning the results of an assessment of the environmental impact of disposing of this waste in order to ensure that WIPP will be able to accept all of the plutonium. Officials from Sandia told us that they are currently conducting an analysis that will contribute to this environmental impact assessment and expect to complete it by fiscal year 2019. According to DOE officials, this analysis includes estimating the impact on WIPP's long-term performance to determine whether disposal of the diluted plutonium at WIPP would cause cumulative radioactive releases exceeding EPA's release limits. If the analysis by Sandia National Laboratories determines that the diluted plutonium would have a significant enough impact, steps to change the design of future disposal space at WIPP in order to reduce the potential impact could be necessary. For example, Sandia officials stated that new panels that are smaller than the current design could be used to reduce the concentration of the diluted plutonium in the repository and thereby reduce the potential for a radiological release.

DOE will also need regulatory approvals from EPA and the New Mexico Environment Department to expand the disposal space at WIPP. To get approval from EPA, DOE will need to submit a formal change request to

the agency. DOE officials told us that expanding WIPP's disposal space would constitute a significant change to the original design of the facility, and according to EPA officials, change requests of this magnitude require significant review. In some cases, the EPA officials said granting this type of change could require EPA to go through the federal rulemaking process, which could include public comment and publication of a proposed federal rule. EPA officials told us that, historically, these change requests may take as long as 2 years. According to officials from the New Mexico Environment Department, to excavate additional waste disposal panels, DOE must also seek a permit modification from their agency. EPA officials told us that approval for these kinds of changes generally take between 1 and 2 years and that they are unsure whether the New Mexico Environment Department would be able to process a permit modification request concurrently with EPA's review. Once all necessary approvals have been completed, DOE could then begin excavating new disposal space at WIPP. There is no set time frame for how long the excavation would take, and DOE officials stated that this time frame would vary based on the design of the new disposal space. However, DOE officials noted that it took about two years to excavate each of the existing panels at the facility.

DOE officials told us they have begun work on the new model and there is sufficient time to complete all necessary actions before WIPP operations are significantly impacted; however, DOE has no plans yet for seeking the approvals that would show that these approvals and subsequent construction can be completed before the facility's existing disposal space is full. DOE's most current formal planning document for WIPP, the TRU waste management plan, covers 5 years. DOE officials told us that the plan is limited to 5 years because it is an operational plan that is used to plan near-term waste shipments, not a long-term strategic plan. The most current version of this plan addresses the period up to 2019 and does not address possible future WIPP expansion needs. Completion of the new model for WIPP that is needed to begin the regulatory approval process for expansion is not expected to be ready until 2024, and then the approval and subsequent construction process could take another 4 years or longer. Given that these time frames extend well beyond the period addressed in the TRU waste management plan, DOE's current planning is insufficient for addressing possible WIPP expansion. As discussed above, under federal standards for internal control, management should use quality information to achieve agency objectives; among other characteristics, quality information is to be complete. However, DOE's TRU waste management plan does not contain information necessary to plan for the future of WIPP through its

closure. Without developing a long-term plan for WIPP that includes the need for expanding WIPP's disposal space and an integrated schedule that describes how DOE will complete the regulatory approval process and construction of new space before WIPP's existing space is full, DOE will not have reasonable assurance that it will be able to expand the repository in a timely manner. Instead, according to DOE officials, they may have to slow or suspend waste shipments to WIPP in the future, which could delay the implementation of the dilute and dispose approach, should it move forward. The slowing or suspension of waste shipments from waste generator sites could also delay the completion of cleanup projects at those sites and could impact their ability to meet cleanup deadlines negotiated with state regulators.

Revision of Method for Counting Waste Volumes

To revise the method DOE uses to count waste volumes disposed of at WIPP against the statutory disposal capacity, DOE officials explained that they will need regulatory approval from the New Mexico Environment Department to change the facility's hazardous waste operating permit, and such approval could take 2 years. DOE has not yet completed its internal deliberations about the specifics of this proposed change and, as such, has not yet sought a determination from the New Mexico Environment Department about what type of review would be required to approve this change or clarified how long this approval process may take. As noted above, DOE officials told us that they have been focused on efforts related to reopening WIPP, and enough time exists to obtain regulatory approval to meet the dilute and dispose milestones. However, one of the assumptions in NNSA's program requirements for the dilute and dispose approach is that WIPP will be able to dispose of the diluted plutonium and that if there are capacity constraints that would impact the facility's ability to do so, they would be addressed by 2020. In order to meet this requirement, DOE would need to implement this change by 2020 or risk delays in planning for the dilute and dispose approach. According to New Mexico Environment Department officials, the request to change the method of counting waste volumes could be completed either through a policy determination by the New Mexico Environment Department or through the formal WIPP hazardous waste facility operating permit modification process. New Mexico Environment Department officials noted that the formal permit modification process could take as long as 2 years as opposed to a policy determination, which would likely be completed more quickly. According to DOE officials, unless they receive approval from the New Mexico Environment Department to change the method for counting waste volumes, Congress

will need to raise WIPP's statutory disposal limit by amending the WIPP Land Withdrawal Act or the repository will be unable to accept significant quantities of additional waste not currently planned for disposal.

With the uncertain time frames involved with receiving approval from regulators to change the volume counting method, it is unclear whether DOE officials responsible for managing WIPP operations will be able to meet NNSA's 2020 milestone for resolving potential disposal space constraints at WIPP for disposing of the waste from the dilute and dispose approach. Under federal standards for internal control,[74] management should use quality information to achieve the entity's objectives, and among other characteristics, quality information is provided on a timely basis.[75] Without DOE developing a timeline to help determine whether it can change its method of counting waste volumes to meet NNSA's 2020 milestone, DOE and other stakeholders may not have the information they need in a timely manner to know whether possible future waste, such as waste from the dilute and dispose approach, can be added to the waste planned for disposal at WIPP without potentially exceeding the facility's statutory disposal capacity.

Conclusions

DOE is currently in the process of reevaluating the best approach for disposing of 34 MT of surplus weapons-grade plutonium. DOE's 2016 revised cost estimate of $17.2 billion for construction of the MOX facility substantially followed best practices, and we believe it can be considered reliable. However, NNSA's revised life-cycle cost estimate for the Plutonium Disposition Program using the MOX approach of $56 billion does not yet incorporate cost estimating best practices as we have previously recommended. Reviews by NNSA and some outside experts found that the dilute and dispose approach has the potential to cost significantly less, but NNSA is still developing a life-cycle cost estimate for this alternative. If the decision is made to move forward with the dilute and dispose approach, DOE will need to ensure that there is sufficient disposal space and statutory capacity at WIPP to dispose of the diluted plutonium. WIPP is a geologic repository for defense TRU waste and will

[74]GAO-14-704G.

[75]As discussed earlier, quality information is appropriate, current, complete, accurate, accessible, and provided on a timely basis.

need to accommodate all such waste unless DOE pursues an additional repository.

DOE has not adequately planned for all possible waste that it may be expected to dispose of in WIPP, complicating its ability to determine whether the waste from the dilute and dispose approach can be disposed of at WIPP. In particular, DOE does not have a schedule for when TRU waste generator sites will complete the determinations on whether the potential waste identified in DOE's annual TRU waste inventory report can be disposed of at WIPP. Without developing this schedule, DOE cannot be assured that it has timely information on whether to include this waste as part of its planning for WIPP's future space and capacity needs. In addition, DOE's TRU waste inventory report does not capture several possible future sources of waste, including waste from the decontamination and decommissioning of facilities or waste that may be generated after 2050. DOE's guidance for estimating future waste does not specify how possible future waste should be estimated and reported. Without developing guidance that helps sites produce a more comprehensive estimate for the volumes of TRU waste that may be generated in the future from cleanup operations, including estimates of buried waste, waste that may be generated from facility closure and cleanup, and other potential sources of TRU waste not currently reflected in the TRU waste inventory report, DOE will not have the information it needs to effectively estimate the need for future space for TRU waste disposal and ensure that its plans are in compliance with WIPP's statutory capacity.

To address WIPP's future space and capacity needs, DOE will need approvals from EPA and the New Mexico Environment Department. However, DOE is uncertain about the extent of approvals required and has not initiated planning efforts to obtain these approvals. DOE does not have plans to show how additional space will be excavated in time to prevent a disruption in waste shipments after the facility's existing disposal space is filled in 2026. Without a long-term plan that includes the need for expanding WIPP's disposal space and an integrated schedule that describes how DOE will complete the regulatory approval process and construction of new space before WIPP's existing space is full, DOE does not have reasonable assurance that it will be able to expand the repository before waste shipments must be slowed or suspended. DOE also does not have a timeline for determining whether it will change its method of counting waste volumes and therefore does not know whether this action will be completed by 2020, when NNSA's program requirements for the dilute and dispose approach assume that potential

capacity constraints at WIPP will have been addressed. Without DOE developing a timeline to help determine whether it can change its method of counting waste volumes to meet NNSA's 2020 milestone for resolving potential disposal space constraints at WIPP, DOE and other stakeholders may not have the information they need in a timely manner to know whether possible future waste, such as waste from the dilute and dispose approach, can be added to the waste planned for disposal at WIPP without potentially exceeding the facility's statutory disposal capacity.

Recommendations for Executive Action

To ensure that DOE has a full understanding of the department's long-term TRU waste disposal requirements and the capability of WIPP to meet those requirements, we recommend that the Secretary of Energy take the following four actions:

- Develop a schedule for deciding whether the volumes of "potential waste" identified in the annual TRU waste inventory report can be disposed of at WIPP.
- Develop guidance that helps sites produce a more comprehensive estimate for the volumes of TRU waste that may be generated in the future from cleanup operations, including estimates of buried waste, waste that may be generated from decontamination and decommissioning of nuclear facilities, and waste that may be generated past WIPP's expected closure date of 2050.
- Develop a long-term plan for disposing of DOE's TRU waste that includes:
  - the need for excavating additional disposal space at WIPP and an integrated schedule that describes how DOE will complete the regulatory approval process and construction of new space before WIPP's existing space is full, and
  - a timeline to help determine whether DOE can change its method of counting waste volumes to meet NNSA's 2020 milestone for resolving potential disposal space constraints at WIPP.

Agency Comments and Our Evaluation

We provided a draft of this report to DOE for review and comment. In written comments, reproduced in appendix VI, DOE concurred with the

report's recommendations. DOE stated that our recommendations were consistent with the department's commitment to improve management of the national TRU waste program and to efficiently and effectively utilize WIPP for disposal of eligible TRU waste. DOE outlined actions that it intends to take in response to our recommendations, including developing disposal schedules for potential waste once certain prerequisite actions are taken that provide the basis for determining whether or not the waste is TRU waste that can be disposed of at WIPP; developing new guidance by December 2018 to assist DOE sites produce more comprehensive estimates of future TRU waste that may be generated from cleanup operations; and developing a long-term plan by December 2018 for disposal of DOE's TRU waste, including an initial design for potential new waste disposal panels at WIPP and options for changing the method of counting waste volumes disposed of at WIPP. We believe that these steps, once implemented, would address our recommendations.

In addition, DOE highlighted the following two points:

- DOE's Office of Environmental Management is focused on the WIPP mission as currently defined by law.
- DOE has not made a final decision to use the dilute and dispose approach to dispose of the 34 metric tons of surplus plutonium that the department previously decided to fabricate into mixed-oxide fuel.

DOE 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, and other interested parties. In addition, the report will be 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 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 VII.

David C. Trimble
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

Our report examined (1) the extent to which the Department of Energy's (DOE) revised cost estimate for completing construction of the Mixed-oxide Fuel Fabrication Facility (MOX facility) and the revised life-cycle estimate for completing the Plutonium Disposition Program using the mixed-oxide (MOX) fuel approach met cost-estimating best practices, (2) the status of the National Nuclear Security Administration's (NNSA) development of a life-cycle cost estimate for completing the Plutonium Disposition Program using the dilute and dispose approach, and (3) the extent to which DOE has sufficient disposal space and statutory capacity at its Waste Isolation Pilot Plant (WIPP) to dispose of all defense transuranic (TRU) waste, including the diluted plutonium resulting from the dilute and dispose approach.

To assess the extent to which DOE's revised cost estimates for completing construction of the MOX facility and for completing the overall Plutonium Disposition Program relying on the MOX approach meet cost estimating best practices, we used the following methodology:

- **DOE's 2016 performance baseline cost estimate to complete the MOX facility.** We compared the process DOE used to develop the 2016 performance baseline cost estimate with the 12 key steps described in the *GAO Cost Estimating and Assessment Guide* that, when followed correctly, should result in a high-quality, reliable cost estimate.[1] We evaluated DOE's 2016 performance baseline report and reviewed backup documentation supporting the information in this report, including the U.S. Army Corps of Engineers' 2013 Independent Cost Estimate of the MOX facility construction, and the contractor's 2015 and 2016 estimate at completion reports. We also interviewed DOE cost estimating experts and officials who prepared DOE's performance baseline cost estimate. We provided a draft of our assessment to DOE and revised the draft, as appropriate, after discussing our assessment with DOE officials and receiving additional information from them, such as data on how DOE included the effects of schedule slippage in the cost estimate.

[1] GAO-09-3SP.

- **NNSA's life-cycle cost estimate for the Plutonium Disposition Program using the MOX approach:** Because NNSA officials stated that they did not prepare the updated 2016 life-cycle cost estimate for the program using the MOX approach based on GAO's 12 steps of a high-quality, reliable cost estimate, we interviewed NNSA officials responsible for developing the estimate as well as officials in charge of various parts of the program to determine whether they took any steps that might have changed the estimate's reliability since we assessed it in a 2014 report. [2] We determined at that time that the estimate did not meet the characteristics of a high-quality, reliable estimate. We also tried to understand what led to cost increases in some areas of the estimate. In addition, we reviewed back-up documentation for the 2016 life-cycle cost estimate and compared it with the documentation we evaluated in our 2014 report.

To determine the status of NNSA's development of a life-cycle cost estimate for completing the Plutonium Disposition Program using the dilute and dispose approach, we reviewed the planning documents that had been completed to date, including the mission need and program requirements documents that outlined the scope of the Plutonium Disposition Program relying on the dilute and dispose approach and dates for completing key program milestones. We also interviewed NNSA officials managing the Plutonium Disposition Program to determine the extent of planning that they had completed to date for this approach and the schedule for completing the remaining plans. To understand what efforts were ongoing to study the impact of disposing of diluted plutonium at WIPP on long term repository performance, we interviewed officials from the Carlsbad Field Office and Sandia National Laboratories and reviewed documents on preliminary analysis work they had begun. We also visited DOE's Savannah River Site to interview NNSA officials responsible for the Plutonium Disposition Program and officials from DOE's Office of Environmental Management (EM) project to dilute the 6 MT of non-pit plutonium. At the site, we also viewed a demonstration mock-up of the plutonium dilution equipment that EM already had in operation.

To determine the extent to which DOE has sufficient physical space and statutory capacity at WIPP to dispose of all defense TRU waste, including

[2]GAO, *Plutonium Disposition Program: DOE Needs to Analyze the Root Causes of Cost Increases and Develop Better Cost Estimates*, GAO-14-231 (Washington, D.C.: Feb. 13, 2014).

the diluted plutonium resulting from the dilute and dispose approach, we reviewed relevant legislation relating to WIPP's statutory capacity, DOE's annual TRU waste inventory report, and data from the Waste Data System, which tracks the waste already disposed of in the repository. We also reviewed DOE's WIPP hazardous waste facility permit and the 1992 WIPP Land Withdrawal Act to understand the legal requirements governing waste disposal at WIPP. To assess the reliability of DOE's inventory, we reviewed documents on its development and interviewed officials responsible for maintaining it. Based on our review, we determined that the data it contains are sufficiently reliable for our purposes. However, in discussions with DOE officials, they told us there is uncertainty in the estimated volume of waste expected to come to WIPP in the future. For example, DOE officials stated that the actual volume of waste that is disposed of at WIPP may be higher than their current estimates, in some cases due to circumstances that DOE cannot currently predict, such as the need to repackage certain stored wastes into multiple containers and thereby increase the total volume of waste. Additionally, a DOE official told us that the actual volume of waste disposed of at WIPP could be lower than what they currently estimate in certain cases because they are working on minimizing the volumes of TRU waste produced in the future by, for example, developing more efficient waste packaging processes. As part of developing its inventory of TRU waste, DOE updates on an annual basis the estimates on the volume of waste expected to be disposed of at WIPP in the future, using a process we found to be reliable; therefore, we used the information from this inventory for our analysis. We also conducted a site visit to WIPP to interview DOE officials responsible for managing WIPP operations to understand how the waste disposal space is managed and how they plan for DOE's future disposal needs. In interviews with DOE officials knowledgeable about DOE's cleanup efforts, we identified other sources of waste that may be disposed of at WIPP in the future but that are not currently included in DOE's inventory report. In particular, we spoke with a DOE official responsible for managing the department's strategy for disposing of greater-than-Class C waste. To understand what efforts were ongoing to study the impact of disposing of diluted plutonium at WIPP, we interviewed officials from Sandia National Laboratories who are responsible for analyzing potential changes at WIPP. To evaluate potential sources of TRU waste from generator sites that may not be included in DOE's inventory report, understand how such sites estimate the amount of TRU waste they will need to ship to WIPP, and get these sites' perspectives on potential disposal space availability and capacity issues, we reviewed documents from and interviewed officials at DOE's five major waste-generating sites. Specifically, we conducted interviews

with officials from the Hanford Site in Washington state, Idaho National Laboratory, Los Alamos National Laboratory in New Mexico, Oak Ridge National Laboratory in Tennessee, and Savannah River Site in South Carolina. These interviews included a site visit to Idaho National Laboratory. In addition, to understand the regulatory process through which DOE must work to operate WIPP, we spoke to officials from agencies that have regulatory authority over the WIPP facility—the U.S. Environmental Protection Agency and the State of New Mexico Environment Department.

Appendix II: GAO Assessment of Department of Energy's (DOE) Revised Cost Estimate for Construction of the Mixed-Oxide (MOX) Fuel Fabrication Facility

Best practice characteristic and overall assessment	Best practice	Detailed Assessment[a]
Comprehensive: *Substantially met*	The cost estimate includes all life-cycle costs.	*Substantially met.* The estimate included all actual and estimated future costs to construct the MOX facility, including government's and contractor's costs. The estimate was an update of the 2013 Independent Cost Estimate, with updates to account for the contractor's actual cost and a new estimate of future work.
	The cost estimate completely defines the program, reflects the current schedule, and is technically reasonable.	*Substantially met.* The estimate was based on the MOX facility construction project's technical baseline and on the methodology and costs in the 2013 Independent Cost Estimate conducted by the U.S. Army Corps of Engineers. DOE used updated installation rates for this estimate that were different than the rates used in the contractor's technical baseline. For example, the contractor counted that 11 percent of the pipes had been installed, while DOE's 2016 estimate used an updated contractor validation report that stated that only 1 percent of the pipe had actually been installed, inspected, and accepted.

Best practice characteristic and overall assessment	Best practice	Detailed Assessment[a]
	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.	*Partially met.* The entire MOX work breakdown structure was taken from the 2013 Independent Cost Estimate. It shows five levels of detail. This structure is the contractor's work breakdown structure, which was decertified by DOE in October 2016. The decertification report stated that one deficiency of the contractor's work breakdown structure was that the contractor did not implement a single product-oriented work breakdown structure to provide direct representation of the project work scope and document the hierarchy and description of tasks to be performed and their relationship to the product deliverables.
	The estimate documents all cost-influencing ground rules and assumptions.	*Fully met.* The estimate was based on well-described ground rules and assumptions that were identified in DOE's revised cost estimate report, as well as the 2013 Independent Cost Estimate. The assumptions were developed by cost estimators who consulted the technical community.
Well-documented: *Substantially met*	The documentation captures the source data used, the reliability of the data, and how the data were normalized.	*Substantially met.* DOE's documentation captures all data sources used for this update, which are all primary sources. For example, in most cases, the source data for the estimate are the contractor's performance data, the 2013 Independent Cost Estimate, and the contractor's estimate at completion. DOE normalized the estimate at completion data used in the 2013 Independent Cost Estimate by adding escalation, obsolescence, level of effort adjustments, and construction adjustments to bring it up to date to 2016.
	The documentation describes in sufficient detail the calculations performed and the estimating methodology used to derive each element's cost.	*Fully met.* Each level 4 work breakdown structure has a description of the methodology used to estimate it. While the 2013 Independent Cost Estimate was a better Class 2 estimate, DOE's 2016 estimate was a Class 3 estimate with a range of minus 10 percent to plus 10.
	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 was mathematically sensible and logical. Some but not all of the supporting data was available in the back up documentation provided by DOE. The data was adequate for easily updating the estimate to reflect actual costs or program changes since it came from the contractor's actuals. However, some costs were added to the historical data that were not based on actuals, such as a factor for obsolescence that was not based on any historical data.

Best practice characteristic and overall assessment	Best practice	Detailed Assessment[a]
	The documentation discusses the technical baseline description and the data in the baseline is consistent with the estimate.	*Fully met.* The estimate was based on the same program and technical description as the 2013 Independent Cost Estimate. Each work breakdown structure element had a brief technical description associated with it. The technical descriptions in the estimate could be found in the technical baseline document.
	The documentation provides evidence that the cost estimate was reviewed and accepted by management.	*Substantially met.* DOE provided documentation that would indicate that management understood all the details of the cost estimate, including the risks associated with the underlying data and methods, before management approved it.
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 included an additional approximately $207 million in extra funding, which might be needed to address known risks. DOE calculated the confidence level at 95 percent. According to our Cost Estimating Guide, while no specific confidence level is considered a best practice, experts agree that project cost estimates should be budgeted with at least 50 percent confidence level, but budgeting at a higher level (of 70 to 80 percent) is now common practice.
	The estimate has been adjusted properly for inflation.	*Fully met.* DOE properly adjusted the estimate for inflation by using a 4 percent escalation rate. This was the same escalation rate used in the 2013 Independent Cost Estimate and, according to DOE's report, was consistent with the escalation rate used by NNSA for this type of projects.
	The estimate contains few, if any, minor mistakes.	*Fully met.* We independently verified a selection of the cost output and found no mathematical errors. The estimating team was also charged with maintaining a quality control plan, which included doing quality checks and reviews throughout the process as well as a technical review of the estimate.
	The cost estimate is regularly updated to reflect significant changes in the program so that it always reflects current status.	*Partially met.* The estimate was an update of the 2013 Independent Cost Estimate. In addition, the contractor's estimate at completion was updated in 2016. However, this was not a full update, and elements of the 2013 Independent Cost Estimate were updated only by re-escalating and making some adjustments.

Best practice characteristic and overall assessment	Best practice	Detailed Assessment[a]
	Variances between planned and actual costs are documented, explained, and reviewed.	*Partially met.* The contractor examined actual costs and variances. DOE used these variances to determine the updated estimate. However, DOE decertified the contractor's earned value management system in October 2016, because DOE determined that the data in this system were not reliable, timely, auditable, traceable, or reconcilable.
	The estimate is based on a historical record of cost estimating and actual experiences from other comparable programs.	*Partially met.* The estimate was mostly based on historical data that was applicable to the MOX construction project. Some costs were added to the historical data that were not based on actual costs incurred, such as obsolescence. The data was current and within 1 year old. The data mostly came from the contractor's earned value management system, which DOE decertified in October 2016.
	The estimating technique for each cost element was used appropriately.	*Fully met.* The estimate was developed using parametric cost estimating techniques, applying statistical relationships between historical costs and other program variables such as facility or process, physical or performance characteristics, contractor output measures, and manpower loading. Each technique appears to be used appropriately for the work breakdown structure element being estimated.
Credible: *Substantially met*	The cost estimate includes a sensitivity analysis that identifies a range of possible costs based on varying major assumptions, parameters, and data inputs.	*Fully met.* DOE conducted statistical sensitivity analysis to understand the biggest cost drivers within management reserve and contingency.
	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.	*Substantially met.* DOE conducted a quantitative risk and uncertainty analysis using Monte Carlo simulation to determine the confidence levels and associated range of contingencies. DOE did not independently identify the risks; the contractor provided the list of risks. Programmatic risks were considered to be bounding assumptions and were not included.
	Major cost elements were cross-checked to see whether results were similar.	*Partially met.* We did not find evidence of cross checking while reviewing the documentation for both the 2016 estimate and 2013 Independent Cost Estimate. DOE stated that the estimating team performed cross checks by evaluating the 2013 Independent Cost Estimate against the contractor's actuals and analyzing the costs on a monthly basis. This allowed DOE to determine that the actuals were close to the 2013 estimate and the contractor's estimate to complete needed adjustments.

Best practice characteristic and overall assessment	Best practice	Detailed Assessment[a]
	An independent cost estimate was conducted by a group outside the acquiring organization to determine whether other estimating methods produce similar results.	*Partially met.* DOE's 2016 cost estimate was not an independent cost estimate, but it was built on the 2013 Independent Cost Estimate. As part of the estimate development, DOE consulted several other independent studies previously conducted on the construction project, such as the Red Team and the Aerospace Corporation reports. DOE concluded that its estimate was in line with these other reviews.

Source: GAO analysis of DOE's revised cost estimate. | GAO-17-390

[a]The ratings we used in this analysis are as follows: "Not met" means DOE provided no evidence that satisfies the best practice. "Minimally met" means DOE provided evidence that satisfies a small portion of the best practice. "Partially met" means DOE provided evidence that satisfies about half of the best practice. "Substantially met" means DOE provided evidence that satisfies a large portion of the best practice. "Fully met" means DOE provided complete evidence that satisfies the entire best practice.

Appendix III: National Nuclear Security Administration's (NNSA) Life-cycle Cost Estimates for the Plutonium Disposition Program Using the Mixed-Oxide (MOX) Approach

Dollars in millions

Facility or Program Component	Type of Cost	April 2013 Plutonium Disposition Program Life-cycle Cost Estimate			September 2016 Plutonium Disposition Program Life-cycle Cost Estimate			Differences Between Totals From 2013 and 2016
		Actual Costs[a]	Projected Costs[b]	Total	Actual Costs[c]	Projected Costs[d]	Total	
MOX Fuel Fabrication Facility[e]	Construction	3,435.6	3,988.6	7,424.2	5,037.4	12,090.8	17,128.2[f]	*9,704.0*
	Operations and maintenance	2.7	8,256.1	8,258.8	3.0	16,004.8	16,007.8	*7,749.0*
Waste Solidification Building[g]	Construction	265.1	132.7	397.9	392.0	-	392.0	*(5.9)*
	Operations and maintenance	-	1,910.2	1,910.2	13.6	6,527.3	6,540.9	*4,630.7*
Pit Disassembly and Conversion Facility[h]	Construction	730.1	-	730.1	730.2	-	730.2	*0.1*
MOX Irradiation, Feedstock, and Transportation[i]	Operations and maintenance	681.7	4,258.9	4,940.6	881.7	13,158.5	14,040.2	*9,099.6*
Program Management and Integration[j]	Operations and maintenance	65.2	427.6	492.8	213.9	959.4	1,173.3	*680.5*
Total		**5,180.6**	**18.974.1**	**$24,154.7**	**7,271.8**	**48,740.8**	**56,012.6**	**31,858.0**

Source: GAO analysis of NNSA estimates. | GAO-17-390

Notes: Dollar amounts may not add up to totals due to rounding.

[a]Actual costs covered fiscal years 1999 through 2012. Data are based on actual costs incurred.

[b]Projected costs covered fiscal years 2013 through 2036. Data are based on projected funding required.

[c]Actual costs covered fiscal years 1999 through 2016. Data are based on actual costs incurred.

[d]Projected costs covered fiscal years 2017 through 2065. Data are based on projected funding required.

[e]The MOX Fuel Fabrication Facility will produce MOX fuel for nuclear reactors.

[f]According to NNSA officials, this figure represents the Department of Energy's updated $17.2 billion cost estimate for the construction of the MOX Fuel Fabrication Facility using a $350 million per year funding profile. NNSA's documentation does not provide an explanation for this difference.

[g]The Waste Solidification Building is designed to dispose of liquid waste from the MOX Fuel Fabrication Facility.

[h]The Pit Disassembly and Conversion Facility was a stand-alone facility for producing feedstock for the MOX Fuel Fabrication Facility. NNSA canceled it in 2012 and is considering alternatives for pit disassembly and conversion.

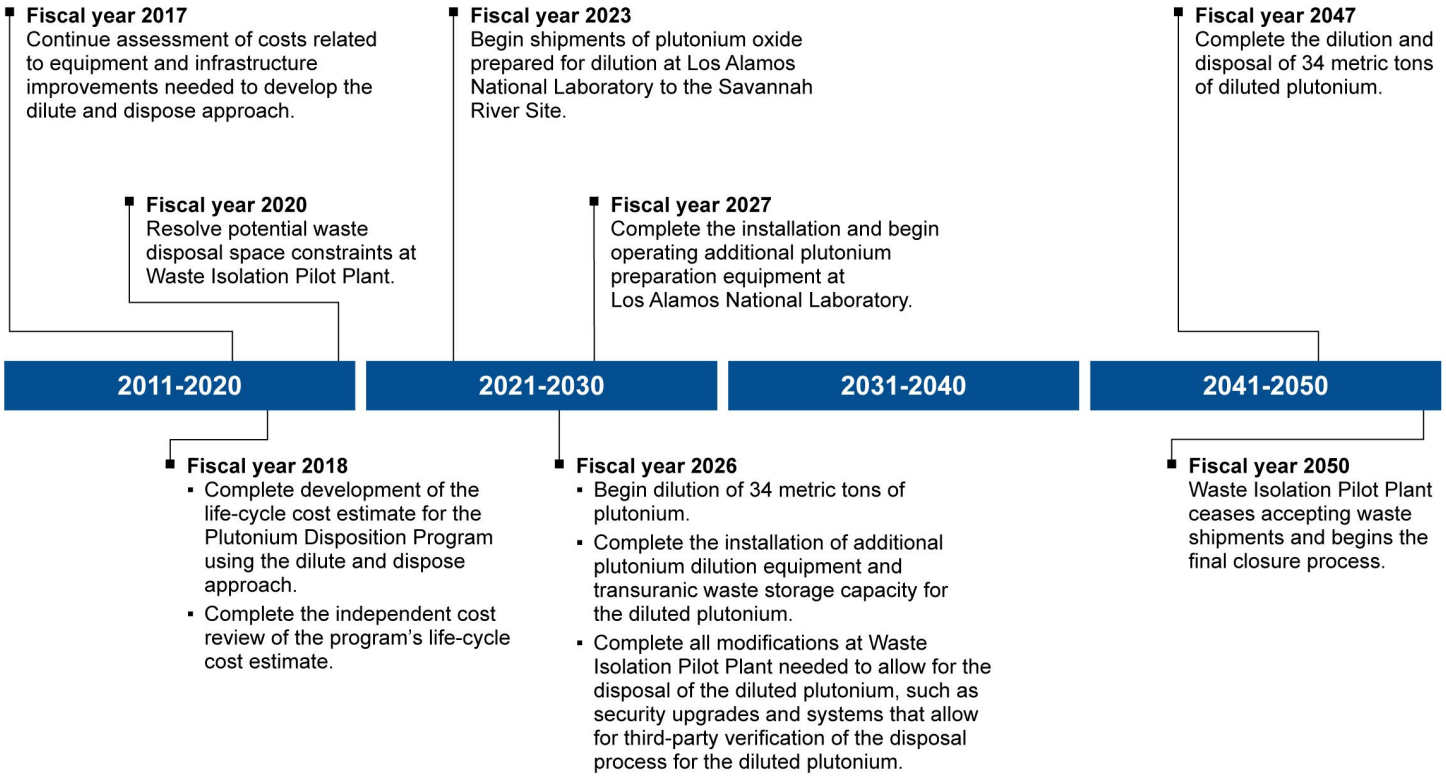
[i]MOX Irradiation, Feedstock, and Transportation is the program component that includes: (1) production of plutonium feedstock for the MOX Fuel Fabrication Facility, (2) qualification of MOX fuel for use in commercial nuclear reactors, and (3) procurement and maintenance of shipping containers for plutonium feedstock and MOX fuel.

[j]The Program Management and Integration is the program component, that includes overall management and integration of the MOX Fuel Fabrication Facility and the Waste Solidification Building projects, and integration of the projects with activities falling under the MOX Irradiation, Feedstock, and Transportation component. The Program Management and Integration component used to be called the Plutonium Disposition and Infrastructure Program.

Appendix IV: Milestones for the Plutonium Disposition Program Using the Dilute and Dispose Approach

To assist with the developing of the life-cycle estimate for the Plutonium Disposition Program using the dilute and dispose approach, the National Nuclear Security Administration (NNSA) established a set of milestones for completing the program. These milestones, according to an NNSA official, will be used to determine the rates at which each element of the program need to operate and the extent that the element would need to be expanded to meet that rate. For example, NNSA will need to install equipment for diluting the plutonium at a rate so that all 34 metric tons of plutonium will be diluted by the end of the program in fiscal year 2047. These milestones are outlined in Figure 4 below.

Figure 4: Milestones for the Plutonium Disposition Program Using the Dilute and Dispose Approach



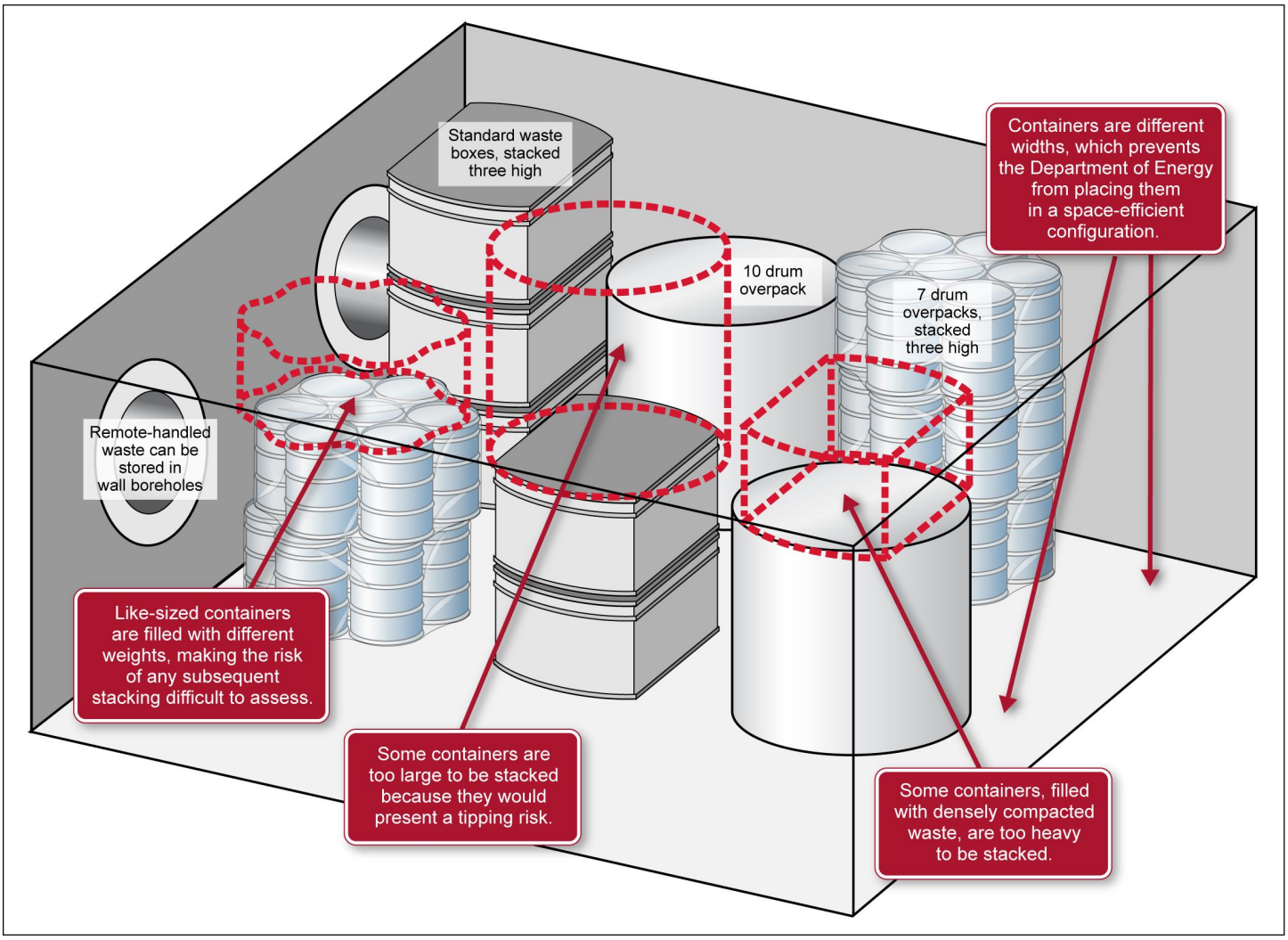
Sources: GAO; National Nuclear Security Administration. | GAO-17-390

Appendix V: History of the Closed Panels at the Waste Isolation Pilot Plant

The closed panels vary in terms of the extent to which they were filled to their maximum permitted volume of waste. One of the six panels accommodated nearly 100 percent of its maximum permitted contact-handled waste, while others ranged from 58 percent to 91 percent full. According to Department of Energy (DOE) officials, DOE was unable to fill the panels with the permitted volume of waste as planned primarily because it approved additional waste packaging called "overpacks," in which waste containers are encased to increase safety for workers handling or transporting the waste and to comply with limits on how much radioactive material can be transported. Encasing waste in overpacks resulted in a less efficient use of the disposal space because some of these packages could not be efficiently arranged next to one another, and others could not be safely stacked on top of one another because of their weight or size. Overpacks also include some empty space between containers within the overpack, further reducing available space.

In addition, DOE has faced challenges accommodating the disposal of remote-handled TRU waste. Because of the higher hazard, there are greater restrictions on how remote-handled waste can be disposed of. To date, remote-handled waste has been permitted for disposal primarily in boreholes drilled into the walls in panels 4 through 8. According to DOE officials, some of the boreholes in the walls of panels 4 through 6 were blocked by overpacks of contact-handled waste containers already disposed of in those panels before sufficient remote-handled waste arrived at the site for disposal. Because of the inability to use the boreholes as planned in panels 4 through 6, none of the borehole disposal space in these panels was filled to more than 35 percent of its permitted volume. See figure 5 for an illustration of how the typical placement of waste in panels has resulted in DOE's inability to use panel space as planned.

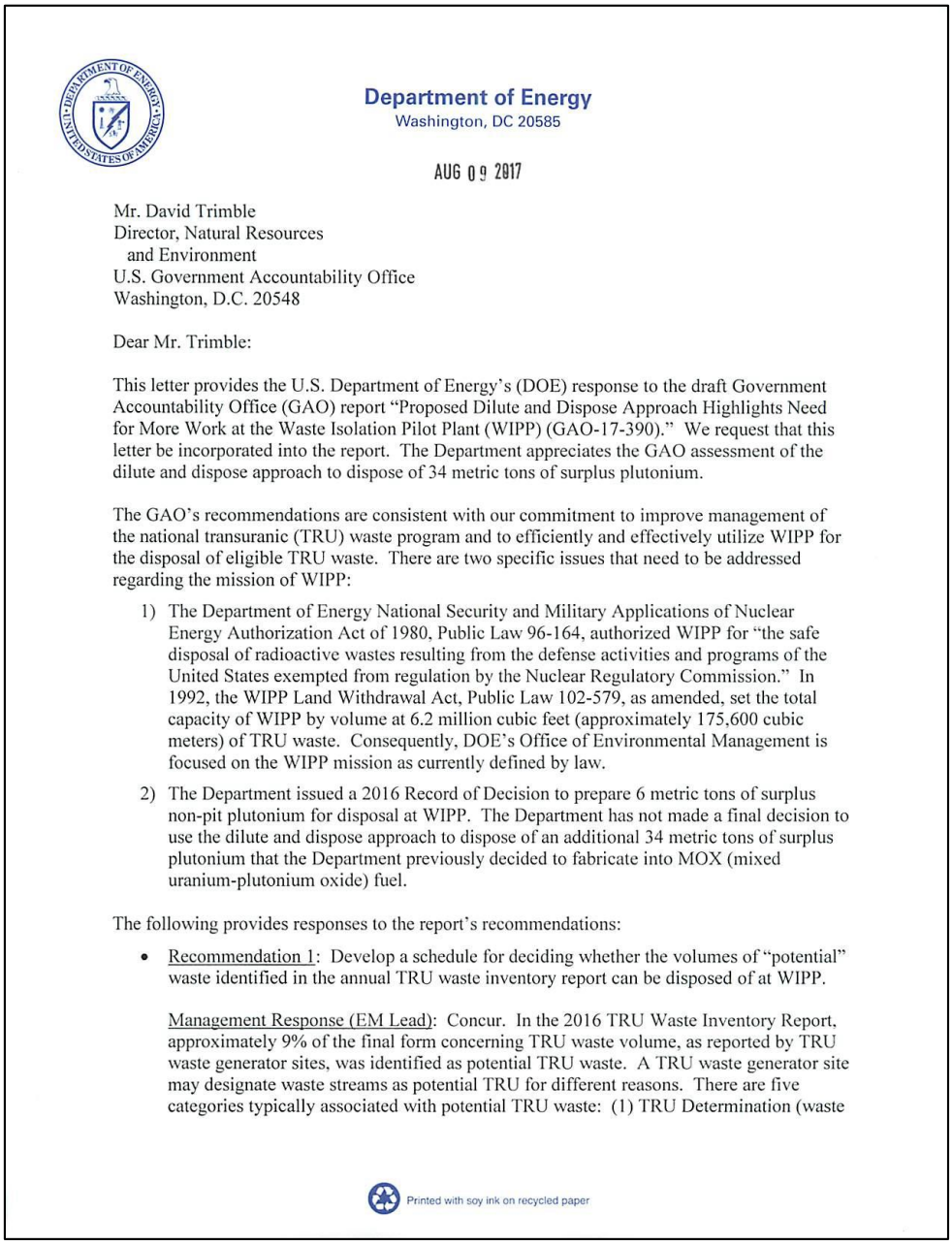
Figure 5: Example of Typical Overpack Emplacement Resulting in Panels Not Filled to Maximum Permitted Volume



Sources: GAO (analysis); Department of Energy (container data). | GAO-17-390

Note: Area shown represents a portion of a panel and is not to scale

Appendix VI: Comments from the Department of Energy



Department of Energy
Washington, DC 20585

AUG 09 2017

Mr. David Trimble
Director, Natural Resources
and Environment
U.S. Government Accountability Office
Washington, D.C. 20548

Dear Mr. Trimble:

This letter provides the U.S. Department of Energy's (DOE) response to the draft Government Accountability Office (GAO) report "Proposed Dilute and Dispose Approach Highlights Need for More Work at the Waste Isolation Pilot Plant (WIPP) (GAO-17-390)." We request that this letter be incorporated into the report. The Department appreciates the GAO assessment of the dilute and dispose approach to dispose of 34 metric tons of surplus plutonium.

The GAO's recommendations are consistent with our commitment to improve management of the national transuranic (TRU) waste program and to efficiently and effectively utilize WIPP for the disposal of eligible TRU waste. There are two specific issues that need to be addressed regarding the mission of WIPP:

1) The Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Public Law 96-164, authorized WIPP for "the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission." In 1992, the WIPP Land Withdrawal Act, Public Law 102-579, as amended, set the total capacity of WIPP by volume at 6.2 million cubic feet (approximately 175,600 cubic meters) of TRU waste. Consequently, DOE's Office of Environmental Management is focused on the WIPP mission as currently defined by law.
2) The Department issued a 2016 Record of Decision to prepare 6 metric tons of surplus non-pit plutonium for disposal at WIPP. The Department has not made a final decision to use the dilute and dispose approach to dispose of an additional 34 metric tons of surplus plutonium that the Department previously decided to fabricate into MOX (mixed uranium-plutonium oxide) fuel.

The following provides responses to the report's recommendations:

- Recommendation 1: Develop a schedule for deciding whether the volumes of "potential" waste identified in the annual TRU waste inventory report can be disposed of at WIPP.

  Management Response (EM Lead): Concur. In the 2016 TRU Waste Inventory Report, approximately 9% of the final form concerning TRU waste volume, as reported by TRU waste generator sites, was identified as potential TRU waste. A TRU waste generator site may designate waste streams as potential TRU for different reasons. There are five categories typically associated with potential TRU waste: (1) TRU Determination (waste

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categorized as "undetermined" will remain potential until the waste is characterized and determined to be TRU waste or non-TRU waste); (2) Defense Determination (waste with an "unknown" defense determination will remain potential until a defense determination is made); (3) Regulatory Restrictions (sites must treat, repackage, or remove any restricted items before restricted waste can be accepted for disposal at WIPP); (4) Incomplete Data (waste with missing or incomplete data, such as radionuclide activity, final form container data, or unknown waste stream information is deemed potential until required data are available); and (5) Directed by DOE to Move to Potential (waste deemed by DOE to be potential TRU waste). For each category of potential TRU waste, certain prerequisite actions must be accomplished to provide the basis for determining whether or not the potential TRU waste is TRU waste that can be disposed at WIPP. These may include, for example: statutory amendments, permit changes, Records of Decision, and other decisions that could take several years to finalize. As the corresponding issues are resolved for potential TRU waste, and a determination is made that such waste can be disposed of at WIPP such that disposal at WIPP becomes anticipated, a schedule for disposal will be developed.

Implementation Schedule: Annually. DOE will revisit whether the volumes of "potential" waste identified in the TRU Waste Inventory Report can be disposed of at WIPP and indicate any changes in the subsequent TRU Waste Inventory Report.

- Recommendation 2: Develop guidance that helps sites produce a more comprehensive estimate for the volumes of TRU waste that may be generated in the future from cleanup operations, including estimates of buried waste, waste that may be generated from decontamination and decommissioning of nuclear facilities, and waste that may be generated past WIPP's current closure date of 2050.

  Management Response (EM Lead): Concur. DOE will develop guidance that provides principles to help sites produce a more comprehensive estimate for future TRU waste volumes from cleanup operations.

  Implementation Schedule: DOE will provide guidance by December 31, 2018.

- Recommendation 3: Develop a long term plan for disposing of DOE's TRU waste that includes:
  - The need for excavating additional disposal space at WIPP, including an integrated schedule that describes how DOE will complete the regulatory approval process and construction of new space before WIPP's existing space is full.
  - A timeline to help determine whether DOE can change its method of counting waste volumes to meet NNSA's 2020 milestone for resolving potential disposal space constraints at WIPP.

  Management Response: Concur. The need to excavate additional disposal panels at WIPP is evident, given that anticipated inventories of defense TRU waste would physically fill or exceed the currently available disposal area. DOE expects to develop an initial design for potential new panels in 2018, and will identify corresponding regulatory

actions as the design develops. In addition to physical limitations on planned disposal areas, WIPP is also subject to statutory limits on the volume of waste allowed for disposal. These limits on the volume capacity at WIPP can potentially restrict receipt of waste. A change in the method of calculating the volume of record at WIPP could provide significant flexibility in accepting waste, provided space is physically available. Such a change would require a Permit Modification Request for a Modification to the Resource Conservation and Recovery Act (RCRA) permit granted by the New Mexico Environment Department. DOE is evaluating options for calculating the volume of record which will be included in the long-term plan.

Implementation Schedule: DOE will develop a long-term plan for disposing of DOE's TRU waste no later than December 31, 2018.

Sincerely,

Candice Robertson for

James M. Owendoff
Acting Assistant Secretary
for Environmental Management

Appendix VII: GAO Contact and Staff Acknowledgments

GAO Contact

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

Staff Acknowledgments

In addition to the contact named above, Daniel Feehan, Assistant Director; Mark Braza; Richard P. Burkard; Lindsey Cross; Jennifer Echard; Quindi Franco; Cristian Ion; Eli Lewine; Ned Malone; Emily Norman; Cynthia Norris; Katrina Pekar-Carpenter; and Kiki Theodoropoulos made key contributions to this report.

Appendix VIII: Accessible Data

Data Tables

Accessible Data for Figure 1: Proposed Approaches for Disposing of U.S. Surplus Plutonium from Nuclear Weapons Pits

- Start
    - **Pantex Plant**
      Nuclear weapons pits are stored
        - Pits are shipped to Los Alamos National Laboratory
    - **Los Alamos National Laboratory**
      Pits are disassembled and converted into metal and/or oxide
- Mixed oxide fuel approach
        - Plutonium metal and oxide shipped to Savannah River Site
    - **Savannah River Site**
      Plutonium is made into mixed oxide fuel at the Mixed Oxide Fuel Fabrication Facility
        - Radioactive liquid waste from the Mixed Oxide Fuel Fabrication Facility
    - **Savannah River Site**
      Radioactive liquid waste is solidified for disposal at the Waste Solidification Building
        - Solidified waste is shipped to the Waste Isolation Pilot Plant

- **Waste Isolation Pilot Plant**
  Waste is placed underground in a permanent geologic repository
    - Mixed oxide fuel shipped to commercial nuclear reactors
- **Commercial reactors**
  Mixed oxide fuel is irradiated
    - Spent mixed oxide fuel is unloaded from the reactor and placed into storage
- **Spent fuel rod storage**
  Spent mixed oxide fuel is stored awaiting disposal

- Dilute and dispose approach
    - Plutonium oxide shipped to Savannah River Site
- **Savannah River Site**
  Plutonium oxide is diluted and then stored before shipment to the Waste Isolation Pilot Plant
    - Diluted plutonium is shipped to Waste Isolation Pilot Plant
- **Waste Isolation Pilot Plant**
  Waste is placed underground in a permanent geologic repository

Accessible Data for Figure 2: Filled and Remaining Transuranic (TRU) Waste Disposal Space at the Waste Isolation Pilot Plant (WIPP), as of December 2016

Panel 1 – closed

CH capacity: 58% filled

Not permitted for RH

Panel 2 -- closed

CH capacity: 100% filled

Not permitted for RH

Panel 3 – closed

CH capacity: 91% filled

Not permitted for RH

Panel 4 – closed

CH capacity: 76% filled

RH capacity: 24% filled

Panel 5 – closed

CH capacity: 85% filled

RH capacity: 35% filled

Panel 6 – closed

CH capacity: 77% filled

RH capacity: 21% filled

Panel 7

57% available for CH

0% available for RH

2% of capacity emplaced before shutdown

Panel 8

100% available for CH

Unknown RH capacity

Panel 9

0% available for CH

0% available for RH

Panel 10

Unknown CH capacity

Unknown RH capacity

Legend

Contact-handled (CH) waste

Remote-handled (RH) waste

Off-limits

Potentially off-limits; use under discussion

Panel still accepting waste

Panel not yet permitted

Not permitted for RH

Accessible Data for Figure 3: Statutory Capacity Filled and Possible Future Waste Requiring Disposal at the Waste Isolation Pilot Plant (WIPP)

Unknown quantity of transuranic waste from site clean-up projects that has not been estimated

23,800 m^3 diluted plutonium

12,000 m^3 greater-than-Class C

3,094 m^3 potential waste

Statutory limit: 175,565 m^3

12,955 m^3 undesignated capacity available under statutory limit

71,510 m^3 waste planned for disposal at the Waste Isolation Pilot Plant

91,100 m^3 already in Waste Isolation Pilot Plant

m^3 = cubic meters

Accessible Data for Figure 4: Milestones for the Plutonium Disposition Program Using the Dilute and Dispose Approach

Fiscal year 2017

Continue assessment of costs related to equipment and infrastructure improvements needed to develop the dilute and dispose approach.

Fiscal year 2018

▪ Complete development of the life-cycle cost estimate for the Plutonium Disposition Program using the dilute and dispose approach.

▪ Complete the independent cost review of the program's life-cycle cost estimate.

Fiscal year 2020

Resolve potential waste disposal space constraints at Waste Isolation Pilot Plant.

Fiscal year 2023

Begin shipments of plutonium oxide prepared for dilution at Los Alamos National Laboratory to the Savannah River Site.

Fiscal year 2026

▪ Begin dilution of 34 metric tons of plutonium.

▪ Complete the installation of additional plutonium dilution equipment and transuranic waste storage capacity for the diluted plutonium.

▪ Complete all modifications at Waste Isolation Pilot Plant needed to allow for the disposal of the diluted plutonium, such as security upgrades and systems that allow for third-party verification of the disposal process for the diluted plutonium.

Fiscal year 2027

Complete the installation and begin operating additional plutonium preparation equipment at Los Alamos National Laboratory.

Fiscal year 2047

Complete the dilution and disposal of 34 metric tons of diluted plutonium.

Fiscal year 2050

Waste Isolation Pilot Plant ceases accepting waste shipments and begins the final closure process.

Accessible Data for Figure 5: Example of Typical Overpack Emplacement Resulting in Panels Not Filled to Maximum Permitted Volume

Remote-handled waste can be stored in wall boreholes

Standard waste boxes, stacked three high

10 drum overpack

7 drum overpacks, stacked three high

Like-sized containers are filled with different weights, making the risk of any subsequent stacking difficult to assess.

Some containers are too large to be stacked because they would present a tipping risk.

Some containers, filled with densely compacted waste, are too heavy to be stacked

Containers are different widths, which prevents the Department of Energy from placing them in a space-efficient configuration.

Agency Comment Letter

Accessible Text for Comments from the Department of Energy

Page 1

Department of Energy

Washington, DC 20585

AUG 09 2017

Mr. David Trimble

Director, Natural Resources and Environment

U.S. Government Accountability Office

Washington, D.C. 20548

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Page 2

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Page 3

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Sincerely,

James M. Owendoff

Acting Assistant Secretary for Environmental Management

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