United States Government Accountability Office

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

October 2019

SURPLUS PLUTONIUM DISPOSITION

NNSA's Long-Term Plutonium Oxide Production Plans Are Uncertain

GAO-20-166

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GAO Highlights

Highlights of GAO-20-166 a report to the Committee on Armed Services, U.S. Senate

Why GAO Did This Study

The United States has 57.2 MT of weapons-usable plutonium that it has declared surplus and that still requires disposition. This plutonium exists in various metal and non-metal forms, including pits—the central core of a nuclear weapon. To prevent insidious use of this plutonium, DOE plans to disassemble pits into metal; convert the plutonium metal to plutonium oxide, a powder-like substance; dilute it with inert material; and dispose of it at WIPP. In May 2018, NNSA issued a plan conceptualizing the dilution and disposal of 34 MT of surplus plutonium at an estimated cost of $19 billion over the next 3 decades. Under this conceptual plan, pit disassembly and production of plutonium oxide would take place at one facility and dilution would be performed in another, with both operations expanding over the next decade.

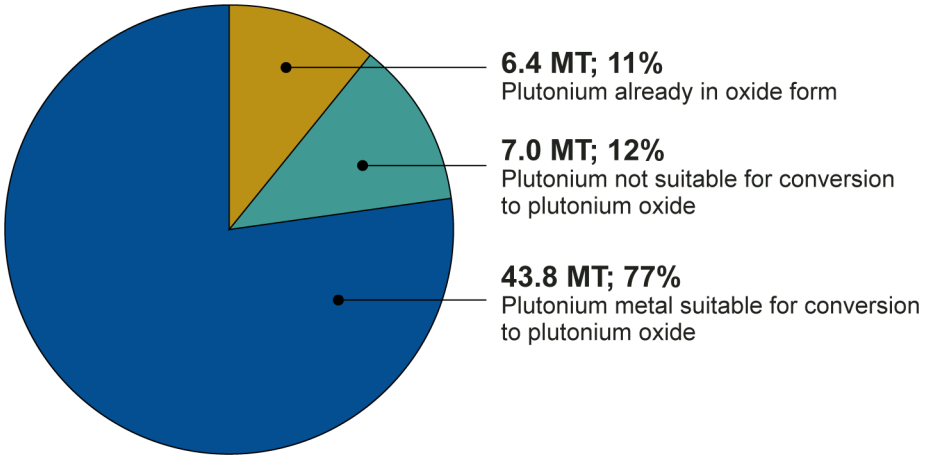
GAO was asked to review DOE's plans for plutonium oxide production to dispose of surplus plutonium. This report (1) examines the amount of surplus plutonium in DOE's inventory that could be converted to plutonium oxide for dilution and disposal and (2) examines DOE's capacity to produce plutonium oxide. GAO reviewed the inventory of surplus plutonium, plutonium oxide production requirements and production capacity, and DOE planning documents, and interviewed DOE officials.

View GAO-20-166. For more information, contact David Trimble at (202) 512-3841 or TrimbleD@gao.gov.

What GAO Found

Of the Department of Energy's (DOE) inventory of surplus plutonium, about 43.8 metric tons (MT), or 77 percent, is plutonium metal that could be converted to plutonium oxide for dilution and disposal. Of this amount, the National Nuclear Security Administration (NNSA) manages 33.3 MT in the form of pits, DOE's Office of Environmental Management (EM) manages 6.5 MT, and DOE's Office of Nuclear Energy manages 4 MT in the form of reactor fuel. EM manages another 11 percent, or 6.4 MT, of DOE's surplus plutonium that is already in oxide form. Most of this is suitable for dilution and disposal at the Waste Isolation Pilot Plant (WIPP), a repository in New Mexico. An additional 12 percent, or 7 MT, of DOE's surplus plutonium is contained in spent nuclear fuel that is planned for disposal in a geologic repository. See figure.

The Department of Energy's (DOE) Surplus Plutonium, of Which 43.8 Metric Tons (MT), or 77 Percent, Could Be Converted to Plutonium Oxide



Source: DOE. | GAO-20-166

NNSA's 2018 conceptual plan calls for converting 26.2 MT of this surplus plutonium into oxide by 2045. In September 2019, NNSA approved the production of about 1.2 MT of plutonium oxide through 2025 at its Los Alamos National Laboratory (LANL) located in New Mexico. However, plans for converting additional surplus plutonium into plutonium oxide are uncertain because of two issues. These issues include NNSA's still-developing plans for new pit production, which will also take place at LANL, and issues surrounding the agency's ability to ship newly produced plutonium oxide for dilution to DOE's Savannah River Site (SRS) in South Carolina. According to agency officials, NNSA and DOE are taking several actions that, if successfully implemented, are designed to allow NNSA to meet its long-term plutonium oxide production goals. These actions include continuing to review plutonium oxide and pit production plans, increasing plutonium storage at LANL, reducing the amount of SRS's surplus plutonium, and accelerating the shipment of diluted plutonium from SRS to WIPP.

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Abbreviations

ARIES	Advanced Recovery and Integrated Extraction System
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EM	Office of Environmental Management
LANL	Los Alamos National Laboratory
MT	Metric ton
MFFF	Mixed Oxide Fuel Fabrication Facility
MOX	Mixed oxide
NE	Office of Nuclear Energy
NNSA	National Nuclear Security Administration
PF-4	Plutonium Facility-4
PMDA	Plutonium Management and Disposition Agreement
SRS	Savannah River Site
WIPP	Waste Isolation Pilot Plant

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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October 23, 2019

The Honorable James M. Inhofe
Chairman
The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate

Plutonium, a radioactive element that is produced by irradiating uranium in nuclear reactors, is an essential component of nuclear weapons and U.S. national defense strategy.[1] Plutonium is used to manufacture pits, the central core of a nuclear weapon.[2] During the Cold War, the United States manufactured thousands of pits to maintain its stockpile of nuclear weapons. However, since the Cold War ended in the early 1990s the stockpile has been reduced, leaving thousands of pits from dismantled nuclear weapons sitting in temporary storage. In addition to plutonium from pits, several metric tons (MT) of non-pit plutonium—some of which were used in the pit manufacturing process—used (spent) nuclear fuel, and other nuclear fuels containing plutonium are also in temporary storage.[3]

Plutonium poses a proliferation risk and a risk to human health and the environment if not managed safely. The threat of state or non-state actors, such as terrorists, developing nuclear or radiological weapons by obtaining some of this plutonium poses one of the greatest challenges to U.S. and international security, according to the National Nuclear Security

[1]U.S. defense-related nuclear reactors for producing plutonium were shut down in the 1980s. The U.S. nuclear weapons program relies on plutonium stockpiled from production in earlier years. Currently operating commercial nuclear reactors do not produce plutonium for defense purposes.

[2]When compressed with high explosives, pits create a primary nuclear explosion that provides the energy to detonate the weapon's main, or secondary, explosion.

[3]Spent nuclear fuel is the used fuel removed from nuclear reactors. The Nuclear Regulatory Commission states that such fuel is still thermally hot, highly radioactive, and potentially harmful. Until a permanent disposal repository for spent nuclear fuel is built, operators must safely store this fuel. Other nuclear fuels that were used in DOE experiments and projects also contain surplus plutonium.

Administration (NNSA), a separately organized agency within the Department of Energy (DOE).[4]

In part to address this proliferation risk, DOE established the Surplus Plutonium Disposition Program in 1997 to dispose of surplus, weapons-usable plutonium at the end of the Cold War.[5] According to NNSA, the disposition of surplus plutonium is central to the nuclear non-proliferation goals of the United States and is primarily managed by its Office of Material Management and Minimization. As of 2007, the United States had declared a total of 61.5 MT of plutonium as surplus to defense needs.[6] DOE has disposed of 3.2 MT of surplus plutonium at the Waste Isolation Pilot Plant (WIPP), an underground repository for transuranic waste located near Carlsbad, New Mexico, and is in the process of disposing of an additional 1.1 MT of surplus plutonium. [7] As a result, as of May 2019 DOE had 57.2 MT of surplus plutonium in its inventory still requiring disposition.

In the 1990s, DOE considered several strategies to dispose of the surplus plutonium and, according to DOE documents, in 1997 decided on two strategies to immobilize and irradiate the surplus plutonium before final

[4]NNSA was created by the National Defense Authorization Act for Fiscal Year 2000, Pub. L. No. 106-65, 113 Stat. 957 (1999). NNSA has responsibility for the nation's nuclear weapons, nonproliferation, and naval reactor programs.

[5]In prior reports, we have referred to this program as the Plutonium Disposition Program. For this report, we refer to the program by NNSA's current title for the program: the Surplus Plutonium Disposition Program.

[6]DOE declared 52.5 MT of weapons-usable plutonium as surplus to defense needs in 1994 and declared an additional 9 MT as surplus in 2007.

[7]Unless otherwise stated, all amounts we provide are of the plutonium quantity in a material, regardless of the form of the material, and all amounts are approximations. DOE's disposition of 4.3 MT of surplus plutonium includes the completed disposition of 3.2 MT of surplus, non-pit plutonium consisting of scraps and residues, and DOE's ongoing activities to dispose of an additional 1.1 MT of surplus, non-pit plutonium. Most of the 4.3 MT of surplus plutonium, including all of the 3.2 MT portion, has been disposed of at WIPP. The surplus plutonium came from DOE sites at the Rocky Flats Environmental Technology Site in Colorado, the Hanford Site in Washington, the Idaho National Laboratory, the Los Alamos National Laboratory in New Mexico, and the Savannah River Site in South Carolina. WIPP was designed to accept defense-related transuranic waste, which generally consists of clothing, tools, rags, residues, debris, soil, and other items contaminated with radioactive elements that are heavier than uranium, such as plutonium, and that were generated as a result of work related to atomic energy defense activities. Diluted plutonium to be disposed of at WIPP would need to be treated and packaged to meet WIPP's waste acceptance criteria.

disposal in a geologic repository for high-level waste, including spent nuclear fuel.[8] Immobilization encapsulates the plutonium in glass or ceramic materials prior to disposal. Irradiation requires that the plutonium be converted to plutonium oxide, a powder-like substance, and then blended with uranium oxide to make mixed oxide (MOX) fuel. This MOX fuel, which DOE planned to fabricate at the Mixed Oxide Fuel Fabrication Facility (MFFF) at the Savannah River Site (SRS) in South Carolina,[9] would then be used in U.S. commercial nuclear reactors to produce electricity. The plutonium in the MOX fuel would be incorporated into spent nuclear fuel, a form that would prevent it from being easily used in nuclear weapons, and would eventually be disposed of in a high-level waste repository.

In 1999, DOE began planning for the disposition of up to 50 MT of surplus plutonium using the immobilization and MOX fuel strategies but changed that amount to 34 MT as part of an agreement signed with Russia. Under the Plutonium Management and Disposition Agreement (PMDA), signed in 2000 and amended in 2006 and 2010, the United States and Russia pledged to dispose of at least 34 MT of surplus weapons-grade plutonium no longer needed for defense purposes, primarily by irradiating certain forms of surplus plutonium as MOX fuel in commercial nuclear reactors.[10]

[8]High-level waste includes (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and (2) spent nuclear fuel. 10 C.F.R. § 63.2. A 1957 National Academy of Sciences report endorsed deep geological formations for the disposal of high-level waste, including spent nuclear fuel. Since then, a deep geologic repository has been considered the safest and most secure method for disposing of high-level waste. Although WIPP is an operational underground repository for transuranic waste, high-level waste cannot be disposed of at WIPP. The United States currently does not have an operational underground repository for high-level waste, including spent nuclear fuel.

[9]SRS is managed by DOE's Office of Environmental Management.

[10]Only certain forms of surplus plutonium can be converted to MOX fuel. For example, spent nuclear fuel cannot be disposed of as MOX fuel using the same processes. The agreement allows for other disposition methods as agreed upon by both parties. However, Russia suspended its implementation of the PMDA in October 2016, citing delays in the United States' implementation of the agreement, among other reasons. The United States intends to continue its efforts to dispose of surplus plutonium. In addition to the 34 MT of surplus plutonium covered in NNSA's 2018 conceptual plan for dilute and dispose, DOE's Office of Environmental Management (EM) is in the early stages of diluting and disposing of 6 MT of plutonium for disposal at WIPP, of which 5.1 MT is surplus, non-pit plutonium and 0.9 MT is non-surplus plutonium from foreign sources. EM's mission is to clean up the nation's Cold War legacy of decades of nuclear weapons production.

As we have previously reported, DOE's cost and schedule estimates for the MFFF grew significantly.[11] In 1997, DOE originally estimated that constructing the MFFF would cost about $1.4 billion and be completed in 2004; however, in 2012, NNSA estimated construction costs of $7.4 billion and completion by 2019. In 2016, DOE estimated that construction of the MFFF would cost about $17.2 billion and be completed by 2048. In September 2017, we found that DOE's 2016 cost estimate for the MFFF could be considered reliable as it substantially met all four characteristics of a high-quality cost estimate: comprehensive, well-documented, accurate, and credible. We also reported that NNSA's life-cycle costs for the Surplus Plutonium Disposition Program were $56 billion, an increase of nearly $32 billion over its 2013 life-cycle costs.[12]

Because of the high cost of the MFFF, NNSA began to assess alternative strategies for plutonium disposition. In April 2014, NNSA identified an alternative strategy that it believed could significantly reduce the life-cycle cost of surplus plutonium disposition. Under this strategy, referred to as dilute and dispose, NNSA would convert surplus metal plutonium to plutonium oxide, which could then be diluted by mixing it with inert material to inhibit plutonium recovery and prevent its future use in weapons or diversion for any insidious use. The plutonium oxide could then be packaged for permanent disposal at WIPP. In a letter to the Senate Armed Services Committee in August 2016, the Secretary of State wrote that the United States remained committed to the safe disposition of surplus U.S. plutonium for broader nonproliferation, arms control, and foreign policy interests and that the dilute and dispose strategy was the only way to meet disposition targets in a fiscally

[11]GAO, *Plutonium Disposition: Observations on DOE and Army Corps Assessments of the Mixed Oxide Fuel Fabrication Facility Contract*, GAO-18-122R (Washington, D.C.: Nov. 15, 2017); *Plutonium Disposition: Proposed Dilute and Dispose Approach Highlights Need for More Work at the Waste Isolation Pilot Plant*, GAO-17-390 (Washington, D.C.: Sept. 5, 2017); *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); *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); *Department of Energy: Major Construction Projects Need a Consistent Approach for Assessing Technology Readiness to Help Avoid Cost Increases and Delays*, GAO-07-336 (Washington, D.C.: Mar. 27, 2007).

[12]GAO-17-390.

sustainable way. In May 2018, NNSA issued a conceptual plan for the dilution and disposal of 34 MT of surplus plutonium.[13]

The National Defense Authorization Act for Fiscal Year 2018 allowed DOE to terminate construction of the MFFF if, among other things, DOE identified an alternative that would cost less than approximately half of the MOX fuel strategy.[14] In its 2018 conceptual plan, NNSA estimated that the dilute and dispose strategy life-cycle cost would be $19.6 billion, less than half the estimated $49.4 billion total life-cycle cost of the MOX fuel strategy.[15] In May 2018, DOE notified Congress of its decision to cancel MFFF construction, and in October 2018, DOE issued a notice of termination of the contract for the MFFF, leaving the dilute and dispose strategy as its preferred potential disposition strategy.

The Senate committee report accompanying S. 1519, a bill for the National Defense Authorization Act for Fiscal Year 2018, included a provision that we review DOE's current capacity and plans to meet the plutonium oxide production needs of the plutonium disposition program. This report (1) examines the amount of surplus plutonium in DOE's inventory that could be converted to plutonium oxide for dilution and disposal and (2) examines DOE's capacity to produce plutonium oxide.

To determine the amount of surplus plutonium in DOE's inventory that could be converted to plutonium oxide for dilution and disposal, we reviewed relevant DOE documents and interviewed officials from DOE, including NNSA and the Office of Environmental Management (EM), on the amounts and forms of surplus plutonium DOE manages, including disposition plans. We also reviewed DOE documents and interviewed officials on the portions of plutonium in DOE's inventory that would

[13]Savannah River Nuclear Solutions, *Surplus Plutonium Disposition Program Dilute and Dispose Approach: Life Cycle Cost Estimate Summary Report, SRNS-RP-2018-00570, Revision 0* (Aiken, SC: May 2018).

[14]Pub. L. No. 115-91, § 3121(b), 131 Stat. 1892 (2018).

[15]Funding for disposition of the 34 MT of surplus plutonium comes from NNSA's Defense Nuclear Nonproliferation account. NNSA provided guidance for the life-cycle cost estimate, issued by Savannah River Nuclear Solutions, the contractor for SRS. We refer to the estimate as NNSA's 2018 conceptual plan and attribute statements from the report to NNSA. In its 2018 conceptual plan, NNSA stated that its estimate of $19.6 billion falls within the range of an independent cost estimate developed by its Office of Cost Estimating and Program Evaluation, which estimated a range of between $17.2 billion and $19.9 billion for the dilute and dispose strategy. Savannah River Nuclear Solutions, *Surplus Plutonium Disposition Program Dilute and Dispose Approach*.

require conversion to an oxide prior to dilution. We visited the Los Alamos National Laboratory (LANL) in New Mexico, where plutonium is converted to an oxide, to review documentation and interview officials in the Surplus Plutonium Disposition Program for information on past management of surplus plutonium.

To examine DOE's capacity to produce plutonium oxide, we reviewed relevant DOE documents and interviewed officials from DOE, including NNSA and EM, on their facilities and plans to convert plutonium metal to an oxide, including time frames, conversion rates, and plans for expanding their conversion capacity. During our site visit to LANL, we toured Plutonium Facility-4 (PF-4), where NNSA's Advanced Recovery and Integrated Extraction System (ARIES) operations disassemble plutonium pits and convert surplus plutonium to an oxide. Also, during our visit to LANL, we reviewed documentation, spoke with officials on plans to expand plutonium oxide conversion capacity in PF-4, and observed the space that NNSA officials said was available for planned expansion. Appendix I contains additional detail on our scope and methodology.

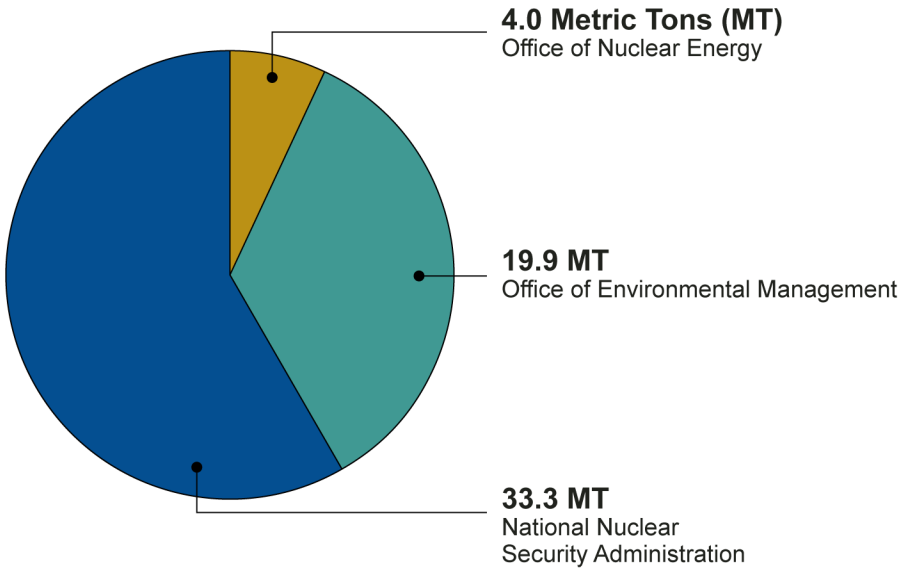
We conducted this performance audit from October 2017 to October 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions 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

Several DOE Offices Manage Multiple Forms of Surplus Plutonium

Three DOE offices manage 57.2 MT of plutonium declared surplus to defense needs. These offices—NNSA, EM, and DOE's Office of Nuclear Energy (NE)[16]—and their sites manage a variety of surplus plutonium in the form of pits, metal, oxide, spent nuclear fuel, and other reactor fuels, and they follow specific procedures to manage the plutonium safely and securely. NNSA manages over half of this surplus plutonium. According to NNSA, all three offices share the responsibility for final disposition of surplus plutonium. Figure 1 shows the amounts of surplus plutonium managed by the offices.

Figure 1: Inventory of Surplus Plutonium in the United States, by Department of Energy (DOE) Office, as of May 2019

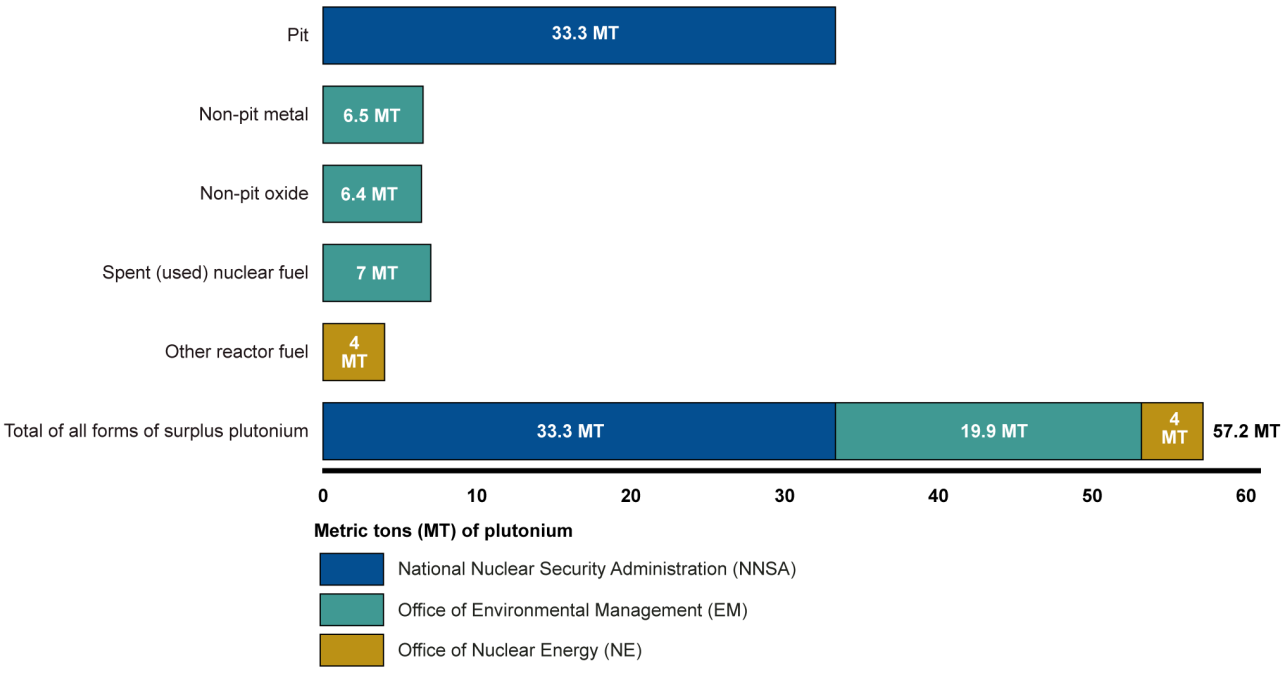


Source: GAO presentation of DOE information. | GAO-20-166

[16]NE's primary mission is to advance nuclear power as a resource capable of meeting the nation's energy, environmental, and national security needs by resolving technical, cost, safety, proliferation resistance, and security barriers. NE oversees DOE's Idaho National Laboratory.

Figure 2 shows the various forms of this surplus plutonium, including pits, non-pit metal, non-pit oxide, and spent nuclear fuel or other reactor fuels in the inventory, by DOE office.

Figure 2: Forms and Amounts of Surplus Plutonium To Be Dispositioned, by Department of Energy (DOE) Office, as of May 2019



Source: GAO presentation of DOE information. | GAO-20-166

Note: Surplus plutonium is contained in spent nuclear fuel and other reactor fuels that were used in DOE experiments and projects.

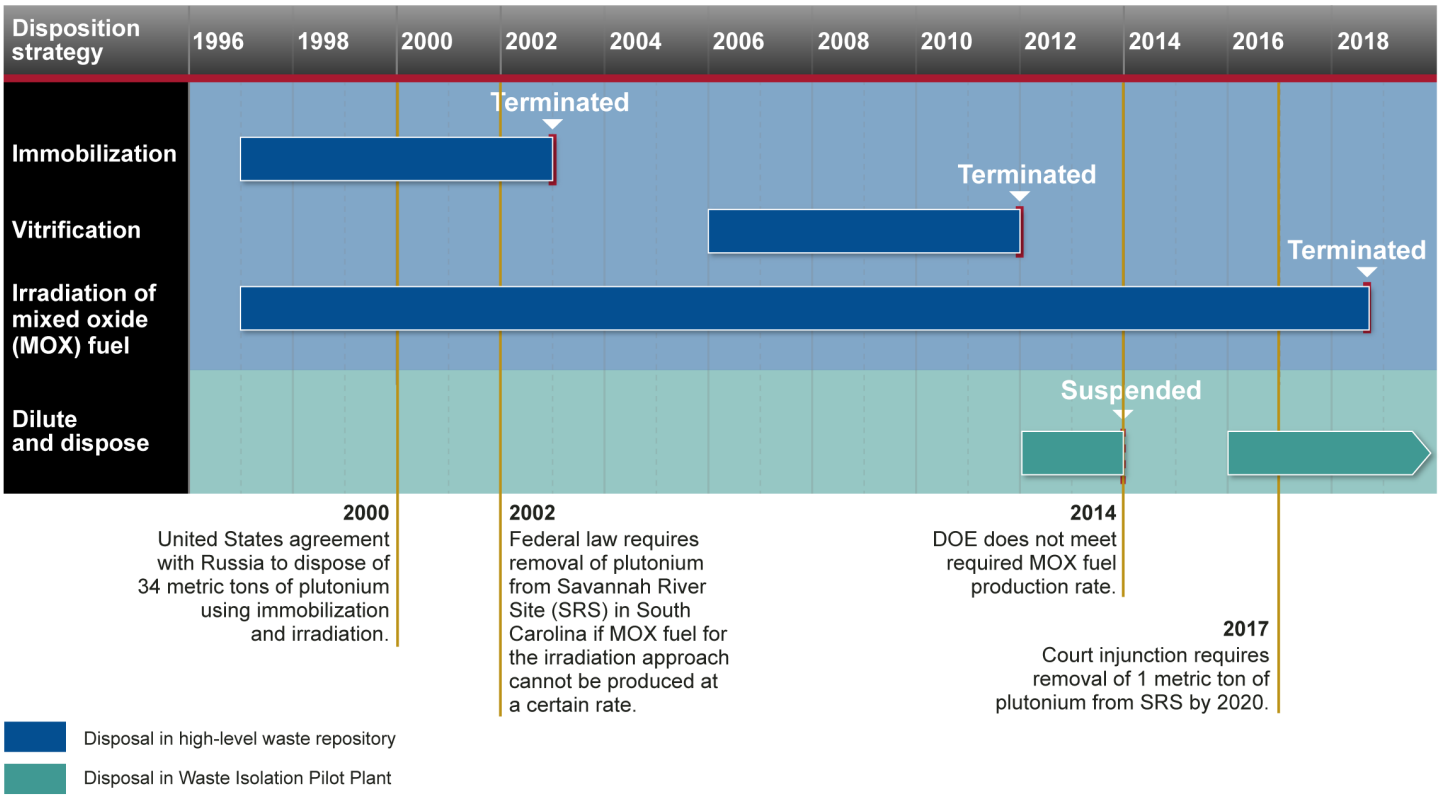
DOE's Surplus Plutonium Disposition Strategies Have Changed over Time

Since 1997, DOE's surplus plutonium disposition strategies have changed in terms of the method of disposal and the location for disposal, according to DOE documents and officials. These disposition strategies have included immobilization, irradiation as MOX fuel, and dilution. In 1997, NNSA planned to immobilize surplus plutonium by encapsulating it in glass or ceramic materials but terminated its plans in 2002 due to budget constraints. In the mid-2000s, EM briefly considered vitrification, which is a form of immobilization using glass, but never developed a plan to implement it. NNSA planned to irradiate surplus plutonium as part of the MOX fuel strategy but terminated its plans in 2018 because of high costs. NNSA's plans for irradiation of MOX fuel would also have required disposal of the spent nuclear fuel in a high-level waste repository. EM

began implementing a dilute and dispose strategy for a separate portion of surplus plutonium in 2012, but suspended its efforts until it resumed them in 2016.[17] NNSA's 2018 conceptual plan for the dilute and dispose strategy would replace the MOX fuel strategy with final disposal of the diluted plutonium at WIPP. Figure 3 shows a timeline of the changes in DOE's strategies since 1997, as well as some key events that have affected the strategies. See appendix II for a timeline of DOE's disposition strategies and appendix III for a timeline of key events concerning DOE's Surplus Plutonium Disposition Program.

[17]EM manages a separate portion of 5.1 MT of surplus plutonium. Under an interim action determination, EM began diluting small amounts of this surplus plutonium for disposal at WIPP in 2012, but suspended those efforts in 2014. EM resumed the dilute and dispose strategy in 2016.

Figure 3: Changes in the Department of Energy's (DOE) Surplus Plutonium Disposition Strategies, 1997 through 2019



Source: GAO analysis of DOE data. | GAO-20-166

Notes: The Waste Isolation Pilot Plant is a deep geologic repository designed to accept defense-related transuranic waste, which generally consists of clothing, tools, rags, residues, debris, soil, and other items contaminated with radioactive elements that are heavier than uranium, such as plutonium, and that were generated as a result of work related to atomic energy defense activities. A 1957 National Academy of Sciences report endorsed deep geological formations for the disposal of high-level waste, including spent nuclear fuel. Since then, a deep geologic repository has been considered the safest and most secure method for disposing of high-level waste. Currently, the United States does not have an operational high-level waste repository.

Even if NNSA and EM had successfully implemented strategies for immobilization, vitrification, or irradiation of MOX fuel, DOE would have had no place to dispose of the surplus plutonium that was prepared for disposal because it planned to dispose of this material in a high-level waste repository, and no high-level waste repository has yet been constructed. WIPP would not have been able to take surplus plutonium from these disposition strategies because federal law authorizing disposal of radioactive waste at WIPP specifically bans the disposal of high-level

waste and spent nuclear fuel, and the final forms of the surplus plutonium from these disposition strategies would have included both.[18] DOE's plans for a high-level waste repository have also changed over time. No progress toward licensing and building a high-level waste repository has been made since DOE terminated its licensing efforts in 2010.[19] A high-level waste repository is likely still decades away from becoming operational. Appendix IV contains more information on the progress DOE has made toward licensing and building a high-level waste repository.

NNSA's Dilute and Dispose Strategy Requires That Pits Be Dismantled and Plutonium Metal Be Converted to an Oxide

NNSA's current dilute and dispose strategy requires that surplus pits, as well as other surplus plutonium in metal form, be converted to plutonium oxide. NNSA's now-terminated strategy to use surplus plutonium to make MOX fuel also required that surplus plutonium be converted to plutonium oxide.

In the early 2000s, NNSA had planned to build a facility—the Pit Disassembly and Conversion Facility at SRS—that was to be dedicated to disassembling pits and converting them to plutonium oxide to meet the high plutonium oxide production requirements for manufacturing MOX fuel.[20] Because of its high costs, however, NNSA canceled the Pit Disassembly and Conversion Facility in January 2012 after having spent $730.1 million on its design, as we reported.[21]

In August 2012, DOE provided a report to Congress that described a mix of plutonium oxide production capabilities to replace the canceled Pit Disassembly and Conversion Facility. According to the 2012 report, DOE planned to convert at least 2 MT of surplus plutonium pits to plutonium oxide by 2018 in PF-4 at LANL and an additional 3.7 MT of plutonium oxide at SRS by 2017.[22] According to its 2012 report, NNSA planned for

[18]Waste Isolation Pilot Plant Land Withdrawal Act of 1992. Pub L. No. 102-579, § 12, 106 Stat. 4777 (1992).

[19]See GAO, *Nuclear Waste: Benefits and Costs Should Be Better Understood Before DOE Commits to a Separate Repository for Defense Waste*, GAO-17-174 (Washington, D.C.: Jan. 31, 2017).

[20]According to NNSA, under the MOX fuel strategy, at its peak operating capacity, the MFFF would have required 3.5 MT (3,500 kilograms) of plutonium oxide annually.

[21]GAO-17-390.

[22]Department of Energy, *MOX Fuel Fabrication Feedstock: Report to Congress* (Washington, D.C.: August 2012).

this plutonium oxide to be a reserve of advance feedstock for the MFFF. NNSA anticipated it would begin operations in 2019. According to NNSA, SRS turned out not to be cost-effective at producing plutonium oxide. Specifically, SRS produced 35 kilograms (0.035 MT) of plutonium oxide at SRS's H Canyon facility over a 2.5-year period ending in 2018.[23] NNSA discontinued plutonium oxide production at H Canyon and focused its plans on expanding ARIES operations at PF-4. According to NNSA, ARIES operations at PF-4 currently host the nation's only cost-effective plutonium oxide production capability.

In 1998, DOE established ARIES at PF-4 at LANL in New Mexico as a technology demonstration project to dismantle pits and convert plutonium metal into an oxide, incorporating automation to reduce liquid waste and workers' exposure to radiation.[24] ARIES's technology for converting plutonium to plutonium oxide was designed to generate very little chemical waste and to permit the application of automation, which significantly reduces the risk of workers' exposure to radiation. Pits have historically been disassembled by a cutting machine. Before ARIES's technology, recovery of plutonium from cut pits was by an aqueous process—that is, by using liquid chemical processing—which generated significant volumes of both liquid and solid waste.

In 2008, NNSA shifted the ARIES mission from a technology demonstration project to a small plutonium oxide production capability. According to NNSA officials, ARIES has produced approximately 1 MT of plutonium oxide from pits since it was established in 1998, with peak production of 242 kilograms (0.242 MT) in 2011 during a partial year of operations. NNSA officials explained that ARIES did not produce larger amounts of plutonium oxide because the agency was still evaluating alternatives for expanding plutonium oxide, but they estimated that ARIES

[23]H Canyon, located at DOE's SRS in South Carolina, is the only hardened nuclear chemical separations plant still in operation in the United States. H Canyon began operations in 1955 and was designed to recover specific materials, such as uranium and plutonium, from irradiated material for reuse in nuclear weapons or to provide energy sources for spacecraft. H Canyon has also been used for other purposes, including manufacturing fuel for nuclear reactors.

[24]PF-4 began operations in 1978 at LANL. In addition to housing ARIES, PF-4 has several plutonium-related missions supported by NNSA, including manufacturing pits for nuclear weapons and heat sources used in civilian space missions. PF-4 also has other missions, such as research into improved methods for reprocessing of spent nuclear fuel. The facility is capable of handling and temporarily storing plutonium and other special nuclear materials, although much of its storage space is currently filled.

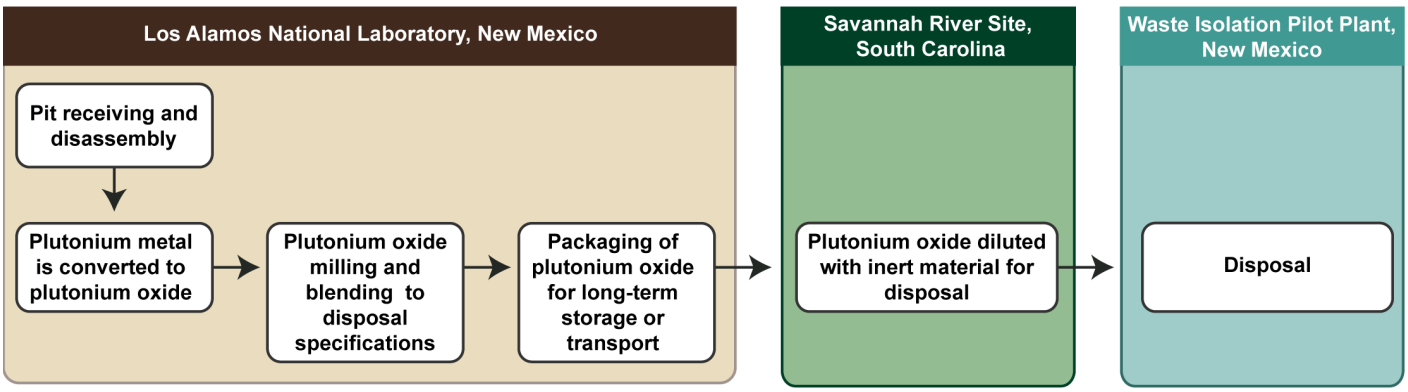
could produce 300 kilograms to 400 kilograms in a full year of operations. In addition, LANL shut down the PF-4 facility, including ARIES, from June 2013 through September 2016 to correct safety and operational issues. During this time, plutonium oxide production using ARIES in PF-4 was suspended.

Plutonium oxide is the preferred form for long-term storage of plutonium because it is relatively stable compared to other forms. Plutonium oxide is also the form of plutonium that is most suited for dilution. ARIES consists of glove boxes,[25] furnaces, and other equipment to

- dismantle a pit and extract the plutonium;
- convert the plutonium into an oxide form;
- mill and blend the plutonium oxide;
- conduct physical and chemical analyses of the plutonium oxide; and
- package and store the plutonium oxide for eventual disposition.

NNSA's 2018 conceptual plan to dilute and dispose of surplus plutonium calls for plutonium metal to be converted to plutonium oxide using ARIES at PF-4 and then for the plutonium oxide to be diluted at SRS for eventual disposal at WIPP. Figure 4 shows the dilute and dispose strategy as described in NNSA's 2018 conceptual plan.

Figure 4: The Department of Energy's (DOE) Dilute and Dispose Strategy for Surplus Plutonium



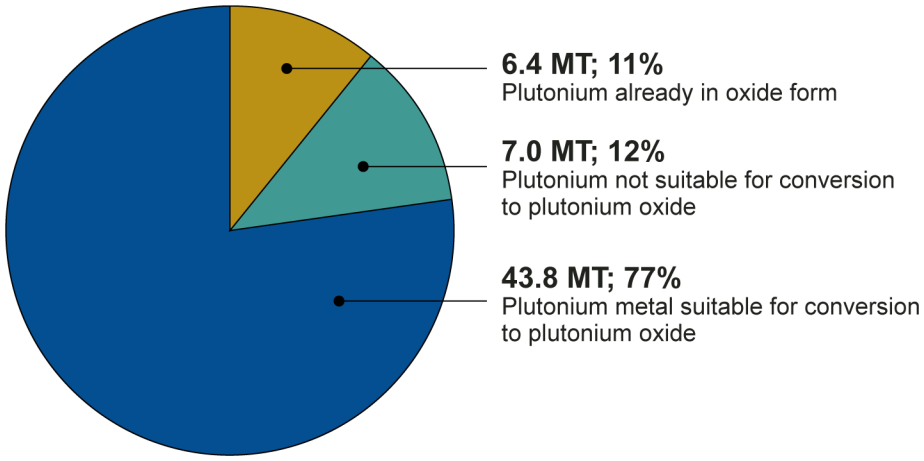
Source: GAO presentation of DOE information. | GAO-20-166

[25]A glove box is a sealed, protectively lined compartment that has holes to which gloves are attached for use in handling especially dangerous materials inside the compartment.

DOE Could Convert 43.8 MT, or About 77 Percent, of Surplus Plutonium in Its Inventory to Plutonium Oxide for Dilution and Disposal

DOE could convert 43.8 MT, or about 77 percent, of surplus plutonium in its inventory of 57.2 MT to plutonium oxide for dilution and disposal because this plutonium is in a metal form suitable to oxidation, based on our review of DOE's inventory of surplus plutonium. Most of this surplus plutonium metal—33.3 MT—is in the form of pits and is managed by NNSA. EM manages 6.5 MT of surplus plutonium metal and NE manages the remaining 4 MT of surplus plutonium metal reactor fuel at Idaho National Laboratory.[26] Separately, EM also manages 6.4 MT of surplus plutonium that is already in oxide form. Figure 5 shows the forms of surplus plutonium in DOE's inventory of 57.2 MT of surplus plutonium requiring disposition.

Figure 5: The Department of Energy's (DOE) Surplus Plutonium, of Which 43.8 Metric Tons (MT), or 77 Percent, Could Be Converted to Plutonium Oxide



Source: DOE. | GAO-20-166

Note: The 7 MT of surplus plutonium that is not suitable for conversion to plutonium oxide consists of spent (used) nuclear fuel.

[26]Although DOE has 43.8 MT of surplus plutonium in metal form that could be converted to plutonium oxide for disposition, as of May 2019, DOE was only planning to convert 32.7 MT of this surplus plutonium metal to an oxide. This surplus plutonium consists of 26.2 MT of pits managed by NNSA and 3.5 MT of non-pit metal managed by EM, both of which are being disposed of under NNSA's 2018 conceptual plan for the dilute and dispose strategy. Under a separate dilute and dispose disposition program, EM is disposing of 6.0 MT of plutonium, of which 5.1 MT is surplus plutonium and 900 kilograms (0.9 MT) is non-surplus plutonium from foreign sources. Of this 5.1 MT, EM reported that 3.0 MT was in metal form and could be converted to plutonium oxide. DOE has not made any decisions on the 4 MT of surplus plutonium contained in metal reactor fuel and managed by NE.

As noted above, EM manages 6.4 MT, or 11 percent, of surplus plutonium that already exists as plutonium oxide. According to NNSA officials, SRS is currently diluting this oxide at a modest rate of about 20 kilograms (0.02 MT) annually. According to NNSA documents, the agency plans to add additional throughput capacity within a decade.

The remaining 7 MT of surplus plutonium, or about 12 percent of DOE's surplus plutonium inventory, is contained in spent nuclear fuel and is not suitable for conversion to plutonium oxide. This material would require additional chemical processing steps to make it suitable for conversion to plutonium oxide. DOE officials said that they planned to dispose of the 7 MT of spent nuclear fuel in a deep geologic repository, which would avoid necessitating development of facilities and processes for conversion to plutonium oxide. DOE officials said that this fuel could also be disposed of through other to-be-determined disposition paths. Currently, EM manages the spent nuclear fuel that contains 7 MT of this surplus plutonium at various locations throughout the country.

NNSA's Long-Term Plutonium Oxide Production Plan Is Uncertain because of Two Key Issues

NNSA's 2018 conceptual plan calls for converting 26.2 MT of surplus plutonium into oxide by 2045.[27] In September 2019, NNSA approved the production of about 1.2 MT of plutonium oxide through 2025 at LANL. However, plans for converting additional surplus plutonium into plutonium oxide are uncertain primarily because of two issues. These issues are (1) NNSA's plans for new pit production, which are still in development and which will also take place at LANL; and (2) issues surrounding the agency's ability to ship newly produced plutonium oxide for dilution to DOE's Savannah River Site (SRS) in South Carolina. According to agency officials, NNSA and DOE are taking several actions that, if successfully implemented, are designed to allow NNSA to meet its long-term plutonium oxide production goals. These actions include continuing to review plutonium oxide and pit production plans, increasing plutonium storage at LANL, reducing the amount of SRS's surplus plutonium, and shipping the diluted plutonium from SRS to WIPP.

[27]NNSA's cost estimate included the cost of converting 29.7 MT of surplus plutonium metal to an oxide to include 3.5 MT managed by EM, but the conversion at PF-4 only included NNSA's 26.2 MT of surplus pits. EM officials said they had not determined how they planned to convert their 3.5 MT of surplus plutonium metal to an oxide.

NNSA's 2018 Conceptual Plan Would Increase Plutonium Oxide Production at LANL

NNSA's 2018 conceptual plan called for expanding plutonium oxide production capacity in PF-4 for the dilute and dispose strategy to achieve production of 1.5 MT per year by 2033.[28] NNSA planned to sustain this rate of production at LANL for 12 years to convert a total of 26.2 MT of pits to plutonium oxide before ramping down operations in 2045. The agency's 2018 conceptual plan estimated that this increased production would cost approximately $5 billion over the life of the program.[29] To achieve the 1.5 MT annual production rate, NNSA planned to expand the physical space of ARIES's operations in PF-4 by about 50 percent,[30] install new equipment such as glove boxes, purchase additional equipment, such as spare parts and new shipping containers, and hire over 200 new staff. To accommodate the larger workforce, NNSA also planned to construct a new employee entrance in PF-4.

In September 2019, NNSA approved a short-term plan to produce a total of nearly 1.2 MT of plutonium oxide at PF-4 from 2019 through 2025. This short-term plan closely matches the total plutonium oxide production outlined in NNSA's 2018 conceptual plan for the same time frame.[31]

Two Key Issues May Affect NNSA's Long-Term Plutonium Oxide Plans

In February 2019, NNSA officials said that they were reevaluating the agency's long-term plutonium oxide production goals in the 2018 conceptual plan because of two key issues. These issues are space constraints relating to (1) the agency's mission to produce new pits in PF-4 and (2) requirements to remove plutonium from SRS. According to agency officials, NNSA and DOE are taking several actions designed to

[28]The NNSA 2018 conceptual plan describes ARIES production operations from 2017 through 2045, producing 26.2 MT of surplus plutonium oxide from pits that were originally planned for the MOX fuel strategy.

[29]The cost estimate for NNSA's 2018 conceptual plan included estimated costs for NNSA's 26.2 MT of surplus pits and EM's 3.5 MT of surplus non-pit plutonium, but the schedule for ARIES through 2045 only included converting NNSA's 26.2 MT of surplus pits. EM officials said they had not determined when or where to convert their 3.5 MT of non-pit plutonium to plutonium oxide.

[30]In July 2019, NNSA officials said that ARIES currently operates in most of two rooms and half of two other rooms, but would need to expand to one more full room, with installed equipment, to achieve a peak production rate of 1.5 MT per year.

[31]The 2018 conceptual plan called for the production of a total of 1.2 MT of plutonium oxide from 2019 through 2025. The approved September 2019 short-term plan includes the production of 1.189 MT of oxide for the same period. The difference between the two plans is 11 kilograms (0.011 MT).

allow NNSA to meet the long-term plutonium oxide production goals described in its 2018 conceptual plan.

New Pit Production Could Impede Plutonium Oxide Production, but NNSA is Taking Some Actions to Address This Issue

As we reported in November 2018, NNSA officials said that a planned nuclear weapons refurbishment and future warhead programs will require the production of new pits.[32] Almost all of the pits in the current U.S. nuclear weapons stockpile were produced before 1990, according to a May 2015 Congressional report.[33] In May 2018, NNSA announced that it intended to build 30 pits annually in PF-4 at LANL by 2026 and 50 pits annually at the MFFF at SRS by 2030, under a plan to repurpose the MFFF for pit production. According to an August 2019 LANL presentation to potential subcontractors, this effort will include the installation of more than 140 new gloveboxes or other enclosures in PF-4 and the construction of more than 700,000 square feet of supporting infrastructure (such as offices, a parking garage, and a cafeteria). The President's budget for fiscal year 2020 includes over $3 billion for this effort through 2024. In April 2019, the NNSA Administrator said meeting pit production requirements was the agency's highest infrastructure priority.[34]

NNSA also may have to increase pit production at LANL beyond 30 pits per year. For example, in May 2018 the Nuclear Weapons Council stated that it was essential that NNSA provide resources for surge pit production capacity in PF-4 at LANL until pit production is fully established at SRS.[35] In addition, the National Defense Authorization Act for fiscal year 2019 requires the Department of Defense and NNSA to contract with a federally funded research and development center to conduct an assessment of, among other things, a strategy for producing 80 pits per

[32]GAO, *Nuclear Weapons: NNSA Has Taken Steps to Prepare to Restart a Program to Replace the W78 Warhead Capability*, GAO-19-84 (Washington, D.C.: Nov. 30, 2018).

[33]Congressional Research Service, *Nuclear Weapon "Pit" Production: Options to Help Meet a Congressional Requirement* (Washington, D.C.: May 14, 2015).

[34]Lisa E. Gordon-Hagerty, Under Secretary for Nuclear Security and Administrator of the National Nuclear Security Administration, U.S. Department of Energy, testimony before the Subcommittee on Energy and Water Development, House Committee on Appropriations, 116th Cong., 1st sess., April 2, 2019.

[35]The Nuclear Weapons Council—a joint Department of Defense (DOD) and DOE activity established by statute in 1986—serves as the focal point for interagency activities to maintain the U.S. nuclear weapons stockpile. The council facilitates cooperation and coordination between DOD and NNSA on nuclear weapons stockpile issues, reaches consensus on those issues, and establishes priorities between DOD and NNSA to align their efforts as they carry out their responsibilities for managing the U.S. nuclear weapons stockpile.

year at LANL.[36] NNSA officials told us in February 2019 that as a result of pit production requirements, the agency might need to use a portion of the processing areas in PF-4 for pit production that the agency had planned to use for plutonium oxide production. Pit production requirements also may use more space in the high-security vault in PF-4 where plutonium must be temporarily stored.[37] Also in February 2019, NNSA officials said that PF-4's high-security storage space is already near full capacity and that pit production may demand storage space that NNSA had planned to use for plutonium oxide production.[38]

NNSA officials said that the agency is taking some actions that are designed to address increasing both pit and plutonium oxide production in PF-4. If successfully implemented, these actions are designed to allow the program to meet the milestones described in the 2018 conceptual plan, according to NNSA officials. These actions include:

- **Reviewing use of operational space in PF-4.** LANL reported in March 2019 that the requirement to produce 30 pits per year would have no significant negative impact on plutonium oxide production.[39] However, LANL reported that a number of programs, including pit production, were planning to increase operations in PF-4, placing demands on the aging facility that could lead to more frequent

[36]John S. McCain National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115-232, § 3120(b)(1)(D) (2018). For an assessment on producing 80 pits per year, see Institute for Defense Analysis, *Independent Assessment of the Plutonium Strategy of the National Nuclear Security Administration* (Alexandria, VA: March 2019). A March 2019 publically released executive summary of this assessment concluded that producing this number of pits at LANL by 2030 appears to be technically possible but would be very challenging to execute and has a high risk of schedule slip, cost growth, and cancellation.

[37]Plutonium pits, other plutonium metals, and plutonium oxides are packaged in special containers that are certified for storage in special vaults and safes.

[38]For plutonium oxide production, LANL would receive surplus pits from DOE's Pantex Plant in Texas and store them in secure space in PF-4 until they could be disassembled and converted to an oxide. The plutonium oxide would be stored until it could be shipped to SRS for dilution and disposal. For pit production, LANL would store plutonium metal in the secure storage space prior to the metal being formed into pits, then store the manufactured pits in the secure space until they could be shipped to Pantex to be placed in reserve or assembled into nuclear weapons.

[39]National Nuclear Security Administration, *ARIES Oxide Production Program: FY19 Program Management Plan, Rev. 10* (Los Alamos, NM: Apr. 11, 2019). The space utilization assessment was based on LANL's task of manufacturing 30 pits per year.

maintenance outages.[40] In August 2019, NNSA officials responsible for plutonium oxide production and pit production said they continue to believe that increased oxide production and pit production can be simultaneously accomplished in PF-4 but that they are continuing to review the issue as the agency's pit production plans evolve. In NNSA's comments on our report, the NNSA Administrator said the agency was working to balance the needs of both missions. The Administrator also noted that NNSA's Office for Cost Estimating and Program Evaluation will assess the effect of plutonium oxide production on pit production as required by section 3120 of the National Defense Authorization Act for fiscal year 2019. The conference report accompanying the act also requires that we review this assessment, which we will initiate in late 2019.

- **Increasing plutonium storage capacity.** LANL also reported in March 2019 that it planned to implement several mitigation measures that would allow the storage of more plutonium oxide and other materials in the PF-4 vault. In addition, DOE and NNSA have "swapped" 1 MT of the declared surplus plutonium at SRS with 1 MT of plutonium residues and other primarily non-pit plutonium already stored in LANL's PF-4 vault.[41] NNSA officials said that the plutonium residues and other primarily non-pit plutonium at LANL would be considered surplus plutonium and would be converted to plutonium oxide, requiring less storage space. Without these mitigation measures, the PF-4 vault would fill up years earlier, according to NNSA officials. NNSA officials said they believe the swap will increase storage space through 2028, at which point LANL would need to ship plutonium oxide to SRS or face a suspension of plutonium oxide production.

Requirement to Remove Plutonium from SRS Could Impede Shipping Plutonium Oxide There, but NNSA is Taking Some Actions to Address This Issue

Storing quantities of plutonium oxide in PF-4's high-security storage vault is critical because, according to NNSA officials, it is not likely that NNSA will ship plutonium oxide or other forms of plutonium to SRS until a dispute with the state of South Carolina is resolved. Specifically, the National Defense Authorization Act for fiscal year 2003 required DOE to prepare a plan for the construction and operation of the MFFF at SRS so that it could produce MOX fuel at an average rate of at least 1 MT per

[40]DOE's 2018 conceptual plan required that pits be converted to plutonium oxide at least through 2045, at which time PF-4 will have been in operation for more than 75 years.

[41]NNSA swapped the plutonium residues and primarily non-pit plutonium material with DOE's Office of Defense Programs.

year.[42] As subsequently amended, the law provides that if DOE did not meet this 1 MT production objective by January 1, 2014, then it was required to remove 1 MT of defense plutonium from South Carolina by January 1, 2016. If DOE missed that deadline, it was required to make substantial payments to South Carolina until the removal was completed.[43] As NNSA faced delays and cost increases in constructing the MFFF and began to reevaluate its surplus disposition strategy, South Carolina sued DOE in February 2016 to begin removing plutonium from the state and to begin to make payments to the state of up to $100 million per year until the surplus plutonium is removed.

In December 2017, the court ordered DOE to remove 1 MT of plutonium from South Carolina by 2020. In response, according to court filings, NNSA moved 0.5 MT of plutonium from SRS to its Nevada National Security Site prior to November 2018 and moved another 0.5 MT of plutonium off-site in August 2019.[44] DOE is still required by statue to remove an amount of defense plutonium or defense plutonium material equal to that which was transferred to SRS after April 15, 2002, but not processed by the MOX facility by January 2022.[45] The officials told us that because of this continuing requirement and the threat of further lawsuits by South Carolina, it was unlikely that NNSA could ship plutonium oxide to SRS until the surplus plutonium at SRS is removed.

NNSA officials said that the agency is taking some actions designed to address these issues. These actions include:

[42]Bob Stump National Defense Authorization Act for Fiscal Year 2003, Pub. L. No. 107-314, § 3182, 116 Stat. 2458, 2747 (2002) (codified as amended at 50 U.S.C. § 2566).

[43]Specifically, if the MOX production objective was not achieved by January 1, 2014, the Secretary of Energy was to remove from South Carolina, not later than January 1, 2016, at least 1 MT of defense plutonium or defense plutonium materials. If the MOX production objective was not achieved by January 1, 2016, the Secretary was, subject to the availability of appropriations, to make economic and impact assistance payments to South Carolina of $1,000,000 per day, not to exceed $100,000,000 per year, until the later of the date on which the MOX production objective was achieved or the date on which the Secretary removed at least 1 MT of defense plutonium or defense plutonium materials. 50 U.S.C. § 2566(c)-(d).

[44]In November 2018, the state of Nevada filed suit in federal district court to block plutonium shipments into the state. In January 2019, DOE acknowledged in a court filing that it had shipped the 0.5 MT of plutonium to Nevada sometime before November 2018. Also in January, the federal district court refused to bar further plutonium shipments into Nevada. Nevada is appealing that ruling.

[45]50 U.S.C. § 2566(c)(2).

- **Increasing plutonium oxide production rates with a priority on oxidizing plutonium material from SRS.** NNSA officials said in August 2019 that they are in discussions with LANL to increase the short-term production of plutonium oxide to speed the removal of surplus plutonium from South Carolina. According to NNSA officials, NNSA and LANL are considering increasing plutonium oxide production through 2025 beyond what is called for in their short-term plan that the agency approved in September 2019.[46] This would involve shipping additional surplus plutonium metal from SRS to LANL and prioritize converting this material to plutonium oxide.[47] According to agency officials, LANL would produce additional plutonium oxide production by using new ARIES equipment installed in PF-4 in 2019.[48] To achieve this increased production, NNSA officials said that LANL would need to hire 70 personnel through 2025 to operate ARIES. Agency officials said that these steps would increase total plutonium oxide production to approximately 2.1 MT through 2025, an increase of nearly 1 MT over the short-term plan NNSA approved in September 2019.
- **Increasing dilution and disposal rates of the inventory of plutonium oxide already at SRS.** DOE and NNSA officials said that they would also increase dilution of existing plutonium oxide at SRS beyond what is called for in the 2018 conceptual plan to help reduce the inventory of plutonium metal already there. In April 2019, NNSA officials said their current dilution rate at SRS was about 20 kilograms (0.02 MT) annually, but that they plan to increase that rate to 1.5 MT by the late 2020s. Under its 2018 conceptual plan, NNSA had planned to achieve that dilution rate by 2031, but the budget request for NNSA

[46]NNSA proposes producing 2 MT of plutonium oxide using ARIES at PF-4. In August 2012, DOE reported to Congress its plan to develop enough plutonium oxide feedstock to sustain operations at the MFFF. The report describes 9.8 MT that would be available for MOX in 2018, including 7.8 MT of surplus non-pit plutonium material that is already in oxide form or will be converted to an oxide at SRS and 2 MT of plutonium pits that would be converted to plutonium oxide at ARIES. See, Department of Energy, *MOX Fuel Fabrication Feedstock: Report to Congress* (Washington, D.C.: August 2012).

[47]According to NNSA officials, NNSA would prioritize the conversion of surplus plutonium metal at SRS instead of focusing on the dismantlement of pits, currently at Pantex. The agency assumes that plutonium material shipped from the SRS to LANL can be matched with offsetting shipments from LANL to SRS because exchanging equivalent quantities of material will not increase the net inventory of plutonium material at SRS.

[48]NNSA officials told us that the new equipment is capable of producing as much as 700 kilograms (0.7 MT) of plutonium oxide annually. However, NNSA has not approved this level of production and LANL has not demonstrated it.

for fiscal year 2020 shows that NNSA plans to complete installation of the capability necessary to achieve that dilution rate by as early as fiscal year 2028. The effort—known as the Surplus Plutonium Disposition project—has an estimated cost range from $200 million to $589 million. It includes removing unnecessary equipment from SRS, accelerating the project's construction schedule, installing long-lead procurement items early in construction, and hiring and certifying additional personnel. According to NNSA officials, this increase in dilution capacity by 2028 would enable NNSA to begin shipping plutonium oxide to SRS for dilution and disposal without suspending plutonium oxide production at PF-4.

While NNSA is taking actions to address pit production and shipment issues, the agency continues to work on refining the long-term plutonium oxide production goals in its 2018 conceptual plan. However, NNSA officials said that establishing firm long-term plutonium oxide production plans now would be premature and that the agency would use the next several years to balance plutonium oxide production, pit production, and shipment issues as they refine long-term production plans.

Agency Comments

We provided a draft of this report to NNSA and DOE for review and comment. In its response to our draft report, reproduced in appendix V, NNSA said that it and DOE are working to balance the needs of its dilute and dispose program, which includes oxide production, and pit production, as well as the need to remove plutonium from the state of South Carolina. NNSA said, as noted in our report, that its Office for Cost Estimating and Program Evaluation would assess the effects of increased plutonium oxide production on pit production.

NNSA also said that even with delays in production of plutonium oxide, the dilution and disposition of surplus plutonium will still be substantially less expensive than if the agency had maintained its MOX fuel approach. As stated in our report, we have a large body of work that has examined the MOX fuel approach, NNSA's management of the MOX project, and DOE's $17 billion cost estimate to complete the project, which we assessed as being reliable.

In addition, NNSA provided us with technical comments and additional documentation, which we incorporated into our report as appropriate. Some of the information that NNSA provided helped clarify near-term plutonium oxide production plans as well as the agency's progress in balancing the plutonium oxide production plans, pit production, and the

need to move plutonium out of the state of South Carolina. This information is incorporated in our report and is reflected in the report's revised title.

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

If you or your staff members have 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 key contributions to this report are listed in appendix VI.

David C. Trimble
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

Our report (1) determines the amount of surplus plutonium in the Department of Energy's (DOE) inventory that could be converted to plutonium oxide for dilution and disposal and (2) examines DOE's capacity to produce plutonium oxide.

To determine the amount of surplus plutonium in DOE's inventory that could be converted to plutonium oxide for dilution and disposal, we reviewed relevant DOE documents and interviewed officials from DOE, including from DOE's National Nuclear Security Administration (NNSA) and DOE's Office of Environmental Management (EM), on the amounts and forms of surplus plutonium in DOE's inventory that would require conversion to an oxide prior to final disposition. Our review included DOE's plans for converting surplus plutonium to plutonium oxide beginning in 1997, when DOE first decided to convert surplus plutonium to plutonium oxide for disposition. We also visited the Los Alamos National Laboratory (LANL) in New Mexico to review documentation and interview officials in the Surplus Plutonium Disposition Program for information on past and current inventories of surplus plutonium. NNSA's Advanced Recovery and Integrated Extraction System (ARIES), the program that currently converts surplus plutonium to plutonium oxide, resides in Plutonium Facility-4 (PF-4) at LANL.

To examine DOE's capacity to produce plutonium oxide, we reviewed relevant DOE documents and interviewed officials from DOE, including from NNSA and EM, on the status of plutonium oxide production in PF-4 and at DOE's Savannah River Site, where surplus plutonium was converted to plutonium oxide over a 2 1/2-year period. We reviewed relevant DOE documents and interviewed officials from DOE, including from NNSA and EM, on their plans. For example, we reviewed records of decision and environmental impact statements that DOE issued during its management of the Surplus Plutonium Disposition Program. We reviewed planning documents related to the dilute and dispose strategy, including DOE's life-cycle cost estimate and supporting documents covering issues such as time frames and conversion rates. We visited the ARIES program in PF-4 in January 2018 to review documentation and conduct interviews with officials responsible for plutonium oxide production and the planned expansion of plutonium oxide production. The site visit included a tour of PF-4, ARIES and its operations, and potential spaces in PF-4 for expansion of ARIES operations for converting surplus plutonium metal to oxide.

We conducted this performance audit from October 2017 to October 2019 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.

Appendix II: Timeline of the Changes to Department of Energy (DOE) Disposition Strategies under the Surplus Plutonium Disposition Program

DOE first established the Surplus Plutonium Disposition Program in 1997 to dispose of surplus, weapons-usable plutonium at the end of the Cold War. As of April 2019, the United States has declared a total of 61.5 metric tons (MT) of plutonium as surplus to defense needs.[1] DOE has disposed of 3.2 MT of surplus plutonium at the Waste Isolation Pilot Plant (WIPP), an underground repository for transuranic waste located near Carlsbad, New Mexico, and is in the process of disposing of an additional 1.1 MT of surplus plutonium. This leaves 57.2 MT of surplus plutonium in its inventory, as of May 2019. The table below shows the timeline of changes to DOE strategies for managing surplus plutonium for final disposition.

[1]In 1994, the United States declared 52.5 MT of plutonium as surplus to defense needs. In 2007, the United States declared an additional 9 MT of plutonium as surplus to defense needs.

Table 1: Timeline of the Changes to Department of Energy's (DOE) Strategies for Managing Surplus Plutonium for Final Disposition, 1997 through 2018

Year	Implementing agency	Disposition strategy
1997	DOE	DOE proposed a dual-path strategy for plutonium disposition that included immobilizing a portion of surplus plutonium in glass or ceramic materials and irradiating the remainder in reactors as mixed oxide (MOX) fuel. Initially, 8 metric tons (MT) was slated for immobilization.
2000	DOE	Immobilization of 17 MT and irradiation of 33 MT as MOX fuel.
2002	National Nuclear Security Administration (NNSA)[a]	Immobilization portion canceled. Irradiation of 34 MT as MOX fuel.
2006	Office of Environmental Management (EM)	Vitrification—a form of immobilization that traps plutonium in a glass material—briefly considered but plan never developed.
2008	EM	DOE began plans to use facilities at the Savannah River Site (SRS) to dispose of 0.6 MT of surplus plutonium at the Waste Isolation Pilot Plant (WIPP).
2011	EM	DOE began plans to use facilities at SRS to dispose of 0.5 MT of surplus plutonium for disposal at WIPP.
2012	NNSA	Pit Disassembly and Conversion Facility canceled.[b]
2015	DOE	Working group established to examine costs and other factors of the MOX fuel production strategy and the dilute and dispose strategy, including ways to reduce costs for the MOX strategy and to assess options for the disposition of 34 MT of surplus plutonium.
2016	EM	Implementation of dilution and disposal of 5.1 MT. DOE also decided that it would dispose of up to 0.9 MT of additional non-surplus plutonium from foreign sources, using the same dilute and dispose strategy.
2016	NNSA	Mission need statement for the dilute and dispose strategy issued.
2018	NNSA	Termination of the contract for construction of the MOX fuel fabrication facility.

Source: DOE | GAO-20-166

[a]NNSA was established by law in 1999.

[b]The Pit Disassembly and Conversion Facility was planned for the MOX fuel strategy.

Appendix III: Timeline of Key Events Concerning the Department of Energy's (DOE) Surplus Plutonium Disposition Program

- 1997 - DOE announces the Surplus Plutonium Disposition Plan, including the Mixed Oxide Fuel Fabrication Facility (MFFF).
- 2000 - The United States and Russia enter into the Plutonium Management and Disposition Agreement (PMDA), each agreeing to dispose of at least 34 metric tons (MT) of plutonium at a rate of at least 2 MT per year.
- 2000 - DOE announced it will construct the MFFF.
- 2002 - The National Defense Authorization Act for fiscal year 2003 requires DOE to prepare a plan for the construction and operation of the MFFF at the Savannah River Site in South Carolina and requires, among other things, that DOE remove 1 MT of plutonium from South Carolina by January 1, 2011, if mixed oxide (MOX) production objectives of an average rate of at least 1 MT per year were not achieved by January 1, 2009.[1] Failure to meet these deadlines would require DOE to make substantial annual payments to South Carolina.
- 2005 – The Energy and Water Development Appropriations Act for Fiscal Year 2006 extends the original plutonium production and removal deadlines by 3 years (thus making the 1 MT plutonium production deadline January 1, 2012, and removal deadline January 1, 2014).[2]
- 2014 – The National Defense Authorization Act for fiscal year 2015 requires DOE to issue a report that would study the plan for the MFFF as well as possible alternatives to the MFFF.
- 2015 - The National Defense Authorization Act for Fiscal Year 2016 requires DOE to carry out an analysis of alternatives for the Surplus Plutonium Disposition Program.

[1]Pub. L. No. 107-314, § 3182, 116 Stat. 2747 (2002), codified as amended at 50 U.S.C. § 2566. As amended, most recently in 2014, the statute states that if the MOX production objective at an average rate of at least 1 MT per year is not achieved by January 1, 2014, the Secretary shall, consistent with the National Environmental Policy Act of 1969 and other applicable laws, remove from the State of South Carolina, for storage or disposal elsewhere—

(1) not later than January 1, 2016, not less than 1 MT of defense plutonium or defense plutonium materials; and

(2) not later than January 1, 2022, an amount of defense plutonium or defense plutonium materials equal to the amount of defense plutonium or defense plutonium materials transferred to the Savannah River Site between April 15, 2002, and January 1, 2022, but not processed by the MOX facility. 50 U.S.C. § 2566(c).

[2]Pub. L. No. 109-103, § 313, 119 Stat. 2247, 2280-81 (2005).

- 2015 and 2017 - Explanatory statements accompanying fiscal years 2016 and 2017 appropriations legislation contained specific direction to explore design issues associated with the dilute and dispose alternative.
- 2016 - South Carolina sues DOE in federal district court, contending that DOE failed to meet the MOX-related statutory deadlines. South Carolina sought monetary relief and an injunction compelling the federal government to remove 1 MT of plutonium from the state.[3]
- 2016 - DOE issues a Record of Decision stating that it would remove plutonium from South Carolina using the dilute and dispose strategy.
- 2017 - Federal district court issues an injunction ordering DOE to remove 1 MT of plutonium from South Carolina and ordering the parties to negotiate a new deadline.
- 2017 - The National Defense Authorization Act for Fiscal Year 2018 allowed DOE to terminate construction of MFFF if, among other things, DOE identified an alternative that would cost less than half of the MOX fuel strategy.[4]
- 2017 - South Carolina and DOE fail to agree on a deadline for removing 1 MT of plutonium from the state, so in December the court imposes a deadline of January 1, 2020.
- 2018 - Federal appellate court rejects DOE's appeal of the district court's order to remove 1 MT of plutonium from South Carolina by January 1, 2020.
- 2018 - DOE terminates the MOX contract for the government's convenience.
- 2019 – DOE acknowledges that it had shipped 0.5 MT of plutonium from South Carolina to Nevada sometime before November 2018 and shipped an additional 0.5 MT out of South Carolina to another state sometime before August 2019.

[3]South Carolina refiled the monetary claim in the Court of Federal Claims.

[4]Section 3121 of the National Defense Authorization Act for Fiscal Year 2018 permitted the Secretary of Energy to waive the requirement in Section 309 of the Consolidated Appropriations Act, 2018, to use funds for construction and project support activities relating to the MOX facility, if the Secretary can certify, among other things, that the life-cycle cost estimate of an alternative is less than half of the cost estimate of the MOX fuel disposition pathway.

Appendix IV: Timeline of Key Events Relating to a High-Level Waste Repository for Disposing of Certain Surplus Plutonium

The Nuclear Waste Policy Act of 1982 directed, among other things, that DOE study sites for a repository and that the President evaluate the capacity for the disposal of high-level waste resulting from atomic energy defense activities at one or more repositories developed for the disposal of commercial used (spent) nuclear fuel. In 1985, President Reagan found that there was no basis to conclude that a separate defense high-level waste repository was required. Table 2 shows the changes in plans for developing a high-level waste repository from 2002 through 2018.

Table 2: Timeline of Changes to the Department of Energy's (DOE) Surplus Plutonium Disposition Strategy for Disposal in a High-Level Waste Repository, 2002 through 2018

Year	Implementing agency	Disposition strategy
2002	Office of Civilian Radioactive Waste Management	Congressional approval of Yucca Mountain in Nevada as the site for a high-level waste repository that would comingle radioactive waste from both commercial and atomic energy defense activities.
2008	Office of Civilian Radioactive Waste Management	License application submitted to the Nuclear Regulatory Commission for the construction of a repository at Yucca Mountain.
2010	Office of Civilian Radioactive Waste Management	Work on Yucca Mountain repository terminated, and the Office of Civilian Radioactive Waste Management disbanded. DOE began studying disposal alternatives.
2015	Department of Energy	The President reversed a 1985 presidential finding and determined that the development of a separate repository for the disposal of high-level waste resulting from atomic energy defense activities is required.
2017	DOE	The President's budget proposal for fiscal year 2018 included funding to resume the license review at Yucca Mountain, planning to return to a single repository and comingling defense and commercial high-level waste, including spent nuclear fuel. The request also includes consolidating spent nuclear fuel in interim storage. Congress did not direct funding for the license application to resume.
2018	DOE	The President's budget proposal for fiscal year 2019 included funding to resume the license review at Yucca Mountain, planning to return to a single repository and comingling defense and commercial high-level waste, including spent nuclear fuel. The budget proposal included plans for consolidating spent nuclear fuel in interim storage. Congress did not direct funding for the license application to resume.

Source: DOE | GAO-20-166

Appendix V: Comments from the Department of Energy

Department of Energy
Under Secretary for Nuclear Security
Administrator, National Nuclear Security Administration
Washington, DC 20585

August 9, 2019

Ms. Allison B. Bawden
Director, Natural Resources
and Environment
U.S. Government Accountability Office
Washington, DC 20548

Dear Ms. Bawden:

Thank you for the opportunity to review the Government Accountability Office (GAO) draft report, *Changing Plutonium Oxide Production Plans Could Delay NNSA's Surplus Plutonium Disposition Efforts* (GAO-19-104). As always, the Department of Energy's National Nuclear Security Administration (DOE/NNSA) appreciates the work performed by the GAO.

In the November 2018, independently validated life-cycle cost estimate for the dilute and dispose strategy, DOE/NNSA stated its plan to gradually ramp up over the next decade its plutonium oxide production to a peak of 1.5 metric tons (MT) per year. As with any decades-long program, we are identifying potential impacts and opportunities as they arise, and are addressing them in our planning going forward. This includes opportunities to accelerate the removal of material from the state of South Carolina. Recognizing the importance of plutonium pit production, as stated in GAO-19-104, DOE/NNSA is working to balance the needs of both the pit production mission and the dilute and dispose strategy. DOE/NNSA remains committed to the disposition of 34 MT of plutonium using the dilute and dispose strategy and to the removal of surplus plutonium from South Carolina.

It is important to recognize that any delay in plutonium oxide production also would have impacted the mixed-oxide (MOX) fuel approach. Any delay in production does not change certain facts. Annual MOX operations would still cost considerably more than dilute and dispose annual operations. It would have required approximately 1,000 staff to operate MOX annually versus approximately 400 staff to operate Dilute and Dispose. Furthermore, the dilute and dispose strategy still removes material from the state of South Carolina sooner than the MOX fuel approach would have, by several decades. In addition, delay in plutonium oxide production does not impact the removal of material from the state of South Carolina.

DOE/NNSA's Office for Cost Estimating and Program Evaluation will be assessing the effect of increased plutonium oxide production activity in support of the dilute and dispose program on the plutonium pit production mission, as requested in Section 3120 of

the *John S. McCain National Defense Authorization Act for Fiscal Year 2019* (P.L. 115-232). The results of that review will be provided to Congress.

If you have any questions about this response, please contact Dean Childs, Director, Audits and Internal Affairs, at (301) 903-1341.

Sincerely,

Lisa E. Gordon-Hagerty

Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the individual named above, the following individuals made contributions to this report: Jonathan Gill (Assistant Director); Robert Sánchez (Analyst in Charge); Antoinette Capaccio; Robert (Scott) Fletcher; Cindy Gilbert; Richard Johnson; Sheryl Stein; Sara Sullivan; and Curtis (Wade) Tanner.