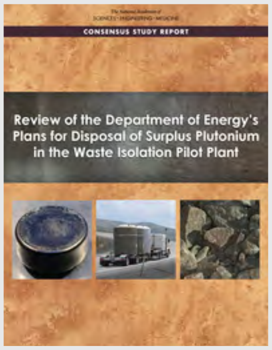

Review of the Department of Energy's Plans for Disposal of Surplus Plutonium in the Waste Isolation Pilot Plant (2020)

DETAILS

224 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-49858-6 | DOI 10.17226/25593

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SUGGESTED CITATION

National Academies of Sciences, Engineering, and Medicine 2020. *Review of the Department of Energy's Plans for Disposal of Surplus Plutonium in the Waste Isolation Pilot Plant*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25593.

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Committee on Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant

Nuclear and Radiation Studies Board

Division on Earth and Life Studies

A Consensus Study Report of
The National Academies of
SCIENCES • ENGINEERING • MEDICINE

THE NATIONAL ACADEMIES PRESS
Washington, DC
www.nap.edu

THE NATIONAL ACADEMIES PRESS **500 Fifth Street, NW** **Washington, DC 20001**

This activity was supported by contracts between the National Academy of Sciences and the Department of Energy's National Nuclear Security Administration, DE-EP0000026/DE-DT0013548. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project.

International Standard Book Number-13: 978-0-309-49858-6
International Standard Book Number-10: 0-309-49858-9
Digital Object Identifier: https://doi.org/10.17226/25593

Additional copies of this publication are available from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu.

Printed in the United States of America

Suggested citation: National Academies of Sciences, Engineering, and Medicine. 2020. *Review of the Department of Energy's Plans for Disposal of Surplus Plutonium in the Waste Isolation Pilot Plant.* Washington, DC: The National Academies Press. https://doi.org/10.17226/25593.

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Preface

When I was initially contacted by the National Academies of Sciences, Engineering, and Medicine to chair this study, based on the Statement of Task I believed the problem we were asked to study was straightforward: Review the Department of Energy's (DOE's) plans to dilute and dispose of surplus plutonium material in the Waste Isolation Pilot Plant (WIPP). To me, this sounded like a systems problem—one that required scaling up of existing processes—but technically not very complex.

In that narrow scope, I was correct. The dilute and dispose plan is not technically complex. The true challenges lay in the many mostly nontechnical threads that are connected to the technical plan. As noted previously—yes, the plan is technically feasible; no, it does not meet the requirements of the U.S.-Russian Plutonium Management and Disposition Agreement (PMDA) (as I understood it at the onset), an agreement that is further described within the main text of the report. But between these black and white answers are many shades of gray. I felt we were asked not only for the yes or no answers but also to deliver the best advice we could going forward. The committee's advice evolved after its careful consideration of the multiple and highly interconnected and complex threads connected to DOE's National Nuclear Security Administration's (DOE-NNSA's) dilute and dispose plan.

Many of the challenges connected to this disposition pathway are nontechnical but nevertheless important to understand in order to appreciate the committee's final analysis and advice. This requires background information and explanation. The answers were straightforward, the advice not so. Complex issues are associated with PMDA noncompliance, which requires a basic understanding of the agreement. Capacity at WIPP is not a simple volumetric or mass-density calculation and the method in which DOE calculated it changed over the course of the study which also requires detailed explanation. As an alternative to the Mixed Oxide Fuel Fabrication Facility (commonly referred to as the "MOX plant"), the dilute and dispose plan, which encompasses four DOE sites and spans over 30 years, was and is under development and evolving. It is important to stress that the program was and is evolving in real time. Other DOE programs that emerged during this study, including the new focus on pit production, which affects three of the four sites within the dilute and dispose plan, also needed to be considered. Finally, even the full quantity of surplus plutonium considered for dilution and disposal at WIPP requires an understanding of past decisions on surplus plutonium disposition and the impacts of potential future ones. It was not simple arithmetic, as I had initially assumed. To those readers familiar with these issues, the committee's resultant advice is concentrated in Chapters 4 and 5 of this report. To readers who seek background information, they are encouraged to read Chapters 2 and 3, which provide background on some of the complexities discussed above and details on DOE-NNSA's dilute and dispose plans.

Finally, it is worth noting the political context at the start of and throughout this study. In November 2017, the MOX plant was under construction, and incorporation of the surplus plutonium into MOX fuel for irradiation in commercial nuclear power plants was the U.S. program of record for disposition. The MOX option was cancelled in the midst of the committee's study in May 2018 and many documents related to the dilute and dispose plan were not available to the committee. This led us to the decision to release an Interim Report in December 2018 to provide initial timely guidance to Congress, who requested this study, on the nascent plan. Much of the committee's advice in the Interim Report is echoed and strengthened in this final report after examining more evidence and exploring more deeply the many complex threads.

This report is the final product of an extremely dedicated diligent and collegial committee and Academies staff. I am enormously grateful to the outstanding assistance and remarkable professionalism of the National Academies staff in preparing the report, especially Laura Llanos and Toni Greenleaf, financial associates; Darlene Gros, senior program assistant, for logistical planning for all of the committee's meetings and project administration; and Richard Rowberg, senior advisor, for his guidance

and his participation in the classified meetings and tour. Jenny Heimberg, study director, was my right and left arms in working through the subsequent complexities of this study. She dealt with the committee, staffers on the Hill, and agency representatives in a way that I could only admire. She got things done.

I am especially thankful for the opportunity to lead this distinguished committee. I thank the members of the committee for their dedication, willingness to teach and to learn, and for their time and energy. The collegiality of this group, although holding a diversity of opinions, was an enormous delight as the study evolved.

Robert C. Dynes, *Chair*
Committee on Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant

Acknowledgments

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following individuals for their review of this report:

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In addition, portions of this report were fact checked by the Department of Energy's National Nuclear Security Administration (DOE-NNSA) and Office of Environmental Management (DOE-EM) as well as the Environmental Protection Agency (EPA). In particular, we thank Lyndsey Adams (DOE-NNSA), Betsy Forinash (DOE-EM), William Kilmartin (DOE-NNSA), and Tom Peake (EPA). We are thankful for their contributions toward improving the accuracy of the report's content.

The committee also wishes to thank the study sponsor, DOE-NNSA, for supporting this project. Special thanks go to William Kilmartin and Lyndsey Adams, who served as the points of contact with DOE-NNSA, and Betsy Forinash, who served as the point of contact with DOE-EM, for their tireless work addressing the many sets of questions generated by the committee throughout the duration of the study.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by Margaret S.Y. Chu, M.S. Chu + Associates, LLC, Review Coordinator, and Chris G. Whipple, ENVIRON (Retired), Review Monitor. They were responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

Contents

Summary

The United States has declared more than 60 metric tons (1 MT is 1,000 kilograms) of weapons-grade plutonium as surplus (i.e., plutonium that has no programmatic use and does not fall into one of the categories of national security reserves). No single document describes disposition plans for the entirety of the U.S. surplus plutonium inventory.[1] Rather, disposition decisions depend on the form of the plutonium which can lead to different disposition pathways. Since the mid-1990s, disposition plans for the U.S. surplus plutonium inventory have evolved. Figure S-1 presents surplus plutonium amounts and varieties of surplus plutonium material and describes current disposition plans. Thirty-four metric tons are associated with the Plutonium Management and Disposition Agreement (PMDA, discussed later in this Summary) and have recently been proposed by the Department of Energy's National Nuclear Security Administration (DOE-NNSA) for dilution and disposal in the Waste Isolation Pilot Plant (WIPP, also discussed later in this Summary). However, additional amounts are associated with DOE's dilution and disposal plans, some of which are managed by DOE's Office of Environmental Management (DOE-EM).[2] Therefore, this report reviews and assesses the viability of DOE's plans to process up to 48.2 MT of surplus plutonium—the amount that is under consideration or slated for disposal—as diluted surplus plutonium transuranic (DSP-TRU) waste in WIPP.[3]

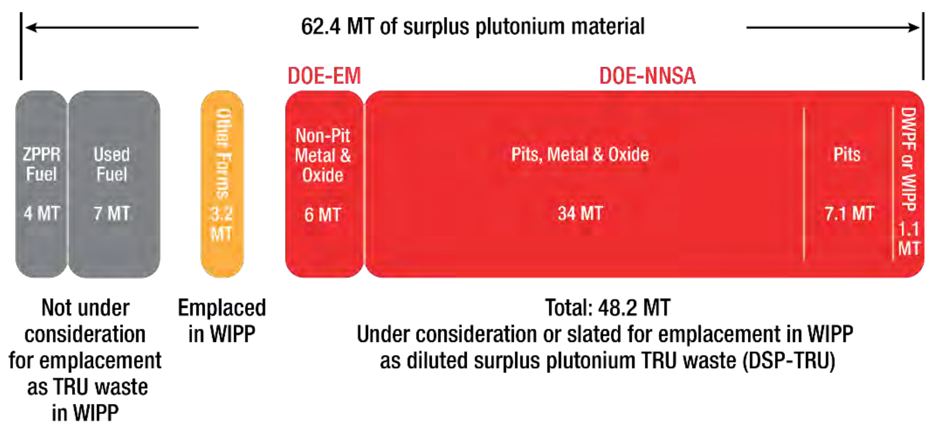

FIGURE S-1 The U.S. surplus plutonium inventory consists of a variety of forms and amounts of plutonium. Plutonium within used fuel or reserved for use in research fuels (ZPPR [Zero Power Physics Reactor]) account for 11 MT (gray boxes). Other forms of plutonium including scraps and residues totaling 3.2 MT have been emplaced as transuranic (TRU) waste in WIPP (yellow box). DOE-EM has issued a record of decision for dispositioning 6 MT, consisting of 5.1 MT plus an additional 0.9 MT for future plutonium wastes, of non-pit metal and plutonium oxide as DSP-TRU waste in WIPP (red box, left side). The remainder, 42.2 MT consisting of plutonium pits, metals, and oxides, is under consideration by DOE-NNSA for dispositioning as DSP-TRU waste in WIPP (red box, right side). SOURCE: Modified from DOE, 2015a, fig. S-7.

[1]Disposition refers to the treatment of plutonium material to render it unusable for weapons, while disposal refers to the emplacement of waste in a geologic repository without the intention of retrieval.

[2]DOE-EM uses the term "downblend" while DOE-NNSA uses the term "dilute" to describe the process for mixing surplus plutonium with an adulterant to ensure that plutonium "is not recoverable without extensive reprocessing" (SRNS, 2016, p. 8). The committee uses "dilute" throughout this report.

[3]Transuranic waste is defined in Section 2 of the Waste Isolation Pilot Plant Land Withdrawal Act (LWA), Pub. L. No. 102-579, 106 Stat. 4777-4796 (1992) (as amended in 1996 by Pub. L. No. 104-201, https://www.congress.gov/104/crpt/hrpt540/CRPT-104hrpt540-pt1.pdf, accessed March 29, 2020).

In 2000, 34 MT of the surplus were to be dispositioned through incorporation of oxidized plutonium into nuclear fuel rods (mixed oxide, or MOX fuel) for irradiation in commercial nuclear reactors. Additional surplus plutonium would be immobilized with high level waste (DOE, 2000).[4] In both cases, high levels of radiation made recovery of the source plutonium difficult. The U.S. government later decided to pursue only the MOX approach (DOE, 2002).

In parallel to these actions, the United States and Russia each committed via the PMDA to disposition at least 34 MT of surplus plutonium. In 2000, Russia agreed to incorporate all 34 MT into MOX fuel to be irradiated in nuclear power reactors while the United States agreed to the dual-pathway approach. In 2010, the PMDA was renegotiated so that the United States and Russia would both disposition at least 34 MT of surplus plutonium as irradiated MOX fuel (DOS, 2000, 2010).

In the early 2000s, the U.S. government moved forward with plans to build a MOX fuel fabrication facility (MOX plant) in South Carolina at the Savannah River Site (SRS). The MOX project involved activities at DOE sites across the United States (i.e., the Pantex Plant in Texas and the Los Alamos National Laboratory [LANL] in New Mexico), but South Carolina would see the largest increases in the amount of plutonium that it would accept to execute the MOX plan. A 2002 federal law outlined schedules for the MOX plant operation with penalties to be paid to the State of South Carolina if not met.[5]

By the mid-2010s, the construction of the MOX plant was behind schedule and the costs for its completion had greatly increased. DOE-NNSA began exploring, through a set of studies, other options for dispositioning the 34 MT of surplus plutonium (DOE, 2014; Mason, 2015; Parsons, 2017). Those studies found that a dilute and dispose approach—diluting the oxidized plutonium material with an inert adulterant to a level that would meet PMDA requirements while meeting the waste acceptance criteria for disposal as TRU waste at WIPP—was the most viable and least expensive option.

WIPP is the nation's only operational deep geologic repository for nuclear waste. It is licensed to receive only defense TRU waste and has a capacity established by law of 175,564 cubic meters (m^3).[6] WIPP is a salt bed repository (see Figure S-2). Panels each the size of several football fields are mined out of the salt bed more than 2,000 feet underground, and TRU waste is emplaced in rooms within the panels. After WIPP is full, the repository will close access to the underground panels and allow the salt to encase the TRU waste (defined as post-closure operations). Safety and performance analyses of WIPP for operations and for post-closure have shown that, if undisturbed, the probability of releases from the underground to the environment are extremely low.

WIPP is located in the southeast corner of New Mexico, in the Permian Basin. This area was recently identified as having the largest gas and oil reserves in the United States (Gaswirth et al., 2018). Surrounding WIPP are an increasingly dense number of drill sites. WIPP's post-closure safety analysis takes into account human intrusion scenarios (e.g., drilling) and indicates that the estimated releases are within regulatory maximums. Based on the independent review of these analyses, the Environmental Protection Agency (EPA, which regulates WIPP) has continued to certify WIPP since its operations began in 1999.

The vast majority of defense TRU wastes emplaced in WIPP are contaminated products that result from working with plutonium and other actinide elements including clothing, tools, rags, residues, debris, and soil. As of the end of September 2019, a total of 180,225 waste containers of various sizes and types have been emplaced in WIPP; the majority, about 70 percent, are 55-gallon drums (see Table 5-1). Three

[4]For definition, see https://www.nrc.gov/waste/high-level-waste.html (accessed March 8, 2020).

[5]The MOX plant was expected to produce 1 MT of MOX fuel by December 31, 2009, and 34 MT by January 1, 2019. If not achieved, DOE would pay the State of South Carolina penalties not to exceed $100,000,000 per year until either the MOX objective is reached or DOE removes at least 1 MT of defense plutonium or plutonium materials from the state per year (Bob Stump National Defense Authorization Act for Fiscal Year 2003, Pub. L. No. 107-314, § 3182, 116 Stat. 2458, https://www.govinfo.gov/content/pkg/PLAW-107publ314/html/PLAW-107publ314.htm, accessed March 29, 2020).

[6]Waste Isolation Pilot Plant Land Withdrawal Act (LWA), Pub. L. No. 102-579, 106 Stat. 4777-4796 (1992) (as amended in 1996 by Pub. L. No. 104-201, https://www.congress.gov/104/crpt/hrpt540/CRPT-104hrpt540-pt1.pdf, accessed March 29, 2020).

types of 55-gallon drums are relevant to this report (see Figure S-3): the direct-loaded 55-gallon drum, the pipe overpack container (POC), and the criticality control container/criticality control overpack (CCC/CCO). Per DOE's plans, DSP-TRU waste will be placed into a CCC, which is positioned inside of a CCO.

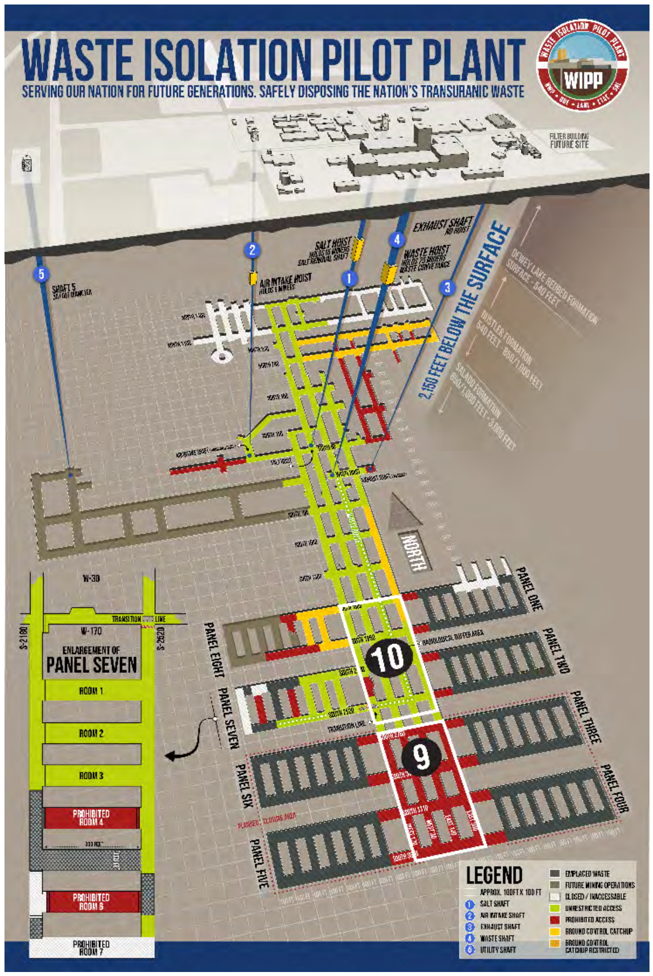

FIGURE S-2 Schematic of the Waste Isolation Pilot Plant (WIPP) showing the aboveground or surface facilities (at the top of the image) and the 10 underground panels. The underground panels are 2,150 feet below the surface. See Chapter 2 and Figure 2-3 for more details. SOURCE: Modified from Shrader, 2018. Image provided by the Department of Energy.

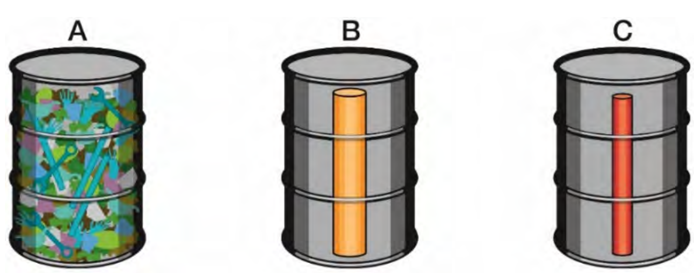

FIGURE S-3 Graphical illustration of 55-gallon drums that are the most common type of authorized container for TRU waste emplaced in WIPP. (A) Direct-loaded containers; (B) pipe overpack containers with a 12-inch-diameter pipe (shown in yellow); (C) criticality control overpack with a criticality control container with 6-inch-diameter stainless steel pipe (shown in red). The CCC/CCO will be used for the DSP-TRU waste.

In fiscal year (FY) 2016, MOX plant construction continued to run over budget and timelines, and no commercial nuclear power plant had yet formally agreed to accept the fuel. That same year, Congress appropriated $5 million for DOE-NNSA to begin to develop a conceptual plan to dilute and dispose surplus weapons-grade plutonium. This plan, if finalized, would provide an alternative to the MOX option. In FY 2017, Congress appropriated additional funds to DOE-NNSA's planning effort ($15 million) while also directing it to contract with the National Academies of Sciences, Engineering, and Medicine to independently review and assess the viability of its early dilute and dispose plans. Central to the plan's concept is disposal of diluted surplus plutonium material as TRU waste in WIPP (see Figure S-4). The National Academies were asked to also explore the impact of DOE-NNSA's plans on WIPP operations and the disposal of other TRU waste streams. Another important component of the tasking was to review how well the dilute and dispose plan met the PMDA (DOS, 2010).

An independent review of DOE-NNSA's plan to dilute and dispose of 34 MT of surplus plutonium estimates that the effort will take 31 years and $18.2 billion to complete (in then-year dollars[7]), beginning with conceptual design in 2018 and ending with emplacement of the full amount of DSP-TRU waste in WIPP in 2049 (DOE, 2018b). First emplacements of DSP-TRU waste in WIPP derived from non-pit and pit plutonium material are FY 2023 and FY 2028, respectively.[8]

COMMITTEE'S ASSESSMENT

The committee issued an Interim Report in late 2018 summarizing its initial findings, conclusions, and recommendations and highlighting remaining issues to be addressed in this final report. A determination of the viability of DOE-NNSA's plans was not made due to lack of sufficient information. The Interim Report highlighted concerns over the lack of concurrence with the PMDA requirements, statutory and physical capacities at WIPP, and the need for sustained support for the length of the planned effort (over 30 years). Having received additional information, the committee revisits those concerns and addresses its remaining tasks—review of transportation and of pre- and post-closure safety of WIPP.

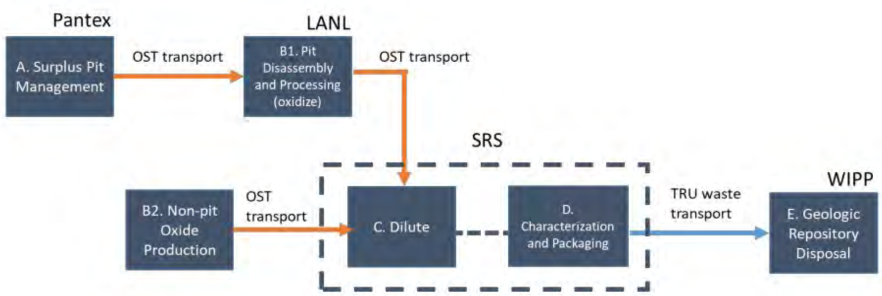

FIGURE S-4 Simplified process diagram for DOE-NNSA's dilute and dispose plan. Four locations are shown: (A) Pantex where surplus plutonium pits, a total of 26.2 metric tons (MT), are stored; (B1) LANL (Los Alamos National Laboratory), where the pits are disassembled and the plutonium is oxidized; (C) and (D) SRS (Savannah River Site), where the oxidized plutonium is diluted with an inert adulterant, characterized, and packaged for transport; and (E) WIPP, where the DSP-TRU waste is emplaced. A total of 7.8 MT surplus non-pit plutonium is oxidized either at LANL or SRS (B2). Methods of transportation between the sites are indicated (Office of Secure Transportation [OST] shown with orange arrows, and TRU waste transport shown with a light blue arrow). SOURCE: Modified from SRNS, 2018f, fig. 2. Image provided by the Department of Energy.

[7]The estimate excludes $20 million in sunk costs. All cost estimates were developed in FY 2017 dollars and converted to then-year dollars using escalation rates found in DOE, 2018b.

[8]The remaining 8.2 MT, from a total of 42.2 MT, is not included in the current schedule; see Figure 3-1 in Chapter 3.

The committee determined that DOE-NNSA's early-stage plans to dilute and dispose at least 34 MT of surplus plutonium provide a technically viable disposition alternative to the MOX plan, provided that implementation challenges and system vulnerabilities that currently exist within the plan are resolved. The rationale for this conclusion is that the individual process steps of the DOE-NNSA dilute and dispose plan have nearly all been demonstrated by a variety of different DOE programs. For example, the plan utilizes the existing MOX plans to process surplus plutonium into plutonium oxide. Equipment and resources will be shared with DOE-EM's current efforts to dilute and dispose of 6 MT of surplus plutonium (see Figure S-1). The plan uses existing and well-established transportation programs such as the Office of Secure Transportation and TRU waste transport for moving the material or waste between sites. Finally, DOE references previous emplacements of similar wastes (diluted and undiluted plutonium) in WIPP.[9]

However, all of the steps described in the dilute and dispose plan have not been sequentially demonstrated from start to end, posing a risk because even well-established capabilities run into unforeseen problems when integrated. Additionally, the process steps have been demonstrated at prototype levels, not at the scale that DOE-NNSA's plans propose. For example, DOE-EM's efforts to process up to 6 MT are less mature than previously understood. Only a very small amount of material (0.052 MT, as of the end of September 2019) has been processed by DOE-EM, and that material has not yet been transported from SRS to WIPP. Furthermore, DOE-EM's plans indicate a completion date of 2046—meaning that DOE-EM's and DOE-NNSA's dilute and dispose activities will concurrently operate for nearly the full duration of DOE-NNSA's dilute and dispose program.

Also, DOE-NNSA's plan to disposition the surplus plutonium via dilute and dispose is neither recognized nor approved by the existing PMDA. This assessment has not changed since the committee issued its Interim Report. Furthermore, international monitoring and verification of the dispositioned surplus plutonium is a requirement of the PMDA but its adherence by DOE's plans is unclear. Although nearly all of the processing steps for the dilute and dispose plans have been previously demonstrated by other DOE programs, as noted above, the details of monitoring and verification of the diluted and emplaced waste have not been defined for the DOE-EM or the DOE-NNSA dilute and dispose plans.

RECOMMENDATION 5-1: Plans for the International Atomic Energy Agency (IAEA) or other monitoring and inspection protocols have not yet been established for the disposition of the material identified in the Plutonium Management and Disposition Agreement (i.e., 34 metric tons of surplus plutonium) as diluted surplus plutonium transuranic (DSP-TRU) waste in the Waste Isolation Pilot Plant. Prior to emplacement of the DSP-TRU waste by the Department of Energy's (DOE's) Office of Environmental Management or DOE's National Nuclear Security Administration (DOE-NNSA), DOE-NNSA and higher-level DOE officials should clarify their intent with respect to whether there will be IAEA monitoring and inspections for this material (and preferably before DSP-TRU waste is disposed of).

WIPP's disposal capacity limits are defined by several different laws, agreements, and permits. As noted above, the LWA limits TRU waste disposal capacity to no greater than 175,564 m^3 of defense-related TRU waste, a limit that is overseen by EPA. WIPP's Hazardous Waste Permit, overseen by the State of New Mexico through its Environment Department (NMED) under the Resource Conservation and Recovery Act (RCRA), may also limit waste volumes through the size limitation of the underground waste panels. Until recently, the capacity limits for LWA and RCRA (Hazardous Waste Permit) were measured by the gross internal volume of the outermost disposal containers and were equivalent.

[9]The committee was initially told that 4.8 MT of plutonium had been downblended/diluted and disposed of at WIPP but was later told that the majority was not a waste form analogous to the DSP-TRU waste currently proposed by DOE. Using the Waste Data System/WIPP Waste Information System, the committee identified 61 kg of diluted plutonium within a total of 666 POCs that have been emplaced in WIPP.

Shortly after the release of the Interim Report, NMED approved a WIPP permit modification that distinguishes between reporting against the LWA capacity limits and the RCRA TRU mixed waste (TMW) capacity limits and allows for a recalculation of the volumes of emplaced and future wastes.

The committee was asked to review additional TRU waste streams and to assess DSP-TRU waste's potential impact on them as well as the impact on LWA capacity limits. To reassess these impacts against the new volume of record (VoR) calculations, the committee updated the volumes of specific waste streams noted in its Interim Report: Greater-Than-Class-C-like wastes, tank wastes, and TRU waste generated by pit production. Recent DOE-reported volumes for emplaced and future TRU wastes were used (DOE-CBFO, 2018a, 2019a; see Table 3-2). The results shown in Figure S-5 highlight two main issues:

- Under the VoR recalculation, the LWA volume of the DSP-TRU waste generated by processing 48.2 MT of surplus plutonium is reduced from 33,740 m^3 to 2,056 m^3, which is approximately 1 percent of the LWA capacity, yet the physical volume is substantial (approximately the physical space of two panels); and
- When additional TRU wastes volumes are taken into account, the LWA capacity will still be challenged—primarily due to initial estimates with potentially large uncertainties of TRU waste from pit production.

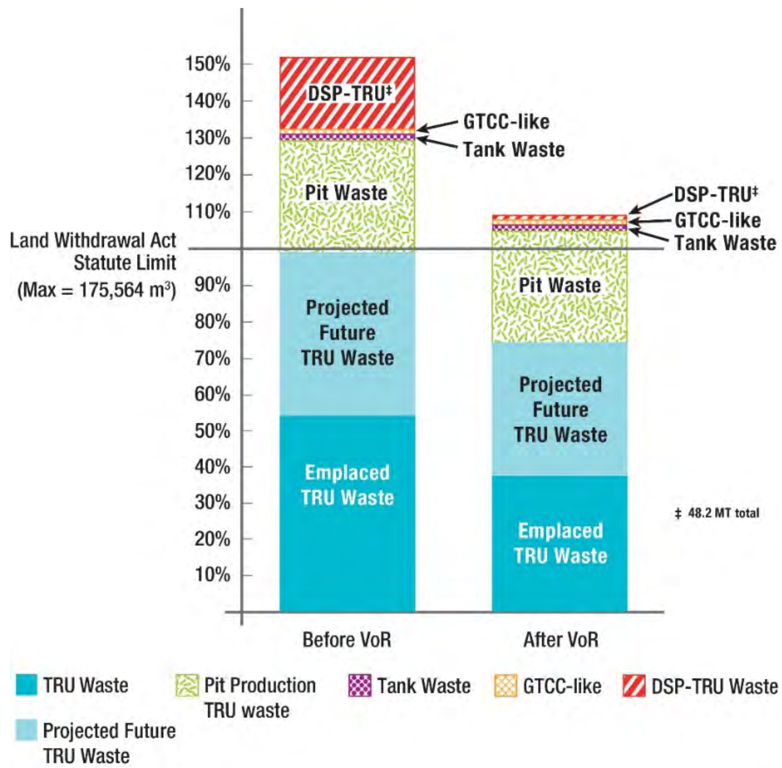

FIGURE S-5 DOE-reported emplaced and future transuranic wastes estimates (DOE-CBFO, 2018a, 2019a) and additional wastes, identified by the committee. Additional wastes are DSP-TRU, Greater-Than-Class-C-like (GTCC-like) TRU wastes, tank wastes, and TRU waste generated from pit production. The graphs illustrate the impact of the volume of record (VoR) recalculation, in particular the large reduction in DSP-TRU waste volumes. Both graphs also show that the Land Withdrawal Act statutory limit is likely to be exceeded. DSP-TRU volumes have been subtracted from TRU waste estimates. See Table 3-2.

RECOMMENDATION 3-1 (modified from Interim Report RECOMMENDATION 1): Capacity at the Waste Isolation Pilot Plant (WIPP) should be treated as a valuable and limited resource by the Department of Energy (DOE). DOE is able to prioritize national security mission waste streams for WIPP (i.e., pit production transuranic [TRU] waste). Because emplacement in WIPP is critical to both DOE's Office of Environmental Management's (DOE-EM's) and DOE's National Nuclear Security Administration's (DOE-NNSA's) dilute and dispose plans, the DOE-NNSA Administrator, in consultation with the DOE-EM Assistant Secretary, should prioritize and reserve Land Withdrawal Act capacity in WIPP for the full amount of diluted surplus plutonium TRU waste (2,057 cubic meters). Otherwise, the DOE-NNSA and the DOE-EM programs are at risk of not being able to disposition the full amount of 48.2 metric tons of surplus plutonium via dilute and dispose.

Acknowledging these updates from the Interim Report, the final report focuses on program execution challenges and discusses two types of findings, conclusions, and recommendations: One set focuses on programmatic *implementation challenges* and another on *system vulnerabilities.*

IMPLEMENTATION CHALLENGES

DOE-NNSA's dilute and dispose option is likely to face implementation challenges (see Chapter 4) during its inception and lifetime of more than three decades including space and resource competition with pit production activities at LANL and SRS, and TRU waste emplacement in WIPP. Implementation challenges that are not addressed could lead to extended timelines and increased costs. None of the implementation challenges identified threaten the technical viability of the plan and many of these challenges could be addressed through improved project plans (as they mature and with independent review) and sufficient, steady funding from Congress. However, such straightforward approaches may not be adequate for some challenges, for example, the ability to hire and qualify sufficient staff or the resilience of the nuclear facilities.

A major implementation challenge is the scaling up of current individual operations to a future processing system that can safely and securely generate, transport, and dispose of the DSP-TRU waste within the desired schedule. Other challenges are maintenance of the infrastructure and expanded trained workforce that will be required for at least 30 years.

Security of the surplus plutonium and DSP-TRU waste was a major concern of the committee and can be summarized by the fact that DSP-TRU waste is not characteristically like the vast majority of previous TRU waste streams, and the standard operating procedures developed for traditional TRU waste may not be sufficient for DSP-TRU. The committee determined that the diluted plutonium does not meet the spent fuel standard and the dilute and dispose option has fewer barriers to recovery than the MOX option, including the loss of a radiation barrier. Furthermore, once emplaced and without monitoring in place,[10] DSP-TRU waste could be retrieved and reprocessed by the United States (in fact, retrieval of emplaced waste post-closure is a WIPP recertification requirement). With sufficient mining expertise (which is becoming more common) and resources, non-state or third-state actors could retrieve emplaced DSP-TRU waste during the post-closure period with its absence left undetected (Tracy, 2019). Other concerns include the increased number of transports of pits, plutonium oxide, and DSP-TRU wastes as well as security concerns over DSP-TRU waste and WIPP operating procedures (including aboveground storage and inventory control of classified waste streams of significant quantity[11]). DOE-NNSA will need

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[10]WIPP does not currently have plans for underground sensors to monitor the emplaced waste after closure (i.e., after the underground is sealed and the facility is decommissioned).

[11]WIPP has emplaced classified TRU waste in the past but of limited quantities (see April 17, 2019, committee discussion, DOE [NNSA and EM] Follow-up to Address Unanswered Questions from Day One, https://vimeo.com/showcase/6028445/video/338029961, accessed May 20, 2020).

to ensure that a security program is in effect and is appropriate to DOE's assessment of the attractiveness of the diluted plutonium material—and is periodically reassessed and updated.

Details of security assessments or updates were not available to the committee for two reasons: the full committee did not hold clearances for access to classified information and, more importantly, the security and risk assessments were not yet complete. As a result, the committee developed the following recommendation:

RECOMMENDATION 5-4 (updated Interim Report RECOMMENDATION 4): In addition to and separate from the independent review organization representing the State of New Mexico described in Recommendation 5-3, periodic reviews for Congress and the Department of Energy (DOE) by a team of independent technical experts should be required until classified aspects of DOE's National Nuclear Security Administration's and DOE's Office of Environmental Management's dilute and dispose plans, including the safety and security plans, are completed and implemented. Because DOE's plans and decisions are expected to mature and evolve, these independent reviews would provide a mechanism to review classified aspects of the programs and would improve public trust in those decisions.

SYSTEM VULNERABILITIES

Several system vulnerabilities exist within the current plan (see Chapter 5). If not addressed, they could have serious consequences for the program and its mission to dispose of at least 34 MT—and as much as 48.2 MT—of surplus plutonium in an efficient, safe, and secure manner. System vulnerabilities include

- WIPP as the single point of failure for the disposal of DSP-TRU waste;
- the changing nature of WIPP with the full amount of DSP-TRU emplacement and shifting public opinion; and
- plans that span multiple DOE sites, offices, functions, and priorities without clear crosscutting leadership support.

An inability of WIPP to accept and emplace TRU wastes is a single point of failure for the dilute and dispose programs as well as for other DOE TRU waste programs. Future accidents resulting in lengthy shutdowns, such as those that occurred in 2014, pose a risk to access for the dilute and dispose programs but so do agreements and priorities of other programs (Idaho National Laboratory shipments or pit production) or other state legal requirements. The risks associated with conflicting priorities of other programs were not captured in DOE-NNSA's Risk and Opportunity Analysis Report (SRNS, 2018c). Additionally, two significant changes in WIPP's operations will be needed to allow for the emplacement of the DSP-TRU waste streams: expansion of underground configuration and an extension of the lifetime of WIPP. These changes have not yet been reviewed or approved by NMED and EPA.

When WIPP was being constructed and undergoing licensing in the 1990s, a social contract was established between DOE and the citizens of New Mexico in which WIPP's mission and the types of wastes that were to be emplaced were outlined. A change in that understanding needs to be recognized even if the proposed DSP-TRU waste inventory is expected to meet the WIPP waste acceptance criteria (WAC) and EPA regulations. Senator Pete Domenici, who was a central figure in successfully bringing WIPP to New Mexico, wrote in a letter to Secretary of Energy Abraham:

> I want to ensure that high level or weapons material wastes can never be simply diluted in order to comply with criteria for WIPP disposal…. In fact, dilution of weapons materials, simply in order to facilitate disposal, raises serious questions about our adherence to the same international controls on weapon-related materials that we expect other nations to follow. (Domenici, 2002)

By virtually any measure (see Table S-1), the proposal to dilute up to 48.2 MT of surplus plutonium and dispose of the DSP-TRU waste in WIPP represents substantial changes to the physical, radiological, and chemical composition of emplaced wastes and the "social contract" for WIPP and the State of New Mexico. No previous waste stream has affected the technical measures of WIPP performance at the same levels. While the initial analyses indicate that the WIPP repository will maintain regulatory compliance with the increased amount of plutonium in its inventory, the potential for such substantive changes raises technical, social, and political questions that translate to additional system vulnerabilities if not addressed. These differences must be recognized in their entirety to have a transparent and complete assessment of the DSP-TRU waste's impact on WIPP and its associated operations (including transportation).

To improve transparency and understanding of DOE's future plans for dispositioning of surplus plutonium as DSP-TRU in WIPP, the committee recommends the following:

RECOMMENDATION 5-7: The Environmental Protection Agency, the Department of Energy, and the State of New Mexico should engage in developing a mutually agreed-upon strategy for vetting the effects of the dilute and dispose inventory, in its entirety (and as added to the rest of the projected and emplaced inventory), on the Waste Isolation Pilot Plant. This vetting could be through a special demonstration of compliance and certification, or other means all agree to, but should occur before committing the substantial resources that will be needed to implement an integrated (48.2 metric tons of surplus plutonium) dilute and dispose program.

To further improve transparency and public trust in DOE decisions, the committee recommends reinstatement of the Environmental Evaluation Group (EEG).

RECOMMENDATION 5-3 (updated Interim Report RECOMMENDATION 3): If the Department of Energy's (DOE's) National Nuclear Security Administration's dilute and dispose plan moves forward, DOE should reinstate the Environmental Evaluation Group (EEG), representing the concerns of the State of New Mexico, throughout the lifetime of processing up to 48.2 metric tons of surplus plutonium material. The independence of the EEG should be supported through mechanisms similar to those established in its original founding. Members of the technical review organization should be technically qualified to address the health and safety issues and a subset should have access authorizations that will allow thorough review of classified aspects of the plans and their implementation.

To address concerns related to plans spanning multiple DOE sites, offices, functions, and priorities without crosscutting leadership support, the committee recommends the following:

RECOMMENDATION 5-5: The Department of Energy should implement a new comprehensive programmatic environmental impact statement (PEIS) to consider fully the environmental impacts of the total diluted surplus plutonium transuranic waste inventory (up to an additional 48.2 metric tons) targeted for dilution at the Savannah River Site and disposal at the Waste Isolation Pilot Plant (WIPP). Given the scale and character of the diluted surplus plutonium inventory, the effect it has on redefining the character of WIPP, the involvement of several facilities at several sites to prepare the plutonium for dilution, a schedule of decades requiring sustained support, and the environmental and programmatic significance of the changes therein, a PEIS for the whole of surplus plutonium that considers all affected sites as a system is appropriate to address the intent and direction of the National Environmental Policy Act and would better support the need for public acceptance and stakeholder engagement by affording all the opportunity to contemplate the full picture.

TABLE S-1 Characteristics and Relevant Amounts and Volumes for Contact-Handled (CH) TRU and Diluted Surplus Plutonium (DSP) TRU Wastes Compared to Wastes in Other 55-Gallon Drum Containers

	Other TRU Waste	**TRU Waste in Pipe Overpack Containers (POCs)**	**DSP-TRU Waste in Criticality Control Containers/Criticality Control Overpacks (CCC/CCOs)**
Composition	Variable: contaminated clothing, tools, rags, residues, debris, soil, and other items	Plutonium residues, heterogeneous debris, salts, and sealed sources	Predictable composition of DSP-TRU[a]
Physical volume (outer container)	0.21 m^3	0.21 m^3	0.21 m^3
LWA volume (inner container)	0.21 m^3	0.046 m^3	0.013 m^3
Current total number of waste streams	202[b]	48[b]	3[c]
Total number of emplaced containers	97,928 (emplaced)[d]	27,025 (emplaced)[d]	160,667 (anticipated)[e]
Total amount of plutonium-239	1.6 MT (emplaced)	3.2 MT (emplaced)	48.2 MT (anticipated)
Percentage of plutonium-239 in total inventory at closure (10,000 years)[f]	15	[included in "Other TRU Waste"]	85
Average amount of plutonium-239 per container/ fissile gram equivalent (FGE) limit[g]	14.4 g/ ≤ 200 g	117 g/ ≤ 200 g	300 g (nominal)/ ≤ 380 g
Material attractiveness level[h]	Level E	Varied	Level D[i]
Classification	Unclassified[j]	Unclassified[j]	Classified aspects (i.e., adulterant)[i]

[a]Technical Baseline Description, SRNS, 2018b.
[b]Number of waste streams derived from WDS/WWIS as of September 30, 2019, from https://wipp.energy.gov/WDSPA, accessed May 20, 2020.
[c]SR-KAC-PuOx, SR-KAC-PuOx-1, SR-KAC-SPD (DOE-CBFO, 2019b; Dunagan et al., 2019).
[d]Emplaced 55-gallon, direct loaded containers or POCs through September 30, 2019; see Table 5-1.
[e]Assumes nominal 300 g per container.
[f]Dunagan et al., 2019.
[g]Per WIPP WAC, table 1, DOE-CBFO, 2018c.
[h]See Box 3-2 for a description of attractiveness levels.
[i]See System Requirements, DOE-NNSA, 2018.
[j]A small number of emplaced containers are known to be classified (Sahd, 2019); no further details are available.

To address concerns of shifting public opinion of DOE-NNSA's plans and its handling of plutonium stockpiles and surplus inventory, the committee recommends the following:

RECOMMENDATION 5-6: The Department of Energy's (DOE's) National Nuclear Security Administration, DOE's Office of Environmental Management, and DOE higher-level officials should take additional actions beyond those defined by the National Environmental Policy Act toward transparency and stakeholder engagement on the whole of the potential scope of surplus plutonium under consideration (48.2 metric tons) for disposal at the Waste Isolation Pilot Plant. Such actions include completing and publicizing the outcome of relevant safety analyses and cost estimates.

1

Introduction

This report is the product of a congressional request[1] to the National Academies of Sciences, Engineering, and Medicine for an evaluation of the general viability of the Department of Energy's National Nuclear Security Administration's (DOE-NNSA's) conceptual plans to disposition surplus plutonium material at the Waste Isolation Pilot Plant (WIPP). Dispositioning 34 metric tons (MT) of surplus plutonium is part of the Plutonium Management and Disposition Agreement (PMDA), an agreement between the United States and the Russian Federation. DOE-NNSA's conceptual plans call for diluting the surplus plutonium material with a classified adulterant, declaring the diluted material as transuranic (TRU) waste, and emplacing the waste in WIPP. Specifically, the National Academies were asked to review DOE-NNSA's plans to ship, receive, and emplace surplus plutonium in WIPP and to assess DOE-NNSA's understanding of the impacts of these plans on WIPP and WIPP-bound waste streams. Ultimately, the National Academies were asked to evaluate the general viability of these conceptual plans. See Box 1-1 for the full Statement of Task.

BOX 1-1 Statement of Task for This Study

The National Academies will evaluate the general viability of the Department of Energy's (DOE's) conceptual plans for disposing of surplus plutonium in the Waste Isolation Pilot Plant (WIPP) to support U.S. commitments under the Plutonium Management and Disposition Agreement, identify gaps, and recommend actions that could be taken by DOE and others to address those gaps. This evaluation will specifically address the following issues:

1. DOE's plans to ship, receive, and emplace surplus plutonium in WIPP.
2. DOE's understanding of the impacts of these plans on the following:
   a. Transportation safety, security, and regulatory compliance.
   b. Current and future WIPP operations, including the need to construct additional waste disposal panels[a] and/or operate WIPP beyond its currently planned closure date.
   c. Disposal of other potential waste streams in WIPP, for example, other plutonium wastes, Greater-Than-Class-C–like wastes, and tank wastes.
   d. WIPP pre- and post-closure safety and performance.
   e. Compliance with WIPP waste acceptance criteria; Environmental Protection Agency disposal regulations; and the Land Withdrawal Act, National Environmental Policy Act, and Resource Conservation and Recovery Act requirements.

The National Academies may examine policy options but should not make policy recommendations that require nontechnical value judgments.

[a]WIPP's waste disposal area consists of multiple waste disposal panels. Currently, WIPP contains a total of eight panels; each panel contains seven disposal rooms. See Chapter 2, Figure 2-3.

[1]The mandate appears in the Energy and Water Development Appropriations Bill (U.S. Congress, House, 2016, p. 114).

In 2018, DOE Secretary Perry announced the cancellation of the mixed oxide (MOX) fuel fabrication facility (Perry, 2018). As an alternative to disposition of surplus plutonium material through irradiated MOX fuel (as was agreed to under the PMDA; DOS, 2010), DOE-NNSA is preparing to use the dilute and dispose approach to disposition 34 MT, and conceivably up to 48.2 MT. The development of the plan was motivated by the need to identify a less costly alternative to the disposition of surplus plutonium material through its incorporation into MOX fuel and later irradiation in commercial nuclear reactors (i.e., the MOX approach). The Defense Nuclear Nonproliferation office within DOE-NNSA developed and is managing the dilute and dispose conceptual plan.

The committee released an Interim Report in November 2018 in order to meet congressionally mandated timelines; it is reproduced in full as Appendix H of this report (NASEM, 2018). The Interim Report provided a high level review of the proposed dilute and dispose process, discussion of the then-current understanding of WIPP capacity, and requirements of the PMDA. At the time of its release, several key planning documents and information such as National Environmental Policy Act strategies and decisions, WIPP criticality and performance assessments, plans for international monitoring and verification, and programmatic information contained within DOE-NNSA's Life-Cycle Cost Estimate (LCCE) were not publicly available for the committee's review. The committee has since received this information and additional briefings (see Appendix B).

This final report fully addresses the Statement of Task (see Box 1-1). Consequently, some text and content from the Interim Report are included. However, several topics that were not covered in the Interim Report will be described in greater detail than other topics in this final report. Specifically, these topics are the viability of DOE-NNSA's conceptual plans on transportation safety, security, and regulatory compliance (Task 2.a), and pre- and post-closure safety and performance of WIPP (Task 2.d). The advice provided in the Interim Report is revisited and updated in this final report, with any changes noted. Advice in the final report supersedes any conflicting advice in the Interim Report.

The National Academies appointed a committee of 14 technical experts to carry out this evaluation; their biographies are provided in Appendix A. A subset of the committee and Academies staff with appropriate clearances were briefed on the classified aspects of the dilute and dispose plan; the subset of the committee did not produce a classified report. The committee held 18 meetings to gather information for this evaluation and prepare the Interim Report and this final report; agendas for the committee's information-gathering meetings are provided in Appendix B.

1.1 INTERPRETATION OF THE STATEMENT OF TASK

The dilute and dispose program is a new program proposed by DOE-NNSA. Funding to allow DOE-NNSA to develop a preconceptual plan for dilute and dispose was allocated in 2016 (U.S. Congress, House, 2016, p. 115). DOE-NNSA has followed several guidance documents including the Government Accountability Office's (GAO's) Cost Estimation and Assessment Guide (GAO, 2009) and the DOE Directive for Program and Project Management for the Acquisition of Capital Assets (DOE Order 413.3B; DOE, 2010). The LCCE for the dilute and dispose plan was developed following GAO's guide; planning documents from the LCCE were provided to the committee in late 2018.[2] An independent review of the LCCE reports a cost estimate of $18.2 billion (in then-year dollars; DOE, 2018b[3]) for the disposition of 34 MT of surplus plutonium at WIPP (SRNS, 2018a). The amount is less than half the cost of the LCCE for the MOX approach, allowing DOE to cancel the MOX facility construction and move forward with dilute and dispose (Perry, 2018).

[2]The full set of LCCE documents were not provided to the committee; the committee received only LCCE documents that were relevant to the committee's tasking.

[3]The estimate excludes $20 million in sunk costs. All cost estimates were developed in fiscal year 2017 dollars and converted to then-year dollars using escalation rates found in DOE, 2018b.

To date, DOE-NNSA's dilute and dispose activities at the Savannah River Site (SRS) (i.e., dilution; see Chapter 2) have completed the Critical Decision 0 (CD-0), CD-1, and CD-3A process steps within the DOE 413.3B framework. The CD-0 milestone indicates that the mission need has been approved by DOE, demonstrating that "[t]here is a need that cannot be met through other than material means" (DOE, 2010, p. A-1). DOE's approval of CD-1 in late 2019 indicated that "the selected alternative and approach is the optimum solution" (DOE, 2010, p. A-1); approval of CD-3A, phase 1, which allows DOE to begin required construction activities at SRS's K Area prior to CD-2 approval, was granted in mid-February 2020.[4]

The level of maturity of DOE-NNSA's plans is an important factor in the committee's ability to assess viability. It has been a challenge to address the tasking at a detailed level because the plans are not yet fully developed. As the program evolves, the plans for dilute and dispose are expected to mature as additional details become better defined and incorporated into the planning.[5] Therefore, in addition to evaluating the plans as they currently exist, the committee has identified areas or concepts that are either not included or insufficiently developed in the DOE-NNSA plans. Advice on how to incorporate these ideas into future development is provided.

After the release of its Interim Report, several technical documents and reports, such as the LCCE summary report (SRNS, 2018b), the WIPP post-closure criticality report (Saylor and Scaglione, 2018), and a draft performance assessment (Zeitler et al., 2018), were made available to the committee.[6] The committee determined that comprehensive independent technical review of the same reports was outside of this committee's Statement of Task (and the time and budget allowed for the project). Nevertheless, reasonable doubt or concern over stated assumptions or assessments within the reports may be noted by the committee. Finally, the committee recognizes that the authority and responsibility for the determination of pre- and post-closure safety rests with the Environmental Protection Agency (EPA), the State of New Mexico, DOE, or others, and that this report is advisory only.

The committee approached its tasking recognizing that the MOX approach is not an option for surplus plutonium material disposition and that continued storage as material is also not under consideration (but might be under an environmental impact assessment as a no-action alternative). Instead, it focused on currently planned approaches for dilution followed by disposal in WIPP, while noting that at some point in the future the United States may develop other geologic repositories for nuclear waste, which might be used for disposal of material of this type.

1.2 REPORT ROADMAP

This report is organized into five chapters. Each chapter was written to be read by itself so that readers who are interested in particular topics can focus their attention on an individual chapter. Chapters 2 and 3 provide background information and details of DOE's dilute and dispose plans. Readers familiar with those topics might choose to read Chapters 4 and 5, in which the committee provides the majority of its assessments via findings, conclusions, and recommendations. Content in Chapters 4 and 5 refers back to details and diagrams found earlier in the report.

- Chapter 1 (this chapter) provides information about, and the committee's interpretation of, the tasking for this study.

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[4]CD-2/3 will follow CD-3A approval.

[5]As noted in the Surplus Plutonium Disposition Technical Baseline Description (SRNS, 2018d, p. 8): "This Guide recognizes that the 'technical baseline tends to evolve as requirements become better defined.'"

[6]Zeitler et al. (2018, p. 13) make clear in their report that it is not a substitute for evaluating compliance: "The analysis is not in support of a planned change request (PCR) or planned change notice (PCN) to be submitted by the DOE to the EPA, and was not performed as a compliance calculation. Instead, the planned use of the analysis is as input into a National Environmental Policy Act (NEPA) analysis."

- Chapter 2 provides background on topics that will be referenced throughout the report, including a summary of the U.S. surplus plutonium inventory; history and background on regulations and management of WIPP and TRU wastes; discussion of the PMDA between the United States and the Russian Federation; and a description of risk assessment.
- Chapter 3 describes DOE-NNSA's dilute and dispose plan by location (Pantex, Los Alamos National Laboratory, SRS, and WIPP) and activities including transportation between the sites. Plans for scaling up operations and risks that have been identified are also discussed.
- Chapter 4 describes and assesses the viability of DOE-NNSA's plans. Implementation challenges are identified and advice is provided to address the challenges, referencing the background in Chapter 2 and the plan description in Chapter 3.
- Chapter 5 identifies system vulnerabilities within the current plan and provides suggestions and advice on how to address these risks, which could threaten the successful, full completion of the program as planned. In its analysis, the committee refers to background in Chapter 2 and the plan description in Chapter 3.

The report has several appendixes that contain additional background and details including Appendix A: Committee and Staff Biographies; Appendix B: Meetings; Appendix C: How Salt Repositories Work; Appendix D: Legal and Regulatory Requirements for Transportation; Appendix E: States' Active Partnership Role in Safe Transportation; Appendix F: High-Risk Items Within the Risk and Opportunity Analysis Report; and Appendix G: Acronyms and Abbreviations. The Interim Report is recreated in its entirety in Appendix H.

The committee distinguishes between findings, conclusions, and recommendations using the following criteria:

- Findings: Summary statements about the evidence with which no reasonable person could argue without rejecting the evidence—no judgment is involved.
- Conclusions: Judgments based on one or more findings or analysis of the evidence—never contain the word "should."
- Recommendations: Proposed actions based on one or more conclusions—usually contain the word "should" and indicate an actor and an action.

2

Background

This chapter provides background information on the following topics: a review of the surplus plutonium inventory in the United States and the volumes that are relevant to the dilute and dispose plan; the Plutonium Management and Disposition Agreement (PMDA) between the United States and the Russian Federation and its current status; the Waste Isolation Pilot Plant (WIPP) and how it operates and recent changes to the accounting of waste container volumes; and risk assessment. This background is needed to understand the dilute and dispose plans as well as the committee's analysis of them. Readers who are familiar with these topics may choose to skip this background chapter.

2.1 SURPLUS PLUTONIUM IN THE UNITED STATES

Plutonium is a fissile chemical element with an atomic number of 94 used in nuclear weapons and in mixed oxide (MOX) fuel in a nuclear reactor; its unique characteristics and properties are described in Box 2-1.[1] The United States has declared more than 60 metric tons (MT[2]) of weapons-useable plutonium material as surplus, meaning it has no programmatic use and does not fall into one of the categories of national security reserves (DOE, 2015a, p. S-1). The plutonium material within the surplus inventory is in many forms ranging from plutonium pits and oxides to plutonium within the Department of Energy (DOE)-managed used fuel (see Figure 2-1).

BOX 2-1 Plutonium: Its History, Uses, Chemistry, and Environmental Behavior

Plutonium is one of the most complex metals known. It is part of the actinide series, element 94 in the periodic table, and has five common isotopes with mass numbers ranging from 238 to 242, all radioactive. All plutonium isotopes have different half-lives—the time it takes for half of the atoms to decay. For example, plutonium-239 has a half-life of ~24,110 years; plutonium-241 of ~14.4 years. Plutonium is very dense, highly reactive in air, toxic, and will persist in the environment for a long time.

Plutonium-238 was first synthesized in small quantities in the laboratory in 1940 by bombarding uranium with deuterons (Seaborg et al., 1946). Although it has been detected in nature in minute quantities within uranium ores (Seaborg and Perlman, 1948), the overwhelming majority of the world's current inventory of plutonium has been produced in large quantities in nuclear reactors (i.e., production reactors). The 2014 global plutonium inventory, including both civilian and declared military stocks, has been estimated at 2,627 metric tons (Institute for Science and International Security, 2015). Plutonium-239, which was synthesized just a few years after the discovery of plutonium-238, is a fissile isotope that can sustain a nuclear chain reaction and, as a result, it is one of the most important plutonium isotopes. It was produced and used primarily for nuclear weapons and to a much lesser extent as fuel for nuclear power.

continued

[1]Although plutonium is used in MOX fuel for use in nuclear power plants in a few countries, there are no nuclear power plants in the United States that use plutonium fuel.

[2]One metric ton is 1,000 kilograms or 1.102 U.S. tons; 1 U.S. ton is equal to 2,000 pounds (lbs).

BOX 2-1 Continued

Weapons-grade plutonium, defined as containing less than 7 percent plutonium-240, used in nuclear weapons primarily consists of plutonium-239. Weapons-grade plutonium metal is machined and placed in the core or "pit" of the device. A significant portion of the U.S. declared surplus plutonium inventory is in the form of pits; other forms include spent reactor fuel from plutonium production reactors, scraps and residues from pit production, and plutonium metals and oxide stocks not made into pits. Finding a way to disposition surplus plutonium is significantly more challenging than for surplus highly enriched uranium (HEU; another material used to make nuclear weapons). A National Academies report noted that "HEU can be 'blended down' isotopically (using abundant uranium-238) to an enrichment level unusable for weapons, but no such isotopic denaturing is practical for plutonium" (NRC, 2000, p. 8). See Figure 2-1 in the main text for amounts of these materials and further description.

Even a small amount of plutonium can be lethal. Plutonium decays by producing alpha particles, and although alpha particles have a low penetration depth and do not pose much of an external threat, alpha emitters are extremely hazardous if they get inside the body through inhalation or ingestion. Plutonium microparticles can enter the bloodstream through the lung and remain in the body for decades. In terms of plutonium toxicity, the lethal dose-50 (LD_{50}) of plutonium-239 (citrate form) determined for rats is 1.6 mg/kg. Humans are about 6 times more sensitive to plutonium than rats, so a person with an average body weight has about a 50 percent chance of dying if she or he ingests only 20 mg of plutonium-239. To protect drinking water in the United States, the maximum contaminant level is set 0.15 picocuries (10^{-12} Ci) per liter for total alpha radioactivity (EPA, 2000). For comparison, a gram of plutonium-239 emits about 0.062 Ci.

In addition to its high toxicity and long persistence in the environment, plutonium has been shown to migrate in groundwater at low concentrations under various geochemical conditions (Kersting et al., 1999; Santschi et al., 2002; Novikov et al., 2006). The geochemical behavior and fate of plutonium in the environment are complex, making predictions of its mobility under various geochemical conditions difficult. Plutonium can dissolve as an aqueous ion, adsorb (attach) to an immobile surface, or adsorb to small mobile particulates or colloids in water; at higher concentrations, it can precipitate out of solution forming its own colloid, plutonium oxide (PuO_2). The ultimate behavior of plutonium in the environment depends not only on its initial chemical form but also the geochemistry of the surrounding geologic environment (Kersting, 2013).

Any disposition pathway for the U.S. inventory of surplus plutonium must consider plutonium's long half-life, fissile characteristics, toxicity, and potential ability to migrate in solids (i.e., underground emplacement). Significant attention must be given during handling and storage of the increased volumes of plutonium both to prevent criticality and to ensure long-term isolation from the biosphere.

Additional reading on the geochemical behavior of plutonium includes the following:

Clark, D. L. 2000. The chemical complexities of plutonium. *Los Alamos Science* No. 26. https://fas.org/sgp/othergov/doe/lanl/pubs/00818038.pdf (accessed May 20, 2020).

Clark, D. L., S. S. Hecker, G. D. Jarvinen, and M. P. Neu. 2011. Plutonium. In *The Chemistry of the Actinide and Transactinide Elements*, 4th ed., L. R. Mores, N. M. Edelstein, J. Fuger, and J. J. Katz, eds. Dordrecht, The Netherlands: Springer, Vol. 2, p. 856.

EPA Facts About Plutonium, https://semspub.epa.gov/work/HQ/176324.pdf (accessed May 20, 2020).

Nair, A. B., and S. Jacob. 2016. A simple practice guide for dose conversion between animals and human. *Journal of Basic Clinical Pharmacology* 7(2):27-31. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4804402 (accessed May 20, 2020).

Reed, D. T., J. Lucchini, S. Aase, and A. Kropf. 2006. Reduction of plutonium(VI) in brine under subsurface conditions. *Radiochimica Acta* 94:591-597. DOI: 10.1524/ract.2006.94.9.591.

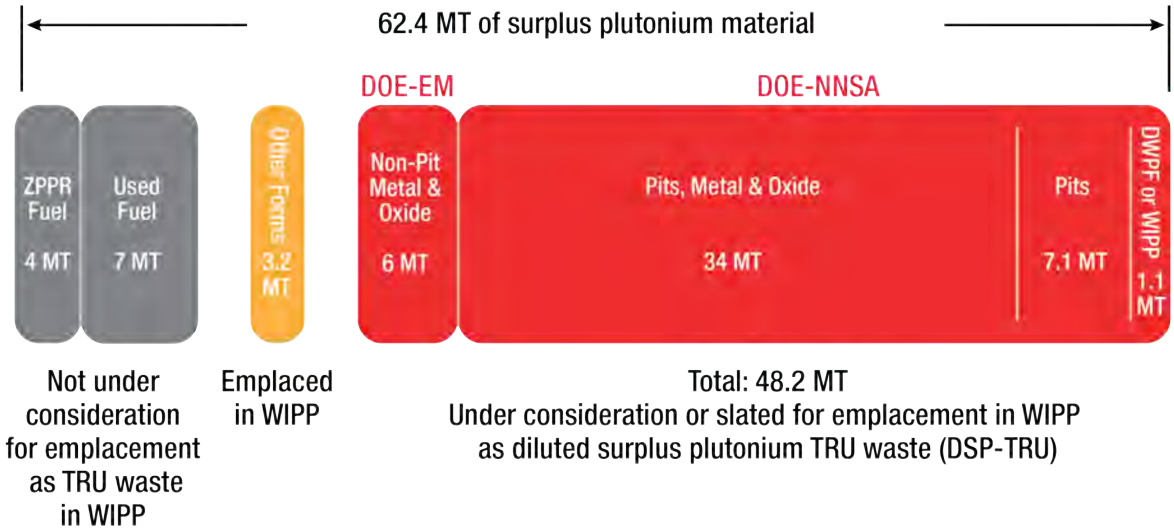

FIGURE 2-1 The U.S. Surplus Plutonium Inventory consists of a variety of forms and amounts of plutonium. A total of 62.4 MT of surplus plutonium is shown above (note that this value exceeds the official declared surplus amount by 0.9 MT, described below). Plutonium within used fuel or previously reserved but no longer needed for use in research reactor fuels (ZPPR, Zero Power Physics Reactor) accounts for 11 MT (gray). Other forms of plutonium including scraps and residues totaling 3.2 MT have been emplaced as transuranic (TRU) waste in the Waste Isolation Pilot Plant (WIPP, yellow). The Department of Energy (DOE) has issued a record of decision for dispositioning 6 MT, consisting of 5.1 MT plus an additional 0.9 MT for future plutonium wastes (the additional amount referenced above) of non-pit metal and plutonium oxide as diluted surplus plutonium TRU (DSP-TRU) waste in WIPP (red); this amount is being managed by DOE's Office of Environmental Management (DOE-EM). The remainder, 42.2 MT consisting of plutonium pits, metals, and oxides, is under consideration by DOE's National Nuclear Security Administration for dispositioning as DSP-TRU waste in WIPP (34 MT + 7.1 MT + 1.1 MT, red). Up to 48.2 MT of surplus plutonium (red) is under consideration or slated for emplacement in WIPP as DSP-TRU waste. SOURCE: Modified from DOE, 2015a, fig. S-7.

2.1.1 Surplus Plutonium Inventory and Its Current Status

The committee developed Figure 2-1, which has been modified from DOE's original diagram (DOE, 2015a, fig. S-7), to clearly identify the various disposition plans and the amounts of surplus plutonium associated with each. Thirty-four metric tons of the total are associated with U.S. commitments under the PMDA (discussed later in this chapter) and have been proposed by DOE-NNSA for dilution and disposal. This amount was the main focus of the Statement of Task (see Box 1-1) and was the initial focus of the committee. However, additional amounts of surplus plutonium, beyond the amount identified in the PMDA, are associated with DOE's dilution and disposal plans and were also within the committee's tasking (see Box 1-1, Task 2.c). The committee determined that up to 48.2 MT of surplus plutonium either is under consideration or is already slated for (a record of decision [ROD] has been issued for) emplacement as diluted surplus plutonium transuranic (DSP-TRU) waste in WIPP.

The United States has officially declared a total of 61.5 MT of weapons-grade plutonium as surplus. In 2016, DOE's ROD for 6.0 MT of surplus non-pit plutonium material to be diluted (or downblended) and disposed of at WIPP consisting of 5.1 MT of material already declared surplus and an additional 0.9 MT of possible future surplus plutonium material included in the analysis but not in the official declaration (DOE, 2016a; see also Box 2-2, below).[3] For purposes of this report, which is focused on the

[3]As used by different offices within DOE, the terms "downblend" and "dilute" are synonymous and describe the process for mixing surplus plutonium with an adulterant to ensure that plutonium "is not recoverable without

proposed amount of surplus plutonium material considered for WIPP, the committee chose to include the 0.9 MT in the inventory total. Therefore, in the committee's analysis there is up to 62.4 MT of U.S. surplus plutonium material for which disposition paths are or need to be identified through National Environmental Policy Act (NEPA) analysis and RODs.[4]

Of the 62.4 MT total, 11 MT is not currently under consideration for disposal at WIPP (see Figure 2-1, gray boxes). The 11 MT consists of 7 MT in DOE-managed used (i.e., irradiated) fuel that is in a proliferation-resistant form with no further action yet identified and 4 MT without a disposition pathway (originally reserved for but no longer needed by the Zero Power Physics Reactor). Another 3.2 MT has already been disposed of in WIPP as transuranic (TRU[5]) waste (see Figure 2-1, yellow box).[6]

The remaining 48.2 MT consists of 6 MT (managed by DOE's Office of Environmental Management [DOE-EM]) and 42.2 MT (managed by DOE's National Nuclear Security Administration [DOE-NNSA]). A ROD for the 6 MT—to dilute and dispose as DSP-TRU in WIPP—was issued in 2016 (DOE, 2016a; see Box 2-2). The 42.2 MT is made up of 34 MT (previously associated with the MOX plan), 7.1 MT of pit plutonium, and 1.1 MT to be disposed of at either WIPP or processed at the Defense Waste Processing Facility at the Savannah River Site (SRS) for eventual disposal in a high level waste repository).[7] The 48.2 MT of surplus plutonium plus the 3.2 MT already emplaced in WIPP totals 51.4 MT, which represents the total amount of surplus plutonium that could eventually be emplaced in WIPP.

A special inventory report, developed by Los Alamos National Laboratory (LANL) for an initial performance assessment (PA; also referred to as an impact assessment) by Sandia National Laboratories uses 42.2 MT for the possible emplacement of DSP-TRU waste by DOE-NNSA. This special inventory report did not include the 6 MT of DOE-EM surplus non-pit plutonium material (LANL, 2017).[8]

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extensive reprocessing." DOE notes in its Surplus Plutonium Disposition System Plan that "[t]he term dilution is the international nomenclature for using an adulterant to provide proliferation resistance and is in no way intended to avoid any applicable regulatory requirements" (SRNS, 2016, p. 8). The committee has chosen to use the terms "dilute" or "dilution" throughout this report, even when referring to DOE-EM's plans and activities.

[4]Disposition refers to the consignment of radioactive waste for some specified (interim or final) destination; disposal refers to the emplacement of waste in an appropriate facility without the intention of retrieval.

[5]Transuranic (TRU) waste is defined in multiple government documents with slight differences in the definitions. In this report, we use the definition from the WIPP Land Withdrawal Act (Waste Isolation Pilot Plant Land Withdrawal Act, Pub. L. No. 102-579, 106 Stat. 4777-4796 (1992) [as amended in 1996 by Pub. L. No. 104-201]): The term "transuranic waste" means 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 has determined, with the concurrence of the Administrator, 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.

[6]This material originated from multiple sites and was placed in pipe overpack containers (POCs) prior to disposal. A POC is similar to a criticality control overpack (see Chapter 4).

[7]Further explanation of the DOE disposition pathway for the 1.1 MT is as follows (DOE, 2015a, p. s-3): "In 2008 and 2009, DOE completed interim action determinations and concluded that 0.6 metric tons (0.66 tons) of surplus non-pit plutonium could be disposed of through H-Canyon/HB-Line and DWPF (DOE, 2008a, 2009); in 2011, DOE amended this determination to add WIPP as a disposal alternative for about 85 kilograms (187 pounds) of these 0.6 metric tons (0.66 tons) (DOE, 2011a). Also in 2011, DOE decided to use H-Canyon/HB-Line to prepare another 0.5 metric tons (0.55 tons) of surplus plutonium for disposal at WIPP (DOE, 2011b); DOE amended this determination in 2013 to also allow preparation in the K-Area Complex (DOE, 2013c). Thus, DOE has determined that a total of 1.1 metric tons (1.2 tons) of surplus plutonium could be dispositioned through H-Canyon/HB-Line and the K-Area Complex to DWPF and WIPP."

[8]"The PA models the impact on performance of the WIPP repository by the National Nuclear Security Administration's (NNSA's) proposal to dispose of ~42.2 metric tons (MT) of surplus plutonium (Pu) in the WIPP" (LANL, 2017, p. 5).

The committee heard that, as of 2009, approximately 4.8 MT of plutonium material had been emplaced at WIPP but it was difficult to determine how much of this total was part of the declared surplus or the exact amount that had been products of past—but not identical—dilute and dispose processes.[9] The analysis in Figure 2-1 uses the 3.2-MT value as the amount of surplus plutonium TRU waste already emplaced in WIPP. There is more plutonium disposed of in WIPP as TRU waste but it is not part of the declared surplus plutonium nor is it in the same waste form as diluted surplus plutonium, being the more conventional waste lightly contaminated with transuranic elements including plutonium contamination from defense activities.

Beginning in the mid-1990s, DOE issued a series of environmental impact statements (EISs) and RODs to shape and modify the disposition strategy for U.S. surplus plutonium (see Box 2-2). There is no single document or ROD that defines the United States' plans to disposition the entirety of its surplus plutonium material inventory. Rather, the disposition pathways depend on the form of the plutonium material, leading to a variety of decisions and different disposition pathways, some of which have changed over the years.

In 2000, DOE issued a ROD selecting two options for dispositioning of 34 MT of surplus plutonium material: the irradiation of MOX[10] fuel using commercial nuclear reactors and the immobilization of the material in combination with high level waste. In 2002, the George W. Bush administration canceled the immobilization program citing budget constraints and made the decision to support only one approach for plutonium disposition, the fabrication and subsequent irradiation of MOX fuel. In 2007, the United States began construction of a facility to manufacture MOX fuel, the Mixed Oxide Fuel Fabrication Facility ("MOX plant"), at the SRS in South Carolina.

In parallel with the decisions being made for the 34 MT of surplus plutonium material, in 2016 DOE-NNSA issued a ROD for the disposition of up to 6 MT of non-pit plutonium material within the U.S. surplus inventory. The ROD states that the surplus non-pit plutonium material "will be prepared and packaged to meet the WIPP waste acceptance criteria for contact-handled TRU waste and other applicable regulatory requirements" and would be disposed of "at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, a geologic repository for disposal of transuranic (TRU) waste generated by atomic energy defense activities" (DOE, 2016a, p. 19588).

Meanwhile, construction of the MOX plant encountered substantial schedule delays and cost overruns. The Obama administration proposed to stop construction of this facility and instead use a "dilute and dispose process" to disposition 34 MT of surplus plutonium (Goodson, 2018) using the process described in the ROD for the 6 MT of surplus non-pit plutonium material. Congress provided $15 million to DOE-NNSA in fiscal year (FY) 2017 to continue planning and developing a conceptual design for the dilute and dispose process; it also mandated this National Academies of Sciences, Engineering, and Medicine evaluation (U.S. Congress, 2016, p. 114). In May 2018, the Trump administration submitted a report to Congress detailing the Life-Cycle Cost Estimate of the dilute and dispose approach, showing total costs of less than half of those estimated for the MOX option. In October 2018, DOE-NNSA canceled the MOX program (see Box 2-2). The Notice of Intent, which would begin the NEPA process for the disposition of 34 MT through dilution and disposal, has not yet been issued. However, there are indications that a NEPA decision on the 7.1 MT of surplus pit plutonium, processed as DSP-TRU waste for disposal in WIPP, may be issued (DOE-CBFO, 2019a, p. 391, new waste stream: SR-KAC-PuOx-1).

[9]Information collected during discussions during the open session of the committee's April 2019 meeting. See video from the meeting at https://vimeo.com/showcase/6028445/video/338026631 (accessed March 30, 2020).

[10]MOX fuel contains plutonium and slightly enriched uranium, both in oxide form (DOS, 2000).

BOX 2-2 Timeline of Actions and Decisions for Disposal of Surplus Plutonium

Below is a timeline for major actions and decisions relevant to the dilution and disposal of surplus plutonium. Items in italic are events relevant to the surplus plutonium disposition program but are not environmental impact statements or records of decision.

1993 *President Clinton issues policy on Nonproliferation and Export Control, which states that the United States will: "Seek to eliminate where possible the accumulation of stockpiles of highly-enriched uranium or plutonium . . . [and] Initiate a comprehensive review of long-term options for plutonium disposition, taking into account technical, nonproliferation, environmental, budgetary and economic considerations. Russia and other nations with relevant interests and experience will be invited to participate in this study"* (White House, 1993).

1995 *DOE declares excess plutonium and identifies plutonium waste throughout the DOE complex: 38.2 MT weapons-grade plutonium is identified as excess and 3.4 MT of plutonium waste* (DOE, 1996a).

1996 **Storage and Disposition Final Programmatic EIS, FPEIS-0229, 1996** (DOE, 1996b)
Considered 37 alternatives for the disposition of up to 50 metric tons of plutonium that has been or in the future may be declared surplus to national security needs.[a]

1997 **Record of Decision (ROD), FPEIS-0229** (DOE, 1997)
Decision to implement immobilization and MOX for disposal of surplus plutonium. Decision to use Safe Secure Transport (now called the Office of Secure Transportation, OST) to transport all plutonium-bearing materials between sites including unirradiated MOX fuel.[b]

1999 **Surplus Plutonium Disposition, SPD EIS-0283** (DOE, 1999a)
Focus on disposition of surplus plutonium.
Tiered from FPEIS-0229.

2000 **ROD SPD EIS-0283** (DOE, 2000, p. 3029, emphasis added)
"[T]o provide for the safe and secure disposition of up to 50 metric tons of surplus plutonium … the Department has decided to use a hybrid approach … [using] **immobilization** … and … **MOX fuel**. The Department has selected the Savannah River Site in South Carolina as the location for all three disposition facilities."

2000 *The United States and the Russian Federation sign the PMDA* (DOS, 2000). (See text for more details.)

2002 **Amended ROD SPD EIS-0283** (DOE, 2002)
Cancellation of the immobilization program due to budget constraints leaving 17 MT of surplus plutonium that was previously to have been immobilized without a disposition pathway.

Bob Stump National Defense Authorization Act for Fiscal Year 2003 (Pub. L. No. 107-314, 116 Stat. 2458), Section 3182, *outlined the following schedule for the MOX fuel fabrication facility to be constructed at SRS in South Carolina:*

The MOX plant would produce 1 MT of MOX fuel by December 31, 2009; and the full amount of 34 MT by January 1, 2019. If the objectives were not achieved, DOE would pay the State of South Carolina $1,000,000 per day not to exceed $100,000,000 per year until either the MOX objective is reached or DOE removes at least 1 MT of defense plutonium or plutonium materials from the state per year.[c]

2003 **Amended ROD SPD EIS-0283** (DOE, 2003, p. 20134)
"The program will dispose of 34 MT of surplus plutonium, including approximately 6.5 MT of the 17 MT of surplus plutonium originally intended for immobilization" and stored at SRS.[d]

2007 *DOE Secretary Bodman declares an additional 9 MT of plutonium as surplus.*

2010 *The United States and the Russian Federation sign the PMDA as amended by the 2010 Protocol (DOS, 2010). (See text for more details.)*

continued

BOX 2-2 Continued

2014 *Disposition of Surplus Plutonium Working Group report (by DOE)* (DOE, 2014)
Reviewed options for plutonium disposal as the costs of the MOX plant were increased significantly. Dilute and dispose was selected as the most viable option.

2015 *AeroSpace and Red Team Reports, independent review and support of 2014 Working Group's recommendations* (Hart et al., 2015; Mason, 2015).

2015 **Supplemental EIS-0283-S2**[e] (DOE, 2015a)
Final supplemental SPD EIS considered disposal options for surplus non-pit plutonium.

2016 **ROD SPD EIS-0283** (DOE, 2016a, p. 19591)
Decision to disposition of 6 MT surplus non-pit plutonium through dilute and dispose at WIPP:

"Blending for disposal at WIPP is a proven process that is ongoing at SRS for disposition of plutonium material…."

2017 ***NDAA for FY2018[f] and Consolidated Appropriations Act, 2018[g]***
Waivers allow for the Secretary of Energy to cease construction of the MOX facility if an alternative to dispositioning surplus plutonium at the cost of less than half the cost of the MOX option can be identified.

2018 ***May 10, 2018, Secretary Perry notifies Congress*** (Perry, 2018)
Perry submits dilute and dispose cost estimate report to Congress indicating the that life-cycle cost estimate for the dilute and dispose program is less than half that of the MOX option (an independent life-cycle cost estimate for the dilute and dispose program for dispositioning 34 MT of surplus plutonium material was shown to be $19.9 billion compared to $49.4 billion for the remaining cost to implement the MOX option). Secretary Perry cancels construction of the MOX plant.

2018 ***October 10, 2018, DOE-NNSA cancels MOX***
Letter issued to CB&I AREVA MOX Services, LLC, cancels the MOX program.

The Notice of Intent initiating NEPA actions for the dilute and dispose plan for 34 MT of surplus plutonium material has not yet been issued.

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[a]"Discarding Plutonium to WIPP" was rejected in this analysis due to lack of capacity at WIPP (see DOE, 1996b, fig. S.3-2).
[b]Transportation of all plutonium-bearing materials under this program, including the transportation of prepared MOX fuel to reactors, will be accomplished using DOE's Transportation Safeguards Division's ''Safe Secure Transports'' (SSTs), which affords these materials the same level of transportation safety, security, and safeguards as is used for nuclear weapons" (DOE, 1997, p. 3029).
[c]See https://www.govinfo.gov/content/pkg/PLAW-107publ314/html/PLAW-107publ314.htm (accessed May 20, 2020).
[d]This entry corrected from Interim Report, Box 3-1.
[e]DOE has issued two supplements to SPD EIS-0283: SPD EIS-0283-S1 identified a set of six reactors that would use MOX fuel, SPD EIS-0283-S2 (DOE, 2015a) assessed disposal options for surplus *non-pit* plutonium and added two more reactors that could potentially use MOX fuel.
[f]National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115-91, 131 Stat. 1283 (2017).
[g]Consolidated Appropriations Act, 2018. Pub. L. No. 115-141, 132 Stat. 348 (2018) (https://www.congress.gov/115/plaws/publ141/PLAW-115publ141.pdf, accessed May 20, 2020).

2.2 PLUTONIUM MANAGEMENT AND DISPOSITION AGREEMENT

The MOX fuel option for surplus plutonium disposition was consistent with U.S. commitments under the PMDA, which was signed by the United States and the Russian Federation in 2000 and amended in 2010. The 2010 agreement commits both countries to the disposition of no less than 34 MT of weapons-grade[11] plutonium by its incorporation into MOX reactor fuel followed by irradiation in nuclear reactors. The United States and the Russian Federation are required under the agreement to begin surplus plutonium disposition by 2018, with implementation to be verified by the International Atomic Energy Agency (DOS, 2000, 2010).

The PMDA Additional Protocol 2010 updated the text in Article III of the 2000 Agreement, outlining the means that are to be used by the United States and the Russian Federation for dispositioning 34 MT of surplus plutonium:[12]

> Disposition shall be by irradiation of disposition plutonium as fuel in nuclear reactors; or any other methods that may be agreed by the Parties in writing. (DOS, 2010, p. 2)

Article XIII of the original PMDA specifies how the agreement can be amended and was unaltered in the 2010 Additional Protocol:

> This Agreement may only be amended by written agreement of the Parties, except that the Annex on Key Program Elements may be updated as specified in paragraph 5 of that Annex. (DOS, 2000, p. 11)

To the committee's knowledge, the United States has not notified the Russian Federation in writing about its plans to pursue the dilute and dispose process in place of MOX. However, the Russian Federation government is aware of DOE's desire to use dilute and dispose to disposition 34 MT of surplus plutonium. Russian Federation President Vladimir Putin raised concerns in an April 2016 meeting with journalists about the United States' use of the dilute and dispose process for dispositioning surplus plutonium under the PMDA:

> [B]ack in the early 2000s, the Americans and we agreed on destroying weapons-grade plutonium. ... Each side had 34 tonnes. We signed this agreement and settled on the procedures for the material's destruction, agreed that this would be done on an industrial basis, which required the construction of special facilities. Russia fulfilled its obligations in this regard and built these facilities, but our American partners did not.
>
> Moreover, only recently, they announced that they plan to dispose of their accumulated highly enriched nuclear fuel by using a method other than what we agreed on when we signed the corresponding agreement, but by diluting and storing it in certain containers. This means that they preserve what is known as the breakout potential, in other words it can be retrieved, reprocessed and converted into weapons-grade plutonium again. This is not what we agreed on. Now we will have to think about what to do about this and how to respond to this.... [O]ur partners should understand that ... serious issues, especially with regard to nuclear arms, are [where] one should be able to meet one's obligations. (IPFM, 2016)

President Putin subsequently suspended Russian implementation of the PMDA in October 2016 "due to Washington's unfriendly actions toward Russia" (RadioFreeEurope RadioLiberty, 2016).

The Department of State releases an annual report providing assessments of the adherence of the United States and other nations to arms control, non-proliferation, and disarmament agreement or commitment obligations. The 2019 compliance statement with regard to the PMDA follows:

> The United States has not undertaken any activities during or prior to the reporting period that are inconsistent with its obligations under the Plutonium Management and Disposition Agreement (PMDA). This includes U.S. activities during the reporting period to terminate the project to

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[11]Defined in the PMDA as "plutonium with an isotopic ratio of plutonium-240 to plutonium-239 of no more than 0.10" (DOS, 2000, p. 2).

[12]The PMDA as amended in 2010 recognized the removal of immobilization as an option for disposition by the United States.

> construct a mixed-oxide (MOX) fuel fabrication facility that would have been used to dispose of plutonium under the agreement by turning it into fuel for irradiation in commercial nuclear reactors and to develop plans for a less expensive alternative disposition through dilution and burial of the plutonium. **Russia's assertion that this change in U.S. disposition plans violates the agreement, which was addressed in the 2018 Compliance Report, remains without merit.** …
>
> In 2018, the Secretary of Energy exercised the authority under the National Defense Authorization Act for Fiscal Year 2018 and the Consolidated Appropriations Act, 2018 to waive the requirement to use funds for construction and project support activities relating to the MOX facility, including certification that an alternative option for carrying out the disposition program for the same amount of plutonium intended to be disposed of in the MOX facility exists. The Department of Energy took additional steps to terminate the project to construct the MOX facility. **The administration will continue to work with Congress to finalize plans for U.S. disposition by the alternative dilute-and-dispose method. Further steps are needed in this respect before engaging Russia to obtain its agreement to this alternative method of disposition as required under the PMDA.** (DOS, 2019, pp. 9-10, emphasis added)

In addition to identifying the methods to be used for disposition, the PMDA outlined international verification requirements for the surplus plutonium material. In Article VII (with further details provided in the Annex on Monitoring and Inspections) inspections by the International Atomic Energy Agency (IAEA) are outlined:

> Each Party, in cooperation with the other Party, shall begin consultations with the International Atomic Energy Agency (IAEA) at an early date and undertake all other necessary steps to conclude appropriate agreements with the IAEA to allow it to implement verification measures with respect to each Party's disposition program. (DOS, 2010, p. 4)

The verification and monitoring of the surplus plutonium material apply to pre- and post-dilution stages as well as disposal. The details of how, when, and where the monitoring and verification take place are determined between the IAEA and each Party. The committee received a briefing from the director of the Office of International Nuclear Safeguards at DOE-NNSA on the voluntary agreement between DOE-NNSA and the IAEA concerning monitoring of the 6 MT of surplus plutonium (Veal, 2019). Though the agreement is not legally binding, DOE-NNSA is in the process of working with the IAEA to discuss what role, if any, the IAEA might play in the disposition of the 6 MT. The director noted that they are not currently working with the IAEA on monitoring and verification of the 34 MT.

The System Plan for the DOE-NNSA dilute and dispose program, for the 34 MT, makes one reference to monitoring and verification protocols:

> The SPD [Surplus Plutonium Disposition] Program scope includes incremental funding to process a portion of the non-pit plutonium materials associated with the 34 MT nuclear nonproliferation objective and incremental funding to add monitoring equipment required to implement verification protocol using an international agency for the dilute and dispose process of non-pit plutonium. (SRNS, 2018f, p. 12)

The Master Schedule (see also Figure 3-1) indicates that verification protocols for the activities at SRS will be in place in FY 2022 and for WIPP in FY 2023.[13]

In the context of current events, including the United States' withdrawal from the Intermediate-Range Nuclear Forces Treaty between the United States and the Russian Federation and currently no

[13]The Master Schedule document was provided to the committee by DOE. Public testimony, documents, and other materials submitted to the committee are available by request through the National Academies' Public Access Records Office at paro@nas.edu.

planned action following the conclusion of the New Strategic Arms Reduction Treaty (New START), a renegotiation of the PMDA may not be a reasonable near-term expectation. Furthermore, based on President Putin's comments about the dilute and dispose option, it could be difficult for the United States to obtain agreement with the Russian Federation for implementing the dilute and dispose process in place of irradiated MOX fuel.

Those same quotes from President Putin juxtaposed with the current stance of the Department of State show that the current status of the PMDA is unclear. To the committee's knowledge, neither country is moving to resolve the issues of alternative disposition pathways and IAEA monitoring and verification. The uncertainty of the PMDA is a key issue for DOE-NNSA's dilute and dispose program and will be discussed later in the report (see Chapter 5).

2.3 BACKGROUND ON WIPP

WIPP is a salt bed repository located in the southeast corner of New Mexico (see Figures 2-2 and 2-3) and managed by DOE-EM, specifically the Carlsbad Field Office (DOE-CBFO). Appendix C provides a discussion on salt repositories and the characteristics that make them suited for disposal of nuclear waste. WIPP is the only operational deep geologic repository in the United States for disposal of defense TRU wastes; its disposal capacity is limited by law to a certain volume of defense TRU waste (discussed below). The current WIPP repository design consists of 10 panels (see Figure 2-3). Eight of the 10 have been permitted for construction and use under the WIPP Hazardous Waste Facility Permit. Panel 8 is presently being mined and is not yet ready for use, and Panel 9 was abandoned after the WIPP accident.

The current contractor managing the site is Nuclear Waste Partnership LLC. After certification by the Environmental Protection Agency (EPA) in 1998, WIPP received its Resource Conservation and Recovery Act (RCRA) Hazardous Waste Facility Permit from the New Mexico Environment Department (NMED) also in 1998, and began disposal operations in 1999. According to the Permit, WIPP was assumed to reach facility closure in 2034, although there are now plans to extend the disposal operations and emplacement past 2050, which is discussed later in the report.

2.3.1 Disposal Capacity in WIPP

WIPP's disposal capacity limits are defined by several different laws, agreements, and permits for the purpose of regulating both the physical space as well as the physiochemical and radiological aspects of TRU and hazardous waste disposal. The Waste Isolation Pilot Plant Land Withdrawal Act (LWA) limits TRU waste disposal capacity to no greater than 6,200,000 ft^3 (175,564 m^3) of defense-related TRU waste, a limit that is overseen by EPA. The ROD for WIPP, issued in 1981, limits the amount of remote-handled TRU (RH-TRU) waste in WIPP to no more than 250,000 ft^3 (7,079 m^3) of the LWA total (DOE, 1981).[14] DSP-TRU waste is contact-handled (CH) TRU and is not affected by the RH-TRU limit. The Hazardous Waste Permit (overseen by NMED) also regulates waste volumes through the size limitation of the underground waste panels.[15] Until recently, the capacity limits for LWA and RCRA (Hazardous Waste Permit) were measured by the gross internal volume of the outermost disposal containers of the CH-TRU waste containers and were the same number (e.g., the volume of each 55-gallon drum was counted as 0.21 m^3).

[14]CH-TRU waste is defined in the LWA as "transuranic waste with a surface dose rate not greater than 200 millirem per hour." RH-TRU waste is defined in the Act as "transuranic waste with a surface dose rate of 200 millirem per hour or greater." LWA section 2.

[15]WIPP is managed as a mixed waste facility and is therefore subject to RCRA. All waste in WIPP is considered mixed TRU waste, meaning that the waste has both a hazardous component and transuranic elements. See "Regulatory Authority" at https://www.env.nm.gov/hazardous-waste/wipp (accessed February 20, 2020).

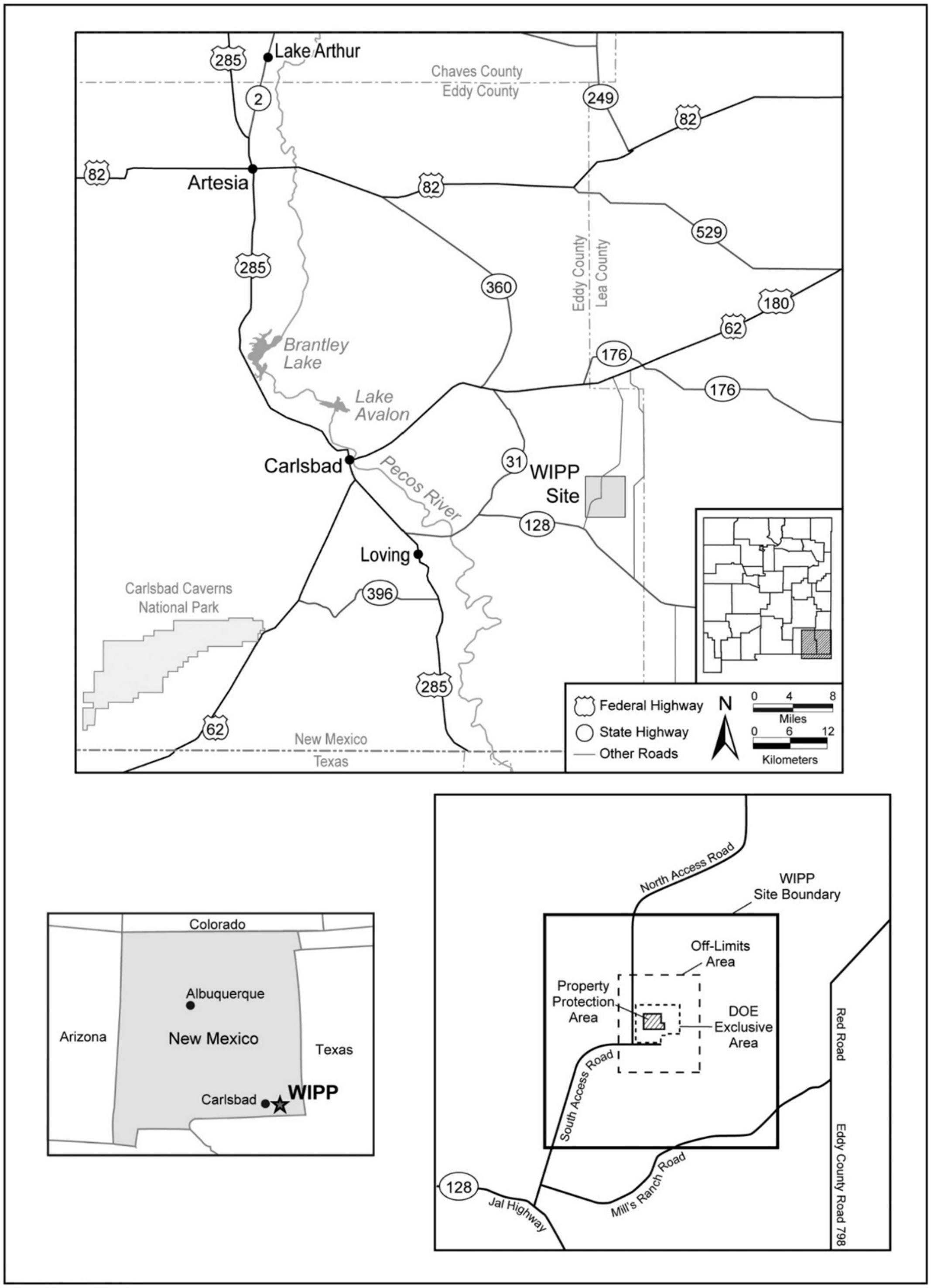


FIGURE 2-2 Map of New Mexico indicating the location of the Waste Isolation Pilot Plant. SOURCE: Sewards et al., 1991, fig. III-1.

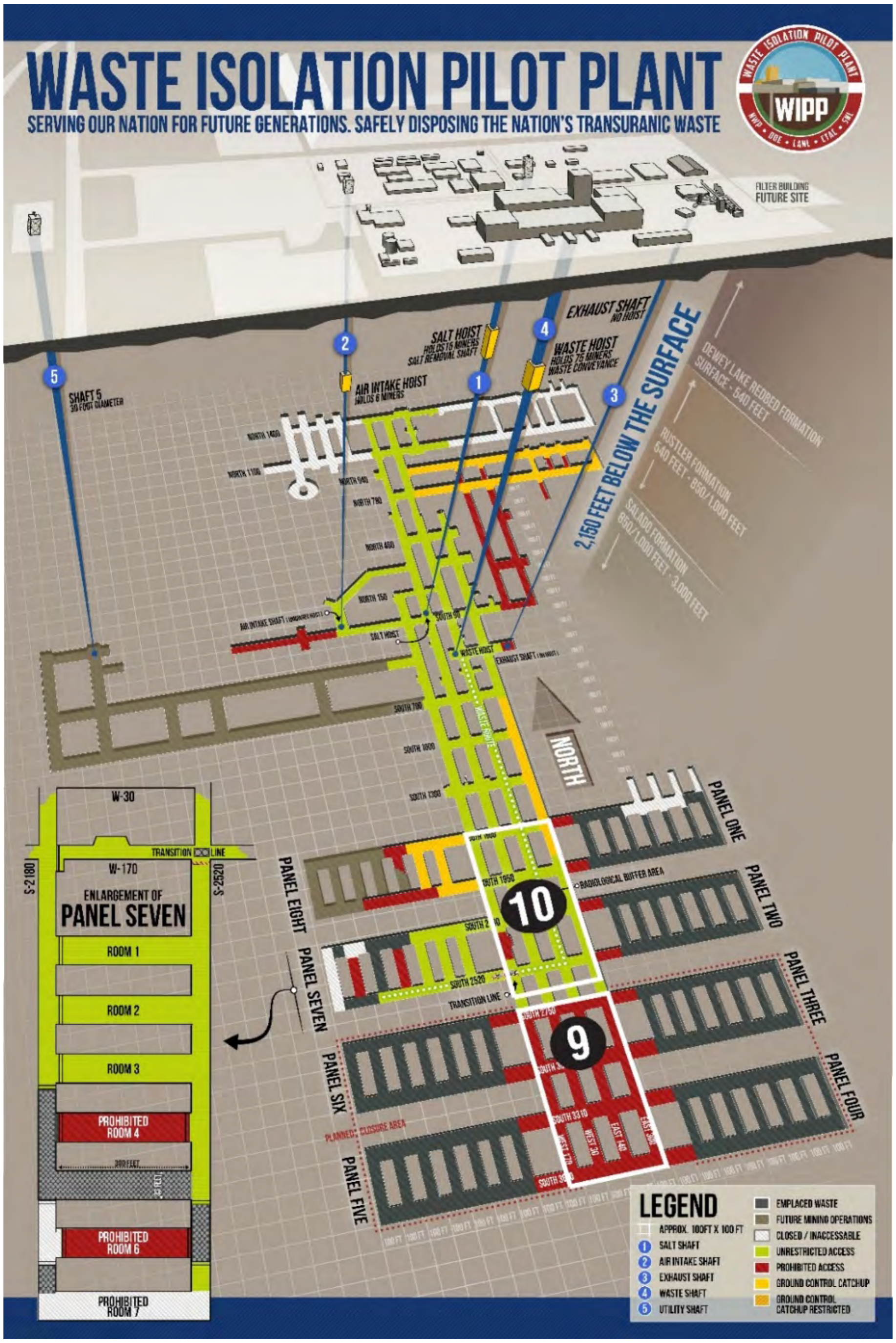


FIGURE 2-3 Schematic layout of the Waste Isolation Pilot Plant, which is located in southeastern New Mexico near Carlsbad. The repository is located about 2,150 feet (655 meters) below the surface. The aboveground facilities are shown in light brown at the top of the image. The 10 underground panels are shown in gray (for emplaced waste), red (for prohibited access), green (unrestricted access), yellow (ground control operations), and dark brown (for future mining operations). The underground panels are 2,150 feet below the surface and are located within the Salado salt formation. A new utility shaft shown in the upper left of the figure has been planned. Equivalent Panels 9 and 10 in the access drifts are shown in white boxes. Note that underground drifts in the area designated at Panel 9 have been abandoned and closed. SOURCE: Modified from Shrader, 2018. Image provided by the Department of Energy.

Shortly after the public release of this committee's Interim Report, NMED approved a pending permit modification request by DOE-CBFO to change the accounting of TRU waste container volumes for already emplaced and future wastes (DOE-CBFO, 2018b). The permit modification allows for a recalculation of emplaced and future wastes and distinguishes between reporting against the LWA limits (i.e., "statutory" limit) and the RCRA TRU Mixed Waste limits. See Box 2-3.

WIPP operations were suspended from 2014 to 2017 in response to two accidents in the underground area—an engine fire in a truck and an "exothermic reaction involving the mixture of the organic materials (Swheat Scoop® absorbent and/or neutralizer) and nitrate salts" in a waste container in a panel that was being filled (DOE-EM, 2015, p. ES-5).[16] WIPP operations are slowly ramping up, currently supporting 8 to 10 shipments per week, with the goal to return to preincident shipment and emplacement rates. These rates may be obtainable once the new ventilation system is operational, and new zero-emission underground vehicles are in use (DOE-CBFO, 2019b).

There are several factors that are increasing public pressure on the area surrounding Carlsbad, New Mexico. In 2018, the U.S. Geological Survey released a report that assessed the Permian Basin to have the largest continuous oil and gas reserves in the United States, announcing that "assessed undiscovered, technically recoverable continuous mean resources of 46.3 billion barrels of oil and 281 trillion cubic feet of gas in the Wolfcamp shale and Bone Spring Formation of the Delaware Basin in the Permian Basin Province, southeast New Mexico and west Texas" (Gaswirth et al., 2018, p. 1). Oil and gas drilling rates have increased in the area surrounding WIPP since it first became operational. The higher density of drilling sites affects the calculation of probabilities for post-closure human intrusion (via drilling) into the facility and could also raise additional concerns about migration of fluids to WIPP from the drilled formations. Figure 2-4 is a map of the Permian Basin with WIPP's location overlaid. Holtec International has also proposed an interim storage site for spent nuclear fuel outside of Carlsbad, New Mexico, which has been met with mixed public support throughout the state.

2.3.2 Regulations for WIPP for Pre- and Post-Closure

In 1992, the Secretary of the Interior transferred its control of land at the WIPP site to the Secretary of Energy and granted authority to the Secretary of Energy through the WIPP LWA. The Secretary of Energy closed the area and its immediate surroundings to public use (NRC, 1996, p. 11).

The committee has divided its assessment of the viability of the surplus plutonium disposition concept into issues arising from the addition of such inventory and potentially affecting pre-closure (i.e., operational) and post-closure safety, as regards the respective regulatory frameworks. The key distinction between the pre- and post-closure periods lies in the use of active versus passive safety provisions, and consequently the means and measures of ensuring safety performance (see Box 2-4).

There are many federal and state regulations as well as DOE Orders governing WIPP's pre- and post-closure periods, which are designed to ensure the health and safety (protection) of the workforce, the public, and the environment from radiological and other hazards.[17] However, a major provision of the LWA requires DOE to demonstrate compliance with federal regulations developed and assessed by EPA. Chief among EPA regulations are 40 CFR Part 191 (EPA, 1994) and 40 CFR Part 194 (EPA, 2014a).[18] Because some waste destined for WIPP also contains hazardous waste constituents (all waste at WIPP is

[16] From the National Transuranic web page: "Changes in NTP oversight and at WIPP established new requirements pertaining to WIPP WAC compliance and in the WIPP Documented Safety Analysis (DSA) in the summer of 2016," https://wipp.energy.gov/national-tru-programs.asp (accessed May 20, 2020).

[17] A full list of laws, regulations, and orders can be found in DOE (2015b, table 5-1, Environmental Laws, Regulations, Executive Orders, and Department of Energy Orders).

[18] Part 191 defines standards (EPA, 1994) and Part 194 along with the Part 191 Disposal Regulations describe the specific WIPP site requirements for compliance with 40 CFR Part 191 standards (EPA, 2014a).

managed as mixed waste), certain provisions of RCRA[19] also apply. The LWA, as amended, exempts waste designated by the Secretary of Energy for disposal at the WIPP facility from the treatment standards of RCRA. By virtue of this exclusion, DOE is not required to demonstrate compliance with the Land Disposal Restrictions of 40 CFR Part 268 for TRU mixed waste designated by the Secretary of Energy for disposal at WIPP.

BOX 2-3 Disposal Containers Impacted by the Volume of Record Recalculation

In late December 2018, the New Mexico Environment Department (NMED) approved a permit modification request submitted by the Department of Energy Carlsbad Field Office (DOE-CBFO) that allowed a recalculation of the volumes of emplaced and future transuranic (TRU) waste (NMED, 2018). Specifically, the TRU waste container volume for reporting purposes against the LWA capacity limit would be calculated as the gross internal volume of the disposal container for *direct-loaded containers* and the innermost disposal container for *overpack containers* (DOE-CBFO, 2019a). The physical volume of the TRU waste containers is still required to be reported against the RCRA TRU mixed waste (TMW) volume limit. Thus, as a result of the permit modification two volumes—the LWA Volume and the TMW Volume—are now reported and tracked for emplaced and future TRU wastes in WIPP. Although some objections to the volume accounting change were vocalized before and after the permit request was approved, the committee is unaware of any effort to overturn the volume of record change. To understand the impact of this decision on DSP-TRU wastes, one must understand the types of containers referred to above.

There is a wide variety of authorized TRU waste containers for emplacement in WIPP. However, the majority are 55-gallon drums, of which three different varieties are most relevant to the permit modification (see Box Figure 1). The first is a direct-loaded 55-gallon drum, used for typical TRU waste emplaced in WIPP (clothing, tools, rags, residues, debris, soil, and other items contaminated with small or moderate amounts of plutonium and other engineered radioactive elements); it has no inner container. The second is a pipe overpack container (POC) that contains an inner pipe, ~12 inches in diameter and ~25 inches long, which is centered within the 55-gallon drum.[a] The third is a criticality control overpack (CCO), which is similar to a POC except that the dimensions of the inner pipe (called the criticality control container or CCC) are ~6-inch diameter and ~26-inch length, also centered within the 55-gallon drum. For POCs, the waste is contained within the inner pipe. DSP-TRU waste will be placed within the CCC.

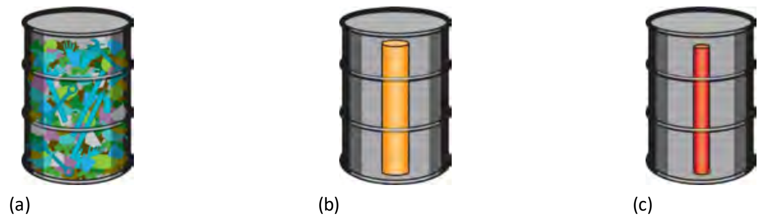
POCs are often used for the disposal of plutonium material that meets the criteria for disposal in WIPP; the amount of plutonium-239 per POC is limited to no more than 200 fissile gram equivalents (FGE of plutonium-239). For the CCCs, the amount is limited to no more than 380 FGE, but DOE-EM's and DOE-NNSA's current plans suggest a nominal loading of 300 FGE of plutonium-239 (see Chapter 3). Direct-loaded 55-gallon drums containing more traditional TRU waste average 14 grams of plutonium-239 per container.

As of the end of September 2019 according to the Waste Data System/WIPP Waste Information System, a total of 124,593 standard 55-gallon drums had been emplaced in WIPP (see Chapter 5, Table 5-1), which is roughly 70 percent of the total number of containers emplaced. Of the 124,593 standard 55-gallon drum total, 26,887 were POCs. Notably, the amount of plutonium-239 material within the emplaced POCs adds up to 3.2 MT, which is consistent with the amount of emplaced surplus plutonium in WIPP shown in Figure 2-1 (yellow box).[b]

continued

[19]RCRA, enacted in 1976, is a statute designed to provide "cradle-to-grave" control of hazardous waste by imposing management requirements on generators and transporters of hazardous wastes and on the owners and operators of treatment, storage, and disposal facilities (see https://www.epa.gov/enforcement/resource-conservation-and-recovery-act-rcra-and-federal-facilities, accessed April 22, 2020).

BOX 2-3 Continued



Characteristics	(a) Direct-loaded	(b) Pipe Overpack Container	(c) Criticality Control Container/Criticality Control Overpack (CCC/CCO)
Inner dimension	N/A	12-inch-diameter pipe	6-inch-diameter pipe
Physical volume	0.21 m^3	0.21 m^3	0.21 m^3
Inner container volume	0.21 m^3	0.046 m^3	0.013 m^3

BOX FIGURE 1 Graphical illustration of the three types of 55-gallon drums approved for disposal of TRU waste at WIPP with information on the physical volumes (outer container volume) and inner container volumes affected by the volume of record decision. (a) A standard sized, direct-loaded 55-gallon drum, (b) a pipe overpack container which has a 12-inch pipe centered within a 55-gallon drum, and (c) the criticality control overpack which has a 6-inch-diameter pipe (the criticality control container) centered in a 55-gallon drum.
SOURCE: Committee-generated with information from (p. 20): https://www.wipp.energy.gov/library/WDS/DOE-WIPP-09-3427_Rev_17.pdf (accessed April 21, 2020).

The dilute and dispose plan would produce approximately 160,666 CCOs (based on a total of 48.2 MT of surplus plutonium and 300 FGE per CCC)—more than the number of 55-gallon drums currently emplaced in WIPP. The LWA volume for the DSP-TRU waste, using the numbers above, would be 2,057 m^3 while the TMW volume would be 33,740 m^3—a factor of 16 larger.

[a]Other types of POCs are used, but the 12-inch POC is the most prevalent.
[b]Only 58 POCs used a 6-inch-diameter inner pipe; the remainder used the 12-inch POC.

The WIPP LWA required EPA to provide an initial certification of WIPP's compliance with EPA's disposal regulations before operations could begin. Thereafter, every 5 years EPA must conduct a recertifcation of WIPP's compliance with EPA's radioactive waste disposal standards, and based on updated information submitted by DOE. Much of the application content and review process is effectively governed by the respective requirements of 40 CFR Parts 191 and 194. These two regulations are described in more detail below.

2.3.2.1 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel and Transuranic Radioactive Wastes (40 CFR Part 191)

The principal federal regulations covering radiation protection for the WIPP operational and post-closure phases are found in 40 CFR Part 191, which is divided into three parts as described by the EPA website:[20]

- Subpart A limits the radiation exposure of members of the public from the management of spent nuclear fuel and radioactive waste prior to its disposal—in other words, during the operational period up to the point when [the WIPP] repository shafts are backfilled and sealed (WIPP facility closure).

[20]See https://www.epa.gov/radiation/environmental-radiation-protection-standards-management-and-disposal-spent-nuclear-fuel (accessed May 20, 2020).

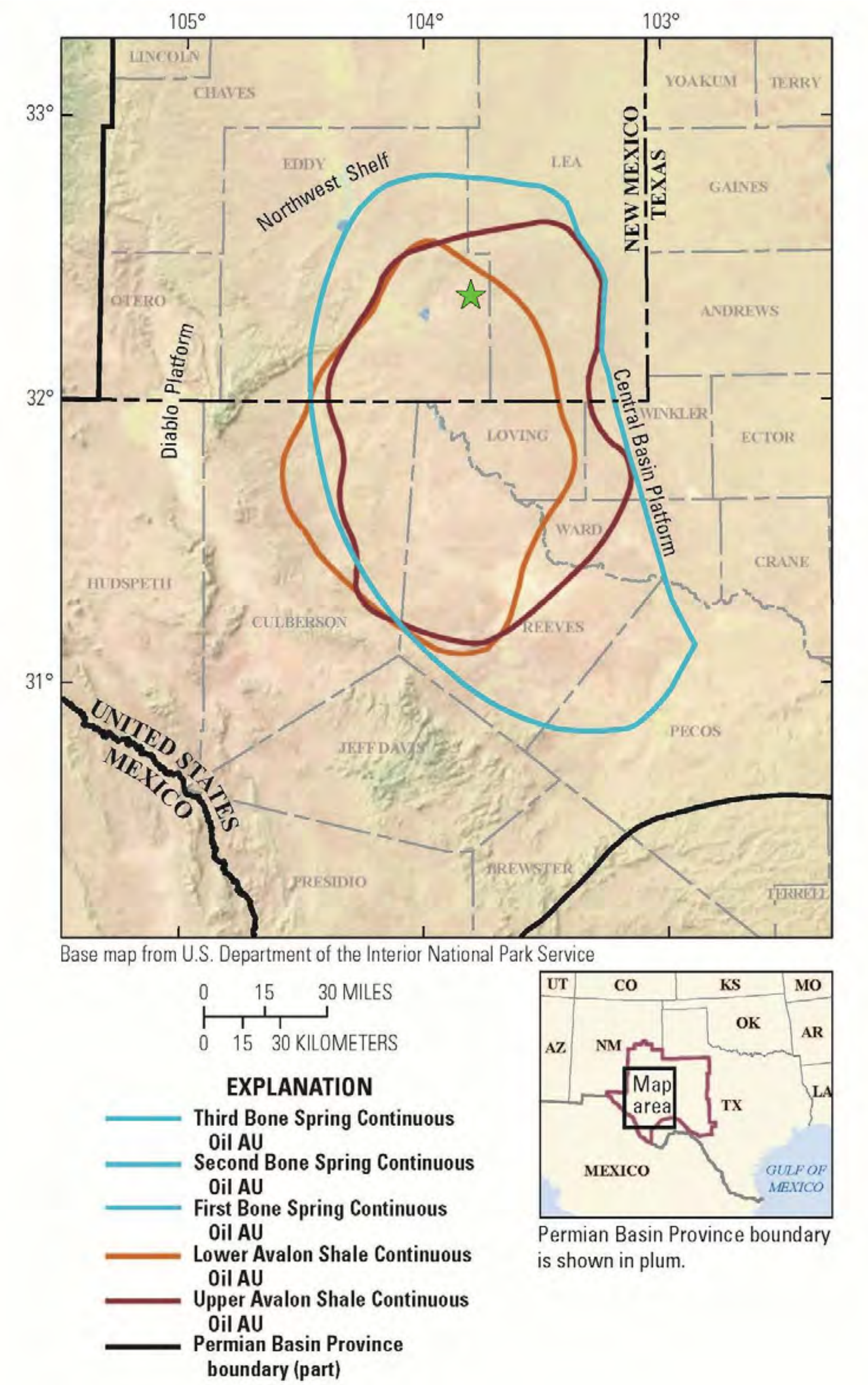


FIGURE 2-4 Oil-bearing shale formations in the Delaware Basin as recently identified by the U.S. Geological Survey. The Third, Second, and First Bone Spring Assessment Units (AUs) are overlapping and are shown by a single blue line. An orange line indicates the Lower Avalon Shale formation, and the maroon line indicates the Upper Avalon Shale formation. A green star (latitude 32.37, longitude 103.79) indicates the 4-mile-by-4-mile WIPP location. SOURCES: Gaswirth et al., 2018; USGS, 2018.

BOX 2-4 Definitions of Pre- and Post-Closure Periods

The committee was directed to evaluate DOE's understanding of the impacts of its dilute and dispose plans on WIPP pre- and post-closure safety and performance. These terms are defined by the International Atomic Energy Agency (IAEA, 2011, p. 7) below.

> *Operational (pre-closure) period:*
>
> The operational period begins when waste is first received at the facility. From this time, radiation exposures may occur as a result of waste management activities, and these are subject to control in accordance with the requirements for protection and safety. Monitoring, surveillance and testing programmes continue to inform operational management decisions and to provide the basis for decisions concerning the closure of the facility or parts of it. Safety assessments for the period of operation and the period after closure and the safety case are updated as necessary to reflect actual experience and increasing knowledge. In the operational period, construction activities may take place at the same time as waste emplacement in, and closure of, other parts of the facility.
>
> *Post-closure period:*
>
> The post-closure period begins at the time when all the engineered containment and isolation features have been put in place, operational buildings and supporting services have been decommissioned and the facility is in its final configuration. After closure, the safety of the disposal facility is provided for by passive means inherent in the characteristics of the site and the facility and in the waste package characteristics, although institutional controls, including some post-closure monitoring, may continue, for example, for the purposes of providing public assurance.

For this report, the terms regarding the *pre-closure, emplacement, disposal, and operational period* refer to the pre-closure period while the *post-closure period* refers to the period after decommissioning (closure) of the facility from further operations.[a]

[a]The Land Withdrawal Act defines a "disposal phase" as the period through the last waste container emplacement, followed by a "decommissioning phase" as the period ending when all shafts at the WIPP repository have been backfilled and sealed.

- Subpart B sets containment requirements for disposal systems, which limit the amount of radioactivity that may enter the environment for 10,000 years after facility closure. Subpart B also sets individual protection requirements that limit the amount of radiation to which an individual can be exposed from an undisturbed repository. Subpart B also provides assurance requirements that involve additional measures (e.g., monitoring, permanent markers, institutional controls) intended to provide confidence in the long-term containment of radioactive waste.
- Subpart C includes groundwater protection requirements that for 10,000 years after waste disposal, contamination in off-site underground sources of drinking water will not exceed the maximum contaminant level for radionuclides established by EPA under the Safe Drinking Water Act.

The relationship and application of 40 CFR Part 191 to the WIPP operations and post-closure phase are illustrated in Figure 2-5.

The 1996 National Research Council report *The Waste Isolation Pilot Plant: A Potential Solution for the Disposal of Transuranic Waste* states that EPA's 40 CFR Part 191 "is unique in that, in addition to regulations based on radiation dose, repository compliance also is based on *calculations of release fractions* of selected radionuclides" (NRC, 1996, p. 16, emphasis added). This containment requirement addresses the ability of a repository to isolate waste from the environment, without distinguishing releases that would lead to significant doses from those that would not. The specified release limits scale with the quantity of waste in a repository (i.e., the more disposed waste, the more radiation that may be released); for this reason, they are specified in terms of curies (Ci) that may be released per 10,000 years per 1,000 metric tons of heavy metal (MTHM). For a repository such as WIPP, which is designed for disposal of TRU wastes, EPA has established in 40 CFR Part 191 that 1,000 MTHM is equivalent to 1,000,000 Ci of TRU wastes with greater than 20-year half-lives (note that 1 MT of plutonium-239 contains approximately 63,000 Ci; see Box 2-1).

2.3.2.2 Criteria for the Certification and Recertification of WIPP's Compliance with the 40 CFR Part 191 Disposal Regulations (40 CFR Part 194)

In addition to the radioactive waste disposal standards in 40 CFR Part 191, EPA issued compliance criteria in 40 CFR Part 194. The criteria are used to guide the initial certification and subsequent recertification of WIPP's compliance with the final radioactive waste disposal standards of Part 191, and are divided into four subparts as described on the EPA website:[21]

- Subpart A contains useful definitions of terms, references, and reporting requirements for DOE, and describes EPA's authority to modify, suspend, or revoke certification or recertification.
- Subpart B specifies the content of applications and the procedure for submission.
- Subpart C consists of requirements for demonstrating compliance with EPA's disposal standards, as well as general requirements regarding quality assurance and the use of computer models to simulate WIPP's performance, for example.
- Subpart D describes the EPA process for public participation in certification and recertification decisions.

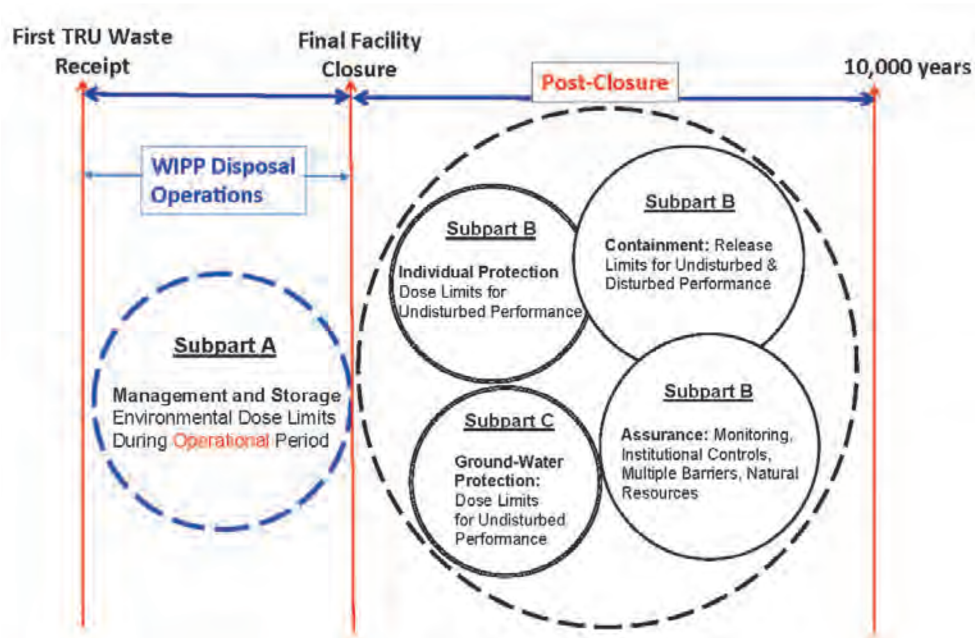


FIGURE 2-5 EPA Regulations in 40 CFR Part 191 diagramming the relationship among Subparts A, B, and C to operational (pre-closure) and post-closure periods. SOURCE: Basabilvazo, 2019, slide 5.

[21]See https://www.epa.gov/radiation/epas-role-waste-isolation-pilot-plant-wipp (accessed May 20, 2020).

2.3.2.3 New Mexico Environment Department's Role

Not all of the TRU waste bound for WIPP contains a hazardous component. However, a decision was made to manage all of the WIPP-bound and emplaced waste as mixed hazardous and radioactive waste and therefore subject to RCRA regulations.[22] The State of New Mexico is authorized by EPA to carry out the State's RCRA and mixed waste programs in lieu of the equivalent federal programs. NMED reviews permit applications for treatment, storage, and disposal facilities for hazardous waste, under Subtitle C of RCRA. In the case of the WIPP facility, it is defined as a "miscellaneous unit," and as such, NMED grants the WIPP Hazardous Waste Facility Permit (HWFP)[23] for such things as the maximum capacity of individual disposal panels (WIPP, 2018) or the more recent permit modification approval (NMED, 2018) regarding the TRU mixed waste disposal volume reporting (see Boxes 2-3 and 2-5). The HWFP has a 10-year term. The first permit renewal application was submitted to NMED in May 2009, and the NMED Secretary issued a final order granting the renewal of the WIPP HWFP, effective on December 30, 2010. The next permit renewal application is due to NMED in July 2020.[24] A draft WIPP Strategic Plan, released for public comment in August 2019, cites the need for new panels, presumably to accommodate future TRU waste and a 10-year reapplication to NMED for the HWFP to operate WIPP (DOE-CBFO, 2019b).

Note that EPA certifies continued compliance with disposal safety regulations every 5 years, and NMED issues a facility permit (to operate WIPP) every 10 years. The assumption of continued sustained operations for the next 20-30 years is subject to compliant operations and periodic regulatory review, both of which pose potential risks for consideration (see Chapter 5).

2.3.2.4 Relevant DOE Orders and Standards

In addition to 40 CFR Part 191, Subpart A reporting requirements applying during the operational phase, the WIPP facility operations are also subject to a number of DOE Orders and Standards for the annual preparation, review, and approval of safety basis documents. For example, DOE Standard, "Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities," compels the development of documented safety analyses and corresponding technical safety requirements (DOE, 2007). See, for example, "Waste Isolation Pilot Plant Documented Safety Analysis, Revision 6a" or "Waste Isolation Pilot Plant Technical Safety Requirements, Revision 6a" (Nuclear Waste Partnership, LLC, 2018a,b), which are usually prepared by the operator/contractor for WIPP, in this case Nuclear Waste Partnership LLC, which are ultimately reviewed and approved by DOE in a safety evaluation report (DOE, 2018a). For another example, see Box 2-6.

The committee considered the possible addition of DSP-TRU waste in the context of its potential effect on the demonstrations of regulatory compliance for the pre-closure and post-closure periods. Such considerations are elaborated in the following two sections. The committee reiterates from Chapter 1 that the evaluation provided below should not be construed as supplanting the regulatory function or influencing the determination of safety by regulatory bodies, but rather is intended to contribute to the objectives noted in the Statement of Task (see Box 1-1).

2.3.3 WIPP Pre-Closure/Disposal Operations Through Emplacement

The following activities are part of the operational phase at WIPP: the receipt at WIPP of the waste transporter (e.g., Transuranic Package Transporter Model 2 [TRUPACT-II] or HalfPACT; see Box 3-4); payload and container handling, and conveyance to and emplacement in the underground.

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[22]See https://www.epa.gov/rcra (accessed May 20, 2020).
[23]See https://www.env.nm.gov/hazardous-waste/wipp-permit-page (accessed May 20, 2020).
[24]New Mexico Administrative Code, http://164.64.110.134/parts/title20/20.004.0001.pdf (accessed May 20, 2020).

The WIPP waste acceptance criteria (WAC; DOE-CBFO, 2018c) places constraints on the physical, chemical, and radiological properties of TRU waste, as well as the properties of the applicable payload containers and packages, and summarizes the quality assurance requirements relating to waste characterization, certification, and transportation, as determined by WIPP's safety authorization basis and regulatory requirements. Waste is not approved for shipment to and disposal at WIPP until it has been certified as meeting these criteria. Within the WIPP safety basis documents for operations, the WIPP WAC is credited with reducing both the likelihood and consequences of adverse events.

2.3.4 WIPP Post-Closure Performance

The documents supporting the most recent 2019 WIPP CRA, for both operational and post-closure safety evaluations, were not available to the committee until its deliberations were substantially complete.[25] However, DOE provided the committee surrogate information supporting much of the same basis and, in April 2019, provided documents supporting the evaluation of post-closure performance with regard to criticality safety and compliance with containment standards per 40 CFR Part 191 (Saylor and Scaglione, 2018; Scaglione and Saylor, 2018; Zeitler et al., 2018).[26] The impact assessment (Zeitler et al., 2018) included the general chemical characteristics of the adulterant, which were included in the special inventory report produced by LANL specifically for this analysis (LANL, 2017).

BOX 2-5 The New Mexico Environment Department's Approval of Permit Modification Requests for WIPP

The State of New Mexico, through NMED, regulates the hazardous waste at WIPP (all waste received at WIPP is managed as hazardous) and permits the WIPP facility and its operation. New Mexico and NMED do not have the authority to regulate the radiological aspects of the waste at WIPP, but in most other respects, the continued operation of WIPP is contingent on the favorable permitting issued by NMED.

WIPP permit modification requests (PMRs) and their class determination are governed by 40 CFR § 270.42 (Permit modification at the request of the permittee). Appendix I of the regulation specifies a number of possible permit modification and their classification, but in general:

- Class 1 modifications are for changes that are largely administrative in nature.
- Class 2 modifications apply to changes that are necessary to enable a permittee to respond, in a timely manner, to common variations in the types and quantities of the wastes managed under the facility permit.
- Class 3 modifications substantially alter the facility or its operation.

Each class of modification carries specific requirements for the level of detail, schedules, appeals, etc. and, importantly, the expectations for public notice and public hearing. Class 3 PMRs allow for greater public involvement and hearing of concerns and a longer review period than Class 1 or 2 requests. The volume of record permit modification request submitted by DOE-CBFO to NMED was submitted as Class 2 PMRs, which was subsequently upgraded to Class 3 PMRs and ultimately approved by NMED (see Box 2-3).

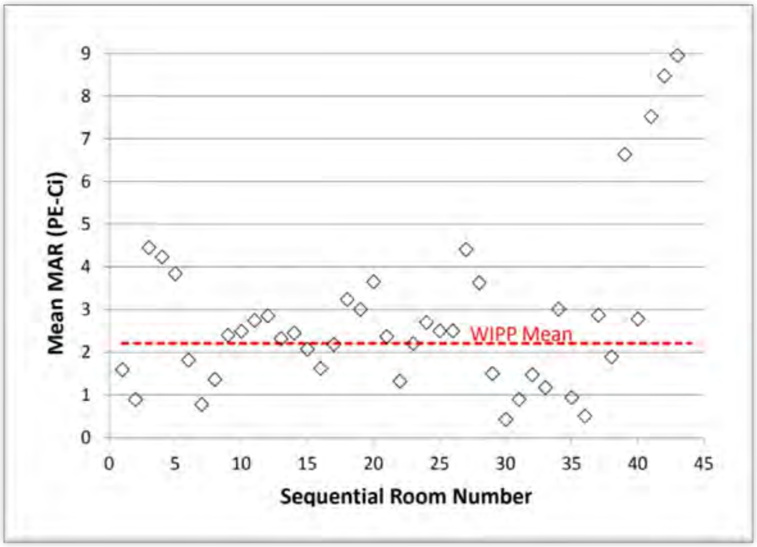
[25]The preparation and delivery of the anticipated March 2019 Compliance Recertification Application (CRA) by DOE-CBFO to EPA has been affected by the 2014 WIPP accident and subsequent recovery efforts; consequently, portions of the application are deferred (DOE-CBFO, 2017a). Notably the post-closure performance assessment calculations were deferred but are now available.

[26]As noted by Zeitler et al. (2018, p. 13), "The analysis is not in support of a planned change request (PCR) or planned change notice (PCN) to be submitted by the DOE to the EPA, and was not performed as a compliance calculation. Instead, the planned use of the analysis is as input into a National Environmental Policy Act (NEPA) analysis."

BOX 2-6 Importance of Documented Safety Analysis and Corresponding Safety Evaluation Report

The Defense Nuclear Facilities Safety Board (DNFSB), whose mission[a] is to provide independent technical advice to the Secretary of Energy, recently issued a report that reviewed and provided advice related to specific deficiencies and weaknesses in Department of Energy Standard 5506-2007, Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities (DNFSB, 2018).

DNFSB's report raised several concerns about possible deficiencies and which could have bearing on the operational safety management for criticality control overpack (CCO) containers. DNFSB noted concerns with the statistical application of the *material at risk* (MAR) methodology that could lead to nonconservative decisions when developing safety bases. Furthermore, the DNFSB noted that while the DOE-STD-5506-2007 MAR methodology can be accepted for waste containers prepared in accordance with the WIPP WAC, the standard also cautions that "attention should be given to whether the scope of container activities could unintentionally concentrate problematic containers, thereby invalidating the MAR methodology" (DOE, 2007, p. 23). To this point, the DNFSB staff evaluated how the quantity (density) of MAR in 55-gallon drums varies within the underground at WIPP, and noted that the mean MAR per disposal room varies considerably (see Box Figure 1).



BOX FIGURE 1 Variation of mean MAR among rooms at WIPP. SOURCE: DNFSB, 2018, fig. 2.

DNFSB's staff concluded that the variability in MAR per room is not random statistical variation and suggested that bias associated with individual waste transfer campaigns from different sources contributed to the variation, calling into question the conservatism of the statistical MAR methodology.[b] The committee notes that this "transfer campaign bias" could be aggravated with the addition of a single waste stream of more than 160,000 containers of DSP-TRU waste over a 30-year campaign, exacerbating concerns over the lack of conservatism in MAR methodology. However, DSP-TRU wastes were not included in DNFSB's review.

The DNFSB staff summarized that "[e]valuation of postulated scenarios in the WIPP DSA using the statistical MAR methodology indicates a likelihood that clusters of problematic containers exist, which would result in higher source terms (i.e., more severe releases with higher consequences) than those analyzed scenarios" (DNFSB, 2018, p. 3-6). The DNFSB concluded that "if the statistical MAR methodology outlined in DOE Standard 5506-2007 continued to be employed in the accident analysis without further administrative controls, there would be a high likelihood that future waste operations would unintentionally concentrate problematic waste containers and create the potential for accidents with higher consequences than those analyzed in the draft DSA" (DNFSB, 2018, p. 3-5).

DNFSB reported that DOE and the WIPP contractor, Nuclear Waste Partnership LLC, cryptically responded that it had "established a key element in the DSA to protect key analytical assumptions associated with the MAR statistics used in the accident analysis" (DNFSB, 2018, p. 3-6).

[a]See https://www.dnfsb.gov/about/mission (accessed February 22, 2020).
[b]See, for example, the shipping campaign from Idaho National Laboratory (Hedden, 2019).

As noted in Box 2-3, the post-closure phase begins once the facility is no longer receiving waste and is in its final configuration (i.e., shafts are closed and sealed). In this post-closure context, the safety and performance of the disposal facility are provided primarily by passive means inherent in the characteristics of the site and the decommissioned facility (i.e., shaft seals) and in the characteristics of the waste and waste package collectively to provide for long-term containment and isolation from the accessible environment.

2.3.5 Principal Post-Closure Safety and Performance Criteria

The principal waste disposal regulations regarding the WIPP post-closure period are provided by 40 CFR Part 191, Subparts B and C, with the WIPP Compliance Criteria at 40 CFR Part 194. The post-closure performance criteria for WIPP are set forth in the containment requirements of 40 CFR § 191.13, which sets normalized standards for cumulative radionuclide releases to the accessible environment assessed over 10,000 years. Containment standards with normalized releases are distinct from more common radiation protection standards based on dose limits. Unlike regulation of other geologic repositories now under development elsewhere in the world, WIPP is unique in its use of containment standards with normalized releases (NRC, 1996). The 40 CFR § 191.13 containment requirements applicable to WIPP allow radionuclide releases *in proportion to the total radioactivity of the disposed inventory*. In other words, the more radioactivity is contained in the repository, the more radioactivity can be released. In contrast, a repository with a dose-based radiation protection standard would limit the total inventory of the repository based on the calculated doses from radioactive species that escape containment.

For a description of the manner in which the containment requirements are evaluated, see below.

2.3.5.1 Compliance Application and Certification

DOE-CBFO demonstrates compliance with the containment requirements according to the Compliance Criteria in 40 CFR Part 194 by means of PA calculations performed by Sandia National Laboratories. WIPP PA calculations estimate the probability of potential radionuclide releases from the repository to the accessible environment for a regulatory period of 10,000 years after facility closure, presently assumed as 2033 (Brunnel, 2019, p. 9). In the context of the 10,000-year regulatory containment requirement, note that the half-life of plutonium-239, a major component of the DSP-TRU waste inventory, is 24,110 years. See Box 2-1.

Via the WIPP Land Withdrawal Act, Congress required EPA to certify that WIPP complies with the waste disposal regulations of 40 CFR Part 191, Subparts B and C, as well as the WIPP Compliance Criteria of 40 CFR Part 194. Congress also required EPA to recertify the facility every 5 years following the initial receipt of transuranic waste until the end of its operational activities.

EPA describes the recertification as "a process that evaluates changes at WIPP to determine whether the facility continues to meet all the requirements of EPA's disposal regulations. The recertification process helps ensure WIPP's continued compliance based on the most accurate, up-to-date information available" (EPA, 2019). The recertification process verifies that changes in the WIPP facility configuration based on the waste emplaced in the preceding 5-year period and the projected inventory comply with EPA's disposal standards for radioactive waste.

As a baseline, EPA initially certified WIPP on May 13, 1998, and WIPP first received TRU waste on March 26, 1999. DOE subsequently submitted applications for recertification in March 2004, 2009, 2014, and 2019. EPA has officially recertified the WIPP facility, confirming that it continues to comply with the agency's radioactive waste disposal regulations as described above. In each case, EPA and others have raised technical concerns over various model and parameter issues used in the PA.[27] Throughout and

[27]Note that each iteration adds further complexity to the baseline code.

between recertifications, DOE-CBFO has worked to address those concerns, and its resolutions are reflected in the subsequent recertification applications; additionally, DOE-CBFO addresses technical concerns without waiting for the next recertification.[28]

2.3.5.2 Performance Assessment Inventories: The ATWIR and the PAIR

DOE-CBFO compiles an Annual Transuranic Waste Inventory Report (ATWIR) to document the forward-looking inventory estimate of TRU waste reported by the TRU waste generator sites as of December 31 of the prior year. TRU waste generator sites are asked to report the most comprehensive TRU inventory estimate available, including decontamination and decommissioning waste and all other defense-related TRU waste information projected through the presumed WIPP closure date and additional estimates beyond then, if available. The 2018 ATWIR "will provide the basis for the Performance Assessment Inventory Report for development of the 2019 Compliance Recertification Application (CRA) deferred performance assessment (PA)" and "focuses on all TRU waste stored or projected to be generated through CY 2033 at the TRU waste generator sites in order to reflect the WIPP facility closure date for the CRA-2019 deferred PA" (DOE-CBFO, 2018a, p. 9).

ATWIR waste streams are designated as either *WIPP-bound* (appear to meet the requirements for emplacement in WIPP) or *Potential* (have one or more criteria-related issues to be resolved) and include estimates for TRU waste volume, radioactivity, waste material parameters, packaging materials, complexing agents, oxyanions, and radionuclides. *Emplaced* waste is derived from the Waste Data System, the official database of record for waste already emplaced in WIPP and merged with the ATWIR inventory to create a Comprehensive Inventory Database.

An example of a waste stream moving from *Potential* to *WIPP-bound* that is important to the committee's analysis is the waste stream from the 6 MT of non-pit plutonium material. The 2016 ROD for the 6 MT allowed that plutonium waste stream to move from *Potential* to *WIPP-bound*. The timing was such that the DSP-TRU waste associated with the 6 MT of non-pit plutonium was not included in EPA's 2014 compliance recertification. This amount has been included, for the first time officially assessing the impact of some of the DSP-TRU waste in WIPP, in the 2019 CRA. Subsequent recertification applications can be expected to include additional fractions of the total DSP-TRU inventory, for example, in response to relevant RODs that may be issued.

The ATWIR information is used for strategic planning and supports DOE input into, for example, WIPP documented safety analysis, and in appropriate years provides the basis for the Performance Assessment Inventory Report (PAIR) for development of the Compliance Recertification Application (LANL, 2012).

The PAIR compiles the inventory of *Emplaced* waste with the inventory identified as *WIPP-bound*, and is used principally as the inventory basis (waste container volume and waste characteristics) for the corresponding PA. If the total inventory volumes in the PAIR compilation are less than the legislated capacity (i.e., 175,564 m^3 total TRU waste) then the inventory values are artificially increased (scaled) in

[28]Information on subsequent compliance recertification applications by DOE-CBFO and compliance decisions by EPA (2019) may be found for the following:

- 2014-2017 Compliance Recertification (https://www.epa.gov/radiation/certification-and-recertification-wipp#2014, accessed March 23, 2020).
- 2009-2010 Compliance Recertification (https://www.epa.gov/radiation/certification-and-recertification-wipp#2009-2010, accessed March 23, 2020).
- 2004-2006 Compliance Recertification (https://www.epa.gov/radiation/certification-and-recertification-wipp#2004-2006, accessed March 23, 2020).
- 1998 Compliance Certification (https://www.epa.gov/radiation/wipp-1998-compliance-certification-documents, accessed March 23, 2020).

order to simulate a "full" repository, as the PA explicitly assumes that WIPP is filled to its legislated capacity at time of closure, as required in 40 CFR § 194.24.[29]

2.3.5.3 Post-Closure Performance Assessment Analyses

In addition to using the PA calculations for the CRAs, PAs may also be used for sensitivity studies in support of, for example, DOE-NNSA's efforts to comply with NEPA-driven environmental assessments or environmental impact statements on proposed actions. This was the case with the 2016 ROD for DOE-EM's 6 MT, which reportedly relied on a WIPP PA analysis in support of the DOE Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement (DOE, 2015a).

2.3.6 Post-Closure Criticality Safety Analysis

As described in more detail later in the report, the surplus plutonium waste form is targeted for packaging in the CCC, which itself is nested within a CCO; see Figure 3-4), which as the name suggests, is designed to safely maintain subcriticality, particularly during the transport and disposal operation phases at WIPP (Washington TRU Solutions, 2008). This safety basis should remain as long as the CCC retains its physical configuration (i.e., the inner can does not sustain damage). Once all the waste is emplaced underground at the end of disposal operations, the post-closure phase begins. The disposal room will eventually close, as the salt creeps around the waste as intended, and this will ultimately damage the waste containers. This needs to be factored in when assessing whether the plutonium mass might someday be reconfigured in a way that could lead to an accidental criticality (see Figure 2-6).

For the post-closure PA at WIPP, the analysis of features, events, and processes (FEP), including those regarding nuclear criticality, is governed by 40 CFR Parts 191 and 194, which allow an FEP to be screened out from incorporation in the PA on either a low-consequence or low-probability rationale. A low-probability rationale includes either a qualitative rationale that the FEP is not credible, or a quantitative demonstration that the probability is less than 10^{-4} in 10,000 years. In prior years, with waste streams anticipated at the time having generally more dispersed fissile material, the issue of potential criticality was routinely screened out as mechanisms to concentrate fissile radioisotopes dispersed throughout the waste were considered absent (e.g., Rechard et al., 2000). Later in the report, the committee explores and reviews the post-closure criticality analysis which includes the diluted surplus plutonium waste streams (see Chapter 5).

FIGURE 2-6 Evolution of emplaced waste and salt creep in WIPP for emplaced TRU waste packages, simulation of 0, 10-15, and 1,000 years (Hansen, 2009). SOURCE: Image provided by Sandia National Laboratories.

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[29]PA scaling has assumed a distribution of 168,485 m^3 CH-TRU and 7,079 m^3 RH-TRU. Under the volume accounting for the TMW volume, it is likely that the CH TMW volume will be greater than the CH LWA volume of 168,485 m^3.

2.4 OVERVIEW OF RISK ASSESSMENT

This section briefly describes the different types of risk considered by the dilute and dispose plan and within this report. Specific risks are explored by the committee in greater detail in key sections of the report, for example, in the committee analysis related to scale-up of operations and transportation.

There is no single definition of "risk," considering the multiple disciplines it spans including public health, environmental science, design and engineering, business, law, and many others. For example, the Society for Risk Analysis found more than two dozen definitions for risk in the literature (Lowrance, 1972; Greenberg et al., 2012; Haimes, 2016). While there is no single definition, for purposes of this dilute and dispose report, which is heavily focused on human health, costs, schedule, and diversion or theft of material, we define risk as a measure of the probability and severity of consequences (Lowrance, 1972; Greenberg et al., 2012; Haimes, 2016).

2.4.1 Human Health, Safety, and Ecological Risks

The field of risk assessment emerged from concerns about human health and safety that had become major public policy issues in the 1970s. Three well-known applications of the risk concept were to chemical carcinogens, nuclear power plants, and hazardous waste management. These early applications focused on human health and safety with researchers defining three risk assessment and three risk management questions. By no means do these six questions represent a universally accepted consensus. Others have as few as four and up to a dozen questions and subquestions (Greenberg et al., 2012; Haimes, 2016).

Risk assessment:

(1) What can go wrong? (hazard event);
(2) What are the chances that something with serious consequences will go wrong? (likelihood); and
(3) What are the consequences if something does go wrong? (consequence).

Risk management:

(1) How can consequences be prevented or reduced? (prevention);
(2) How can recovery be enhanced, if the event occurs? (resilience); and
(3) How can officials, expert staff, and the public organize and be informed to reduce risk and concern and increase trust and confidence? (organization).

PA is a version of human health-and-safety-oriented risk analysis used by designers who are called upon to demonstrate that a facility or structure is able to withstand stresses and contain material over a required lifespan. DOE's PAs at WIPP represent among the most important and challenging applications insofar as DOE must demonstrate the effectiveness of geological and engineered barriers to prevent movement of hazards from a contained environment to an open one that could expose people and the environment over a 10,000-year period. To address these requirements, analysts have used deterministic simulations to drive the process and added probability tools to simulate epistemic (knowledge-related) and aleatory (time-related) uncertainty (Helton, 1994; Helton et al., 1999; Society for Risk Analysis, 1999).

The PA's parallel in traditional risk assessment is a "level 3 probabilistic risk assessment," which is a multistage analytical process that begins with identifying hazard events and ends with an estimate of human health and safety risks in the environment. For example, when DOE-NNSA was considering the MOX fuel option, it used a level 3 PRA to compare the human health consequences of design-basis and beyond-design-basis accidents with normal nuclear fuel and a combination of MOX and normal uranium fuel (DOE, 2015c, Appendix J).

2.4.2 Economic Risks and Opportunities

Economic risk and opportunity analysis focuses primarily on costs. Human health and safety risks are or should be part of cost considerations but are not explicitly calculated (Epstein and Rejc Buhovac, 2005; World Bank, 2013; Stebbins-Wheelock and Turgeon, 2018). The essence of an economic risk and opportunity analysis is to sort through many options to find those with the lowest level of economic risk and highest level of economic opportunity, and then narrow down the list to an affordable and manageable set of priorities so one can most effectively invest to reduce economic risks and increase economic benefits. A common business example in the early 21st century is that many manufacturers are reluctant to invest in major new facilities because of the health, ecological, regulatory, and community challenges involved. Instead of building entirely new facilities, many are increasing capacity by adding on to existing sites and at the same time upgrading the technology of existing facilities so that they represent the latest, cleanest, most efficient, most reliable, and safest technology. Those steps are made to reduce both human health and economic risks (Greenberg, 2018; Kunreuther and Isseem, 2018).

Traditional risk analysis, PA, and risk and opportunity analysis share and face many major challenges with traditional analyses. Two of the many major challenges are discussed here. First, each requires likelihood estimates (hence Bayesian Monte Carlo simulation is a component of applications of the dilute and dispose option). Second, the complexity of these applications poses a challenge to those charged with explaining these risks to a diverse set of audiences.

As discussed above, the dilute and dispose project has international implications for the surplus plutonium management as well as political, legal, and social challenges for the states and local governments that are origination and destination points for the plutonium (such as New Mexico, where the DSP-TRU waste will be disposed, and South Carolina, where it will be processed). These challenges along with risks to human health, safety, and diversion and theft of material are discussed in the chapters that follow.

3

Plans to Dilute and Dispose

This chapter describes the Department of Energy's National Nuclear Security Administration's (DOE-NNSA's) conceptual plan to dilute and dispose of surplus plutonium material as transuranic (TRU) waste in the Waste Isolation Pilot Plant (WIPP). The plan is described by key locations throughout the DOE complex (Pantex, Los Alamos National Laboratory [LANL], Savannah River Site [SRS], and WIPP) and activities including transportation between the sites. Plans for scaling up operations and DOE-identified risks are presented. Analogous plans, developed by DOE's Office of Environmental Management (DOE-EM), for downblending (i.e., diluting) and disposing of up to 6 MT of surplus non-pit plutonium in WIPP are also described.[1]

The committee received a set of documents and several briefings from DOE-NNSA that describe its plans to dilute and dispose of 34 metric tons (MT) of surplus plutonium material. The list of documents shown in Table 3-1 is part of a larger set of DOE-NNSA's Life-Cycle Cost Estimate documents (SRNS, 2018a).[2] Several documents in Table 3-1 were updated from those that the committee had available when it released its Interim Report, and other documents were new to the committee. For example, the system plan was updated; risk-based documents, the Risk and Opportunity Management Plan (ROMP; SRNS, 2018d) and the Risk and Opportunity Analysis Report (ROAR; SRNS, 2018e), were new to the committee as were analysis reports of criticality (Saylor and Scaglione, 2018) and initial performance assessment with the added diluted surplus plutonium transuranic (DSP-TRU) waste streams (Zeitler et al., 2018).

The scope and overview of DOE-NNSA's dilute and dispose plan are described below. Any differences between this description of the dilute and dispose plan and the one provided in the Interim Report are noted.

3.1 CURRENT STATUS OF DOE-NNSA's DILUTE AND DISPOSE PLANNING EFFORT

DOE-NNSA began planning for the dilute and dispose process in 2016, following the completion of a DOE-led Red Team review of alternative options to the mixed oxide (MOX) plan (Mason, 2015; see Box 3-1). A high level schedule of DOE-NNSA's dilute and dispose plan is shown in Figure 3-1.

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[1]As used by different offices within DOE, the terms "downblend" and "dilute" are synonymous and describe the process for mixing surplus plutonium with an adulterant to ensure that plutonium "is not recoverable without extensive reprocessing." DOE notes in its Surplus Plutonium Disposition System Plan that "[t]he term dilution is the international nomenclature for using an adulterant to provide proliferation resistance and is in no way intended to avoid any applicable regulatory requirements" (SRNS, 2016, p. 8). The committee has chosen to use the terms "dilute" or "dilution" throughout this report, even when referring to DOE-EM plans and activities.

[2]DOE-NNSA's dilute and dispose documents that are not releasable to the public were not shared with the committee. For example, DOE-NNSA's planning documents that contain proprietary or pre-decisional information could not be shared with the committee. Information and data gathered throughout a National Academies consensus study are made available to the public based on Federal Advisory Committee Act Section 15 requirements. For access to the publicly available documents used by the committee, contact the National Academies' Public Access Records Office (PARO) at paro@nas.edu.

TABLE 3-1 Set of DOE-NNSA Planning Documents for the Dilute and Dispose Program That Were Available to the Committee and Referenced Throughout This Chapter

Authoring Organization	Report Title
U.S. Army Corps of Engineers	Independent Validation of GAO Compliance of Life-Cycle Cost Estimate (LCCE) for Surplus Plutonium Disposition (SPD) Program Dilute and Dispose Approach
National Nuclear Security Administration (DOE-NNSA) and Savannah River Nuclear Solutions (SRNS)	Surplus Plutonium Disposition Program Dilute and Dispose Approach Life Cycle Cost Estimate Summary Report [SRNS-RP-2018-00570, Revision 0]
DOE-NNSA, Material Management and Minimization (M^3)	Material Management and Minimization - Surplus Plutonium Disposition Program Requirements Document for the Proposed Dilute and Dispose Approach [M3-SR-16-0009, Revision 1] (Cleansed)
DOE-NNSA and SRNS	Surplus Plutonium Disposition - Technical Baseline Description for the Proposed Dilute and Dispose Approach [SRNS-TR-2016-00285, Revision 1]
DOE-NNSA and SRNS	Surplus Plutonium Disposition - System Plan for the Proposed Dilute and Dispose Approach [SRNS-TR-2016-00136, Revision 1]
DOE-NNSA and SRNS	Surplus Plutonium Disposition Program Technology Readiness Assessment [SRNS-TR-2016-00295, Revision 1]
DOE-NNSA, M^3	Surplus Pu Disposition Master Summary Schedule
DOE-NNSA and SRNS	Risk and Opportunity Management Plan for the National Nuclear Security Administration Surplus Plutonium Disposition Program Dilute and Dispose Approach [ROMP, Y-RMP-G-00023, Revision 1]
DOE-NNSA and SRNS	Surplus Plutonium Disposition Program Dilute and Dispose Approach Risk and Opportunity Analysis Report [ROAR, Y-RAR-G-00064, Revision 1]
DOE-NNSA, M^3	NEPA Timeline / Summary (NAS milestones)
Zeitler, Todd R., et al.; Sandia National Laboratories	Sandia National Laboratories Waste Isolation Pilot Plant: Summary Report for Surplus Plutonium Disposition Analysis Revision 1 [SAND2019-2307 O]
Saylor, E. M., and J. M. Scaglione	Nuclear Criticality Safety Assessment of Potential Plutonium Disposition at the Waste Isolation Pilot Plant [ORNL/TM-2017/751/R1]
Scaglione, J. M., and E. M. Saylor	Summary of US Surplus Weapons-Usable Plutonium WIPP Postclosure Criticality Analysis

NOTES: All documents listed are available for public access. Savannah River Nuclear Solutions is a contractor that reports to DOE.

BOX 3-1 Red Team and Independent Reviews of MOX Alternatives

Following a 2014 report issued by a DOE working group created to identify more cost-effective alternatives to the MOX approach (DOE, 2014), an independent 2015 DOE Red Team review compared the MOX option to the dilute and dispose option and concluded that the latter process was technically viable and could be implemented at about half the cost of the former process (Mason, 2015). The Red Team also concluded in its executive summary that the "[economic] risks associated with the Dilute and Dispose option are far lower than the MOX approach, since both the technology and the disposition process associated with Dilute and Dispose are far simpler" (Mason, 2015, p. xi).[a] The review also identified regulatory and other issues, including WIPP capacity, that "are not insurmountable" but should be addressed as early as possible during the planning phase. Neither report considered the no-action alternative; the focus of both studies was to assess disposition alternatives relative to MOX.

[a]The type of risk quoted refers to the assessment of programmatic and technical risks (see Mason, 2015, p. 34, for more discussion).

DOE-NNSA's planning effort is being managed under DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets, and has passed Critical Decision 0 (CD-0), Approve Mission Need; CD-1 in late 2019, which marked the completion of the project definition phase and the conceptual design (DOE, 2010, p. A-6, table 2.1); and CD-3A, in mid-February 2020 to allow for specific construction activities to begin (DOE, 2010).[3] DOE-NNSA currently estimates that the effort to dilute and dispose of 34 MT of surplus plutonium will cost $18.2 billion (in then-year dollars) and take 31 years to complete, beginning with conceptual design in 2018 and ending with emplacement of all 34 MT of DSP-TRU waste in WIPP in 2049 (DOE, 2018b).[4]

The process outlined in the National Environmental Policy Act (NEPA) requires DOE-NNSA to obtain public comments and inputs on decisions and actions. The NEPA plans for dilute and dispose were presented in April 2019 to the committee (Richard, 2019). A notice of intent was expected to be issued in late 2019, but as of the writing of this report in early 2020, it had not yet been issued. A final environmental impact statement (EIS) was expected in mid-FY 2020, although this date appears unlikely (see Figure 3-1; an updated schedule was not available to the committee). The committee has not yet seen a detailed NEPA strategy for the conceptual plan or details on what constitutes a final EIS. Also shown in Figure 3-1 is the duration of the dilute and dispose process. The committee provides recommendations related to NEPA in Chapter 5.

3.2 SCOPE AND PLAN OVERVIEW

The goal of DOE-NNSA's dilute and dispose program is defined in the project's System Plan: "to plan and execute the disposition of 34 MT of surplus weapons-usable plutonium consistent with United States (U.S.) nuclear nonproliferation policies in a cost-effective manner" (SRNS, 2018c, p. 8). DOE-NNSA's Defense Nuclear Nonproliferation office is managing the dilute and dispose project and is focused on the disposition of 34 MT of surplus plutonium. However, the amount of diluted surplus plutonium material that is under consideration for dilution and disposal in WIPP is as large as 48.2 MT (see Figure 2-1). The 48.2 MT consists of up to 42.2 MT being managed by DOE-NNSA (34 + 7.1 + 1.1 MT) and 6 MT from DOE-EM for which there is a Record of Decision issued (DOE, 2016a; LANL, 2017).

[3]Order 413.3B outlines an internal DOE process for reviewing and approving large acquisition programs through Critical Decision milestones. After reaching CD-0, DOE program managers may proceed with conceptual planning. See discussion in Chapter 2 and DOE (2010, p. A-5, table 2.0).

[4]First emplacements of diluted non-pit plutonium and pit plutonium as DSP-TRU waste in WIPP are fiscal year (FY) 2023 and FY 2028, respectively (see Figure 3-1). Recall that the cost estimates were developed in FY 2017 dollars and converted to then-year dollars using escalation rates found in DOE (2018b).

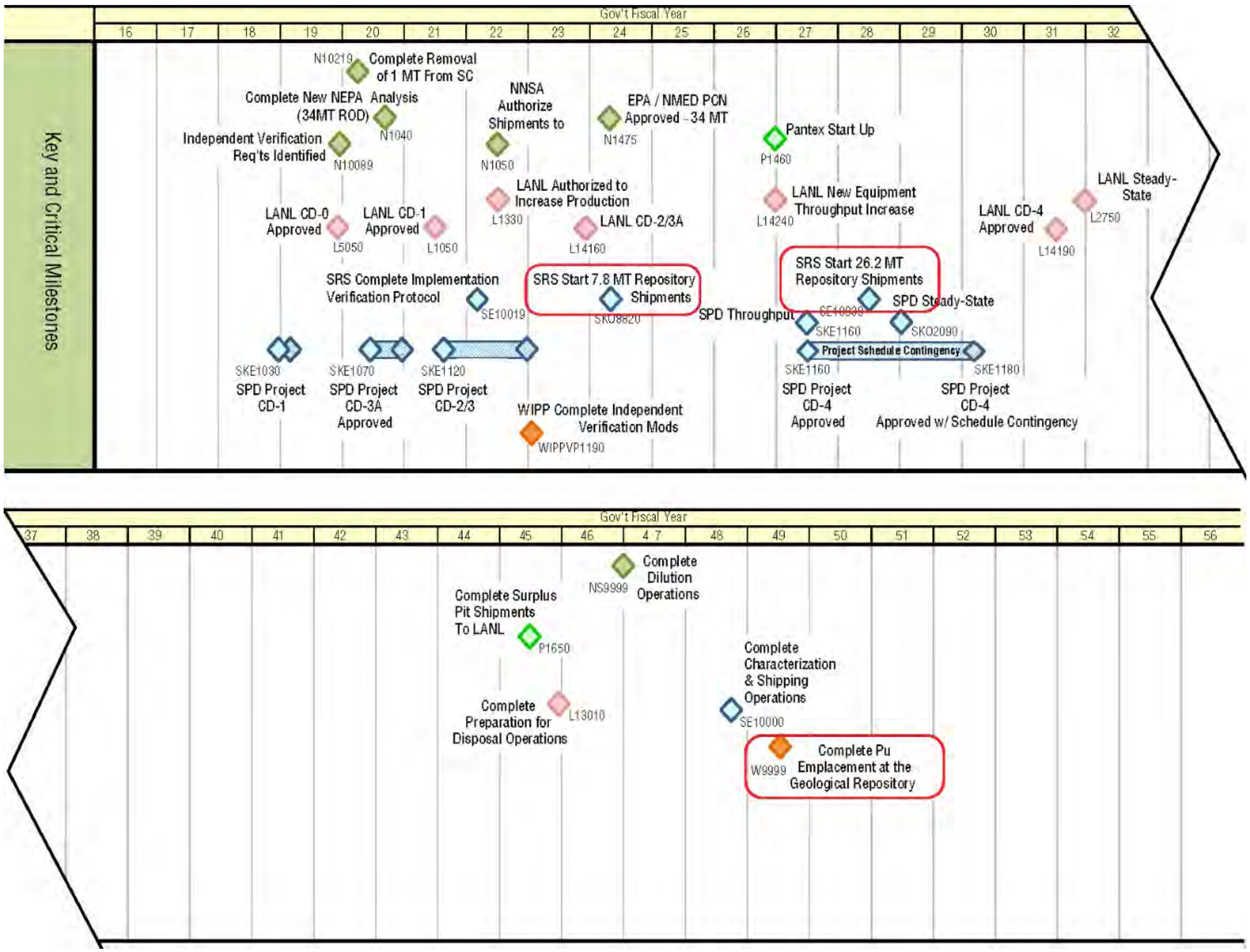

FIGURE 3-1 Key and critical milestones for the dilute and dispose conceptual plan, dated June 7, 2018. Red rectangles highlight the start of emplacement of the 7.8 MT diluted surplus non-pit plutonium TRU waste (FY 2024), the 26.2 MT of diluted surplus pit plutonium (FY 2028), and the end date (FY 2049). There are no key or critical milestones between FY 2033 and FY 2037, and these years are excluded from the figure. SOURCE: Modified from the DOE Master Schedule, available by request through the National Academies' Public Access Records Office at paro@nas.edu. Image provided by the Department of Energy.

As noted below, DOE-NNSA's plans for dilution and disposal are based on DOE-EM's current work on the 6 MT. In the committee's analysis below, 48.2 MT will be used when considering the full impact of emplacing DSP-TRU waste in WIPP.

DOE-NNSA's general plan and process steps are outlined in the System Plan (SRNS, 2018c) and are described below with the key process steps shown in a simplified process flow diagram in Figure 3-2. DOE-NNSA's dilute and dispose plans make use of other existing plans and processes to reduce both costs and risk. For example, all of the transportation within the conceptual plan will make use of existing federal transportation programs: DOE's Office of Secure Transportation (DOE-OST) and Carlsbad Field Office (DOE-CBFO) TRU Waste Transportation program. Similarly, the pit management, disassembly, and oxidation processes were originally developed for the MOX approach, and these steps have been reviewed for critical risks.

After the plutonium oxide material reaches SRS, it will follow a process path developed by DOE-EM to address the processing and disposing of up to 6 MT of surplus non-pit plutonium material, some of which is currently stored at SRS (DOE, 2016a). The committee was told that DOE-NNSA's plans for dilution and disposal (process steps C through E in Figure 3-2) were identical to DOE-EM's process steps for its 6 MT of material and that the two DOE offices will share resources and infrastructure.[5] Once the DSP-TRU waste has been packaged, characterized, and determined to meet the WIPP waste acceptance criteria, it becomes approved for inclusion in payloads and awaits shipment to WIPP. For nuclear material control and accountability (MC&A) purposes, the diluted plutonium waste product is tracked as material until it is loaded into a TRUPACT-II for shipment to WIPP.[6]

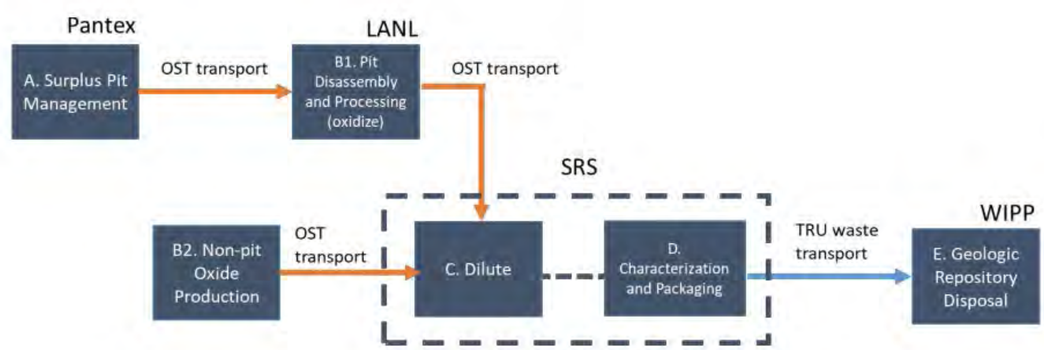

FIGURE 3-2 Simplified process diagram for dilute and dispose. Four locations are shown: (A) Pantex in Texas, where the surplus plutonium pits, a total of 26.2 metric tons (MT), are stored until they are ready to be processed; (B1) Los Alamos National Laboratory (LANL) in New Mexico, where the pits are disassembled and the plutonium material is oxidized; (C) and (D) Savannah River Site (SRS) in South Carolina, where the oxidized plutonium material is diluted with a classified adulterant, packaged, characterized, and if determined to meet the WIPP waste acceptance criteria, it becomes approved for inclusion in payloads and awaits shipment to WIPP via TRU Waste Transport; and (E) the Waste Isolation Pilot Plant (WIPP) in New Mexico, where the diluted plutonium TRU waste is emplaced. A total of 7.8 MT of surplus non-pit plutonium is oxidized at either LANL or SRS (B2). Methods of transportation between the sites are indicated with arrows (Office of Secure Transportation [OST], orange, and TRU waste transport, light blue). SOURCE: Modified from SRNS, 2018c, fig. 2. Image provided by the Department of Energy.

[5]Based on the documents received by the committee, there is not an integrated schedule that includes the downblending (dilution) and disposal of the 6 MT of surplus plutonium material being managed by DOE-EM. Also, DOE-EM's work on downblending (dilution) and disposal does not fall under DOE Order 413.3B (as does DOE-NNSA's plan) as it is an ongoing operation. Therefore, there are no critical decision milestones required to conduct the 6 MT program (see DOE-EM and DOE-NNSA responses to the committee's questions, February 19, 2020, available by request through the National Academies' Public Access Records Office at paro@nas.edu).

[6]See DOE-EM and DOE-NNSA responses to the committee's questions, February 19, 2020. Available by request through the National Academies' Public Access Records Office at paro@nas.edu.

All of the individual processes described above have been conducted and exercised by DOE (see Figure 4-1 for a schematic of the process steps and DOE programs from which they are modeled). However, the end-to-end process as described in the DOE-NNSA dilute and dispose plan has not been exercised. Additionally, some of the important process steps have not been demonstrated at levels or rates even remotely approaching the throughput proposed by the dilute and dispose plan. The committee reviews the processing steps below and highlights several risks from scaling up to meet the plan's milestones.

3.2.1 Dilute and Dispose Scaling-Up Plans

As shown on Figure 3-2, there are four locations in which different activities and processes take place. Each of the high level processes and DOE-NNSA's plans to scale up to meet the plan's goals at each site are described. Additional details are available in the documents listed in Table 3-1.

3.2.1.1 Pantex Operations

DOE-NNSA's dilute and dispose activities at Pantex are related to the 26.2 MT of surplus plutonium pits, which are currently stored there. Activities include retrieving, storing, and staging the pit containers; shipping the containers to LANL; and monitoring conditions for safety and accountability (see Figure 3-2, process steps A to B1). The pits will be shipped from the Pantex Plant to LANL via OST (see Section 3.3.2 for details on OST). These steps are similar to those designed for the MOX option. Staffing is expected to increase from a baseline of 18-22 persons to 30-42 persons during sustained operations for the dilute and dispose program. Efficiencies are expected to be gained through the use of new containers, which are under development and expected to be ready for the start of DOE-NNSA's program.

3.2.1.2 ARIES at LANL

The LANL operations described in DOE-NNSA's dilute and dispose plan consist of receiving pits from Pantex, storage and staging, size reduction to particles, thermal oxidation of particles, packaging, storage, staging, and shipping to SRS, with monitoring throughout (see Figure 3-2, process step B1). The size reduction and oxidation processes are conducted in the Advanced Recovery and Integration Extraction System (ARIES). ARIES was originally designed to demonstrate, at a pilot level, that pits could be safely and securely disassembled and oxidized in support of the MOX plan (Dillingham, 2012). ARIES is located in the Plutonium Facility at Technical Area 55, also referred to as "PF-4," at LANL. Notably, this is the same facility in which DOE-NNSA has committed to increased pit production by 2030.

The non-pit oxide production step will process a total of 7.8 MT of surplus non-pit plutonium stored in different DOE sites (see Figure 3-2, process step B2). At this time, DOE-NNSA has not decided how much if any of the 7.8 MT of surplus non-pit plutonium material will be shipped to LANL or to SRS for oxidation (SRNS, 2018c, p. 21).

ARIES rates of disassembly and oxidation were obtained from the Office of Cost Estimating and Program Evaluation (DOE-CEPE) independent review of DOE-NNSA's Life-Cycle Cost Estimate (LCCE) plan. The DOE-CEPE report shows a current rate of plutonium oxide production of 100 kilograms per year (kg/yr), ramping up to 1,117 kg/yr between FY 2022 and FY 2023 (DOE, 2018b, p. 5).[7] Staffing increases from an 82-person baseline to 296 persons during maximum sustained operations (DOE, 2018b). DOE-NNSA's ROAR identified equipment failures in the disassembly and oxidation steps as one of the highest risks for the dilute and dispose plan. To address these risks and to increase throughput, DOE-NNSA plans to purchase additional equipment to provide additional processing lines and to provide backup equipment in case of failure (SRNS, 2018e).

[7]DOE-NNSA's more recently released LCCE summary indicates a ramp-up from 400 kg/yr in FY 2024, 700 kg/yr in FY 2027, 1,000 kg/yr in FY 2030, and 1,500 kg/yr in FY 2032 (SRNS, 2018a, p. 31).

All shipments from Pantex to LANL and from LANL to SRS for the dilute and dispose plan are shipped via OST and are consistent with the transportation plans developed to ship the surplus plutonium material for the MOX plan (see Transportation Section 3.3.1).

3.2.1.3 Savannah River Site

When the plutonium oxide reaches SRS, it will follow a different processing path than that proposed for the MOX process. The process steps to be completed at SRS are receive and store plutonium oxide from LANL, dry blend with adulterant, perform non-destructive assay (NDA) and package, and stage and ship diluted plutonium (SRNS, 2018a). The processes described in DOE-NNSA's plan are modeled after DOE-EM's plans to dilute and dispose of 6 MT of surplus non-pit plutonium material (see Figure 3-3).

Dilution of the plutonium oxide is central to DOE-NNSA's plans, and several details are important to other discussions within this report, and so some of the process steps are described in greater detail here. The process of dry blending the plutonium oxide with adulterant, shown in the green boxes of Figure 3-3, begins with the transfer of 3013 containers into a glovebox.[8] Many of the operations within the glovebox are performed manually. The 3013 container is punctured to relieve any gas pressure that may have built up during storage and then is cut open to remove the plutonium oxide. A new twist-off container, SAVY, is proposed by DOE-NNSA's plan to improve processing efficiency for this step (Cantey and Robertson, 2019, slide 8). The plutonium oxide is sieved and, if necessary, size reduced (i.e., using mortar and pestle). The plutonium oxide is then transferred in 170-gram allotments (or 150 fissile gram equivalent [FGE] plutonium-239) into blend cans prefilled with adulterant powder by an offsite supplier.[9] Mixing the plutonium oxide with an adulterant to less than 10 weight percent produces a safeguards attractiveness level "D" material, which allows for the termination of certain nuclear MC&A requirements and also meets Plutonium Management and Disposition Agreement (PMDA) requirements (DOE, 2011; SRNS, 2018c; see Box 3-2).

The blend can is agitated using a Turbula blender (a 3-D mixer) to mix the dry powdered plutonium oxide with the dry powdered adulterant. The DOE-NNSA dilute and dispose planning documents consistently refer to this as a dry process (DOE-NNSA, 2018; SRNS, 2018a,b,c). The blend can is then "bagged out," that is, encased in a plastic bag after removal from the glovebox. This bag is then inserted into an outer can (slip-lid can) which is also closed. See Figures 3-4 and 3-5.

The encased blend cans are subjected to NDA to confirm the intended composition of diluted surplus plutonium in the cans. These tests include measurements using a neutron multiplicity counter, a gamma isotopic system, and, for selected cans, a calorimeter (SRNS, 2018c). The current process uses 150 FGE operating limit per can to account for measurement uncertainty in waste assay. However, the drum limit is 380 FGE and is split between two cans of diluted material. After assurance of the proper amount of plutonium-239 in each blend can, two of the encased blend cans are inserted into a criticality control container (CCC) that is then sealed and inserted into a criticality control overpack (CCO) with the dimensions of a standard 55-gallon drum. NDA is important for two reasons: the data are used, first, to determine that the diluted surplus plutonium material meets the WIPP waste acceptance criteria (WAC), and second, for the tracking and accounting of the surplus plutonium material since the material is still under material safeguards.

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[8]As received from LANL at SRS, the 9975 (or 9977) shipping packages house 3013 containers with the plutonium oxide.

[9]The adulterant powder is described as follows: "The adulterant is a combination of materials that are considered non-reactive, and the final waste form, including the adulterant, complies with WIPP waste acceptance criteria (WAC). . . . The dilute process blends a mixture of dry powders with plutonium oxide and packages this mixture in a configuration authorized for disposal at the WIPP geologic repository" (SRNS, 2018a, p. 18). The composition of the adulterant is not available to the public but information on the DSP-TRU waste form can be found in the Annual TRU Waste Inventory Report (ATWIR). For example, the 2016 ATWIR, the first to include the new SRS waste stream, SR-KAC-PuOx, for the 6 MT of diluted plutonium, has information on the waste stream's material parameters and radionuclides (DOE-CBFO, 2016a, p. 314).

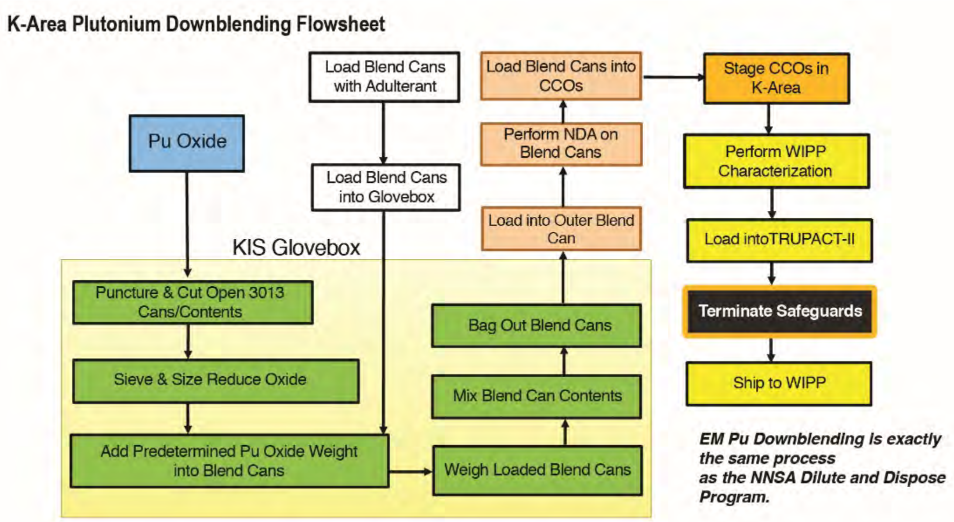

FIGURE 3-3 Process steps for dilution of the 6 MT of surplus non-pit plutonium material that is managed by DOE-EM. As noted in the figure, DOE-NNSA's processing steps are the same as shown. A similar flowchart outlining the same steps is in DOE-NNSA's dilute and dispose planning documents and can be seen in the committee's Interim Report as Figure 2-3a. Safeguards are terminated when the packaged and characterized DSP-TRU waste is placed into the TRUPACT-II shipping container. The termination of safeguards step has been added to this flowchart based on information the committee was provided by DOE-NNSA. "Termination of safeguards" means the requirements for material control and accountability are removed but it does not mean that security is terminated (see Box 2-3 for more details). KIS = K Interim Surveillance. SOURCE: Modified from Maxted, 2019, slide 8.

To date, no CCOs have been shipped to or emplaced in WIPP. However, DOE-EM has emplaced similar downblended/diluted material-associated debris from an earlier SRS campaign (emplaced in WIPP between August 2012 and September 2017): a total of 33.34 m^3 (using the WIPP Land Withdrawal Act [LWA] inner container volume) waste was emplaced from waste stream SR-221H-PuOx, all in pipe overpack containers (POCs) with the exception of three standard waste boxes.[10] Notably, POCs have been used for TRU wastes originating from not only SRS (i.e., a total of 27,025 POCs have been emplaced up to September 2019; see Table 5-4). To be emplaced in WIPP, the safeguards for this material required termination (see Box 3-2).

Up to seven CCOs containing DSP-TRU waste will be grouped together for transport (see Figure 3-6). Two groups of seven CCOs are placed on top of each other inside of a TRUPACT-II container (see Box 3-4, Box Figure 1). Thus, the DOE-NNSA and the DOE-EM dilute and dispose plans, which both anticipate a nominal fissile gram equivalent per CCO of 300 grams (with a 380-FGE limit), allow for 14 CCOs containing a nominal 4,200 (5,320 maximum) FGE of plutonium-239 to be placed into a single TRUPACT-II for shipment to WIPP. Up to three TRUPACT-IIs are loaded onto a trailer for a single shipment to WIPP.

The K-Area at SRS has the capacity to stage about 600 CCOs with options to expand as needed (SRNS, 2018c). The plans indicate that about 6,000 CCOs will be staged each year at maximum production, and interim safe storage space will be needed for 6,000 to 7,000 CCOs (about 1 year of production) to accommodate possible delays in shipments to WIPP (SRNS, 2018c).

[10]Information collected during discussions in the open session of the committee's April 2019 meeting. See video from the meeting available at https://vimeo.com/showcase/6028445/video/338026631 (accessed May 20, 2020). Also, data from the Performance Assessment Inventory Report or ATWIR (see Chapter 2) confirm that from 2012 to 2017, SRS shipped to and emplaced in WIPP at total of 666, 12-inch POCs stated to contain 61 kg of diluted surplus plutonium oxide.

BOX 3-2 Material Attractiveness Levels and Termination of Safeguards

DOE has issued an order to address the safeguards and security of special nuclear material by establishing "performance objectives, metrics, and requirements for developing, implementing, and maintaining a nuclear material control and accountability (MC&A) program" (DOE Order 474.2, DOE, 2011, p. 1).[a] Within DOE-NNSA's dilute and dispose plan, there is a requirement that the diluted surplus plutonium TRU (DSP-TRU) waste conform to Safeguards Criteria for a maximum attractiveness level "D" and for safeguards on the material to be terminated before it may be emplaced at WIPP.[b]

The Graded Safeguards Table within DOE O474.2 categorizes special nuclear materials by three main characteristics and is used when assessing whether safeguards can be terminated:

- **type,** such as weapons, pure grade materials (i.e., pits), or high- and low-grade materials (i.e., oxides or nitrites);
- **quantity,** the number in kilograms of the material under consideration; and
- **material attractiveness,** an assessment of how attractive the material may be to an adversary attempting to use it for nuclear devices (Bathke et al., 2012).

Nuclear weapons and test devices are assigned Attractiveness Level A (the most attractive), and highly irradiated or very diluted solutions are Attractiveness Level E (the least attractive). Attractiveness Level D is associated with low-grade materials such as process residues requiring extensive reprocessing, as has been stated about DSP-TRU waste.

Safeguards termination is also required prior to disposal in WIPP. The process is described in text provided to the committee by DOE-NNSA (2019, p. 3):

> For disposition of surplus plutonium TRU Waste at WIPP, termination of safeguards is requested for all TRU waste when the materials depart the Savannah River Site (SRS). Requirements for termination of safeguards are provided in DOE Order 474.2, Nuclear Material Control and Accountability (NMC&A). Accounting requirements of the NMC&A order are no longer necessary following the termination of safeguards; however, this does not imply that DOE no longer provides security for protection of nuclear material present in waste. Department of Energy requirements for security of nuclear materials are presented in DOE Order 473.3A, Protection Program Operations. Under this Order, physical protection requirements for downblended/diluted plutonium TRU waste must be implemented at both WIPP and SRS and will be in place to prevent loss or theft of any nuclear material, even as a waste product. The requirements for nuclear material security are based on nuclear material quantity and attractiveness level, but details of DOE protection strategies and response are classified and not publicly available.
>
> Similarly, the termination of safeguards does not imply that the downblended/diluted plutonium TRU waste is not measured or tracked for emplacement in the WIPP repository. As previously explained, DOE thoroughly characterizes and tracks the contents of WIPP-bound waste. Furthermore, all waste disposed at WIPP, including downblended/diluted plutonium TRU waste, must be characterized based on instruments and measurement procedures approved by the U.S. Environmental Protection Agency (EPA) and must be certified to meet the WIPP waste acceptance criteria.
>
> The NMC&A measurements used for plutonium disposition are approved by DOE/NNSA, and designed to provide accurate non-destructive evaluation of special nuclear materials in order to protect against any possible diversion of nuclear material. These NMC&A measurements are used to analyze plutonium mass prior to dilute and dispose operations and assure surplus plutonium is properly tracked during processing and staging operations. In contrast, WIPP certification requires characterization of a broader range of radionuclides and other waste components (e.g., potential liquids, cellulosics, etc.) that could affect repository performance. Additional measurements—e.g., fissile gram equivalent and decay heat—are conducted to comply with requirements for NRC [Nuclear Regulatory Commission]-certified shipping. Such characterization will be performed on the resulting downblended/diluted plutonium TRU waste from dilute and dispose operations and the waste contents are documented in the Annual WIPP Waste Inventory Report and in the Waste Data System that tracks waste approved for, shipped and emplaced for disposal at WIPP.

continued

BOX 3-2 Continued

[a]"Special nuclear material" is defined by Title I of the Atomic Energy Act of 1954 as plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235 (https://www.nrc.gov/materials/sp-nucmaterials.html, accessed May 20, 2020).
[b]See Program Requirements for receiving DOE-OST shipments and the termination of safeguards (DOE-NNSA, 2018, pp. 14, 15):

> Requirement P33: Dilute and Process shall perform activities required for termination of safeguards prior to shipping to the Repository. However, the appropriate level of security shall be maintained during interim storage of the diluted plutonium prior to shipping. The security design for the interim storage of diluted plutonium shall utilize a performance based approach.
>
> Requirement P39: Dilute and Process shall demonstrate that the diluted plutonium conforms to Safeguards Criteria for a maximum attractiveness level "D."

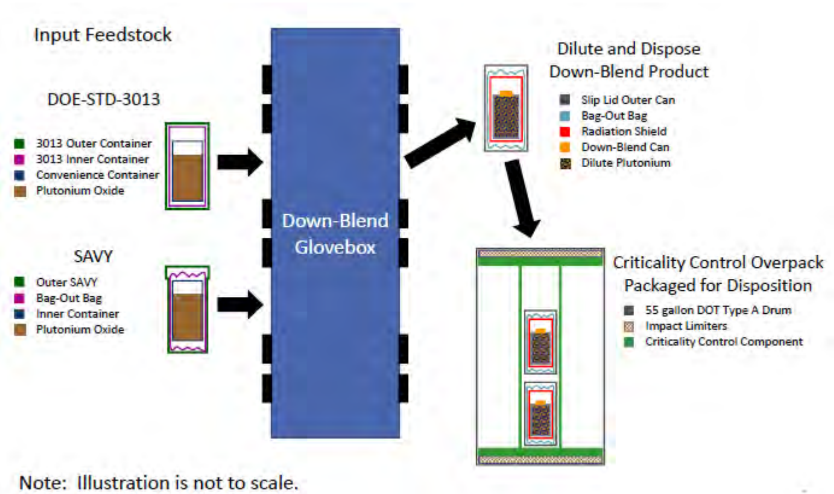

FIGURE 3-4 A schematic showing the different surplus plutonium containers that are used in the process of dilution. The 3013 and SAVY containers store plutonium oxide from LANL. The 3013 has welded closures, the SAVY container has a twisted closure and has been proposed by the dilute and dispose program for processing efficiency gains. The surplus plutonium oxide is diluted and mixed within an inner can which is bagged outside of the downblend glovebox and then placed into an outer can (KIS Glovebox in Figure 3-3). Two outer cans are placed into a single criticality control container (CCC, green outline and arrow), which is positioned inside of the criticality control overpack (CCO). NOTE: The figure refers to this as a Criticality Control *Component*; the committee has seen both terms used, but criticality control *container* is used more frequently. SOURCE: Cantey and Robertson, 2019, slide 7. Image provided by the Department of Energy.

If safeguards are terminated and the DSP-TRU is certified to meet the WIPP WAC, the packaged plutonium waste form will be organizationally transferred to DOE-CBFO, which will ship it to WIPP using TRU Waste Transport and emplace it in the repository as contact-handled transuranic[11] (CH-TRU) waste (DOE, 2016a). See Transportation Section 3.3.

[11]The term "transuranic waste" is defined in the Waste Isolation Pilot Plant Land Withdrawal Act (LWA) 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 has determined, with the concurrence of the Administrator, 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."

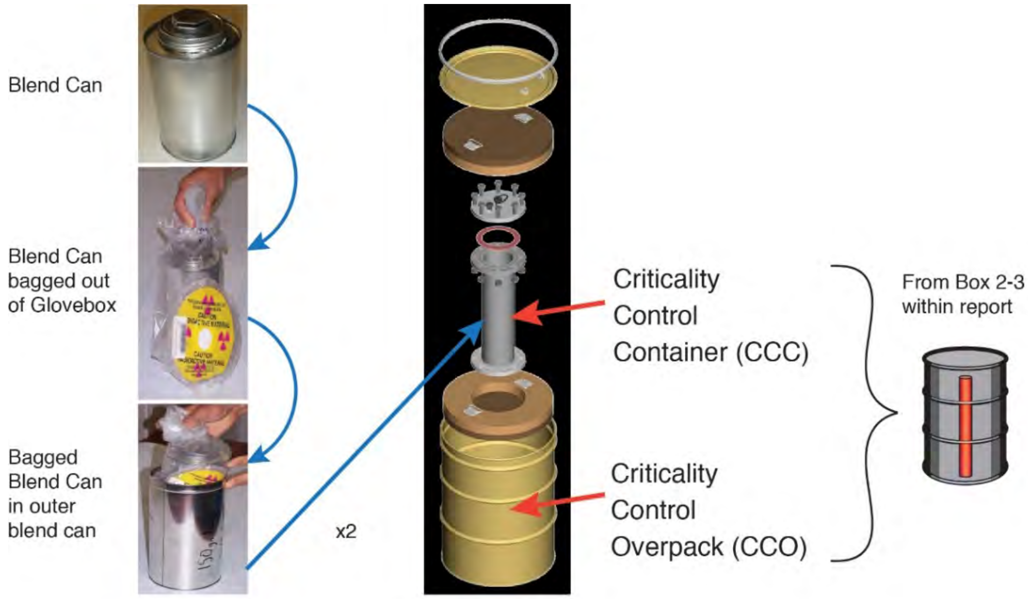

FIGURE 3-5 Shown are the blend can, the bagged blend can as it exits the glovebox, insertion of the blend can, after bagging, into an outer blend can, and a detailed schematic of the criticality control container (CCC) and the criticality control overpack (CCO). Included for reference is the CCC/CCO graphic from Box 2-3 within this report. The diluted surplus plutonium oxide is bagged inside of an outer can. Two outer cans of diluted surplus plutonium oxide, each containing nominally 150 fissile gram equivalents (FGE) of plutonium-239, are placed into a CCC. Each CCC is placed inside of a CCO, which has the same dimensions as a 55-gallon drum. SOURCE: Modified from Maxted, 2019.

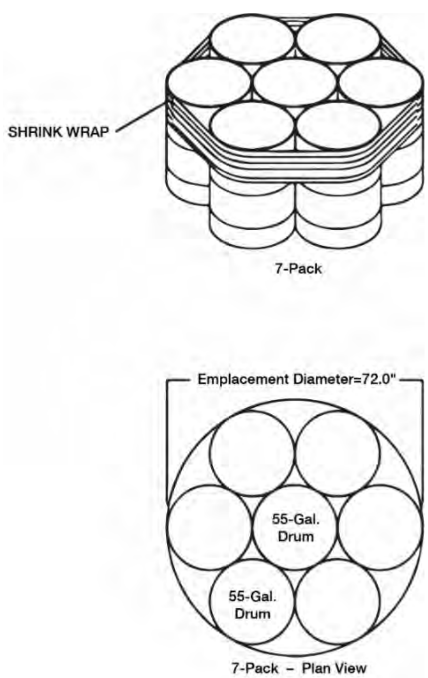

FIGURE 3-6 Configuration of a seven-pack of 55-gallon drums, prepared for shipment and disposal at WIPP. Criticality control overpacks would be grouped similarly, as per the DOE-NNSA dilute and dispose plan. SOURCE: Modified from https://wipp.energy.gov/library/CRA/CRA-2014/CRA/Appendix_DATA_Attachment_B/Appendix_DATA_Attachment_B.htm (accessed May 20, 2020). Image provided by the Department of Energy.

The dilution process at SRS is currently carried out at a small scale in order to process 6 MT of surplus non-pit plutonium for dilution and disposal (Maxted, 2019). As of the end of FY 2019, approximately 52 kg (or 0.052 MT) of surplus non-pit plutonium oxide had been diluted in the K-Area KIS glovebox following the process outlined in Figure 3-3. This diluted material was packaged in 250 CCOs and remains at SRS, awaiting the installation of characterization equipment in the K-Area expected to be operational by FY 2021.[12] As noted earlier, a separate ~61 kg of surplus non-pit plutonium material was diluted, packaged in a total of 666 12-inch POCs, assessed, safeguards terminated, shipped, and emplaced at WIPP, but the processes were conducted in a different glovebox and were not identical to the plans proposed by DOE-NNSA in the dilute and dispose plan.

FINDING 3-1: The Department of Energy's National Nuclear Security Administration's (DOE-NNSA's) dilute and dispose plan relies on dilution experience gained through DOE's Office of Environmental Management (DOE-EM) efforts to dilute and dispose of 6 metric tons (MT) of surplus non-pit plutonium. However, so far, less than 1 percent (0.052 MT, as of the end of September 2019) has been processed following the steps proposed in DOE-NNSA's plan and that material has not yet been emplaced in the Waste Isolation Pilot Plant. Furthermore, DOE-EM's plans for diluting and disposing of up to 6 MT of non-pit plutonium indicate a completion date of 2046—meaning that the two dilute and dispose programs will concurrently operate and compete for resources for nearly the full duration of DOE-NNSA's dilute and dispose program.

DOE-CEPE conducted a review of DOE-NNSA's LCCE documentation in 2018. The DOE-CEPE report states that the DOE-NNSA dilute and dispose plans propose a 410-kg/yr dilution rate in FY 2026 at SRS, increasing to a sustained rate of 1,640 kg/yr by FY 2028 (DOE, 2018b). The current target dilution rate obtained by DOE-EM in the KIS glovebox is 25 kg/yr in FY 2019 (Nuclear Security & Deterrence Monitor, 2019). DOE-NNSA plans to achieve the sustained dilution rate through the purchase of additional gloveboxes and 24/7 glovebox operations (see Figure 3-7). Staffing projections show 15 personnel in 2018 rising to 241 for maximum steady-state operations through 2047 (DOE, 2018b). The sustained rate begins in FY 2028 and ends in FY 2047.

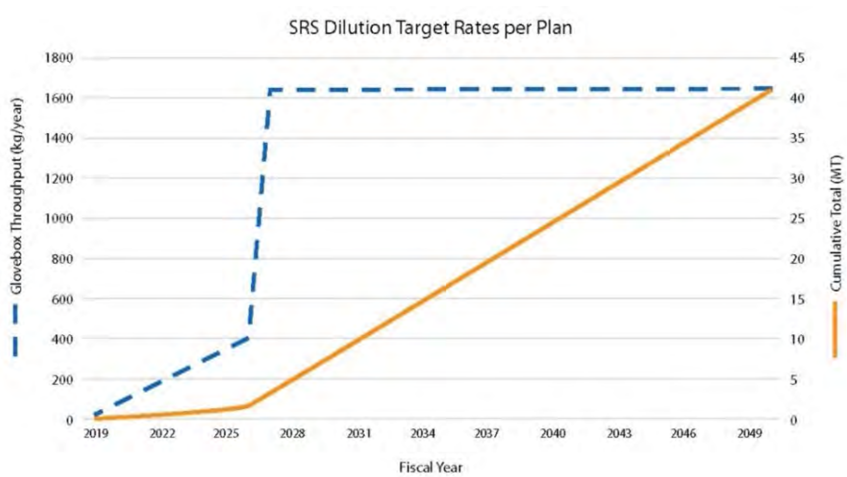

FIGURE 3-7 Graph of the dilution rates and cumulative production of diluted surplus plutonium as a function of time.

[12]This implies that not all of the CCOs were filled to the current maximum of 300 FGEs of plutonium-239. See also "DOE-EM and NNSA responses to the committee's questions," February 2020. Available by request through the National Academies' Public Access Records Office at paro@nas.edu.

Similar to the ROAR's assessment of LANL operations, the dilution and NDA operations that take place at SRS are assigned a high program execution risk due to potential equipment failures, which are proposed to be addressed by multiple parallel dilution gloveboxes and efficiencies in waste characterization. One example of such an opportunity is to recognize the low variability of the DSP-TRU waste stream by streamlining the waste characterization process.

3.2.1.4 Receive and Unload at WIPP

According to DOE-NNSA, the DSP-TRU waste "meets all the criteria of transuranic (TRU) waste and the WIPP WAC. The DSP-TRU waste stream is handled the same as other TRU waste when containers are received at WIPP. The normal processing times for receipt and unloading of TRU wastes at WIPP are within 8 to 12 hours of receipt" (DOE-NNSA, 2019, p. 2).

Historically, once TRU waste shipments arrive from DOE generator sites at WIPP, they are cleared by WIPP site security, and then undergo a radiological survey and a shipping documentation review. The loaded trailer is moved next to the Waste Handling Building. The TRUPACT-IIs are inspected and surveyed to ensure that they are not damaged or radiologically contaminated. Any significant problems or discrepancies are addressed before a TRUPACT-II is returned to service. A schedule is maintained for routine maintenance and evaluation of the casks. The TRUPACT-II is then brought into the Waste Handling Building for unloading (DOE-CBFO, 2016b, pp. 48-49).

The TRUPACT-IIs containing DSP-TRU waste assessed at Attractiveness Level D would include electronic tamper indicators and may be staged for several days in secured waste handling areas.[13] Processing steps for the TRUPACT-IIs once inside the Waste Handling Building and through emplacement of the CCOs in the underground can be found in the System Plan (SRNS, 2018c, p. 28).

Finally, as reported by DOE-NNSA,

> The priority and exact sequence of emplacement underground is determined by multiple operational factors including container configuration, radiation protection (worker dose) controls, and volatile organic compounds, for example. The receipt and disposal prioritization/flow for downblended/diluted plutonium TRU waste would also take into account security and roll-up considerations for the waste staging area. Once designated for the emplacement queue, waste is disposed underground typically the same day that the shipping container is unsealed. If WIPP emplacement operations are significantly delayed, then shipment of the surplus plutonium TRU waste will be paused at the Savannah River Site. The standard WIPP procedure for TRU waste emplacement may be adjusted to support future verification activities, if required. (DOE-NNSA, 2019, p. 2)

3.3 TRANSPORTATION

Transportation is an important component of the dilute and dispose plans. The safe and uneventful transportation of all nuclear materials and defense-generated nuclear wastes is important to a varied and diverse audience which includes the general public, the host state of the repository, communities and states within the transportation corridor that could be impacted, as well as businesses, industry, and a variety of levels of government.

As shown in Figure 3-2, OST will be responsible for shipping undiluted plutonium material from Pantex to LANL and from LANL to SRS. The packaged DSP-TRU waste will be shipped from SRS to the WIPP site utilizing the DOE-CBFO TRU waste shipment programs to WIPP (TRU waste transportation within the United States is managed by DOE-CBFO). From start to end, the estimated length of a single shipment from Pantex to its final destination at WIPP is more than 3,300 miles via

[13]See "NNSA - Input for Final NAS Report 7.2.2019_publicly releasable," July 2019. Available by request through the National Academies' Public Access Records Office at paro@nas.edu.

interstate truck transport.[14] Details of the transport of the surplus plutonium pits, oxide, and DSP-TRU waste are not well detailed in DOE-NNSA's plans to dilute and dispose of surplus plutonium. We present below background information about OST and TRU waste transport as well as information pertaining to DOE-NNSA's dilute and dispose plans.

3.3.1 DOE Office of Secure Transportation

As part of its mission to maintain national security and public safety, OST is responsible for the protection and transportation of special nuclear materials within the United States.[15] As shown in Figure 3-2, OST is responsible for shipping undiluted plutonium materials from the Pantex Plant to LANL and oxidized plutonium material from LANL to SRS, utilizing safety, security, and safeguarding protocols that have been in use for more than 70 years without an accident causing either a fatality or release of radioactive material.[16] Enhanced government-owned security resources such as packaging, technologically advanced self-protecting transportation assets, federal agents serving as escorts (who will deny unauthorized access), nonpublic continuous shipment monitoring, and confidential routing and timing for classified shipments are used by OST.

While OST is responsible for obtaining appropriate federal and state permits for its conveyances, such as hazardous materials, nuclear materials, and oversize overweight permits, it applies for annual rather than single trip permits so as to not predetermine potential routes. As an additional security measure, advance notifications of potential shipments, timing, or routes are not made outside of the DOE organization. OST convoys are continuously monitored en route by the OST Transportation and Emergency Control Center located in Albuquerque, New Mexico. Any off-normal situations are resolved internally and are not reported publicly.

Additional security measures are required for OST conveyances due to the attractiveness of its cargo to adversaries (i.e., special nuclear material). OST security and safety risk assessments are not shared publicly, and the committee did not review OST documents related directly to the dilute and dispose program.

3.3.2 Transuranic Waste Transportation in the United States

DOE-NNSA's dilute and dispose plans rely on the existing TRU waste transportation infrastructure to ship the packaged DSP-TRU waste from SRS to WIPP (see Figure 3-2). DOE-CBFO is responsible for the transportation of TRU waste to WIPP from DOE sites.[17]

The WIPP TRU waste transportation system has always utilized contract commercial motor carriers whose sole responsibility is to transport TRU waste within a DOE site, between DOE sites, and from one DOE site to the WIPP facility. States are active partners in safe highway transportation because they enforce federal and state laws regarding commercial motor vehicle compliance. They also enforce state statutes, rules, and laws (see Appendix D). Box 3-3 describes the collaborative role played by the states in establishing early coordination on TRU waste transportation. Appendix E provides further background on the states' active partnership in maintaining transportation safety.

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[14]WIPP does not accept waste via rail (WIPP, n.d.).

[15]As set forth in DOE Order 460.1D, the Atomic Energy Act of 1954 broadly regulates how DOE will conduct its packaging and transportation activities. Because of the nature of certain types of shipments, DOE-NNSA must achieve a level of safety equivalent to that required by the Department of Transportation (DOT) and the U.S. Nuclear Regulatory Commission (U.S. NRC) for comparable commercial shipments. Thus, DOE-NNSA self-certifies transportation packages as meeting the Type B requirements set forth by the U.S. NRC. The U.S. NRC does not recertify DOE-NNSA packages (https://www.energy.gov/nnsa/office-secure-transportation, accessed May 20, 2020).

[16]See https://www.energy.gov/nnsa/office-secure-transportation (accessed February 19, 2020).

[17]The waste destined for WIPP may contain hazardous material in addition to transuranic contamination and materials; currently all waste that is emplaced in WIPP is considered mixed (hazardous and TRU) waste. Therefore, all TRU waste shipments are subject to transport regulations related to both hazardous and radiological materials.

BOX 3-3 Origin of WIPP Transportation Program

The origin of WIPP's transuranic (TRU) waste transportation system was as a state-driven and regional initiative rather than one initiated by the federal government. In 1985, the consortium of western states within the Western Governors' Association (WGA) passed a policy resolution urging DOE to develop a comprehensive transportation plan to the WIPP facility. In 1989, WGA sent a report to Congress that described the western states' opinions, concerns, and strategies to ensure the safe and uneventful movement of TRU wastes (WGA, 1989). The report detailed priorities for action, responsibilities, accountability, and DOE funding. The report illustrated operational efficiencies that could be gained through integration of a TRU waste safety program into a state's hazardous materials transportation safety program. It also emphasized that a collaborative, regional approach to planning would be a key step toward developing and implementing a credible accident prevention and safety program for transporting TRU waste.

In preparation for DOE's planned test phase to evaluate the transport safety program, WGA issued a report in 1991 on the status of each of the concerns and recommendations that had been raised in the 1989 report to Congress (WGA, 1991). Notably, it highlighted an improved working partnership between DOE and western states that emphasized collaborative problem solving in several operational areas, including accident prevention, emergency preparedness, and public involvement and information. Ultimately, during this period, collaboration between western states and DOE led to agreement on the development of programmatic standards, procedures, and protocols which are still in use today. As DOE began to identify other possible transportation routes, it expanded involvement to include other key regional organizations across the United States.

Since the 1990s, the DOE Secretary of Energy has promulgated formal memoranda of agreement addressing a meaningful interactive relationship among DOE, states, and tribes on such matters as the safe and uneventful transportation of radioactive materials/waste and nuclear waste across the United States. Reinforcing the essential principles of communication, collaboration, consultation, and cooperation, the memoranda of agreement continue to serve as foundational documents for the TRU waste transportation program.

OST has taken a more focused approach to engagement. OST has an ongoing liaison program whose focus is to build relationships with state and local law enforcement authorities along possible routes. These relationships are encouraged in the DOE Directives Program or DOE-NNSA equivalencies.[18] This effort is key to cooperative and collaborative emergency response with state and local emergency response officials.

The TRU waste transportation corridor identified in the dilute and dispose plans involves the following states: Alabama, Georgia, Louisiana, Mississippi, New Mexico (the WIPP host state),

[18]OST provides information about its program to state and local law enforcement in three ways:

- one of the OST liaisons will conduct an in-person community-level presentation where the liaison describes the program, shows a comprehensive video, then holds a question and answer period;
- OST has a computer-based training program; and
- an OST module with video (https://www.youtube.com/watch?v=OasNhj1i2ic&t=6s, accessed March 31, 2020) is taught as part of the DOE Modular Emergency Response Radiological Transportation Training course for emergency response personnel.

The OST in-person presentation and training focuses on tactics in the event of an accident or incident involving an OST convoy, how to approach and interact with the Convoy Commander, and how OST participates in the incident command system.

South Carolina, Tennessee, and Texas[19] (see Figure 3-8). Two cognizant state regional organizations, the Southern States Energy Board (SSEB, 2018) and WGA (2019), have memoranda of agreement with DOE to enhance safety, security, and communication.[20] There are no tribes along the transportation route from SRS to WIPP.

The TRU waste transportation program is documented in the TRU Transportation Plan, DOE-CBFO-38-3103 (DOE-CBFO, 2016b), excerpts of which were used to provide significant details to this section of the report. The DOE TRU Waste Transportation Plan was developed by incorporating the guiding principles of the state regional planning guides. Over 32 years, a robust transportation system for TRU waste has been designed, implemented, maintained, and updated. As evidence of the success of this approach, the Blue Ribbon Commission on America's Nuclear Future cited the TRU waste transportation model as a proven transportation system and recommended that DOE utilize it as a prototype for other nuclear materials and waste transportation campaigns including spent nuclear fuel and high level waste (BRC, 2012, p. 85).

FIGURE 3-8 Map of WIPP routes for interstate transport of TRU waste. The SRS-to-WIPP route is highlighted in yellow with SRS and WIPP shown as yellow stars. Also shown is the alternate route from Texas to New Mexico. SOURCE: See http://www.wipp.energy.gov/routes.htm (accessed May 20, 2020). Image provided by the Department of Energy.

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[19]Under the DOE TRU Transportation Plan, the Supplemental Stipulated Agreement with New Mexico is "an agreement resolving certain New Mexico State off-site concerns (dated December 27, 1982)" (DOE-CBFO, 2016b, p. 113). It includes funding to the state for transportation activities related to accident prevention, emergency management, public information, and information sharing and development within New Mexico, the western states, and across the nation.

[20]There are two other regional organizations who are engaged in the transportation of TRU waste along other transportation corridors to WIPP: the Council of State Governments East and Midwest. They are the Council of State Governments East and Midwest (https://www.csg.org, accessed May 23, 2020).

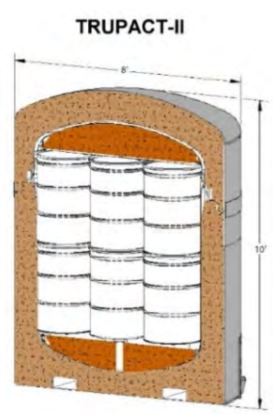
DOE-CBFO provides advance notice to state gubernatorial designees of TRU waste shipments bound for WIPP so those officials can accomplish a variety of activities. These advanced notices include semiannual notifications of planned shipments, an 8-week rolling schedule containing more detailed information about the shipments, an 8-week rolling schedule summary that is suitable for distribution to emergency response personnel, and a 2-hour notification made by the driver of the shipment to the WIPP Central Monitoring Room (who calls the state 24-hour point-of-contact) before that shipment is expected to cross state lines. States depend on these notifications to monitor TRANSCOM (see Box Figure 2 in Box 3-4 below); to schedule inspections; to coordinate if or how they will provide escorts for WIPP shipments off-route or through their jurisdictions; and to maintain awareness and vigilance in order to provide emergency and other assistance. Because of the classified nature of special nuclear materials and as noted previously, OST does not make advance notifications along its intended route.

3.3.2.1 Legal and Regulatory Requirements

DOE's special nuclear materials transportation (i.e., OST) and its TRU waste transportation programs operate under guidance established in law, regulation, statute, rule, and internal DOE orders including development of DOE-NNSA equivalency orders. These documents define safety and security requirements for transportation (see Appendix D).

BOX 3-4 Transportation Equipment Including Packaging, Communications, and Monitoring

TRUPACT-II (see Box Figure 1) has been identified by the Department of Energy's National Nuclear Security Administration (DOE-NNSA) as the package of choice for transportation of the dilute and dispose plutonium waste to be sent from the Savannah River Site (SRS) to the Waste Isolation Pilot Plant (WIPP) facility (DOE-NNSA, 2018, pp. 10, 15; SRNS, 2018a, pp. 19, 20, 2018b, pp. 7, 12, 17, 19, 23, 26, 32).



BOX FIGURE 1 The TRUPACT-II package is constructed of stainless steel with a multilayer wall and a dome-shaped top to withstand severe accidents. Testing has shown the TRUPACT-II can withstand a 30-foot drop test simulating conditions that are more severe than conceivable highway accidents. It can hold up to fourteen 55-gallon drums in two layers of seven. SOURCE: Modified from DOE-CBFO, 2016b, appendix 2, p. 63. Image provided by the Department of Energy.

Up to three Type B packages[a] are transported in the upright position on specially designed trailers conveyed by diesel-powered tractors. These tractors and trailers must meet the requirements of the Commercial Vehicle Safety Alliance's Enhanced North American Inspection Standards Level VI Program.

continued

BOX 3-4 Continued

(a) (b)

BOX FIGURE 2 (a) TRU Waste Transportation vehicle loaded with three TRUPACT-IIs, (b) TRANSCOM beacons are placed on the tractor as shown by the orange circle. SOURCE: Colorado State Patrol.

DOE-CBFO requires that tractors used to haul TRU waste to WIPP have special tracking and communication equipment including TRANSCOM, a DOE-operated satellite-based tracking and communications system that provides near-real-time monitoring of DOE shipments of certain radioactive materials (DOE-EM, 2018). The secure system is monitored continuously by DOE, and access is made available to state governments for monitoring shipments through their jurisdictions. The system provides authorized users with information on scheduled shipments on the day of departure, shipping manifests, tractor position locations, and messages at 5-minute update intervals while in transit.

Additionally, each tractor is equipped with a panic button and video recording capability to capture activity while en route during a trip; the video can be downloaded after a shipment is completed and the vehicle has returned to the Carlsbad carrier terminal.

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[a]The Type B package used by DOE-CBFO for shipping TRU waste generated by both of DOE's dilute and dispose projects is TRUPACT-II waste packages. Three U.S. NRC-certified packages are used by DOE-CBFO to transport contact-handled TRU waste to WIPP:

1. Transuranic Packaging Transporter-II (TRUPACT–II),
2. A shorter version of the TRUPACT-II, referred to as a HalfPACT, and
3. TRUPACT-III.

3.3.2.2 Routing

For highway shipments of TRU waste to WIPP, DOE-CBFO uses preferred routes under DOT regulations specified in 49 CFR Part 397 (Transportation of Hazardous Materials). Subpart D establishes requirements for routing shipments of Highway Route Controlled Quantities (HRCQ) of radioactive materials. Route deviations are coordinated with states on a case-by-case basis (DOE-CBFO, 2016b).

DOE-CBFO has selected a route for transporting TRU waste from SRS to WIPP (see Figure 3-8). The route utilizes U.S. Interstate Highway I-20 from South Carolina to west Texas and then either U.S. or state highways from there to WIPP. I-20 passes through several large cities including Atlanta (Georgia), Birmingham (Alabama), Jackson (Mississippi), Shreveport (Louisiana), and Dallas (Texas).

3.3.2.3 Packages

Packages[21] used to transport TRU waste to WIPP must meet U.S. NRC requirements in 10 CFR Part 71 (Packaging and Transportation of Radioactive Material) for "Type B" packages.[22] The package design must be certified by the U.S. NRC, and the design, fabrication, assembly, testing, maintenance, repair, modification, and use of the package must be carried out under a U.S. NRC-approved quality assurance program (see Box 3-4).

3.3.2.4 Accident/Incident History

The National TRU Program (NTP) and TRU Waste Transportation Program report that there have been 20 incident/accidents involving empty and loaded TRU transporters, none of which resulted in the release of radioactive or hazardous material since shipments to WIPP began in 1999. Of the 20 incidents/accidents, 6 occurred along the route from SRS to WIPP between 2005 and 2013.

The most severe accident in the history of the TRU waste program occurred in Idaho on December 27, 2005. The accident highlights the type of safety risks present during transport—which in this case were not related to radiological releases (DOE-CBFO, 2005). While hauling three empty TRUPACT-IIs, which were secured to the trailer, the WIPP driver lost control of the vehicle, causing first the tractor then the trailer to roll over onto their side. All three TRUPACT-II containers became detached from the trailer; one rolled across two lanes of traffic, through the highway median, across two oncoming lanes of traffic, and came to rest against a right-of-way fence (Idaho State Police, 2006). The other two landed on the edge of the highway on the same side as the WIPP tractor and trailer. All three TRUPACT-II casks sustained surface damage but maintained their integrity according to field testing. The WIPP drivers sustained minor injuries. After it was determined that the cause of the accident was that the driver lost consciousness, the driver was charged with inattentive driving and was released by the carrier.

DOE-CBFO has developed detailed procedures to respond to such an accident (DOE-CBFO, 2017b),[23] reaffirming the DOT regulations (49 CFR §§ 177.843, 177.854, 107.117, and 107.105), which provide required instructions for actions after an incident or accident. The "Recovery Guide" also provides other comprehensive procedures and functional processes (DOE-CBFO, 2017b).[24]

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[21]According to the U.S. NRC website, "*Package* means the packaging together with its radioactive contents as presented for transport." See https://www.nrc.gov/reading-rm/doc-collections/cfr/part071/part071-0004.html (accessed May 20, 2020).

[22]Type B packages are designed to maintain containment effectiveness during normal transport conditions and withstand severe accidents without containment losses or increases in external radiation levels that would endanger emergency responders or the public.

[23]These detailed procedures are also in the tractor cab for use by the drivers and emergency response personnel. DOE is immediately available to provide technical assistance over the telephone, utilizing these procedures, and will deploy assets from across the nation to respond in the shortest time possible, including

- The team that will be deployed after an incident, which is called the CBFO Incident/Accident Response Team (IART). The IART serves as a technical advisor in a unified command system to ensure appropriate package recovery and movement.
- The regional Radiological Assistance Program Teams, which are available and, if called upon, will be deployed to verify containment of contents of the packaging.
- Additional regional and national DOE resources will be made available.

[24]The Recovery Guide is also a unique resource on where to obtain a 50-ton crane, how to weld lugs onto packages, and appropriate load securement for final movement of the recovered package when released from the scene.

3.3.2.5 Shipment Projections

DOE has a long history of shipping TRU waste from SRS to WIPP. Since 2001, DOE has made 1,623 shipments of CH-TRU waste from SRS to WIPP, involving 17,674 m^3 total transuranic mixed waste (TMW) volume and 10,844 m^3 total LWA volume, as of late October 2019.[25] The commercial motor vehicles that transported this waste traveled almost 2.5 million loaded miles. This equates to about 1,500 loaded miles per trip. Since 1999, the entire TRU Waste Transportation Program has made more than 12,000 shipments of TRU waste to WIPP, representing almost 15 million miles of transport (DOE-EM, 2017).

The TRU Waste Transportation Program is operationally mature: the highway route for transporting TRU waste from SRS to WIPP has been established; emergency response personnel along the route have been and continued to be trained; and TRU waste shipments have been made along the route since 2001 (except for a 3-year pause in shipments when operations at WIPP were temporarily halted). DOE has demonstrated that it is able to ship TRU waste from SRS to WIPP on a routine basis.

For shipments from SRS to WIPP, prior to the temporary closure of WIPP in 2014, DOE-CBFO was making, on average, about 120 shipments per year, or a little over 2 shipments per week (SRS, 2018). In the future, DOE-CBFO plans to make about four shipments of diluted surplus plutonium per week to WIPP through 2049 with no more than two in transit at a time (SRNS, 2018b).

The total number of shipments that will be required for DSP-TRU waste can be estimated using the current assumed amount of plutonium-239 per CCO (i.e., 300 FGE). For the 34 MT, approximately 2,700 shipments will be made between 2024 and 2049, assuming 4.2 kg plutonium per TRUPACT-II and three TRUPACT-IIs per shipment. For the 6 MT, there are expected to be approximately 475 shipments; and for the 8.2 MT, if this material is determined to be diluted and disposed, there would be an additional 650 shipments. In total and for DSP-TRU waste only, there would be approximately 3,825 shipments of DSP-TRU waste from SRS to WIPP—more than twice the number of shipments from SRS to WIPP between 2001 and the end of October 2019.

3.3.2.6 Transportation Security

DOE-CBFO is required to have a transportation security plan that is based on a layered approach (or a graded resource) and details the responsibility for engagement at the local, state, regional, and national government levels with full integration of DOE and other federal agency personnel and resources. According to the TRU Waste Transportation Plan (DOE-CBFO, 2016b), the nonpublic TRU Waste Transportation Security Plan (DOE/WIPP-03-03233) was written to meet the DOT requirements in 49 CFR Part 172, Subpart I, Safety and Security Plans.[26]

DOE-NNSA's dilute and dispose plan states that once the diluted plutonium material has been packaged, characterized, and shown to meet the WIPP WAC, it will be shipped using the same process and equipment as other TRU waste shipments (SRNS, 2018b, p. 19). However, in response to committee questions, DOE-NNSA noted that the following additional security measures will be put in place:

> As shipments of the dilute and dispose TRU waste are initiated, NNSA will deploy an electronic tamper indicating seal to demonstrate continuity of knowledge for U.S. surplus plutonium disposition. Implementation of this electronic seal on TRUPACT-IIs used for transportation of the dilute and dispose TRU waste will enable NNSA to independently verify receipt of surplus plutonium materials at WIPP, if required. (DOE-NNSA, 2019, p. 2)

The committee was told of a Campaign Plan that was under development for the dilute and dispose program and will require eventual approval by the DOE Deputy Secretary. The Campaign Plan was being

[25] See https://www.wipp.energy.gov/general/GenerateWippStatusReport.pdf (accessed November 19, 2019).
[26] The plan is nonpublic and was not made available to the committee.

developed to assess security requirements for the transportation and emplacement of the diluted surplus plutonium TRU waste. The Campaign Plan will document security strategies for protection of material, facilities involved, transportation, and equivalencies that may be required throughout the duration of the combined DOE-EM and DOE-NNSA 40-MT (6 MT plus 34 MT) surplus plutonium disposition campaign and includes the follow information:

- Describes each facility and the security strategies in place today;
- Identifies roles and responsibilities;
- Aligns and adjusts with installation of new capabilities and increased production;
- Security continues throughout program, including at WIPP, consistent with operations today;
- Evaluates threats periodically throughout the program; and
- Identifies processes for contingency planning—incorporates risk mitigation strategies (McAlhany et al., 2018, slide 14).

3.3.2.6.1 Materials Risk Review Committee

The process for review of the Campaign Plan and eventual approval by the DOE Deputy Secretary has been handled by the Materials Risk Review Committee (MRRC). The MRRC was established by DOE Order in 2016 to adjudicate technical risk analyses of special nuclear material (SNM) holdings, security postures implemented to safeguard those materials, and material holding/storage configurations across the DOE complex. The Office of Defense Programs (NA-10), the Office of Defense Nuclear Security, and the Office of Counterterrorism and Counterproliferation (NA-80) are all represented on the MRRC, and the reviews are coordinated by the Director of the Office of Security (AU-50). Key components of these reviews are technical assessments performed by teams within NA-80 and NA-10. NA-80 conducts material risk assessments for the MRRC to help understand sensitivities or potential risks associated with various nuclear material operations, leveraging experts in materials science, physics, actinide chemistry, and nuclear engineering from across the DOE complex to assist with these reviews. The committee understands that NA-80 was intimately involved in reviewing the dilute and dispose approach and flowsheet, including informing and assessing potential risks of the proposed material dilution and packaging approaches to prepare excess plutonium materials for disposition. The NA-80 technical review also involved consideration of safeguards termination and extensive reviews of the long-term Campaign Plan, which outlines the technical requirements and planned operations for disposition of the surplus plutonium over a multidecade period. The committee further understands that any potential security risks identified by the MRRC process will be forwarded to the DOE Deputy Secretary together with mitigation strategies that seek to provide equivalencies to risk acceptance consistent with relevant procedures and policies for SNM.

3.3.2.7 Review of Plans for Funding Transportation

DOE-NNSA's dilute and dispose plan utilizes many existing DOE facilities, processes, and systems. In support of that effort, several intra-DOE partner programs have, according to the LCCE, agreed to support DOE-NNSA's Dispose and Dilute Mission Need through utilization of current transportation and repository emplacement systems already in use. DOE-NNSA's partner programs have accepted and will incorporate base operations costs and capacities of dilute and dispose into their ongoing program missions (SRNS, 2018a). For example, the DOE-CBFO and the OST programs have agreed to accept these costs. Transportation and emplacement at WIPP were not included in the LCCE (SRNS, 2018a, pp. 6, 9, 22) because these activities are determined to be within base operating costs of existing DOE programs (DOE, 2018b, p. 6).

The U.S. Army Corps of Engineers conducted an independent assessment of the cost estimation used in the LCCE for the dilute and dispose program. They noted that DOE-NNSA's approach of not including transportation costs may have been:

appropriate for estimation of "program" related lifecycle costs since the program has assumed that all non-NNSA funded support of facilities and personnel will continue to be funded by their existing partner programs. However, this assumption appears to be inconsistent with expectations of GAO guidance that LCCEs capture all relevant life cycle costs, without regard to funding source. Further, the absence of these costs may result in inappropriate conclusions if the estimate is used to compare the LCCE for the Dilute and Dispose approach and the LCCE resulting from continuation of the MOX approach for disposition of surplus plutonium. This is because the values of these cost elements will not necessarily be the same for the MOX approach. (USACE, 2018, p. 29)

3.4 PLUTONIUM MANAGEMENT AND DISPOSITION AGREEMENT AND THE SPENT FUEL STANDARD

A key aspect of the PMDA (see Chapter 2) is to render the surplus plutonium into "forms unusable for nuclear weapons" (DOS, 2000, p. 1), thus making it "practicably irrecoverable" by International Atomic Energy Agency (IAEA) definitions (IAEA, 1972, p. 4). The agreed-upon method for disposition by both the United States and the Russian Federation in the PMDA is irradiated MOX fuel. The spent fuel standard has been used as a recoverability metric to compare various plutonium disposition options and is defined by DOE as follows: "The surplus weapons usable plutonium should be made as inaccessible and unattractive for weapons use as the much larger and growing quantity of plutonium that exists in spent nuclear fuel from commercial power reactors" (DOE, 1997, footnote 5). While the PMDA does not use this term, irradiated MOX fuel meets the spent fuel standard.

The current PMDA-approved method of disposition is the MOX fuel option that includes irradiation in a reactor and would provide the following barriers for reuse in weapons (NRC, 1994):

1. **Chemical:** Oxidation of the plutonium metal, and dilution of the oxidized plutonium with uranium oxide (UO_2) to form MOX fuel.
2. **Isotopic:** The plutonium-239 isotopic composition is shifted during irradiation by the fission of plutonium-239 and -241 and by the transmutation of plutonium-239 to -240, plutonium-240 to -241, and plutonium-241 to -242. The ratio of plutonium-240/plutonium-239 would be increased to at least 0.1, making the plutonium much more difficult to use for production of normal weapons.
3. **Radiation:** Irradiation in a reactor creates a radiation barrier sufficient to be self-protecting for decades.
4. **Physical:** The weight and size of a nuclear fuel assembly is sufficient to require special-handling equipment for processing.[27]

In contrast, the dilute and dispose option has been argued to provide the following barriers (NRC, 1994; NASEM, 2018):

1. **Chemical:** Oxidation of the plutonium metal and dilution of the plutonium-239 with a classified dry-blended adulterant, and
2. **Physical:** Packaging of the diluted plutonium within a stainless steel pipe (the CCC) within a 55-gallon drum and emplaced in the underground at WIPP.

DOE-NNSA asserts that the end state (after both dilution and emplacement in a repository) of the dilute and dispose process would introduce sufficient chemical and physical barriers to practical recovery of the material to meet non-proliferation objectives (i.e., deterring future recovery by the United States or by others).

[27] A fuel assembly consisting of ~200 rods and 12 feet long is more than 2 MT (see, e.g., https://www.nrc.gov/materials/fuel-cycle-fac/fuel-fab.html (accessed May 20, 2020) for light-water reactor fuel assemblies).

3.5 DISPOSAL CAPACITY IN WIPP AND ITS IMPACT ON THE DILUTE AND DISPOSE PLANS

The committee was asked to review additional waste streams and to assess DSP-TRU waste's potential impact on them as well as the impact on LWA capacity limits. In updating the volume information reported in the Interim Report with the new volume of record (VoR) calculation (see Box 2-2), the committee updated the volumes of specific waste streams noted in its Interim Report and used DOE-reported volumes for emplaced and future TRU wastes (DOE-CBFO, 2018a, 2019a).

3.5.1 Estimates of Volumes of Other Potential TRU Wastes

A summary of the volume estimates for specific wastes updated from the Interim Report are below. The committee makes the assumption that, for future waste estimates, the three TRU wastes streams listed below will be placed into direct-loaded 55-gallon drums and will therefore have equivalent LWA and Resource Conservation and Recovery Act TMW volumes (see Box 2-2). Also, estimated future volumes are based on currently available information. Future volume estimates have uncertainties and can vary from one estimate to the next. The numbers presented below are used to illustrate the issue of the possible over-subscription of the LWA limits at WIPP, and hence the issue of competition for limited remaining space:

Tank wastes = 3,187 m^3
Greater-Than-Class-C (GTCC)-like waste = 2,900 m^3
TRU waste from pit production = 57,550 m^3

Further notes, references, and assumptions about these waste volumes are highlighted below:

- DOE has not made a decision to dispose of tank waste in WIPP but the volumes have been included in future estimates of WIPP waste. Disposal of some TRU waste stored in tanks at Idaho and Hanford would require 3,187 m^3 based on recent estimates.[28] However, the tank waste estimates vary by year. For example, earlier estimates of tank wastes from Hanford indicate up to 8,400 m^3 of disposal space, not including the volume of tank waste solidifier (DOE-CBFO, 2014, section 24.5.1.7).
- Disposal in WIPP of GTCC and GTCC-like waste was identified as one of several preferred alternatives in the final EIS for GTCC and GTCC-like waste. The volume of DOE-owned and generated GTCC-like waste is 2,900 m^3 (DOE, 2016b, table S-1, GTCC-like totals for Groups 1 and 2). The total volume of both GTCC and GTCC-like waste would require about 12,000 m^3 of disposal space.
- Estimated volumes for TRU waste generated from future pit production are provided in the Final EIS (DOE, 2019).[29] For the most likely scenario, 30 pits per year at LANL and 50 pits per year at SRS, DOE estimated that over 50 years of the program, 57,550 m^3 of TRU waste would be generated. Of note was the ability of DOE to prioritize TRU waste streams for emplacement in WIPP (DOE, 2019, p. 65): "In addition, use of WIPP capacity for national security missions such as pit production would be given priority in the allocation process."
  - Estimates of projected TRU waste generated from pit production activities at LANL have been separately reported. For example, a recent draft supplemental analysis of the Site-wide EIS for Continued Operations of LANL reported TRU waste generation estimates for pit production to

[28] See "DOE written responses to NAS Question Set Two," available by request through the National Academies' Public Access Records Office at paro@nas.edu.

[29] At the time of the Interim Report's release, estimated volumes of TRU waste generated by pit production activities were not available. All volumes noted here are assuming the TMW (outermost container) volume. The LWA volume may be less because some waste may be overpacked.

be 5,350 m^3 (DOE, 2020, table 4-5). In another, waste stream LA-MHD01.001 was identified in the 2019 Annual TRU Waste Inventory Report (ATWIR) as TRU waste generated by LANL's pit production activities ("Mixed heterogeneous debris waste generated in TA-55") with an estimated total volume of 4,756 m^3 (DOE-CBFO, 2019b, p. 147). This latter volume is subtracted from the 57,550 m^3 total from the pit production EIS in Table 3-2.

- Another recent decision by DOE could affect the shipping capacity needed for dilute and dispose plans. DOE, the U.S. Navy, and Idaho agreed that DOE-CBFO would prioritize TRU waste shipments from Idaho National Laboratory (INL) until nearly all of the TRU waste has been removed from INL. DOE-CBFO has agreed to allocate at least 55 percent of WIPP shipments to INL.[30]

TABLE 3-2 Volumes of Emplaced and Future TRU Wastes for WIPP

	Before VoR (m^3)	After VoR (m^3)	Reference
DSP-TRU (48.2 MT)	33,740	2,056	Committee calculation (based on 300 FGE per container)
Emplaced TRU waste in WIPP through end of 2018[a]	94,936	67,175	WDS/WWIS datasets, October 2018 and April 2019
Projected TRU waste thru 2033 and beyond	80,080[d]	63,011[e]	(DOE-CBFO, 2018a, tables 3-3 and 4-4; DOE-CBFO, 2019a, tables 3-3 and 4-4)
GTCC-like[b]	2,900	2,900	(DOE, 2016b, table S-1, CH + RH values from Groups 1 and 2)
Tank waste[b]	3,187	3,187	DOE-EM[f]
Pit production TRU waste[b,c]	52,794	52,794	DOE, 2019; DOE-CBFO, 2019b
Total	267,637	191,123	
% LWA capacity limit	**152**	**109**	Maximum: 175,564 m^3

NOTES: References for the table values are included. ATWIR = Annual TRU Waste Inventory Report; DSP-TRU = diluted surplus plutonium transuranic; EIS = environmental impact statement; GTCC = Greater Than Class C; LWA = Land Withdrawal Act; VoR = volume of record; WDS/WWIS = Waste Data System/WIPP Waste Information System.
[a]The values are interpolated from data reported on October 13, 2018, and April 3, 2019, in the WDS/WWIS as an estimate for the emplaced volume on December 31, 2018.
[b]Assumed to be direct loaded so volumes are not affected by VoR calculation.
[c]In the 2019 ATWIR, waste stream LA-MHD01.001 (TRU waste generated by LANL's pit production activities) estimated total volume is listed as 4,756 m^3 (DOE-CBFO, 2019b, p. 147). This total is subtracted from the 57,550 m^3 total from the pit production EIS.
[d]DSP-TRU waste volume associated with waste stream SR-KAC-PuOx (6 MT of surplus plutonium) has been subtracted from the total (4,620 m^3, before VoR, DOE-CBFO, 2018a).
[e]DSP-TRU waste volumes associated with waste streams SR-KAC-PuOx (6 MT of surplus plutonium) and SR-KAC-PuOX-1 (7.1 MT of surplus plutonium) has been subtracted from the total (589 m^3, after VoR, see DOE-CBFO, 2019a) noting that a portion of the 7.1 MT volume is not included in the projected totals.
[f]See "Questions for NNSA - Round Two - Final Answers," available by request through the National Academies' Public Access Records Office at paro@nas.edu.

[30]See the Idaho/DOE/Navy Supplement Agreement Concerning Conditional Waiver of Sections D.2.e and K.1 and the 1995 Settlement Agreement (see p. 5): https://gov.idaho.gov/wp-content/uploads/sites/74/2019/11/doe-inl-2019-supplemental-agreement-signed.pdf (accessed May 20, 2020).

3.5.2 Emplaced and Future TRU Wastes Volumes

The committee used several sources from DOE-CBFO to assess the impact of DSP-TRU on future waste streams in addition to those listed above (because the waste streams discussed above are mostly not included in current DOE-CBFO estimates of future TRU wastes). The sources are emplacement volumes in WIPP reported by WDS,[31] to determine a value for emplaced wastes; and the two most recent ATWIRs, to estimate future waste volumes. The 2018 ATWIR (DOE-CBFO, 2018a), which provided estimates of future TRU waste volumes as of December 31, 2017, is the last inventory released by DOE-CBFO before the VoR changes took effect. The 2019 ATWIR (DOE-CBFO, 2019b) was released in December 2019, with estimates of TRU as of December 31, 2018, and is the first to report LWA and TMV volumes separately. The 2019 ATWIR includes adjusted volumes from the 2018 ATWIR—which are recalculated according to the VoR instructions. The committee chose to use the 2018 estimated and adjusted volumes to illustrate the impact of the VoR on emplaced and future TRU wastes.

The relevant tables from the two reports (DOE-CBFO, 2018a, 2019a) are

- Table 3-3. CH/RH [Contact Handled/Remote Handled] Waste Volume Changes—which lists the grand total volume for the current and previous year estimated through 2033 (in the 2019 ATWIR, this includes the column Adjusted ATWIR-2018 Totals); and
- Table 4-4. Projected WIPP CH/RH-TRU Volume Beyond 2033—which provides estimated projected volumes in addition to the values listed in Table 3-3.

The committee's assessment is summarized in Table 3-2. At the beginning of the committee deliberations, under the outer container volume accounting, it was evident that the total surplus plutonium inventory would exceed the WIPP capacity, as was noted in the DOE-NNSA Surplus Plutonium Disposition Performance Assessment Inventory Report—2017: "The volume of anticipated (stored plus projected) and emplaced TRU waste reported by the DOE TRU waste sites … including the SPD proposal, exceeds the legislated volume capacity for WIPP by approximately 17,700 m^3" (LANL, 2017, p. 10).

Additionally, there is inordinate pressure on WIPP to accommodate all federal needs for disposal of defense TRU wastes for decades to come, and reliable access to its capacity, both physical and statutory, is an essential and critical requirement for the success of DOE-NNSA's conceptual plans. The DSP-TRU waste streams, both DOE-NNSA's and DOE-EM's, can be well estimated decades in advance.[32] Previously, the committee was told that there were no mechanisms for prioritizing disposal space years in advance or reserving space in WIPP for high-priority waste streams.[33]

However, the data in Table 3-2 and Figure 3-9 make clear that LWA statutory capacity remains an issue, primarily due to pit production TRU waste. In fact, the impact of the DSP-TRU waste on other wastes is miniscule—which represents ~1 percent of the LWA capacity (or 2,057 m^3)—but the impact of other wastes on DSP-TRU is large. The committee's recommendation to prioritize DSP-TRU waste and to reserve space in WIPP remains valid—especially since DOE has made similar agreements for pit production TRU waste and guaranteed shipment rates from Idaho.

[31] TMW and LWA totals as reported by WDS/WWIS Repository volumes dates October 13, 2018, and April 3, 2019; two reports that were downloaded by the committee.

[32] The character and form of the DSP-TRU waste is deliberately produced (not a waste derived from other processes) and the volume of the containers is standardized, allowing high-resolution projections to be made, unlike much of the TRU waste that is generated through routine operations across the DOE complex. The physical volume of DSP-TRU waste generated from 48.2 MT would fill approximately two of WIPP's existing panels.

[33] See "Questions for NNSA - Round Two - Final Answers," available by request through the National Academies' Public Access Records Office at paro@nas.edu.

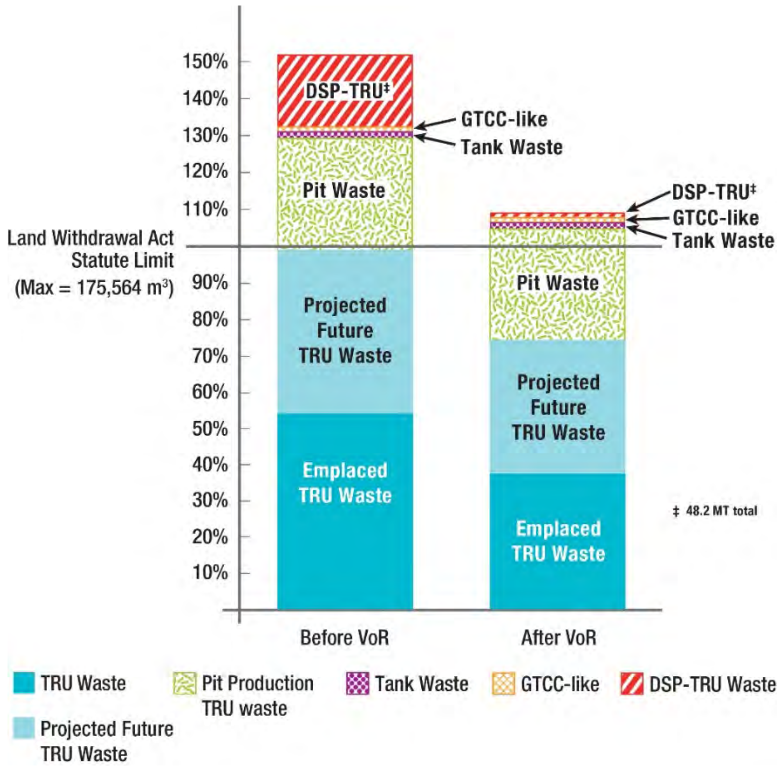

FIGURE 3-9 Using the data from Table 3-2, the emplaced and future TRU wastes estimates, as reported by DOE (DOE-CBFO, 2018a, 2019a); and additional wastes, identified by the committee. Additional wastes are DSP-TRU, Greater-Than-Class-C-like (GTCC-like) TRU wastes, tank wastes, and TRU waste generated from pit production. The graphs illustrate the impact of the volume of record (VoR) recalculation, in particular the large reduction in DSP-TRU waste volumes. Both graphs also show that the Land Withdrawal Act statutory limit is likely to be exceeded.

RECOMMENDATION 3-1 (modified from Interim Report RECOMMENDATION 1): Capacity at the Waste Isolation Pilot Plant (WIPP) should be treated as a valuable and limited resource by the Department of Energy (DOE). DOE is able to prioritize national security mission waste streams for WIPP (i.e., pit production transuranic [TRU] waste). Because emplacement in WIPP is critical to both DOE's Office of Environmental Management's (DOE-EM's) and DOE's National Nuclear Security Administration's (DOE-NNSA's) dilute and dispose plans, the DOE-NNSA Administrator, in consultation with the DOE-EM Assistant Secretary, should prioritize and reserve Land Withdrawal Act capacity in WIPP for the full amount of diluted surplus plutonium TRU waste (2,057 cubic meters). Otherwise, the DOE-NNSA and the DOE-EM programs are at risk of not being able to disposition the full amount of 48.2 metric tons of surplus plutonium via dilute and dispose.

3.6 RISK ASSESSMENT OF THE DILUTE AND DISPOSE PLAN

DOE-NNSA has promulgated two documents to address risk management and analysis for the dilute and dispose program. The first of these documents, the Risks and Opportunities Management Plan (SRNS, 2018d, table 3), formalizes DOE's risk management plan consistent with Government Accountability Office (GAO) criteria for cost estimating and assessments. The U.S. Army Corps of Engineers has independently reviewed the ROMP and found that the overall plan meets GAO criteria, but noted some deficiencies. The committee has not undertaken a separate analysis of the ROMP given that DOE has already adopted this risk management approach and because it has been evaluated formally.

The second document, the Risk and Opportunity Analysis Report (SRNS, 2018e, table ES.3), contains the DOE-NNSA risk team's assessments of program and execution risks for the dilute and dispose approach. The dilute and dispose ROAR seeks to identify, quantify, and evaluate economic consequences of the dilute and dispose program. This application is similar to most economic risk and opportunity approaches with some interesting differences because it is a government-funded project and a large investment with numerous options. Several key points are that 28 experts were involved as primary contributors and many more contributed from the following sites:

- NNSA
- Pantex
- WIPP
- LANL
- SRS

The research team followed a typical process, including

- Reading documents,
- Identifying assumptions,
- Sorting out many options to find those with the highest level of risk and opportunity, and
- Narrowing the list and evaluating options.

The ROAR indicates that 124 actions/events were identified. Of these, 76 were excluded according to the authors as duplicative and too improbable. The authors of the ROAR acknowledge that three risk sources were excluded from consideration, including revision of the baseline requirements for the project; changes in funding from the initial authorization; and events out of control of the responsible organizations. The ROAR summarizes key conclusions and summarizes 48 risks and opportunities. Most summaries are 1 to 1.5 pages and include background, event, and impact of the event on cost should it occur, as well as brief notes on the likelihood of the event.

This committee focused on the 10 boxes in the "high" category for "program" and "execution" risks. Given the materials provided, the committee has no basis to question the classification of high versus moderate versus low risks and benefits. However, three issues are of concern, listed in order of importance below.

The first is that the ROAR risk analysis is focused on cost, not on human or ecological health. For example, *an anomalous event at WIPP causing delays in shipments from SRS* (Event ID 2716, SRNS, 2018e) is rated a "moderate" risk. The report notes that such an event occurred in 2014 leading to the well-known 3-year shutdown of WIPP. At the time of the event, there was an expectation that the event might cost $2 billion to remediate. However, some venting to the surface did occur as a result, and although it was minimal, this fact is not noted in the risk analysis. It could be argued that this is not a "moderate" risk when human or ecological health are accounted for.

The second of these issues is the lack of data and technical justification for the findings. For example, the ROAR identifies a program risk, *anomalous events occur at SRS causing delays in shipments to WIPP* (ID 2635), as a schedule risk with a reported frequency of occurrence of once every 10 years, or at least three times over the program life. The committee has no data to independently substantiate the estimated frequency of unplanned events in the proposed program and there is concern over the fidelity of these data used in the ROAR based on the early phases of both the DOE-EM and the DOE-NNSA programs.

The third issue is the brevity of the descriptions and the collapsing of several events into another. The committee was unable to satisfy itself that all risks are sufficiently captured and reviewed—especially in terms of health and safety. Examples include certain potential exposure events, such as an incident in which K-Area infrastructure fails or a site safety incident occurs (*Infrastructure Failure of Less Than 6 Months May Cause Delays [K-Area, SRS]*, Event ID 2603), which addressed health and safety a bit more explicitly than others. In the ROAR, that event was then rolled into *K-Area Infrastructure Failures Causing Disruption in Operations May Cause Delays and Impact Production* (Event ID 2608)—which was closed. Event ID 2608 made no mention of the exposure or health and safety concerns, and so Event ID 2603 was seemingly lost rather than included. In another example, *Blend Can Non-Destructive Assay (NDA) Equipment Calibration Failure Causes Rework and Additional Operator Exposure* (Event ID 2606) includes exposure risks in its title and statement of event, but the description focuses on the operational element in the rest of the summary.

These types of events are clearly presented in the detailed event sheets in the appendixes, but they are buried in the main body of the ROAR. The descriptions of the risks and mitigations could be made explicit about all the types of risks addressed and properly represented in summary.

RECOMMENDATION 3-2: The focus of the Risk and Opportunity Analysis Report (ROAR) is on cost and schedule. This approach is different from a standard risk assessment and performance assessment and the Department of Energy's National Nuclear Security Administration (DOE-NNSA) should clearly communicate what types of risks it addresses in the ROAR and what types it does not. It is not clear how human and ecological health (and other risks) within the dilute and dispose program are identified and managed in addition to the numerous DOE nuclear safety and security orders to which all programs must comply. Therefore, DOE-NNSA should clearly state how the risks to human health and safety are addressed in its plans. One option is to add a category to the ROAR events to indicate plausible risks and consequences of exposing workers and especially the public.

4

Implementation Challenges

The committee outlines two types of concerns over the Department of Energy's National Nuclear Security Administration's (DOE-NNSA's) conceptual plans to ship, receive, and emplace surplus plutonium in the Waste Isolation Pilot Plant (WIPP). The first—discussed in this chapter—are implementation challenges, which by the committee's definition, are related to the execution of the plan and include serious concerns about the plan's duration, proposed schedule, and workforce. The second are system vulnerabilities, which have larger consequences if not addressed, and are discussed in Chapter 5. Specific implementation challenges discussed below are grouped by early development challenges and long-term sustainability challenges.

DOE-NNSA has developed conceptual plans for the dilute and dispose program. It is expected that those plans as well as the specific operational plans at the various sites will continue to evolve as they mature. The early stage of DOE-NNSA's dilute and dispose plans introduces uncertainty and a lack of fidelity in the details, which the committee recognized. The assessment below of the plan introduced in the previous chapter provides a high level review and guidance to be used as the plans are further developed. Several implementation challenges are identified that are likely to affect the plan's schedule and cost.

In summary of the plan, DOE-NNSA's mission to dilute and dispose of 34 metric tons (MT) of surplus plutonium material is justified by the United States' commitment to non-proliferation and the disposition of its inventory of declared surplus weapons material (DOE-NNSA, 2018).[1] The current plan was developed and is managed by the Defense Nuclear Nonproliferation office within DOE-NNSA. The plan indicates emplacement operations to be completed in fiscal year (FY) 2049, with 7 years of schedule contingency, bringing the probable completion to FY 2056, as calculated by the U.S. Army Corps of Engineers (USACE) at a 70 percent confidence level (see Figure 3-1). The operations and processes described in the plan span four DOE sites (see Figure 3-2); the transportation of materials and transuranic (TRU) waste will affect at least seven different states. The plan includes details on the amount of material that will be processed and the volume of TRU waste that will be created. Details of scaling up of existing processes to meet the schedule outlined above are described and include increases in personnel and equipment to allow factors of ~15 or more increases in throughput rates.

DOE-NNSA's dilute and dispose program has assessed cost and schedule risk through a process defined by the Government Accountability Office (GAO) and has produced a Life-Cycle Cost Estimate (LCCE) estimating that the full life-cycle cost of the dilute and dispose program will be $18.2 billion (in FY 2017 dollars; SRNS, 2018a). A Risk and Opportunities Management Plan (SRNS, 2018d) and a Risk and Opportunities Analysis Report (ROAR; SRNS, 2018e) are included as part of the LCCE package of documents. Many of the highest assessed cost and schedule risks are related to equipment failure or lack of qualified personnel. As stated previously, the committee did not independently verify the stated frequency of realized cost and schedule risks such as unplanned process excursions, equipment breakdowns, or accidents that were used by DOE-NNSA to determine programmatic risks to cost and schedule. Based on the lack of maturity of some of the processes involved, there is some concern over the accuracy of the quoted failure rates.

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[1]Adherence by the United States and the Russian Federation to the Plutonium Management and Disposition Agreement is currently uncertain—and is discussed in the next chapter.

In the discussion that follows, implementation challenges are described and are grouped as, first, early program development challenges and, next, as sustainability challenges. As defined by the committee, implementation challenges are related to the execution of DOE-NNSA's plan and include serious concerns about the plan's duration, proposed schedule, and workforce. System vulnerabilities, discussed in Chapter 5, consider DOE-NNSA's plan in the context of broader system issues across the DOE complex and question its approach, assumptions, and motivation which could ultimately threaten the successful, full completion of the program.

4.1 EARLY PROGRAM DEVELOPMENT CHALLENGES

DOE-NNSA's dilute and dispose plan for operations makes use of existing facilities and previously developed processes which reduces technical risk to and cost of the program. Figure 4-1 shows the process steps described in Chapter 3 and how they map to various existing DOE capabilities (the different programs are shown by different colors in the figure). Scaling-up details are also captured. In addition to operations, DOE-NNSA's plan includes management actions such as National Environmental Policy Act analysis and permit modification requests. Details of how DOE-NNSA plans to achieve International Atomic Energy Agency (IAEA) inspections and verification with a target date of FY 2023, as shown on the Master Schedule and included as a requirement for disposal (DOE-NNSA, 2018), are absent in the other documents that the committee received.[2]

As shown in Figure 4-1, there is prior experience within DOE for nearly all of the individual processes described in DOE-NNSA's dilute and dispose planning documents. However, the full dilute and dispose plan has not yet been demonstrated from start to finish. This is a concern because even well-established capabilities run into unforeseen problems when integrated. Furthermore, DOE's experience with some of the dilute and dispose processes and their demonstrated baseline values are not well established. For example, one could assume that few pits have been processed and shipped to Los Alamos National Laboratory (LANL) beyond pilot demonstration for the Advanced Recovery and Integrated Extraction System (ARIES) equipment in support of the MOX plan (exact numbers are not available to the public). The ARIES equipment has processed as much as 242 kg/yr of plutonium oxide but more recently the rates have been lower (producing 50, 0, and 100 kg in 2015, 2016, and 2017, respectively; see DOE, 2018d, table 7).

CONCLUSION 4-1 (Updated Interim Report CONCLUSION 1): The Department of Energy's National Nuclear Security Administration's (DOE-NNSA's) early-stage plans to dilute and dispose at least 34 metric tons (MT), and as much as 42.2 MT, take advantage of individual process steps that have nearly all been demonstrated by a variety of different DOE programs. As such, the early-stage plans to dilute and dispose provide a technically viable disposition alternative to the mixed oxide (MOX) plan, provided that implementation challenges and system vulnerabilities that currently exist within the plan are resolved.

More concerning is the slow progress to date in processing the 6 MT of non-pit plutonium material, reported in Chapter 3; only about 52 kg (or 0.052 MT) of plutonium oxide has been diluted by DOE's Office of Environmental Management (DOE-EM) in the Savannah River Site's (SRS's) K Interim Surveillance (KIS) glovebox and has not yet been shipped to WIPP. DOE-NNSA has highlighted DOE-EM's activities to dilute and dispose of 6 MT of surplus non-pit plutonium material as a "proving ground" for its program. However, DOE-EM's plutonium processing program is in its early stages of development

[2]The Master Schedule is available by request through the National Academies' Public Access Records Office at paro@nas.edu. The Surplus Plutonium Disposition Program Requirements Document for the Dilute and Dispose Approach (DOE-NNSA, 2018) lists the following requirement (p. 15): Requirement P49: Geological Repository Disposal shall provide monitoring capability to support international verification of surplus plutonium disposal.

as well. It now appears that this material will be diluted at the same time and using the same facility as the DOE-NNSA processes as much as 42.2 MT, increasing demand on the facility and resources at SRS.[3] Because the 6-MT DOE-EM program is slated to run concurrently with the dilute and dispose program for much of the projected life of the dilute and dispose program, it will not be a particularly robust proving ground for DOE-NNSA's dilute and dispose program.

Location	Processing Step	Process independently demonstrated	Process independently demonstrated by	Process not yet demonstrated	Current Capacity	Planned Sustained Capacity
Pantex	Surveillance	✓	MOX plans			
	Staging and monitoring	✓				
	Packaging and shipping	✓				
	Staffing	✓			18–22 FTE	30–42 FTE
	OST	✓			not disclosed	
LANL/ ARIES	Receive and unpack surplus pits	✓				
	Disassemble surplus pits	✓				
	Oxidize plutonium metal	✓			100 kg/yr (2018)	1,500 kg/yr (2033)
	Process and analyze (NDA) PuOx	✓				
	Package and interim storage	✓				
	Ship oxide	✓				
	Staffing	✓			82 FTE	296 FTE
	OST	✓			not disclosed	
SRS	Receive and store plutonium oxide	✓	DOE-EM 6 MT plans			
	IAEA inspections TBD			x		
	Dry blend with adulterant, dilute	✓			410 kg/yr (2026)	1,300 kg/yr (2028)
	Perform NDA and package	✓				
	Staffing	✓			15	~300
	Terminate safeguards	✓	DOE-EM's ~61 kg of diluted in HB-line, packaged in POCs			
	Stage and prepare to dilute PuOx	✓				
	Interim storage	✓				
	Certification	✓				
	Package and ship	✓	TRU waste shipped from SRS to WIPP			
	TRU Waste Transport	✓			0 shipments/week	4 shipments/week
WIPP	Receive and unload	✓				
	IAEA inspections TBD			x		
	Waste transfer and emplacement	✓				
	Staffing	✓				

FIGURE 4-1 Summary of DOE-NNSA's plans to dilute and dispose 34 MT of surplus plutonium material and how the planned processes map to existing or previous programs. Each different program is identified by a different color and the name of the pre-existing program or activity is noted: MOX (green); DOE's Office of Environmental Management's (DOE-EM's) plans for diluting (downblending) and disposing 6 MT of non-pit plutonium (light blue); DOE-EM's dilution of ~61 kg in its HB-Line (dark blue); and TRU waste transportation from SRS to WIPP (purple). Nearly all of the steps have been previously demonstrated, except for IAEA inspection and verification, indicated by black boxes. Also shown are the proposed scaling-up rates for specific process steps. NOTE: FTE = full-time equivalent, HB-Line = a chemical processing facility at SRS, IAEA = International Atomic Energy Agency, LANL = Los Alamos National Laboratory, MOX = mixed oxide, OST = Office of Secure Transportation, POC = pipe overpack container, SRS = Savannah River Site, TRU = transuranic, WIPP = Waste Isolation Pilot Plant.

[3]One significant difference is that a record of decision has been issued for the 6 MT.

In the context of presenting the dilute and dispose plan, DOE-NNSA identified approximately 4.8 MT of plutonium material from Rocky Flats Environmental Technology Site and other sites that had been disposed of at WIPP, some of which was diluted with an adulterant, to show prior capability (McAlhany, 2017). However, the experience gained from processing this earlier material is not completely analogous to the currently proposed dilute and dispose process in that the adulterant, the packaging, and much of the material had different characteristics (Maxted, 2019, and others[4]). Absent more experience with the dilute and dispose processes as a baseline, there is no reliable set of data to predict the frequency of equipment breakdowns, maintenance, and work stoppages (i.e., unavailability due to planned sharing of equipment and unexpected occurrences).

The committee's assessments of details of DOE-NNSA's plan for scaling up operations at Pantex, LANL, and SRS—which are largely manual glovebox operations—can be found in Box 4-1. There was no indication in DOE-NNSA's planning documents that a technology development plan, for example, to automate glovebox operations, was under development or planned. Further details can be found in Appendix F.

Finally, another committee concern is the development and implementation of a security plan. A security program appropriate to DOE's assessment of the attractiveness of this diluted plutonium material (see Box 3-2) given the quantity and attractiveness of the source material (e.g., weapons-grade plutonium) requires finalized security and campaign plans. As noted in Chapter 3, parts of DOE-NNSA's dilute and dispose security plans and their implementation are still under development.

4.2 SUSTAINABILITY CHALLENGES

Normally, an extended schedule translates to increased costs. This is true for the dilute and dispose programs, but extended schedules have additional risks: the availability and operational capability of WIPP past 2050 and aging infrastructure at SRS and LANL.

DOE-NNSA estimates completion of the plan to dilute and dispose of 34 MT of surplus plutonium by FY 2049. DOE-EM's estimated completion date to dilute and dispose of 6 MT is FY 2046 (Maxted, 2019)—a significant overlap of the two programs that was only recently highlighted to the committee. An additional 8.2 MT of surplus plutonium material that could be dispositioned through dilute and dispose methods is not included in these schedules (see Figure 2-1). If there is a decision to disposition these additional materials via dilute and dispose, the timelines would be expected to increase accordingly.

WIPP's current closure date is 2034, but DOE's Carlsbad Field Office (DOE-CBFO) plans to request an extension of WIPP's lifetime to at least 2050 from the New Mexico Environment Department, which manages the permit for WIPP (see Chapter 2). The lifetime extension would conceivably accommodate the emplacement schedule for diluted surplus plutonium transuranic (DSP-TRU) waste as well as TRU waste generated from across the DOE complex.

An independent review of DOE-NNSA's approach to the LCCE by USACE estimated an end date of at least FY 2056 when contingencies are taken into account; the USACE report states that the dilute and dispose "program finish date does not align with mission requirements" (SRNS, 2018a, fig. 4; USACE, 2018, p. i).[5] See Figure 4-2.

Separately, a recent congressionally mandated assessment of pit production options conducted by the Institute for Defense Analyses (IDA, 2019) for DOE-NNSA reviewed DOE's major projects (those that cost more than $700 million) and found that every one of the projects experienced cost growth and schedule slippage. IDA found no successful major project that achieved CD-4 (CD-4 is Project

[4]Information collected during discussions during the open session of the committee's April 2019 meeting. See video from the meeting available at https://vimeo.com/showcase/6028445/video/338026631 (accessed May 20, 2020).

[5]The purpose of the USACE review was to assess compliance of the LCCE approach with "the requirements and best practices of the Government Accounting Office (GAO) for development of capital program cost and schedule estimates, GAO-09-3SP and GAO-16-89G, respectively" (USACE, 2018, p. i).

Completion per DOE Order 413.3B; DOE, 2010) in less than 16 years. DOE-NNSA's dilute and dispose plan, which qualifies as a major project based on IDA's criteria, estimates it will reach CD-4 as early as 2027 or 2030 with schedule contingency (8 or 11 years, respectively; see Figure 3-1).

BOX 4-1 Committee Assessment per Site for Operations: Pantex, LANL, and SRS

Details on the activities for each site listed below can be found in Chapter 3.

Pantex Operations

DOE-NNSA's dilute and dispose activities at Pantex are to retrieve, store, and stage the pit containers; ship the containers to the Advanced Recovery and Integration Extraction System (ARIES) facility at the Los Alamos National Laboratory (LANL); and monitor conditions for safety and accountability (see Figure 3-2, process steps A to B1). These activities are not new to the site and none are expected to affect the viability of the proposed dilute and dispose program. Within DOE-NNSA's dilute and dispose program, several efforts are focused on updating packages for transporting and storing the surplus plutonium material and are meant to improve the efficiency of the current processes. These are highlighted in Appendix F.

LANL

Oxidation at LANL will apply to surplus plutonium material as well as some mixed plutonium/highly enriched uranium material. Oxidation has been demonstrated at the Technology Readiness Level (TRL)-6 level; again, no risk to program is anticipated. These processes have been performed at the ARIES facility in the past and have continued at small throughput rates. DOE-NNSA's plans identify several process improvements for activities at LANL, which are described in Appendix F.

Recalling information from Chapter 3, LANL oxide product throughput is planned to scale up from a current 100-kg/yr capacity to 400-kg/yr by FY 2025 and then to 1,500 kg/yr by FY 2032, a factor of nearly 15 (SRNS, 2018a, p. 31). Staffing is expected to scale up from 82 to 296 by FY 2033, a factor of more than 3.5. These are large increases beyond current practice. Staffing could be a major issue (SRNS, 2018e, p. 138). The scale-up question is whether these can be achieved and sustained for the full duration of the dilute and dispose program of more than 30 years. Major issues identified by DOE-NNSA are oxidation rate, process shutdowns, and storage space sufficient to equalize material flow to SRS and thence to the Waste Isolation Pilot Plant (WIPP) when backups occur at SRS and WIPP (SRNS, 2018e). The challenge will be retaining qualified operators to sustain operations and competition for space and resources with the expanded pit production activities at PF-4, not equipment procurement and readiness. Therefore, LANL may be a major bottleneck in the DOE-NNSA dilute and dispose system.

SRS

SRS scaling up of the dilution and packaging operations is also significant. DOE-NNSA's scale-up plans include the acquisition of three new gloveboxes so that up to four gloveboxes could be used in rotation throughout the duration of the program. The rotation serves two purposes: (1) a margin for one glovebox to be out of service for recovery from mishaps, and (2) an averaging of worker radiation exposure since the current glovebox line is not as well shielded as the three new gloveboxes that are planned to meet the needed production rate. It is worth noting that the KIS glovebox, used for the dilution of DOE-EM's 6 MT of surplus plutonium, shares its operational availability with the 3013 surveillance program (Maxted, 2019).

DOE-EM has had limited experience in diluting the plutonium oxide. It has diluted on average a single 3013 can in three shifts, equivalent to 1 day's output for an intended three-shift/day use of the gloveboxes.[a] The incoming 9975 shipping containers hold one 3013 container with a maximum of 4.4 kg of surplus plutonium (5 kg of plutonium oxide) (SRNS, 2018c,f). Assuming an average of 4 kg of plutonium per 3013 and utilizing the gloveboxes on a three-shift, 7-day workweek for 40 weeks/yr (280 days), output would be more than 1 MT per glovebox per year. Thus, DOE-NNSA's plan of using two gloveboxes with the third as a contingency spare would be required in order to process the 1.3 to 1.5 MT per year that would be required to meet the NNSA proposed schedule. (The committee has no data on how much plutonium an average 3013 contains, which could affect this calculation.) Staffing in the K-Area at SRS is expected to increase by a factor of 20, from 15 to approximately 300 personnel. At peak levels, the major activities include dilution, packaging and shipping, assay, and facility operations (DOE, 2018d, fig. 20). However, DOE-EM's dilution and disposal program for 6 MT of surplus non-pit plutonium is expected to be completed in FY 2046 and will operate in parallel with DOE-NNSA's operations for its 34 MT of surplus plutonium for a large fraction of the program duration, increasing the demand for the same gloveboxes.

continued

BOX 4-1 Continued

Of major importance (with the associated risk) will be the recruiting, training, and retention of skilled and cleared operators for the processes involved. The new operators and radiological personnel will be involved with glovebox operation, non-destructive assay steps, and loading criticality control overpack (CCO) containers (SRNS, 2018b). Many of these operations, which are largely manual, are intended to function on a 24-hour, 7-day schedule in a classified facility that is aging (SRNS, 2018b).

[a]Information received from Maxcine Maxted, May 18, 2019, via e-mail to National Academies study director Jennifer Heimberg.

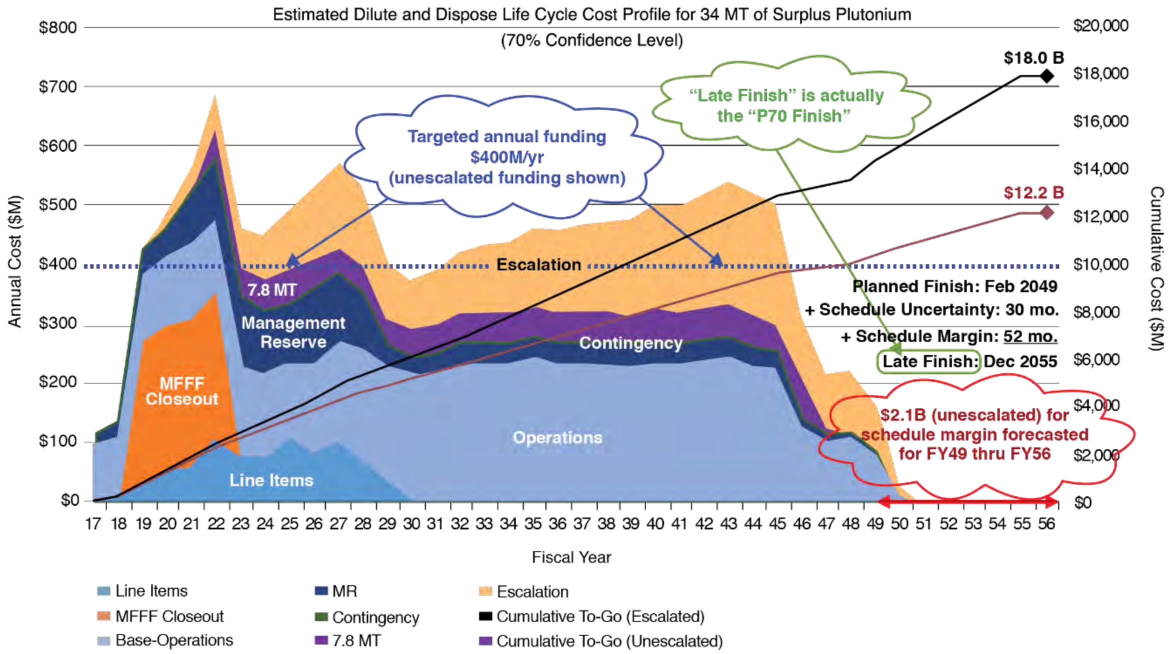

FIGURE 4-2 Summary diagram from the U.S. Army Corps of Engineers independent assessment of DOE-NNSA's Life-Cycle Cost Estimate (LCCE) report showing a planned finish date of FY 2049 moving to FY 2056 when schedule uncertainty and schedule margin are taken into account. "P70" is 70 percent confidence level. SOURCE: USACE, 2018, p. iii, fig. ES-1.

An extension of the dilute and dispose program timeline, which USACE calculates to be 7 years or more, has serious implications for the availability of WIPP and maintenance of the other infrastructure required. WIPP began operations to accept TRU waste in 1999, but the underground and infrastructure have been in place since 1988. As one example of aging systems at WIPP, during the committee tour of WIPP, the committee was told that the freight elevator was purchased as used equipment when WIPP was originally constructed. The K-Area at SRS, where the round-the-clock dilution, packaging, and storage activities are planned and will be needed for more than two decades, has been assessed by DOE as being in "poor condition" and is 65 years old; at the end of the dilute and dispose campaign, assuming an end date of FY 2049, K-Area will be close to 100 years old. Aging infrastructure in K-Area is acknowledged in the ROAR (SRNS, 2018e, p. 105), which states that the infrastructure has exceeded its design life; infrastructure risks associated with aging included the electrical, fire, exhaust, and chilled water systems and the roof. Similarly, the ARIES facility will be nearly 50 years old. Other infrastructure within DOE sites is, of course, also aging. To highlight the impact of aging infrastructure not specified in the dilute and dispose plans, we cite an example from the risk assessment at SRS from the 2014 Omnibus Risk Review Committee (2015, p. 159):

Several staff noted one particularly serious example of critical infrastructure-related risks. On January 6, 2014, a polar vortex weather event enveloped the SRS area with unusually cold weather. The … steam and power plant … broke down shutting off steam to site facilities for a week because of a lack of backup steam generation facilities … offsite services that might be counted on normally may not be available and this could compromise safety.

FINDING 4-1 (updated Interim Report Finding 1): The Department of Energy's National Nuclear Security Administration's (DOE-NNSA's) dilute and dispose plan, if implemented, is likely to face several implementation challenges as the program matures (early program development challenges) and over its 30-year lifetime (sustainability challenges). The following are early program development challenges:

- **All of the processing steps described in the dilute and dispose plan have not been sequentially demonstrated from start to end, posing a risk since even well-established capabilities run into unforeseen problems when integrated.**
- **The individual process steps have been demonstrated at prototype levels and the scaling up of current individual operations to a future processing system that can safely and securely generate, transport, and dispose of the diluted surplus plutonium transuranic waste within the desired schedule will be challenging. Some of the process steps such as the glovebox operations lack sufficient operations data to establish baseline throughput values with confidence.**
- **The initial security assessments and campaign plan have not yet been approved. DOE-NNSA will need to ensure that a security program appropriate to DOE's assessment of the attractiveness of this diluted plutonium material is in effect and is periodically reassessed and updated, given the quantity and attractiveness of the source material (e.g., weapons-grade plutonium).**

The following are sustainability challenges:

- **Competition for processing space, human and financial resources, transportation capacity, as well as the Waste Isolation Pilot Plant (WIPP) capacity with other DOE priorities such as DOE's Office of Environmental Management's downblending/dilution and disposal plans, pit production activities at the Los Alamos National Laboratory and the Savannah River Site, and transportation of TRU wastes to emplacement in WIPP.**
- **Maintenance of the infrastructure and expansion of the trained workforce across multiple sites and including transportation that will be required for at least 30 years.**

CONCLUSION 4-2: If not addressed, these implementation challenges could lead to extended timelines and increased costs. None of the implementation challenges identified threaten the technical viability of the plan, and many of these challenges could be addressed through improved project plans (as they mature and with independent review), clarified priority for the dilute and dispose program within the Department of Energy, and sufficient, steady funding from Congress. However, such straightforward approaches may not be adequate for some challenges, for example, the ability to hire and qualify sufficient staff, resilience of the nuclear facilities such as the Savannah River Site and the Los Alamos National Laboratory, or the availability of the Waste Isolation Pilot Plant.

FINDING 4-2: The current approach to processing surplus plutonium, from pit size reduction to oxidization to dilution and packaging, relies on many manual glovebox operations (i.e., crushing plutonium oxide pieces that do not pass through a sieve using a mortar and pestle).

Plans to scale up processing to meet the throughput goals for the program rely on duplicating the current processing lines and following the current processing steps. This is a low-risk approach from a technical standpoint but it fails to take advantage of economies of scale and automation. Furthermore, the plan introduces risks associated with aging equipment. The committee saw no evidence of a technology improvement plan.

FINDING 4-3: Plutonium operations are complex and require adherence to many safety and security standards. The dilute and dispose program depends on the long-term availability of adequate nuclear facilities at the Savannah River Site and the Los Alamos National Laboratory and the successful recruiting of a large qualified workforce that can obtain the needed security clearances and be trained and retained to perform the skilled glovebox operations and maintain the stringent safety posture of the facility and equipment over decades.

RECOMMENDATION 4-1: As the dilute and dispose program plans mature, the Department of Energy's National Nuclear Security Administration (DOE-NNSA) should develop a technology improvement plan that would put more emphasis on seeking newer automated, safer, labor-saving technologies that could avoid human radiation exposure and human error, as well as reduce costs. Once these new technologies are proven safe and technically mature for operational use, DOE-NNSA should be prepared to introduce them into the program.

4.2.1 Transportation

DOE-NNSA's dilute and dispose plan relies on existing transportation programs—the Office of Secure Transportation (OST) managed by DOE-NNSA and TRU Waste Transportation managed by DOE-CBFO. Both programs are well established with defined procedures and excellent safety records.

One important aspect of both transportation programs, OST and TRU Waste Transportation, is its coordination with the states. Close coordination and communication along with emergency response training and exercises will need to be conducted and practiced throughout the dilute and dispose duration of at least 30 years and with the expected increased number of transports containing the surplus plutonium material and the DSP-TRU waste.

RECOMMENDATION 4-2: The relationships between the Department of Energy (DOE) and the states' gubernatorial and operational levels need to be maintained throughout the duration of the multiple dilute and dispose programs in order to support cooperation and to meet the tenets of agreements among state, local, and federal levels of government. Therefore, DOE should maintain communications and its collaborative cooperation with the states through which surplus plutonium material and diluted surplus plutonium transuranic waste will be transported and emplaced.

4.2.2 Risks and Security During Transportation

Nuclear and radiological materials are often considered most vulnerable to theft or loss during transit, as reported by the IAEA and the James Martin Center for Nonproliferation Studies (CNS)[6] and other reports (Trimble, 2014; IAEA, 2015). DOE-NNSA and DOE-EM propose to transport up to 48.2 MT of DSP-TRU waste for at least the next 30 years. DOE-NNSA and DOE-EM limit the amount of

[6]The CNS report states: "In 2018, 68 incidents (41% of total incidents) occurred during transport, consistent with similarly high rates in previous years…. In many cases, radioactive material theft may have been incidental to the thief's efforts to steal a vehicle or other valuable equipment. Nonetheless, the occurrence of thefts while material is in transit represents perhaps the most dangerous nexus for incidents in the database" (Meyer et al., 2019, p. 5).

plutonium-239 to a maximum of 300 grams of plutonium-239 per CCO. There are a maximum of 42 CCOs—or 12.4 kilograms of plutonium-239—per shipment (see Chapter 3). This will require up to an additional 3,887 shipments (4.764 million loaded miles) from SRS to WIPP over the projected 30-year life of the dilute and dispose program (assuming 48.2 MT). During steady-state operations, the plan indicates up to four TRU waste shipments per week between SRS and WIPP during the 42-week annual operating window at WIPP from 2024 to 2049.

When this rate is reached and sustained, the levels of risk and concern about theft or diversion increase due to the use of an observable and predictable route, shipment schedule, truck stops for the drivers, and multiple inspection stops. Additionally, more shipments on the road simultaneously provide more targets of opportunity and greater transport security challenges.[7]

FINDING 4-4: The number of shipments of diluted surplus plutonium transuranic (DSP-TRU) waste from the Savannah River Site to the Waste Isolation Pilot Plant over the proposed schedule will be far greater than for any other TRU waste stream. Additionally, each shipment under the current Department of Energy's National Nuclear Security Administration's plans could contain up to 12.4 kilograms of plutonium-239, albeit in diluted form and distributed across 42 criticality control overpacks (i.e., 55-gallon drums).

As discussed in Chapter 3, both OST and TRU waste transportation programs require security plans per Department of Transportation regulation, and both programs have security features in trucks that transport the waste. Although many of the details of the transportation security plans for OST and TRU waste transport are not publicly available, it is known that both the OST and WIPP transportation programs call for redundancy in staffing. WIPP drivers travel in pairs and the loaded vehicle is always under direct observation by one of the drivers.[8] The OST shipments are always accompanied by multiple federal agents (Nuclear Materials Couriers) who maintain direct observation as well as ensuring the safety and security of the classified cargo using specialized hardware and equipment.[9] Additionally, OST has established mitigating actions to address security risks during transport. As shown in Box 3-4, DOE-CBFO uses TRANSCOM tracking beacons for its TRU waste transport (security tracking capabilities and details are not publicly available for OST). The TRANSCOM tracking beacon is located on the tractor of the TRU waste truck, but neither the trailers nor the individual TRUPACT-IIs currently have satellite tracking beacons.[10] As long as the tractor and trailer are connected, authorized TRANSCOM users would be able to approximate the location of the trailers.[11] However, should the tractor and trailer become detached, for any reason, the trailer does not have a tracking beacon and could with considerable effort be stolen.

Other mitigating actions to increase security are or have been considered by DOE. For instance, federal escorts were successfully utilized from 1994 to 1995 during the DOE Urgent Cesium-137 Return Campaign from Northglenn, Colorado, to Hanford Reservation, Washington (DOE-EM, 1994, pp. 3, 8).

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[7]It is worth noting the transportation plan for the MOX option: "Once assembled, each of the fuel assemblies would be transported in SST/SGTs [safe, secure trailer/SafeGuards Transport—a predecessor to OST] to one of the domestic, commercial reactors for use" (DOE, 1999b, p. s-27). The committee was told that the dilute and dispose plan's campaign plan (see Box 3-2) will assess the risks during TRU waste transport of the DSP-TRU waste from SRS to WIPP. The campaign plan is not publicly available and was not finalized during the committee's study.

[8]For example, see WIPP's webpage, which states that "Drivers work in pairs to assure that the truck and payload are attended at all times.…" See https://wipp.energy.gov/waste-transportation.asp (accessed March 8, 2020).

[9]For example, see Office of Secure Transportation (OST): Mission—Video 2, https://www.youtube.com/watch?v=OasNhj1i2ic&t=6s (accessed March 8, 2020).

[10]It is either a common transportation interpretation or an oversimplification of DOE operational procedures that often conveys the concept that "During shipment, the location of each TRUPACT-II is monitored while in transit by using TRANSCOM tracking (tracking is provided for security purposes)" (Haddal et al., 2018, p. 15).

[11]TRANSCOM updates every 5 minutes; the transporter is traveling at 60-65 mph and will have traveled along the route before being picked up again by cell tower to satellite.

There is value in securing packages (i.e., TRUPACT-IIs) with electronic tamper indicators, as discussed in Chapter 3, so that DOE-CBFO may independently verify receipt of surplus plutonium TRU waste at point-of-destination. However, electronic tamper indicators do not provide remote tracking capabilities.

RECOMMENDATION 4-3: The Department of Energy's National Nuclear Security Administration (DOE-NNSA) should periodically update its security assessment for the dilute and disposal campaign given the long duration of the program and the potential that a future operational environment may require different approaches to mitigate potential security risks. The current DOE-NNSA process for such an assessment, utilizing the Materials Risk Review Committee, is viewed as an appropriate approach for such a future assessment that considers both the potential attractiveness of the source material as weapons-grade plutonium and the shipment frequency.

Risk assessment provides a method to identify, understand, and address aspects of an activity that pose the greatest harm (considering both likelihood and consequences). A transportation risk assessment was not specifically conducted within the dilute and dispose plans but is addressed by adherence to multiple regulations and agreements (see Appendix D). For example, the WIPP Transportation Assessment Update in 1998 provides a model transportation risk assessment (ANL, 1998). The 1998 study considered risks to safety; security risks were not considered. Transportation risk also was not assessed in the ROAR. Therefore, the committee is concerned that the existing capabilities and risk assessments have not been adequately considered against the demands that will be encountered by DOE-NNSA's dilute and dispose plan.

4.2.3 Workforce Development Across the Dilute and Dispose Program

DOE-NNSA's and DOE-EM's plans to oxidize surplus plutonium material and dilute the plutonium oxide require the use of gloveboxes, and glovebox operations are largely manual. DOE-NNSA's plans show significant scaling up of the workforce (a plan from DOE-EM was not available). In addition, the DSP-TRU waste will be transported using commercial transport companies, through contracts with DOE-CBFO.

Many of the jobs require highly specialized workers whose jobs can require significant training time before they become qualified to work. Examples include glovebox work for pit disassembly at Los Alamos, glovebox work for the dilution of plutonium oxide at Savannah River, and the transportation of the diluted plutonium from Savannah River to WIPP. In addition, retention of the skilled workforce will be needed to ensure the success of this program. The programs have additional workforce challenges with the risks of delays at one site (i.e., LANL or WIPP) affecting other sites (i.e., SRS). DOE-NNSA's plan does have some contingencies for infrequent events, but the committee has concerns about the fidelity of those rates.

The ROAR identifies as moderate risk of causing delays to program execution the need to hire and train staff for SRS operations and limited staffing at LANL (SRNS, 2018d, table 5-3). Workforce attrition and training at Pantex is listed as low risk. As an example, background text for the LANL staffing risk states that "the program is currently (8/2017) experiencing difficulty in adding new staff and is competing with other programs for resources" (SRNS, 2018e, p. 138). Other activities competing for workforce resources are likely to be pit production and other weapons programs that are hiring at higher rates than in the past.

As another example, America's trucking industry is currently struggling with the inability to acquire trained and experienced drivers who have commercial driver's licenses, several years of experience with a good safety record over that time with no incidents, and insurance companies willing to insure those drivers. It is forecasted that a shortage of qualified drivers will continue even with the emergence of automated vehicles. Therefore, the need for drivers or operators to monitor vehicles in transit will persist. On July 24, 2019, the American Trucking Association reported that at the end of 2018, America had an unmet need for 60,800 drivers. If conditions remain the same, they estimate the trucking industry could be short 100,000 drivers in 5 years, and 160,000 drivers in 2028 (Costello and Karickhoff, 2019). In future decades, DOE-CBFO will likely be pressed into innovative hiring practices in order to maintain a workforce of drivers within a competitive environment vying for those drivers.

RECOMMENDATION 4-4: Workforce hiring and retention challenges for the dilute and dispose programs for both the Department of Energy's (DOE's) Office of Environmental Management and DOE's National Nuclear Security Administration will require a focused and sustained effort. The current assessment of risks to the programs may be undervalued. DOE's Carlsbad Field Office should ensure that it has planned for the future costs of these workforce needs to its transportation system.

5

System Vulnerabilities

The preceding chapter outlined implementation challenges to the dilute and dispose program. Most of those risks and challenges involve project-level issues and their mitigation—such as operations scale-up, human resource availability, sustainable funding, security demands, facility modifications, and life extensions. System vulnerabilities are identified by considering the plan in the context of broader system issues across the Department of Energy (DOE) complex and questioning its approach, assumptions, and motivations that could ultimately threaten the successful, full completion of the program. This chapter outlines these vulnerabilities and suggests ways they could be addressed.

The system vulnerabilities to the dilute and dispose program have serious consequences if not addressed and in some cases can be considered deterministic of full mission success. The issues identified here are fundamental to designing, building, and sustaining the multidecade support that will be required for the full completion of the dilute and dispose plan. The issues, many of which are nontechnical, span policy, strategy, social, and political realms. Addressing them will require actions by both the current DOE's National Nuclear Security Administration's (DOE-NNSA's) program management and higher levels of leadership.

5.1 UNCLEAR FUTURE FOR THE PMDA AND ITS IMPACT ON THE DILUTE AND DISPOSE PLAN

Several concerns regarding the Plutonium Management and Disposition Agreement (PMDA) between the Russian Federation and the United States, its uncertain future, and its relevance to the implementation and sustainability of the dilute and dispose plans for U.S. surplus plutonium are highlighted below.

The PMDA and its current status are described in Chapter 2. The salient points are the following:

- The Agreement applies to at least 34 metric tons (MT) of surplus plutonium for both countries;
- The Russian Federation and the United States disagree on the current status of the PMDA with the Russian Federation suspending the agreement in 2016 but the United States considering it in effect;
- Irradiated mixed oxide (MOX) fuel was the last agreed-to method for disposition and the United States has canceled its MOX program;
- The United States asserts that the dilute and dispose approach fulfills the intent of the agreement but the new disposition method requires agreement by the Russian Federation, which has not yet been provided; and
- Protocols for International Atomic Energy Agency (IAEA) monitoring and inspection (as per the PMDA) for disposal have not been developed and are not presently being pursued by DOE-NNSA for the 34 MT disposition.

Furthermore, DOE-NNSA's recently updated conceptual plans no longer cite the PMDA in the mission need statement for the dilute and dispose program, leaving the future adherence to the PMDA timelines and disposition requirements in question (DOE-NNSA, 2016, 2018).

In Chapter 3, the committee presented the recovery barriers for the irradiated MOX option and the dilute and dispose option. Irradiated MOX fuel, which meets the spent fuel standard, has more barriers to recovery than the dilute and dispose option, which does not meet the spent fuel standard. Conceptually, recovery of diluted plutonium inventory emplaced in the underground requires two steps: (1) the presumed *physical removal* of the diluted waste form from the underground by the host country or third state or non-state actors, and (2) the presumed *physiochemical processing* of the diluted waste form to extract the plutonium.

It is a common misconception that nuclear waste—once emplaced in a sealed (i.e., post-closure) repository—is not easily removed especially in the case of salt repositories such as the Waste Isolation Pilot Plant (WIPP) because salt creep is intended to entomb the waste within a few decades of emplacement and closure, adding to the difficulty of removal.[1] However, WIPP, like many repositories in the world now in development, has a regulatory requirement for not precluding the possible post-closure removal of waste. Specifically, the Environmental Protection Agency's (EPA's) 40 CFR § 194.46 (Part 46: Removal of Waste) requires: "Any compliance application shall include documentation which demonstrates that removal of waste from the disposal system is feasible for a reasonable period of time after disposal. Such documentation shall include an analysis of the technological feasibility of mining the sealed disposal system, given technology levels at the time a compliance application is prepared" (EPA, 2014b, p. 46-1).

DOE's Carlsbad Field Office (DOE-CBFO) proposed the following approach to comply with EPA "removal of waste" requirements in the original Compliance Certification Application (CCA; DOE-CBFO, 1996, Appendix WRAC):

- "[I]t is technically feasible to remove the waste any time during the [10,000-year] regulatory time frame" (DOE-CBFO, 1996, p. WRAC-1).
- "Regardless of when removal is initiated, the inventory of the **waste documentation** that will be accumulated by the DOE during operations and archived after closure **will contain sufficient information to determine rather precisely the radioactivity levels to be anticipated and the locations of any containers of waste** that may pose higher radioactivity hazards" (DOE-CBFO, 1996, p. WRAC-20, emphasis added).
- "A practical approach to CH-TRU removal is to excavate an area approximately three feet high directly below the waste and then, using a hydraulic breaker/scaler system … to dislodge the waste above" (DOE-CBFO, 1996, p. WRAC-32).

From the first CCA to the most recent 2019 Compliance Recertification Application (CRA), DOE-CBFO has asserted that it is possible to remove waste from the repository for a reasonable period of time after disposal ("during the regulatory time frame," which is 10,000 years post-closure; DOE-CBFO, 1996, Appendix WRAC).[2] EPA has found DOE-CBFO to be in compliance with 40 CFR § 194.46 at each issued Certification Decision for the CCA and subsequent CRAs.[3]

[1]Note that DOE-CBFO, who manages the WIPP site, distinguishes between waste removal and waste retrieval. Waste removal refers to actions taken after the repository is closed and sealed. Waste retrieval refers to recovering the waste prior to waste panel or repository closure and is essentially the reverse of emplacement. As DOE has suggested that emplacement in the subsequently closed and sealed repository is the barrier to meet the intent of the PMDA, we use the term waste removal. Additionally, the diversion, theft, or recovery of diluted surplus plutonium while in transit or storage is not addressed here.

[2]As examples, two emplaced waste containers have been retrieved (i.e., prior to panel closure) from WIPP; the State of New Mexico required DOE to retrieve a container in August 2007, and DOE elected to retrieve a container in June 2008. Both were returned to the generator site for remediation as they did not meet the waste acceptance criteria upon audit of the documentation.

[3]The 2019 CRA is still in review, but nothing substantive has changed from all previous applications regarding waste removal.

Once emplaced and without in-place monitoring, the diluted surplus plutonium transuranic (DSP-TRU) waste could be retrieved not only by the United States; with sufficient mining expertise (which is becoming more common) and resources, non-state or third-state actors may also be able to retrieve emplaced DSP-TRU waste during the post-closure period with its absence left undetected without additional monitoring or sensors (Tracy, 2019).[4]

DSP-TRU waste removed from WIPP would still need to be processed to recover the plutonium—the barrier that exists from the plutonium mixed with the adulterant would need to be overcome. DOE-NNSA's documents describe this barrier as "mixing surplus plutonium with an adulterant to ensure plutonium is not recoverable without extensive processing" (DOE-NNSA, 2016, p. 6). The composition of the adulterant is classified, and not much can be said about the processing that might be necessary to recover the plutonium. Regardless, presumably the U.S. government would have the resources and capability to recover plutonium from the diluted product if it were retrieved from WIPP. Given enough time and resources, the plutonium could be recovered from any process that dilutes the plutonium oxide with adulterant material(s) by employing a series of available procedures. As compared to the irradiated MOX fuel, the dilute and dispose waste form does not require the degree or complexity of remote and special handling equipment required to recover the plutonium.

5.1.1 Uncertain Protocols for International Inspection and Verification for Emplaced Waste

IAEA monitoring and inspections are an important component of the PMDA requirements and they could also provide enhanced public and international confidence that the material is properly accounted for and emplaced in WIPP. As noted in Chapter 2, the director of the Office of International Nuclear Safeguards at DOE-NNSA reported to the committee that DOE-NNSA is in the process of working with the IAEA to discuss what role, if any, IAEA involvement might play in the disposition of DOE's Office of Environmental Management's (DOE-EM's) 6 MT (Veal, 2019). Typical international safeguards (monitoring and verification) use accountancy to ensure that declared nuclear material is present as intended, coupled with a containment and surveillance system to ensure that no changes occur between inspections. Implementation of IAEA protocols for verification and monitoring of materials for pre-disposal are well established, but IAEA verification protocols for material emplacement in any repository are still under development. Inspection and verification protocols for repository emplacement, where access for monitoring may be a challenge and remote devices may compromise required passive safety measures, could have a significant impact on both repository operations and design (Haddal et al., 2014).

The DOE-NNSA dilute and dispose Master Schedule for the 34 MT (see Figure 3-1) indicates verification protocols for the activities at the Savannah River Site (SRS) are to be in place in fiscal year (FY) 2022 and for WIPP in FY 2023, yet DOE-NNSA may emplace DSP-TRU waste with or without IAEA inspection protocols in place.[5] Therefore, substantial uncertainty remains on the applicability and possible implementation of IAEA monitoring and verification protocols. Resolution of this uncertainty holds substantial implications for WIPP operations and future design changes (such as the new shaft and panels now under development), and therefore this issue remains a significant system vulnerability.

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[4]WIPP does not currently have underground sensors to monitor the emplaced waste after closure (i.e., after the underground is sealed off by the movement of the salt bed). Post-closure monitoring and security details are not yet defined but previously emplaced wastes do not have sensors that would indicate removal of waste.

[5]Discussion between dilute and dispose DOE-NNSA program manager, William Kilmartin, and National Academies study director Jennifer Heimberg on September 12, 2019.

5.1.2 Loss of Program Priority

DOE-NNSA's dilute and dispose plan spans at least 30 years and therefore will require sustained support and recognized priority across several administrations, within DOE, and through congressional appropriations.

DOE-EM's plans to dilute and dispose of 6 MT of surplus non-pit plutonium indicate that those activities will continue through 2046, presenting potential prioritization conflicts within DOE because DOE-EM and DOE-NNSA have different mission spaces and priorities within their organizations.[6] Both projects are in their early stages of development and there are current indications that the two organizations are working closely together to support their combined goal of dilution and disposal of at least 40 MT and as much as 48.2 MT (see Figure 2-1) of surplus plutonium. However, long-term success depends on sustained, consistent budgets, for both DOE-NNSA and DOE-EM, allocated across multiple sites with competing demands and priorities. DOE-EM's and DOE-NNSA's dilute and dispose programs will both have to compete for resources and space with the new pit production mission, which DOE-NNSA has made its highest priority.[7]

Beyond the challenges of a sustained and coordinated budget and competing priorities, enduring social and political support from the affected states (e.g., New Mexico, South Carolina) will be needed. Adherence to an international agreement such as the PMDA provides the public, DOE-NNSA, and the U.S. government a compelling rationale for a sustainable program budget and priority.[8] A renegotiated PMDA could provide a strong assurance over decades that the dilute and dispose program would receive congressional support it needs to meet its non-proliferation objectives. However, recovery of emplaced diluted surplus plutonium by the United States and the lack of established IAEA monitoring and inspection protocols add challenges to the renegotiation. Without the PMDA, the "good stewardship" of surplus plutonium would be the driving force and could lessen the focus and sustainability of the program.

While dilution and disposal of surplus plutonium has merit toward non-proliferation goals in general, the value of a revised PMDA embraced by both parties should not be discounted and would afford the opportunity to address uncertainties regarding safeguards and international monitoring and verification.

The committee maintains the pertinence of the PMDA to the non-proliferation objectives of the U.S. government, and to the dilute and dispose program in particular, must be resolved, as the particulars of a PMDA factor into decisions affecting significant implementation details (e.g., verification, program priority, and schedule).

FINDING 5-1 (Updated from INTERIM REPORT FINDING 5): The dilute and dispose option for surplus plutonium disposition is neither recognized nor approved by the existing Plutonium Management and Disposition Agreement (PMDA). Irradiated mixed oxide (MOX) fuel containing the surplus plutonium is the currently approved disposition option for plutonium within the PMDA and is an option that is consistent with the standard established with commercial spent fuel (i.e., that the plutonium would be as inaccessible for recovery for reuse in weapons by the host state as if it were in spent fuel, or the "spent fuel standard"). Disposition options that use chemical barriers alone, such as dilution or combining plutonium

[6]The DOE-EM mission is to complete the safe cleanup of environmental legacy resulting from five decades of nuclear weapons development and government-sponsored nuclear energy research (https://www.energy.gov/em/mission, accessed May 20, 2020), while DOE-NNSA's mission is devoted to maintaining the stockpile, non-proliferation, counterterrorism, and the nuclear navy (https://www.energy.gov/nnsa/missions, accessed May 20, 2020).

[7]See https://www.energy.gov/nnsa/articles/joint-statement-ellen-m-lord-and-lisa-e-gordon-hagerty-recapitalization-plutonium-pit (accessed February 25, 2020).

[8]This rationale was evident in the initial congressional and public support for the MOX program, until the cost and schedule overruns became untenable.

with other elements, do not meet this standard. The physical barrier of deep geologic disposal is offered by the Department of Energy's National Nuclear Security Administration (DOE-NNSA) as a necessary barrier to meet the intent of the PMDA. However, an approved approach for recovery of the emplaced diluted plutonium in the Waste Isolation Pilot Plant throughout the post-closure regulatory time frame (10,000 years) is a regulatory requirement that has been repeatedly established by DOE's Office of Environmental Management's Carlsbad Field Office and accepted by its regulator, the Environmental Protection Agency. Furthermore, international monitoring and verification of the dispositioned surplus plutonium is a requirement of the PMDA, but its adherence is unclear within DOE-NNSA's dilute and dispose plans. International Atomic Energy Agency (IAEA) monitoring and inspection protocols for material emplaced in deep geologic repositories have not yet been developed, tested, and implemented. An approved approach for recovery by the United States of the emplaced diluted surplus plutonium waste form and lack of a clear plan for implementing IAEA inspections add further barriers to adherence of PMDA principles.

CONCLUSION 5-1: Although not required for the Department of Energy's National Nuclear Security Administration's dilute and dispose program to move forward, a renegotiated Plutonium Management and Disposition Agreement (PMDA) would provide a commitment to achieving program success defined by the agreed-upon methods for disposition of all 34 metric tons of material that the agreement identifies. For a program that is planned for at least 30 years, a renegotiated PMDA could improve the chances of successful completion.

RECOMMENDATION 5-1: Plans for the International Atomic Energy Agency (IAEA) or other monitoring and inspection protocols have not yet been established for the disposition of the material identified in the Plutonium Management and Disposition Agreement (i.e., 34 metric tons of surplus plutonium) as diluted surplus plutonium transuranic (DSP-TRU) waste in the Waste Isolation Pilot Plant. Prior to emplacement of the DSP-TRU waste by the Department of Energy's (DOE's) Office of Environmental Management or DOE's National Nuclear Security Administration (DOE-NNSA), DOE-NNSA and higher-level DOE officials should clarify their intent with respect to whether there will be IAEA monitoring and inspections for this material (and preferably before DSP-TRU waste is disposed of).

5.2 WIPP AVAILABILITY

WIPP is the only deep geologic repository currently available in the United States for surplus plutonium disposal. Other potentially suitable disposal options for surplus plutonium (e.g., Yucca Mountain in Nevada or deep boreholes in as-yet unspecified locations) are not presently being pursued by the U.S. government.[9] Development and licensing of additional disposal options are substantial social and political challenges (more so than a technical challenge) and thus increases the pressure on WIPP.

There are two aspects to the WIPP availability issue: (1) the availability of sufficient disposal volume—both statutory and physical space (see volume of record modification in Box 2-3)—in the underground to accommodate the dilute and dispose program objectives for up to 48.2 MT (see Figure 2-1), in addition to all other current and future demands for TRU waste disposal from throughout the DOE-EM program; and (2) the availability of WIPP as an operating facility.

[9]U.S. surplus plutonium was included in the inventory for the environmental assessments of Yucca Mountain, in the form of MOX and/or vitrified high-level waste. A deep borehole disposal demonstration program was also in progress until May 2017, when DOE announced: "Due to changes in budget priorities, the Department of Energy does not intend to continue supporting the Deep Borehole Field Test (DBFT) project and has initiated a process to effectively end the project immediately," https://www.energy.gov/articles/studying-feasibility-deep-boreholes (accessed April 2, 2020).

5.2.1 WIPP Waste Volume Availability

As noted in Chapter 2 (Section 2.3.1, Disposal Capacity in WIPP), WIPP has a statutory disposal capacity of 175,564 m^3 defined in the Waste Isolation Pilot Plant Land Withdrawal Act (LWA). The New Mexico Environment Department (NMED) approved in late 2018 a permit modification request by DOE-CBFO to alter the accounting and reporting of TRU waste volumes, as described in detail in Box 2-3. In summary, the change created two reporting volumes: a "Land Withdrawal Act TRU Waste Volume of Record" or LWA volume to refer to the volume as calculated using the gross internal volume of the disposal container for *direct-loaded containers* and the innermost disposal container for *overpack containers* and the "TRU Mixed Waste Volume," or TMW volume, to refer to the physical volume of all of the containers. Since January 2019, DOE-CBFO has reported weekly the contact-handled (CH) TRU emplaced waste as a cumulative TMW container volume emplaced, and the LWA container volume emplaced. Table 5-1 is a snapshot of DOE-CBFO's reporting, captured at the end of September 2019.

TABLE 5-1 WIPP Repository Volume Totals

REPOSITORY

Emplaced Waste	Panel 1 CLOSED	Panel 2 CLOSED	Panel 3 CLOSED	Panel 4 CLOSED	Panel 5 CLOSED	Panel 6 CLOSED	Panel 7 ACTIVE	Total
# of 55-GALLON DRUMS	38,139	23,865	8,394	12,858	21,255	12,317	8,125	**124,953**
# of STANDARD WASTE BOXES	1,239	3,176	1,730	1,405	2,200	3,033	424	**13,207**
# of TEN DRUM OVERPACKS	35	1,451	2,227	1,048	788	459	784	**6,792**
# of 85-GALLON DRUM - TALLS	2	0	0	3	0	0	0	**5**
# of 100-GALLON DRUMS	0	1,278	5,409	11,050	9,951	6,546	56	**34,290**
# of STANDARD LARGE BOX 2S	0	0	0	0	0	220	12	**232**
# of REMOVABLE-LID 72-B	0	0	0	198	246	239	18	**701**
# of FIXED-LID 72-B CANISTERS	0	0	0	0	18	0	0	**18**
# of SHIELDED CONTAINERS	0	0	0	0	0	9	18	**27**
TMW CH container volume (m^3)	10,496.65	17,997.67	17,092.06	14,257.54	15,926.93	14,467.39	6,141.33	**96,379.57**
TMW RH container volume (m^3)	0.00	0.00	0.00	176.22	234.96	214.60	19.80	**645.58**
TMW Total Volume (m^3)	**10,496.65**	**17,997.67**	**17,092.06**	**14,433.76**	**16,161.89**	**14,681.99**	**6,161.13**	**97,025.15**
LWA CH container volume (m^3)	7,563.33	13,102.55	9,862.75	10,419.86	12,112.52	11,427.82	3,843.64	**68,332.47**
LWA RH container volume (m^3)	0.00	0.00	0.00	84.24	153.37	112.99	7.94	**358.54**
LWA Total Volume (m^3)	**7,563.33**	**13,102.55**	**9,862.75**	**10,504.10**	**12,265.89**	**11,540.81**	**3,851.58**	**68,691.01**

NOTES: TRU Mixed Waste (TMW) Total Volume refers to the volume measured by the outermost disposal container, and the Land Withdrawal Act (LWA) Total Volume refers to the inner volume of TRU waste disposal container, when an inner container is present. See text for details. The data are emplaced waste volumes as reported by DOE-CBFO WDS/WWIS as of the end of September 2019. SOURCE: Data excerpted from WIPP Weekly Status Report as of end of September 2019, latest available from https://www.wipp.energy.gov/general/GenerateWippStatusReport.pdf (accessed April 21, 2020).

The change in TMW to LWA accounting resulted in an average ~28 percent volume recovery from *all past* waste emplacements. However, some waste forms contributed to the volume recovery much more than others, as shown by Box 2-3. The change in volume accounting for the pipe overpack containers (POCs) is a ~78 percent LWA volume recovery over TMW volume; and the criticality control container/criticality control overpack (CCC/CCO), which will be used for DSP-TRU wastes, yields an even greater recovery of volume (94 percent) due to the large LWA/TMW container volume ratio (0.013 m^3/0.21 m^3). The CCC/CCO has an increased fissile gram equivalent (FGE) loading of the CCC over the pipe overpack (380 grams versus 200 grams), which far exceeds the average amount of plutonium-239 in other containers at 14.4 grams.[10] Despite the LWA volume savings through the volume of record recalculation, the TRU waste capacity discussion in Chapter 3 (see Table 3-2 and Figure 3-9) and Recommendation 3-1 make clear that LWA volume limits are still likely to be challenged—in particular with the addition of the pit production TRU wastes. These additional wastes put completion of the DSP-TRU waste emplacement plans at risk.

5.2.2 WIPP Operational Availability

Beyond sufficient waste volume capacity to fully support the dilute and dispose program objectives, another aspect of the WIPP availability issue concerns the mitigation of risks that threaten the ongoing and continuous availability of WIPP.

Exclusive reliance on WIPP for disposal is a single-point failure risk for the success of the dilute and dispose program. For example, the Risk and Opportunity Analysis Report (ROAR) identifies several moderate risks associated with WIPP; one is an unexpected outage for WIPP (associated with aging infrastructure of its hoist controller; SRNS, 2018e, table 5.3). Any unplanned shutdowns or suspensions of WIPP lasting more than perhaps a few weeks would have a substantial ripple effect in the upstream portions of the system, incurring disruptions, delay, and added cost in the processing of surplus plutonium into and out of the Savannah River Site. While each site (i.e., Los Alamos National Laboratory [LANL], SRS) and part of the dilute and dispose process flow has a certain amount of capacity (i.e., lag storage or curtailing shipping) to absorb disruptions, this excess capacity is generally small and finite.

Shipments to WIPP were suspended in February 2014 when two incidents, an underground salt haul truck fire and a radiological release that occurred as a result of an exothermic chemical reaction in a waste drum, caused the temporary closure of the facility. WIPP officially reopened in January 2017 with a reduced shipment schedule resuming in April 2017. This shutdown resulted in several upstream issues (e.g., shipping TRU waste containers to Waste Control Specialist in Texas for temporary storage, and missed compliance milestones at several DOE-EM sites) and efforts to re-establish operations (e.g., a new shaft and drifts and abandonment of the south end of WIPP) have proven costly. Although waste shipments were resumed in April 2017, WIPP cannot re-establish design waste receipt and emplacement rates until the new ventilation system and shaft are put into operation in the coming years. These incidents provide ample evidence of the sensitivity of the system to WIPP availability, and contrasts with the aggressive schedule and processing rates embedded in DOE-NNSA's dilute and dispose summary master plan.

DOE-NNSA asserts that *both dilution and disposal* of the DSP-TRU are required to meet DOE's non-proliferation goals and the intent (if not the letter) of the PMDA. The assured availability of the WIPP facility hinges on internal and external factors that must be addressed in order to exhibit the characteristics of "high-reliability organizations," with the intent that system accidents and disruptions are not inevitable.

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[10]Using data from September 30, 2019, from the Waste Data System/WIPP Waste Information System database, the total amount of plutonium-239 emplaced in WIPP was 5.36 MT. Of this total, 3.17 MT of plutonium-239 is emplaced in POCs, of which there are 27,060 POCs, or on average, 117 grams/POC. The remaining 2.19 MT of plutonium-239 is assumed to be equally distributed among the remaining emplaced containers (minus the POCs): 2.19 MT/152,524 containers, arriving at 14.4 grams/container.

Looking internally, the committee and DOE are mindful of the extraordinary efforts that are necessary to ensure a safety-conscious work environment and a nuclear safety culture that both exists and is sustained. Any of the contributing factors (e.g., accelerated shipping and disposal campaigns or complacency) that led to the WIPP accidents can recur, and over the next several decades of operations, similar conditions arising might be assumed.

The dilute and dispose program, as well as other waste streams, will drive the need to extend the operational lifetime of WIPP beyond its current operation permit by ~20 years. In addition to requiring approvals from New Mexico (through permit modification requests by DOE-CBFO to NMED, see Box 2-5) and most certainly additional appropriations from Congress, the facility will also need to operate safely beyond its original expected lifetime. WIPP has been operationally ready since 1988, though waste shipments and disposal emplacements were not permitted to commence until 1999. Parts of the facility and underground access ways are thus approaching 30 years old. Extending the operations lifetime of WIPP will require that some of its facilities, operation systems, and equipment be upgraded to ensure continued safe and secure operating conditions during the life of this program. This is most evident in the efforts to permit and construct a new shaft and drifts, abandon the south end, and alter the panel closures. Keeping a facility such as WIPP open, functional, and safe is a complex engineering and human resource endeavor.

In its Interim Report, the committee identified three barriers that would require resolution through permit modifications from NMED and/or changes to legislation through congressional action in order for DOE-NNSA's conceptual plans for dilute and dispose to be viable. The first of those three, the volume of record permit modification, has been approved by NMED. The remaining two are still critical barriers, with both requiring NMED's approval of future permit modification requests and approval by EPA through planned change requests (neither of which has been submitted):

1. Increasing physical capacity at WIPP by adding more disposal space, and
2. Extending the end date of WIPP to 2050 or later.

The technical issues associated with the expansion and extending the closure date of WIPP are expected to be complicated. The need to update the modeling code on which WIPP's performance assessments are based is one example (see Box 5-1). NMED will either approve or reject these expected future permit modification requests, yet NMED has limited technical resources to perform a detailed technical review of either issue.

5.3 CHANGING NATURE OF WIPP

In the past, the TRU waste emplaced in WIPP has routinely been described as clothing, tools, rags, residues, debris, soil, and other items contaminated with small or moderate amounts of plutonium and other man-made radioactive elements, the unavoidable by-products of processes related to weapons production.[11] This notion extends to the original Compliance Certification Application where it is also noted that this type of waste is expected to be the largest category by volume:

[11]This notion that TRU waste comprises things modestly contaminated with plutonium (as opposed to conditioned plutonium material) has been and continues to be pervasive. For example:

- DOE WIPP homepage (https://wipp.energy.gov/about-us.asp, accessed May 20, 2020): "TRU waste consists of clothing, tools, rags, residues, debris, soil and other items contaminated with small amounts of plutonium and other man-made radioactive elements." and "Disposal of transuranic waste is critical to the cleanup of Cold War nuclear production sites."
- WIPP Fact Sheet (https://wipp.energy.gov/pdfs/Why_WIPP.pdf, accessed May 20, 2020): "Generally, TRU waste consists of clothing, tools, rags, residues, debris, soil and other items contaminated with radioactive elements, mostly plutonium."

> TRU wastes consisting of scrap materials, cleaning agents, tools, piping, filters, plexiglass, gloveboxes, concrete rubble, asphalt, cinder blocks, and other building materials. *This is expected to be the largest category by volume of TRU waste to be generated.* (DOE-CBFO, 1996, Section 4.1.1, emphasis added)

In contrast to the common and historic notion that TRU waste consists of "clothing, tools, rags, residues, debris, soil and other items contaminated with" plutonium, the DSP-TRU waste is primarily plutonium oxide purposefully derived from up to 48.2 MT of surplus plutonium material that is then diluted by a classified adulterant (see Figure 2-1). The character and form of the DSP-TRU is different from typical TRU waste in many aspects.

BOX 5-1 New Computer Models and the Expansion of WIPP's Underground

The currently available physical capacity in WIPP is limited by the number of panels in its original design. A Government Accountability Office report (GAO, 2017) concluded that WIPP would reach current available physical capacity by 2026 and that at least two additional panels would be needed to accommodate future diluted surplus plutonium TRU waste. The existing panels in the WIPP underground are nearly full, and so new panels will have to be designed and mined to accommodate future wastes.

A new mathematical modeling tool, PFLOTRAN, is under development at Sandia National Laboratories that might be integrated into a suite of other modeling tools used to assess WIPP's regulatory performance. PFLOTRAN is needed because it is expected that there will be an asymmetry introduced when new panels are designed and located. PFLOTRAN would replace an earlier code, BRAGFLO, which relies on a symmetrical geometry of the underground.

DOE-EM told the committee that:

> The proposed additional panels are still at the conceptual stage and PFLOTRAN is still in development. It is unknown precisely when PFLOTRAN will be used for any compliance calculations (with or without the 34 MT) for submittal to the EPA because future funding, resources, and priorities will impact the code's availability. The analysis that is being performed regarding the 34 MT for the NEPA process utilizes the existing performance assessment software (e.g. BRAFLO [sic]) and disposal panels.[a]

DOE-EM estimates that the model verification and validation for PFLOTRAN, which will be managed by Sandia and will follow an NQA-1 Quality Assurance program that is approved and audited by the Environmental Protection Agency (EPA), is scheduled to be completed in May 2022. It is not expected that EPA will perform any additional verification and validation of the code because it has not done so in the past. DOE-EM further stated that: "If PFLOTRAN is to be used in a compliance calculation for the March 2024 recertification, the data cutoff for that recertification would be December 31, 2022 and any inputs to that recertification would need to be completed prior to this date."[a]

[a]See "August 28 Answers to PFLOTRAN Questions," available by request through the National Academies' Public Access Records Office at paro@nas.edu.

- WIPP Plutonium Fact Sheet (https://wipp.energy.gov/pdfs/Plutonium.pdf, accessed May 20, 2020): "[WIPP] safely, effectively and permanently disposes of materials contaminated with traces of plutonium and other transuranic elements that have no value."
- Pioneering Nuclear Waste Disposal (DOE-CBFO, 2000, p. 4): "Most of this waste is everyday industrial trash, including used protective clothing, rags, old tools and equipment, and pieces of dismantled buildings. Some of the waste contains residues from chemical processes or soils from cleanup activities. A small portion consists of plutonium chips, cuttings, and other scraps that were not economically recoverable."

To illustrate these characteristics, the committee points to the nominal baseline performance assessment (which does not include any portion of the 48.2 MT), referred to as the APCS (Abandonment of Panel Closures in the South) performance assessment (PA).[12] Figure 5-1 shows the effect of adding surplus plutonium disposition (SPD) inventories (48.2 MT) to the EPA units[13] and the total radioactivity in WIPP, both plotted as a function of time through 10,000 years. The SPD inventory increases the EPA units by a factor of 2 and increases the long-term radioactivity by nearly a factor of 4.[14]

In Table 5-2, the DSP-TRU waste stream for *the 6 MT only* increases the total radioactivity by 2.4 million curies, the majority of the increase of 2.9 million curies from CH-TRU waste between CRA-2014 and CRA-2019 (the 42.2 MT is not yet included in CRA-2019; DOE-CBFO, 2019b).[15] The addition of the balance of the DSP-TRU surplus plutonium (42.2 MT) results in a total radioactivity (Ci) at WIPP closure greater than 9,000,000 curies, a *three-fold increase* in radioactivity at closure increasing to a four-fold increase at 10,000 years post-closure (Zeitler et al., 2018).

Table 5-3 shows that the combined SPD waste streams, SR-KAC-PuOx for the 6 MT and SR-KAC-SPD for the 42.2 MT, will occupy 19 percent of the total physical volume (measured by the outer container) of WIPP and will account for 85 percent of the plutonium-239 emplaced in WIPP (Dunagan, 2019).

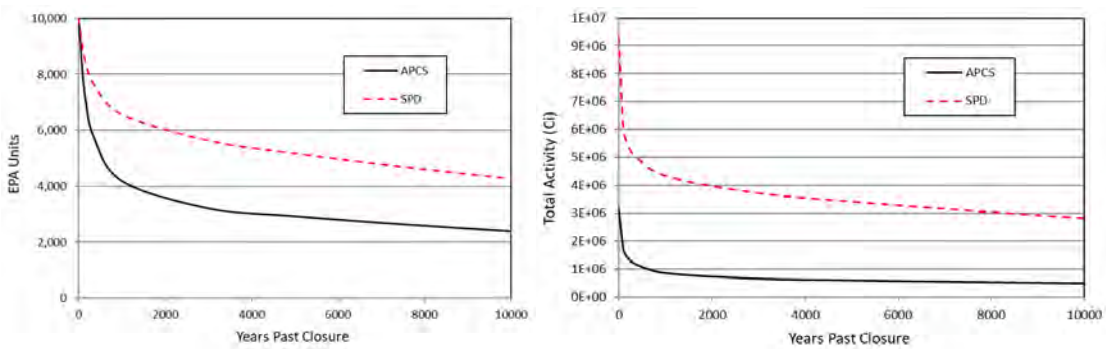

FIGURE 5-1 Increase in EPA units and total radioactivity [activity] (Ci) from the addition of 48.2 MT of diluted surplus plutonium (the SPD line) to the WIPP disposal inventory over the APCS (Abandonment of Panel Closures in the South) baseline performance assessment, which is absent the 48.2 MT inventory. The SPD waste streams significantly increase the long-term radioactivity inventory (nearly three times higher at closure and four times higher after 10,000 years) and EPA units (almost twice as large after 10,000 years). The increased quantity of plutonium-239 is evident; its persistence is due to the long half-life of plutonium-239 (see Box 2-1). SOURCE: Zeitler et al., 2018, fig. 4-5. Provided by Sandia National Laboratories.

TABLE 5-2 Increase in Total Radioactivity Reported by the Generator Sites for CH-TRU and RH-TRU Waste Between CRA-2014 and CRA-2109

	CRA-2014 (cutoff 12/31/2011)	CRA-2019 (cutoff 12/31/2016)
CH-TRU	3,480,000	6,390,000
RH-TRU	1,200,000	1,180,000

NOTE: The majority of this increase (2.4 million Ci) is from SRS and is mainly due to the addition of the projected waste stream SR-KAC-PuOx representing the 6 MT DSP-TRU (accounted as ~4,200 m^3 of TMW volume, and ~256 m^3 of LWA Waste Container Volume). SOURCES: DOE-CBFO, 2014, 2019b, table 24-3.

[12]Modified from the PA used in the CRA-2014.

[13]For an explanation of EPA units, see Zeitler et al. (2018).

[14] Zeitler, et al., refer to the diluted surplus plutonium as "surplus plutonium disposition (SPD) inventory" while the committee refers to it as "diluted surplus plutonium transuranic (DSP-TRU) waste inventory."

[15]For the recently submitted CRA-2019 (DOE-CBFO, 2019b) the PA was deferred until late 2019.

TABLE 5-3 Percentage of Total Initial Waste Inventory (Selected Radionuclides, Ci) for Two Waste Streams

Waste Stream ID	Volume	Am-241	Np-237	Pu-238	Pu-239	Pu-240	Pu-241	U-236
SR-KAC-PuOx (6 MT)	3	20	15	6	8	15	28	5
SR-KAC-SPD (42.2 MT)	16	43	21	10	78	68	46	29
Sum	**19**	**64**	**36**	**16**	**85**	**83**	**74**	**35**

NOTE: SR-KAC-PuOx is 6 MT of diluted non-pit plutonium TRU waste within DOE-EM's program, and SR-KAC-SPD is 42.2 MT of diluted surplus plutonium TRU waste within the DOE-NNSA dilute and dispose plan. Sums in the table do not necessarily add up due to rounding errors (Dunagan, 2019). SOURCE: Dunagan, 2019, Day Two slide.

A summary of the characteristics and amounts between the DSP-TRU wastes and other TRU wastes is provided in Table 5-4. By almost any measure, the addition of two DSP-TRU waste streams (SR-KAC-PuOx for the 6 MT and SR-KAC-SPD for the 42.2 MT) from a total of ~500 existing waste streams introduces substantive changes to the character of the WIPP inventory. Worth noting and not included in the table is that these two waste streams also become the significant contributor to calculated releases due to human intrusion (Dunagan et al., 2019, slide 47). In the 2019 Annual Transuranic Waste Inventory Report (ATWIR; DOE-CBFO, 2019b), DOE has added a new waste stream, SR-KAC-PuOx-1, which accounts for 7.1 MT of surplus plutonium—a subset of SR-KAC-SPD in Table 5-3.

Several documents, reports, and briefings provided to the committee offered early insights into the safety and performance of WIPP in consideration of the transport, receipt, and emplacement of up to 48.2 MT of DSP-TRU wastes, such as Zeitler et al. (2018), discussed above. The timely completion and release of reports to the public (with or without the opportunity for public comment or independent review) are important in addressing public and regulator concerns and fostering trust and confidence in DOE's plans for surplus plutonium disposition. However, in some cases, conducting studies before waste emplacement is inconsistent with established practice, regulations, and plans. The committee suggests that the following types of reports and analyses be conducted acknowledging and exploring the addition of 48.2 MT of surplus plutonium in WIPP and made available: criticality assessments, a post-closure performance assessment, and updates to the WIPP documented safety analysis.

5.3.1 Examples of Relevant Safety Analyses

One example of a safety analysis is the recent criticality assessment performed by Oak Ridge National Laboratory (ORNL) scientists for the full 48.2 MT of DSP-TRU waste (Saylor and Scaglione, 2018).[16] A full nuclear criticality assessment had not previously been performed for WIPP inventories because historically the TRU waste streams were characterized as having generally more dispersed fissile material and the mechanisms to concentrate the dispersed fissile material were considered absent (Rechard et al., 2000). As designs for inventory, waste forms, and disposal packages have changed, new criticality analyses have been performed, and updates have been made to address any potential effects to the WIPP safety basis owing to the addition of large stocks of surplus plutonium.

[16]Nuclear criticality assessments examine the condition and configurations under which criticality can occur with the intent to support design and licensing considerations that ensure nuclear safety, such as was done for the CCC.

TABLE 5-4 Characteristics and Relevant Amounts and Volumes for Contact-Handled (CH) TRU and Diluted Surplus Plutonium (DSP) TRU Wastes Compared to Wastes in Other 55-Gallon Drum Containers

	Other TRU Waste	TRU Waste in Pipe Overpack Containers (POCs)	DSP-TRU Waste in Criticality Control Containers/Criticality Control Overpacks (CCC/CCOs)
Composition	Variable: contaminated clothing, tools, rags, residues, debris, soil, and other items	Plutonium residues, heterogeneous debris, salts, and sealed sources	Predictable composition of DSP-TRU[a]
Physical volume (outer container)	0.21 m^3	0.21 m^3	0.21 m^3
LWA volume (inner container)	0.21 m^3	0.046 m^3	0.013 m^3
Current total number of waste streams	202[b]	48[b]	3[c]
Total number of emplaced containers	97,928 (emplaced)[d]	27,025 (emplaced)[d]	160,667 (anticipated)[e]
Total amount of plutonium-239	1.6 MT (emplaced)	3.2 MT (emplaced)	48.2 MT (anticipated)
Percentage of plutonium-239 in total inventory at closure (10,000 years)[f]	15	[included in "Other TRU Waste"]	85
Average amount of plutonium-239 per container/ fissile gram equivalent (FGE) limit[g]	14.4 g/ ≤ 200 g	117 g/ ≤ 200 g	300 g (nominal)/ ≤ 380 g
Material attractiveness level[h]	Level E	Varied	Level D[i]
Classification	Unclassified[j]	Unclassified[j]	Classified aspects (i.e., adulterant)[i]

[a]Technical Baseline Description, SRNS, 2018b.
[b]Number of waste streams derived from WDS/WWIS as of September 30, 2019, from https://wipp.energy.gov/WDSPA (accessed May 20, 2020).
[c]SR-KAC-PuOx, SR-KAC-PuOx-1, SR-KAC-SPD (DOE-CBFO, 2019b; Dunagan et al., 2019).
[d]Emplaced 55-gallon, direct loaded containers and POCs through September 30, 2019, see Table 5-1.
[e]Assumes nominal 300g per container.
[f]Dunagan et al., 2019.
[g]Per WIPP WAC, table 1, DOE-CBFO, 2018c.
[h]See Box 3-2 for a description of attractiveness levels.
[i]See System Requirements, DOE-NNSA, 2018.
[j]A small number of emplaced containers are known to be classified (Sahd, 2019); no further details are available.

The ORNL nuclear criticality assessment developed models for optimally configured (i.e., an optimal environment for criticality), infinite arrays of CCC/CCOs that contain the maximum allowed quantity of DSP-TRU residing within an optimal environment for conservative results. Criticality occurs when the effective neutron multiplication factor is greater than or equal to unity ($k_{eff} \geq 1$). The ORNL models predicted $k_{eff} > 1$ if the inner containers (pipes) in the infinite array were moved together (see top curve of Figure 5-2). To remove the potential for criticality ($k_{eff} \geq 1$), it was determined that boron carbide (B_4C) additive needed to be included as part of the overall mix of plutonium oxide and adulterant. The addition of boron carbide readily removes the potential for criticality as seen in Figure 5-2.[17]

The criticality safety assessment (evaluated over the 10,000-year compliance period) suggests that effective quality assurance and quality control are needed to ensure that boron carbide is added during the dilution process. Additionally, attention to load management within panels (i.e., deliberate distributed placement of CCC/CCO packages in the underground) is a prudent measure to eliminate the potential for the formation of large arrays of close-packed pipes containing DSP-TRU material.

While the committee concurs with the approach and conclusions of the nuclear criticality assessment report, the principal issue here is that concerns over post-closure criticality are renewed (particularly beyond the 10,000-year regulatory period), and DOE would be best served if such reports were made publicly and widely available.

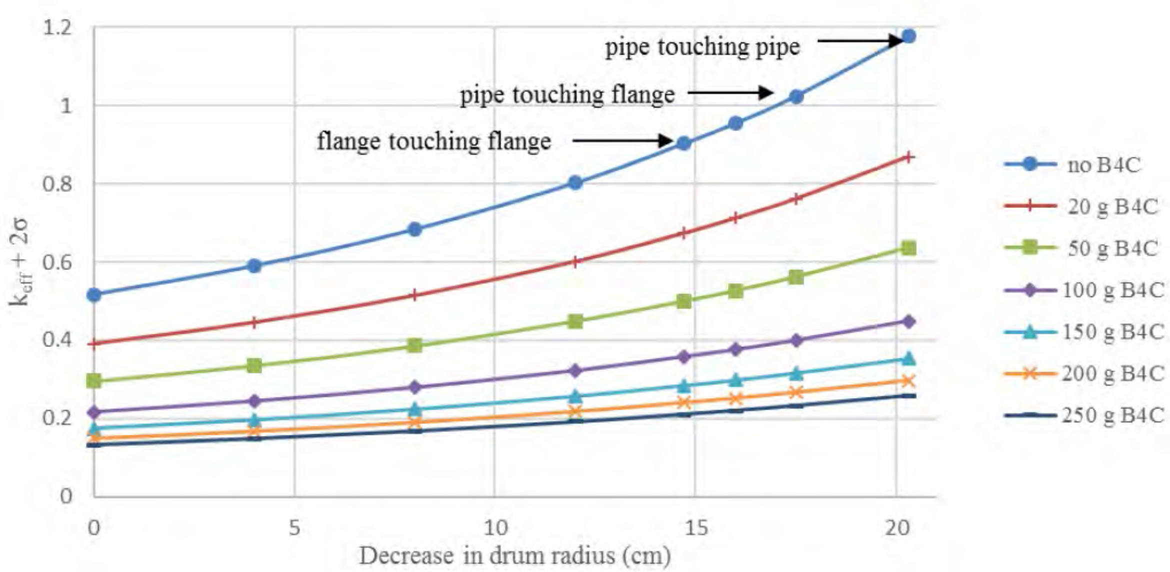

FIGURE 5-2 Results of criticality analysis with boron carbide (B_4C) added to the diluted plutonium oxide contained within the 6-inch-diameter inner pipe of the criticality control container (see Figure 1 in Box 2-1). SOURCE: Saylor and Scaglione, 2018, fig. 9. ORNL/TM-2017/751.

[17]The CCC is designed and U.S. Nuclear Regulatory Commission certified to prevent criticality (hence its name) during loading, transport, and emplacement, as long as the condition and configuration (i.e., the stainless-steel flanged pipe) are kept intact. The design may contribute to but is not relied on for maintaining post-closure criticality, because the condition and configuration are expected to change over time. Thus, post-closure criticality is considered separately.

Post-closure performance assessments are another example of assessments and analyses that could be made available to the public to increase transparency. As noted in Chapter 2 of this report, EPA regulations call for a post-closure PA to demonstrate compliance with the long-term performance standards of 40 CFR Part 191 and to support CRA per 40 CFR Part 194. Congress requires EPA to recertify the facility every 5 years following the initial receipt of TRU waste until the end of its operational activities. This recertification requires DOE-CBFO to submit results of a PA with every CRA to EPA.[18]

While the demonstration of continued compliance with the post-closure performance criteria is fully expected, the CRA-2019 PA will be the first official and publicly available report to provide a complete understanding of the expected impacts from the addition of the 6 MT of DSP-TRU to the WIPP inventory.

The 6-MT inventory is now included in the WIPP and PA inventory upon issuance of the 2016 Surplus Plutonium Disposition Record of Decision (SPD ROD). Text in the announcement of the 2016 SPD ROD suggests that a special PA sensitivity analysis was performed, and if it were, it has not been made available to the committee or public (DOE, 2016a). Rather, DOE-NNSA appears to have relied on the basis for assessing environmental impact by pointing to the WIPP supplemental environmental impact statement (SEIS) and further supplements: "The potential environmental impacts of TRU waste disposal at WIPP are evaluated in the Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement (WIPP SEIS-II) (DOE/EIS-0026-S-2, September 1997) and subsequent Supplement Analyses from 2005 (DOE/EIS-0026-SA-05) and 2009 (DOE/EIS-0026-SA-07)" (DOE, 2016a, p. 19590). Pointing to the SEIS is analogous to asserting the waste will meet the WIPP waste acceptance criteria (WAC).

In April 2019, the committee was given and briefed on a special PA sensitivity analysis report (Zeitler et al., 2018; Dunagan, 2019) that summarized performance analysis results for the inclusion of up to 48.2 MT of DSP-TRU waste in WIPP. Previously, the committee received the corresponding PA Inventory Report (LANL, 2017). Together these documents provided information and data into the effects that the added inventory of 48.2 MT might have on the repository performance metrics, as well as the likely continued compliance with the regulations for post-closure performance (see Tables 5-2 through 5-4 and Figure 5-1). These documents are publicly available by request through the National Academies' Public Access Records Office (paro@nas.edu) but could be more widely accessible through, for example, a special section on the DOE WIPP website (similar to what was done for the recent accident recovery). This would serve to enhance transparency and outreach efforts.

A final example of assessments and analyses that could be made available to the public to increase transparency is the WIPP documented safety analysis (DSA). As noted in Chapter 2, the Defense Nuclear Facilities Safety Board (DNFSB) raised concerns regarding deficiencies in DOE Standard 5506-2007 (DOE, 2007) and its application to the WIPP DSA, and that could have bearing on the operational safety management for the large number of CCOs anticipated for the dilute and dispose program. In short, the DNFSB took issue with the assumed statistical variation of the density of plutonium in the waste streams arriving via generator site shipping campaigns. It noted that in some cases the variation within a room (there are seven rooms within each panel in WIPP) was not in accordance with the statistical variation

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[18]This year, DOE-CBFO submitted the PA results after the March 2019 CRA submission—an unusual step since normally the PA results are submitted with the CRA. The PA was deferred due to schedule and resource limitations arising from the WIPP recovery efforts after the 2014 accident. From the CRA-2019 Executive Summary (DOE-CBFO, 2019c): "A PA has been included as part of the recertification application for all past recertification cycles, although it is not explicitly required for recertification by the LWA, 40 CFR 191 or 40 CFR 194. The DOE has decided, with agreement from EPA, not to include an updated PA in CRA-2019. The CRA-2019 contains all updated information and data required by 40 CFR 194.15, Content of compliance recertification applications. DOE plans to separately submit PA results based on CRA-2019 data in late 2019. The PA used in the CRA-2014 continues to be the baseline PA for the WIPP certification and is included in this CRA-2019 submittal by reference. This PA shows WIPP is compliant with 40 CFR 194."

that is assumed in the Material at Risk (MAR) and the calculation of source term.[19] The DNFSB cautioned that if use of the statistical MAR continued without additional administrative controls, there would be a high likelihood that future waste operations would continue to concentrate waste containers with higher-than-average fissile loadings and create the potential for accidents with higher consequences than analyzed (DNFSB, 2018). As shown in Tables 5-2 through 5-4, the DSP-TRU waste streams are likely to exacerbate the transfer campaign bias. Even within the current room/panel design, the DSP-TRU waste physical volumes require the space of nearly two equivalent panels and could, quite possibly, be more concentrated in the future for the as-yet unmined panels. One potential outcome is to revisit the room-level MAR as future room and panel configurations through a revision of DOE Standard 5506-2007 and the WIPP DSA to explicitly acknowledge the additional administrative controls that may be applied to ensure that the safety basis is in line with realistic assumptions for the receipt of the DSP-TRU.

FINDING 5-2: The diluted surplus plutonium transuranic (DSP-TRU) waste streams appear to have little impact on the Waste Isolation Pilot Plant's (WIPP's) pre-closure safety and operations:

- **The DSP-TRU waste meets the WIPP waste acceptance criteria, and**
- **No operational changes other than extension of physical space and extended lifetime of WIPP are required—which are likely also needed for other TRU waste streams such as TRU waste from pit production.**

The DSP-TRU waste streams' impact on WIPP's post-closure safety and performance is also minimal. Based on the current analyses evaluated over the 10,000-year performance period, it appears that the addition of up to 48.2 metric tons of surplus plutonium processed into DSP-TRU waste

- **Will meet the Environmental Protection Agency's regulatory limits and**
- **Will stay below risks for criticality events with the addition of boron carbide in the adulterant.**

FINDING 5-3: The anticipated emplacement of up to 48.2 metric tons of diluted surplus plutonium as diluted surplus plutonium transuranic (DSP-TRU) waste in the Waste Isolation Pilot Plant (WIPP) appears to be within regulatory pre-closure and post-closure safety and performance limits. Yet, DSP-TRU waste is characteristically different from past TRU waste and has larger impacts on the repository. Notably, the Environmental Protection Agency–developed regulations allow higher releases when more radioactivity is emplaced. The DSP-TRU waste streams alone increase radioactivity in WIPP at the end of the post-closure period (i.e., 10,000 years) by a factor of 4.

CONCLUSION 5-2: The emplacement of the proposed diluted surplus plutonium transuranic (DSP-TRU) wastes fundamentally changes the nature of the Waste Isolation Pilot Plant (WIPP) as a repository for the disposal of the Department of Energy defense TRU wastes. No previous waste stream has held such significance to the technical measures of WIPP performance. While the initial analyses indicate that the WIPP repository will maintain regulatory compliance with the increased amount of plutonium in its inventory, the potential for such substantive changes raises technical, social, and political questions that translate to additional system vulnerabilities if not addressed.

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[19]Within the WIPP DSA and according to DOE Standard 5506-2007, the MAR is the amount of radioactive material available to be acted on by a given physical stress (i.e., from a postulated accident scenario). The WIPP DSA expresses the MAR as the product of the number of waste containers (e.g., CCC/CCO) involved in a postulated event causing physical stress, and, with other factors, calculates the possible source term that could be released in that event.

Beyond the technical considerations and analyses, there is a "social contract" perspective that may be equally important to the long-term public support and sustainability of the dilute and dispose program objectives. The common presentation of WIPP TRU waste as modestly contaminated debris generated through defense activities related to nuclear weapons maintenance and development is incongruent with the characteristics of the DSP-TRU waste streams. Indeed, the DSP-TRU waste streams (SRS-KAC-PuOx, SR-KAC-PuOx-1, and SRS-KAC-SPD) could be viewed as closer to conditioned nuclear material than traditional TRU waste. In a 2002 letter to DOE Secretary Abraham, Senator Domenici foresaw the potential for diluted weapons material to be sent to WIPP when he wrote:

> I want to ensure that high level or weapons material wastes can never be simply diluted in order to comply with criteria for WIPP disposal…. In fact, dilution of weapons materials, simply in order to facilitate disposal, raises serious questions about our adherence to the same international controls on weapon-related materials that we expect other nations to follow. (Domenici, 2002)

Similarly and more recently, Senator Udall[20] of New Mexico expressed concern over the volume of record change (see Box 2-3) when he noted that WIPP's volume limits were critical to federal-state negotiations that led to WIPP's creation "and were a major reason New Mexico agreed to this mission in the first place.… I am encouraging the new [State] administration to take a hard look at this action, and hopeful that it will pause and reconsider this last-minute change that has major ramifications for our state" (Oswald, 2019).

> **FINDING 5-4: By virtually any measure, the proposal to dilute 48.2 metric tons of surplus plutonium and dispose at the Waste Isolation Pilot Plant (WIPP) represents a substantial technical and "social contract" change for WIPP and the State of New Mexico.**

Several other converging factors occurring in the next 5 to 8 years could further exacerbate the ability of the regulatory institutions (EPA, NMED) and the State of New Mexico to consider the significance of the dilute and dispose program in its entirety. These other factors include the following:

- The recent new shaft and access drift being developed are expected to lead to a request for new disposal panels to accommodate the space lost in the abandoned south end, the additional volumes of waste that are enabled by the LWA volume of record accounting change, and the SPD-TRU volumes (6 MT already in the WIPP-bound inventory). It is unclear where or what new room/panel configurations might be proposed, but they will introduce new asymmetries in the repository modeling and have to be reflected in the future PAs of long-term performance, EPA's compliance recertification reviews, NMED review and approval, etc.
- The conceptual models and software code used in the performance assessment are expected to transition from BRAGFLO to PFLOTRAN, allowing greater fidelity in the PA modeling and allowing a three-dimensional analysis (see Box 5-1). It is unclear if this new code base will be relied on for the March 2024 or March 2029 recertification application.
- As noted earlier, the DSP-TRU waste inventory has caused a renewed look at the potential for criticality, and the simple features, events, and processes (FEP) screening arguments used in the past are now augmented by a full criticality safety assessment, but this work has not yet received regulatory review. The initial criticality safety assessment, which has noted that abatement of criticality concerns may require boron carbide additives or load management, is in the context of the current room/panel design and evaluated for the 10,000-year regulatory compliance period.

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[20]Senator Udall helped establish the legal limits in the Waste Isolation Pilot Plant Land Withdrawal Act that resulted following a lawsuit that New Mexico won against DOE when he served as Attorney General for New Mexico.

- The LWA volume of record change ostensibly translates to a greater total radionuclide inventory in WIPP (owing to the radionuclide quantity now being focused within an inner rather than outer container volume) which is intensified by the CCC/CCO configuration for diluted surplus plutonium (i.e., ~300 FGE in 0.013 m^3 instead of 0.21 m^3).

This confluence of events and changes, if approached in the traditional manner, will confound a transparent regulatory and public review of the full dilute and dispose program scope and deny the public and especially the State of New Mexico the opportunity to consider the significance of the dilute and dispose programs in their entirety.

CONCLUSION 5-3: The possible accommodation of the dilute and dispose program inventory, representing a significant demonstrable change in the character of the Waste Isolation Pilot Plant repository and the social contract with the State of New Mexico, warrants a strategic approach to seeking its technical evaluation, regulatory review, safety analysis, and public engagement.

An essential element to engender public trust and stakeholder acceptance is the use of independent oversight (versus regulatory) bodies with the capacity to conduct independent technical evaluation. The former Environmental Evaluation Group (EEG) is one such example (see Section 5.3.1, Examples of Relevant Safety Analyses).

The EEG was a part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department, funded by DOE and administered through the Board of Regents of the New Mexico Institute of Mining and Technology. Previously, the EEG has served as an independent technical advisor to NMED, and Section 74-4A-4 of the New Mexico State Statutes recognizes and defines the EEG as an independent state review organization (Walker and Silva, 2002). Important to its independence and credibility, the EEG was neither a proponent nor an opponent of WIPP and focused on reviewing and evaluating potential health, safety, and environmental impacts from WIPP.

Details of how the EEG was established were critical to its independence. These details can be found in Box 5-2.

FINDING 5-5: In addition to the implementation challenges outlined in Finding 4-1, several system vulnerabilities exist within the current plan. If not addressed, system vulnerabilities could have serious consequences to the program and its mission to dispose of at least 34 metric tons (MT)—and as much as 48.2 MT—of surplus plutonium in an efficient, safe, and secure manner. Addressing the system vulnerabilities will require actions by the current Department of Energy's National Nuclear Security Administration's (DOE-NNSA's) program management and higher levels of government. System vulnerabilities include

- **The Waste Isolation Pilot Plant (WIPP) as the single point of failure for the disposal of diluted surplus plutonium transuranic waste;**
- **Plans that span multiple DOE sites, offices, functions, and competing priorities without clear crosscutting leadership support;**
- **Shifting public opinion of DOE-NNSA's plans and its handling of plutonium stockpiles and surplus inventory; and**
- **Reliance on a plan that changes the nature and function of the United States' only operational deep geologic waste repository (WIPP).**

FINDING 5-6 (updated Interim Report FINDING 7): The Department of Energy's National Nuclear Security Administration and Office of Environmental Management do not have well-developed public outreach plans for each of the host sites for processes or for the transportation corridor states (i.e., the current plan is to follow public input requirements defined by the National Environmental Policy Act) for the dilute and dispose program.

BOX 5-2 Criteria for Establishing an Independent Technical Review Group for the Citizens of New Mexico

The Environmental Evaluation Group (EEG), an independent technical group overseeing the protection of the public health and environment on behalf of the State of New Mexico and its citizens, was created in response to a 1981 lawsuit filed by the New Mexico Attorney General against the Department of Energy and was to be created for "the full operational life of WIPP through and including the decontamination and decommissioning" (DOE-CBFO, 1988, p. 29).

The EEG was created in 1978 and operated until 2004, when its funding was eliminated. Its responsibility was to conduct an independent technical evaluation on the impact of the Waste Isolation Pilot Plant (WIPP) on the public health and safety on the people of New Mexico because the interests of the federal government are not always consistent with those of the state, and so independent overview was essential. During its 26-year operation, the EEG identified criteria essential to ensure that the interests of the state are addressed, to ensure acceptability of the repository, and to promote its safe operation. The EEG's guiding principles and contributions are detailed elsewhere (Channell and Silva, 2001; Neill and Silva, 2001). It has been argued that the oversight roles played by the EEG as well as the National Research Council's WIPP Committee were crucial to the success of the WIPP project (Kerr, 1999).

For EEG to function as an independent technical body, several fundamental criteria aim to ensure the trust of the public and of elected officials. Toward this end, the director must have the responsibility to hire full-time professional staff and to identify the technical reviews to be done. While there are social, legal, and political issues, the reviews must be confined to technical issues. The technical reviews must be published publicly and widely distributed. The independence of the organization and the independence of its reviews must be protected. Central to this goal is the ability to publish technical reviews without prior editing or approval by either state or federal officials of reports or analyses.

An Act of Congress (NDAA, 1988) specified the authority and responsibility of the EEG. As initially enacted, it promoted the criteria identified above and went far to honor the federal government's commitment to the people of New Mexico. The initial version of that law could serve as a template for reinstatement of the group for the purpose of reviewing the federal intent to dispose of surplus plutonium at WIPP.

CONCLUSION 5-4 (updated Interim Report CONCLUSION 2): Public trust will need to be developed and maintained throughout the lifetime of the dilute and dispose program because the program will change and evolve as new knowledge is obtained, and modifications and potential changes to legislation will be required for the Waste Isolation Pilot Plant. These changes will require assuring the regulators and the public of the safety and security of the Department of Energy (DOE) plans. This is particularly challenging for the dilute and dispose program because of several factors: security classification of aspects of the planning (constituents of the adulterant, processing steps, security and safeguards assessments); early stage of program development with changes likely to occur as more information is known; and potential impacts that cross many states and DOE sites.

RECOMMENDATION 5-2 (updated Interim Report RECOMMENDATION 2): The Department of Energy's National Nuclear Security Administration and Office of Environmental Management should engage New Mexico and South Carolina as well as their congressional delegations prior to the public engagement required by the National Environmental Policy Act process to assess prospects for successfully amending the existing legal agreements to allow for the dilution and packaging of up to 48.2 metric tons of surplus plutonium at the Savannah River Site and its disposal in the Waste Isolation Pilot Plant.

RECOMMENDATION 5-3 (updated Interim Report RECOMMENDATION 3): If the Department of Energy's (DOE's) National Nuclear Security Administration's dilute and dispose plan moves forward, DOE should reinstate the Environmental Evaluation Group (EEG), representing the concerns of the State of New Mexico, throughout the lifetime of processing up to 48.2 metric tons of surplus plutonium material. The independence of the EEG should be supported through mechanisms similar to those established in its original founding. Members of the technical review organization should be technically qualified to address the health and safety issues and a subset should have access authorizations that will allow thorough review of classified aspects of the plans and their implementation.

RECOMMENDATION 5-4 (updated Interim Report RECOMMENDATION 4): In addition to and separate from the independent review organization representing the State of New Mexico described in Recommendation 5-3, periodic reviews for Congress and the Department of Energy (DOE) by a team of independent technical experts should be required until classified aspects of DOE's National Nuclear Security Administration's and DOE's Office of Environmental Management's dilute and dispose plans, including the safety and security plans, are completed and implemented. Because DOE's plans and decisions are expected to mature and evolve, these independent reviews would provide a mechanism to review classified aspects of the programs and would improve public trust in those decisions.

Because DOE-NNSA's, DOE-EM's, and DOE-CBFO's plans and decisions are expected to mature and evolve, these independent reviews would provide a mechanism to review all aspects of the program, including the classified elements, and would do much to improve public trust in those decisions.

Several incremental actions taken by DOE, while administratively compliant, could be interpreted as obscuring the fact that as much as 48.2 MT of surplus plutonium is being proposed for dilution and disposal in an expanded (in physical space) and extended (in lifetime) WIPP. For example, numerous site-specific SEIS actions for smaller amounts of surplus plutonium material are confusing to track and have been proposed as the basis for the 34-MT National Environmental Policy Act (NEPA) actions (Richard, 2019; see also Box 2-2). DOE-NNSA's NEPA strategy includes moving forward with a SEIS for the 34 MT of surplus plutonium material; this would be in addition to the SEIS for 6 MT of non-pit plutonium. A notice of intent for the disposition of 34 MT still has not been issued, an action that has been delayed by over a year. Another 7.1 MT is currently without a disposition pathway but associated with the ROD for the 6 MT (see below). Yet, another 1.1 MT could be considered for dilute and dispose but may also be dispositioned in the Defense Waste Processing Facility (see Figure 2-1). Any of these plans for smaller amounts of surplus plutonium when individually considered would appear to have little impact on WIPP, the environment, safety, or security. Yet, when considered in total, their impact is clear.

There are many reasons why implementation of programs responsible for the dilution and disposal of up to 48.2 MT may have to proceed in segments (e.g., 6 MT, 7.1 MT, 34 MT, and so on). Such an approach, while technically permissible, goes against the notion of transparency that could impact public support and thus represents a substantial system vulnerability. If DOE leadership, such as the Deputy Secretary, has decided on a strategic objective to disposition the majority (48.2 MT) of the surplus plutonium inventory in WIPP as DSP-TRU waste, actions could be taken to clarify these objectives and to transparently report their potential impacts. Members of the public and the State of New Mexico should be afforded the opportunity to consider the significance of the dilute and dispose program in its entirety. As noted previously, a new DSP-TRU waste stream was recently identified, SR-KAC-PuOx-1, and associated with the 7.1 MT of surplus pit plutonium material (DOE-CBFO, 2019b). This indicates that DOE is moving forward with another increment of DSP-TRU waste for WIPP rather than addressing the full amount in a single assessment.

In the examples in Section 5.3.1 and summarized in Findings 5-2 and 5-3, the analyses and results indicate that it is possible to emplace up to 48.2 MT of DSP-TRU in WIPP but that precautions may need to be taken and revisions of earlier WIPP analyses, which assumed more dispersed and far less fissile material, may also be needed. The timely revision of these important safety documents, in particular, before waste receipt, would better improve DOE transparency and address public concerns over the potential effects and safety impacts of the dilute and dispose program.

NEPA sets requirements for major federal actions requiring the preparation of environmental impact statements (EISs). It is DOE policy to follow NEPA and to apply the NEPA review process early in program development. To date however, DOE and DOE-NNSA have leveraged or relied on existing EISs for a variety of sites, issuing supplements, amendments, and interim actions where necessary or expedient, while also trying to accommodate changes in an uncertain strategy toward the disposition of surplus plutonium. DOE-NNSA has issued a number of EISs, SEISs, and RODs for dispositioning surplus plutonium (see Box 2-2). Below, two federal actions and decisions relevant to the dilute and dispose programs are highlighted:

- The final programmatic EIS, FPEIS-0229, evaluated strategies and locations for storing and dispositioning weapons-usable[21] fissile materials (DOE, 1996b); the associated ROD selected MOX and immobilization as the preferred options for surplus plutonium disposition. The Surplus Plutonium Disposition EIS-0283 (tiered from the FPEIS-0229, DOE, 1996b) evaluated site-specific alternatives for the construction and operation of facilities for disposition of up to ~45 MT of surplus plutonium (DOE, 1999a). The associated ROD in 2000 identified immobilization and irradiation of MOX fuel as the preferred dual alternatives for surplus plutonium disposal. Two years later, the immobilization program was canceled due to budget constraints and MOX was selected as the only method for plutonium disposition for the United States (DOE, 2002). The PMDA was later renegotiated with the Russian Federation and updated (DOS, 2010). Immobilization was removed from the listed disposition options; some of the material selected for immobilization was to be processed at the MOX plant to make it useable in MOX fuel.
- In 2015, dilute and dispose was specifically considered as one of the disposition options for surplus non-pit plutonium (referred to as "WIPP Disposal") in the Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement (DOE, 2015a).[22] Under this disposition option, plutonium oxide would be "mixed/blended with inert material…. Inert material would be added to dilute the plutonium-239 content and inhibit plutonium recovery and could include dry mixtures of commercially available materials" (DOE, 2015a, p. S-31). The subsequent April 2016 ROD selected the dilute and dispose at WIPP option for dispositioning 6 MT of diluted non-pit plutonium and reserved a decision on the other 7.1 MT for a later time, though it seems likely the same option could be exercised (DOE, 2016a).

A point of the preceding two bulleted items is to illustrate the DOE efforts to comply with the NEPA requirements for major federal actions requiring the preparation of EISs, but it may also serve to illustrate the impacts such indirect paths have on public trust and transparency.

While DOE has moved forward with a ROD for 6 MT, there are still several more surplus plutonium stocks under consideration for disposal at WIPP, and totaling at least 42.2 MT, and will need to be actioned under NEPA. In the past, the DOE approach has been to

- Use SEISs covering the SRS: "*prepare the SPD Supplemental EIS to evaluate the potential environmental impacts at the Savannah River Site (SRS) in South Carolina of disposition pathways for surplus weapons-usable plutonium (referred to as "surplus plutonium") originally planned for immobilization*" (DOE, 2015b, p. iii);

[21]A fissionable nuclear material such as uranium-235 or plutonium-239 that is pure enough to be usable in a nuclear weapon.

[22]DOE/EIS-0283-S2 evaluates environmental impacts for disposition of 13.1 MT of surplus plutonium, including 6 MT of surplus non-pit plutonium (managed by DOE-EM) as well as 7.1 MT of plutonium from pits shown in DOE (2015a, fig. 1).

- Point to assurances the diluted waste will be compliant with the WIPP WAC: "*This plutonium will be prepared and packaged to meet the WIPP waste acceptance criteria…*" (DOE, 2016a, p. 19588); and
- Use the existing WIPP SEIS to maintain that the environmental impact of adding surplus plutonium at WIPP were evaluated: "*The potential environmental impacts of TRU waste disposal at WIPP are evaluated in the Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement (WIPP SEIS-II) (DOE/EIS-0026-S-2, September 1997) and subsequent Supplement Analyses from 2005 (DOE/EIS-0026-SA-05) and 2009.*" (DOE, 2016a, p. 19590)

In a 2011 SRS Interim Action Determination, justification for the emplacement in WIPP of previous diluted plutonium amounts rested on the small amount of material relative to remaining capacity in WIPP (Moody, 2011).[23] Then for the 6-MT SEIS, DOE noted that small amounts of PuOx were similarly diluted and already emplaced at WIPP as justification for the expansion to 6 MT. Presumably the decision on the remaining 7.1 MT will point to the previous decision on the 6 MT. The April 2019 briefing on DOE-NNSA's NEPA strategy indicated that DOE-NNSA would pursue a supplemental EIS for the 34 MT, which could potentially point to the small amounts of emplaced diluted material for justification (Richard, 2019).[24] The logic begins with justification of small amounts relative to the WIPP inventory and ends with the majority of surplus plutonium constituting 85 percent of the total plutonium-239 emplaced in WIPP.

The committee recognizes that such an incremental and disaggregated SRS SEIS approach may have the advantage of limiting scope and appear expedient, even if permissible by NEPA guidance. The committee further recognizes that realistically all of the surplus plutonium inventory has no real alternative at this time other than disposal at WIPP or "no action."

However, with regard to following the same approach as was done for the 6 MT, the committee expresses concern that, when applied across the total 48.2 MT inventory including the remaining 42.2 MT, such an approach is counter to public transparency, and the development of a sustainable sociopolitical relationship.

In reviewing the implementing procedures governing NEPA (10 CFR Part 1021), and the related regulations requiring the preparation of EISs (40 CFR § 1502.4) for major federal actions (40 CFR § 1508.18), the committee notes the following (excerpted and edited for clarity, emphasis added):

- A programmatic NEPA document means a *broad-scope EIS identifying and assessing the environmental impact of a DOE program*[25];
- A program means a *sequence of connected or related DOE actions or projects*[26];

[23]Moody, 2011, p. 2: "WIPP has been safely disposing of TRU waste for more than 10 years, and the 880 cubic meters that would result from this action represents a small fraction, about 3%, of the unsubscribed WIPP disposal capacity." NOTE: The 3 percent figure seems in error, and the volume would have been relative to the TMW (outer container) volume definition.

[24]DOE has not yet issued a notice of intent (NOI), an EIS, or ROD for dispositioning 34 MT of pit and non-pit surplus plutonium using the dilute and dispose process. The committee received information on NEPA plans (Richard, 2019, slide 2) that stated that DOE-NNSA planned to initiate a supplemental EIS for the 34-MT mission. Its plans include a posting of an NOI in the near future, public comment periods required by NEPA, plans to analyze dilute and dispose as the preferred alternative as well as the no-action alternative, and to complete the NEPA analysis by late 2020.

[25]See 10 CFR § 1021.104 Definitions: https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:4.0.3.5.14#se10.4.1021_1104 (accessed April 26, 2020).

[26]See 10 CFR § 1021.104 Definitions: https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:4.0.3.5.14#se10.4.1021_1104 (accessed April 26, 2020).

- When required to support a DOE programmatic decision, including *the adoption of programs—such as a group of concerted actions to implement a specific policy or plan* or systematic and connected agency decisions allocating agency resources to implement a specific statutory program or executive directive—*DOE shall prepare a programmatic EIS*[27]; and
- "Proposals or parts of *proposals [that] are related to each other closely enough to be, in effect, a single course of action shall be evaluated in a single impact statement*."[28]

As such, when considering the whole of the surplus plutonium dilute and dispose program, the several connected sites directly affected by the plan (including at least SRS and WIPP, and possibly LANL), and the quantities that challenge the scope of the existing EIS, a broad-scope PEIS is warranted.

Simply, the total quantities of surplus plutonium now being considered for disposal at WIPP are far larger than those assessed in the 2015 Supplemental EIS. Additionally, while compliance with the WIPP WAC is required of all TRU waste, the existing WIPP SEIS did not contemplate either the quantity or character of the surplus plutonium or the future underground configuration. Finally, several processing facility changes must all happen to implement a dilute and dispose program. Recent efforts to expand the nation's pit production capacity will also impact the sites and facilities that are being proposed in DOE-NNSA's dilute and dispose plans. There is likelihood of conflicts across programs for human resources, infrastructure, and facilities usage, as noted in Chapter 4.

RECOMMENDATION 5-5: The Department of Energy should implement a new comprehensive programmatic environmental impact statement (PEIS) to consider fully the environmental impacts of the total diluted surplus plutonium transuranic waste inventory (up to an additional 48.2 metric tons) targeted for dilution at the Savannah River Site and disposal at the Waste Isolation Pilot Plant (WIPP). Given the scale and character of the diluted surplus plutonium inventory, the effect it has on redefining the character of WIPP, the involvement of several facilities at several sites to prepare the plutonium for dilution, a schedule of decades requiring sustained support, and the environmental and programmatic significance of the changes therein, a PEIS for the whole of surplus plutonium that considers all affected sites as a system is appropriate to address the intent and direction of the National Environmental Policy Act and would better support the need for public acceptance and stakeholder engagement by affording all the opportunity to contemplate the full picture.

RECOMMENDATION 5-6: The Department of Energy's (DOE's) National Nuclear Security Administration, DOE's Office of Environmental Management, and DOE higher-level officials should take additional actions beyond those defined by the National Environmental Policy Act toward transparency and stakeholder engagement on the whole of the potential scope of surplus plutonium under consideration (48.2 metric tons) for disposal at the Waste Isolation Pilot Plant. Such actions include completing and publicizing the outcome of relevant safety analyses and cost estimates.

5.4 ENGAGE NMED AND EPA

A dual regulatory framework exists for WIPP, with EPA and NMED having separate but coupled roles in regulating worker, public, and environmental safety (see Chapter 2). A positive "regulator–permittee" relationship between DOE and NMED is a prerequisite for smooth general operation of the

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[27]See 40 CFR § 1508.18 (b.3) Major Federal Action: https://www.govinfo.gov/content/pkg/CFR-2010-title40-vol32/pdf/CFR-2010-title40-vol32-sec1508-18.pdf (accessed April 26, 2020).

[28]See 40 CFR § 1502.4 Major federal actions requiring the preparation of environmental impact statements, part (a): https://www.govinfo.gov/content/pkg/CFR-1996-title40-vol18/html/CFR-1996-title40-vol18-sec1502-4.htm (accessed April 26, 2020).

WIPP, but it becomes especially important when potentially controversial issues come into play and public scrutiny and skepticism are likely to increase. Such was the case with the WIPP accidents and its subsequent recovery, the effort to change the accounting of waste volumes, and the occasional but recurring mention of accepting other TRU wastes (see Boxes 2-3 and 2-5).

One could argue that the anticipated changes to the WIPP underground configuration, its lifetime extension (both of which are likely even without the DSP-TRU waste), and the changes contemplated by the receipt of the DSP-TRU inventory place WIPP on the cusp of a new phase of operations. How DOE-CBFO, DOE-NNSA, and DOE decision makers approach the upcoming WIPP permit modification requests to NMED could have a demonstrable effect on the regulatory review duration and the degree of skepticism and scrutiny exercised by the public.

DOE-CBFO's engagement with EPA, as with NMED, provides another critical opportunity to promote transparency and involvement with the public and interested stakeholders. The committee has given consideration to how and why DOE-CBFO might approach EPA beyond the requirements for the quinquennial recertifications, as DOE-EM and DOE-NNSA contemplate a future implementation of a dilute and dispose program.

As presented in Chapter 2, the principal WIPP EPA regulations of concern are the radiation protection criteria described in 40 CFR Part 191 (see Figure 2-5) and in 40 CFR Part 194, which lay out the compliance certification criteria.

As noted previously, the addition of the DSP-TRU inventory (up to 48.2 MT) is expected to involve the handling of more than 160,000 containers (i.e., CCC/CCOs), will require two additional underground panels (GAO, 2017), and at closure will have quadrupled the total radioactivity (curies) of disposed TRU waste (Zeitler et al., 2018).

Regarding compliance with post-closure performance criteria, the committee notes:

- Repository compliance is based on calculations of release fractions of selected radionuclides and the specified release limits scale with the quantity of waste in a repository (i.e., the more disposed waste, the more radiation that may be released).
- As demonstrated in all previous compliance certifications, the only releases are from the disturbed scenario (i.e., human intrusion through drilling) and have been within the compliance limits.
- Results of a special post-closure performance assessment (Zeitler et al., 2018) suggest continued compliance is expected with all of the DSP-TRU inventory (48.2 MT) included.[29]

EPA now has the deferred PA associated with the 2019 CRA (see Chapter 2 for a discussion on the deferred PA) which is the first recertification application that includes a substantial portion (6 MT) of the surplus plutonium inventory that EPA will review.[30] The results of this regulatory review will be available in about a year from the writing of this report and may thus provide some technical or regulatory foresight on the inclusion of an additional 42.2 MT.

The volume and density of the total DSP-TRU inventory under consideration, combined with the pending inevitable changes in the surface and underground configurations, could be considered a significant change to WIPP's inventory. Thus, EPA could seek a new determination of regulatory compliance (formally or informally) prior to program implementation to improve transparency on such a significant change.

In a briefing by EPA to the committee (Peake, 2019), it was noted that 40 CFR § 194.4 requires DOE to notify EPA of "any planned or unplanned changes in activities or conditions pertaining to the

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[29]The committee commentary should not be construed as supplanting the regulatory function or influencing the determination of safety by regulatory bodies.

[30]Recall that 6 MT is the waste stream SRS-KAC-PuOx (see Table 5-2), the second-largest contributor (after the SRS-KAC-SPD 42.2 MT) to total EPA units (11 percent) at closure and at 10,000 years.

disposal system that differ significantly from the most recent compliance application." EPA reported that DOE has recently submitted to EPA several notices of planned changes to EPA:

- A notice of the new shaft and access drift, which will be reviewed as part of CRA-2019 now under way;
- A notice on changing panel closures and the abandonment of panel 9 without waste, which was approved in March 2019; and
- A notice on the LWA volume of record change, which is currently under review by EPA.

The DOE-NNSA Master Schedule and the ROAR both indicate that DOE-CBFO will submit a planned change notice (PCN) to EPA in early FY 2022 (this is not the same as a recertification application); this is after mid-FY 2020, when DOE-NNSA expects to issue a ROD for the disposition of 34 MT of surplus plutonium (see the relevant portion of the Master Schedule in Figure 3-1). The full scope and extent of this PCN, or how it will be managed by EPA, is not clear, although the Master Schedule indicates that EPA will review the PCN throughout FY 2023 and is expected to approve the PCN by the end of the first quarter of FY 2024. The expected EPA approval is coincident with (and independent of) the DOE-CBFO submission of the 2024 CRA and the beginning of repository disposal of the 7.8 MT of non-pit plutonium.

After DOE-CBFO submits the PCN, EPA may request additional information, and if EPA determines that, in accordance with 40 CFR § 194.65, "changes in activities or conditions pertaining to the disposal system depart significantly from the most recent compliance application," EPA would need to modify the existing certification (as opposed to waiting for the next 5-year recertification). EPA would then need to propose a rulemaking to modify the certification and take public comment. This has raised in the EPA and elsewhere the question, At what point would a change "depart significantly from the most recent compliance application"?

In its briefing to the committee, EPA noted that if the certification needs to be modified, a rulemaking would take more than 2 years and indicated that such activities need to be coordinated with recertification applications as much as possible to minimize multiple reviews.

It remains to be seen whether EPA will seek a rulemaking or other form of review, before or after various RODs trigger the inclusion of increments of the total SPD-TRU inventory. However, this sequence raises some uncertainty as to how EPA would evaluate, in full, the sum total of DSP-TRU inventory and its effect on WIPP compliance.[31]

Given the significance of the issues and their potential consequences for WIPP and the State of New Mexico, and in the interest of fostering a positive, sustained sociopolitical acceptance of the future WIPP, it is prudent to seek a high level of confidence that the dilute and dispose program as proposed and emplaced under a revised WIPP configuration will be or is compliant with all WIPP regulations including post-closure safety. A sufficiently high level of confidence could be established through EPA formal certification or other means that provides the same level of technical review and public participation.

FINDING 5-7: A segmented and incremental approach to revealing the full inventory under consideration for disposal as diluted surplus plutonium transuranic waste in the Waste Isolation Pilot Plant (WIPP) (initially 6 metric tons [MT], then 7.1 MT, and 34 MT, and so on) obfuscates the total anticipated inventory expected for WIPP and its consequences. An

[31]Although the results of Zeitler et al. (2018) suggest that WIPP can demonstrate compliance with the full inventory of 48.2 MT of diluted surplus plutonium, a decision to accept and support a future WIPP with all of the discussed surplus plutonium inventory will rely on a determination by EPA. Note that Zeitler et al. (2018) make clear that this is not a substitute for evaluating compliance: "The analysis is not in support of a planned change request (PCR) or planned change notice (PCN) to be submitted by the DOE to the EPA, and was not performed as a compliance calculation. Instead, the planned use of the analysis is as input into a National Environmental Policy Act (NEPA) analysis" (p. 13).

incremental approach inhibits a comprehensive review by regulators and the public of the full impact of the proposed dilute and dispose program on a future WIPP. The punctuated (5-year) Environmental Protection Agency compliance recertification schedule and limited scope of the New Mexico Environment Department's reviews (which exclude nuclear material) add to these challenges.

RECOMMENDATION 5-7: The Environmental Protection Agency, the Department of Energy, and the State of New Mexico should engage in developing a mutually agreed-upon strategy for vetting the effects of the dilute and dispose inventory, in its entirety (and as added to the rest of the projected and emplaced inventory), on the Waste Isolation Pilot Plant. This vetting could be through a special demonstration of compliance and certification, or other means all agree to, but should occur before committing the substantial resources that will be needed to implement an integrated (48.2 metric tons of surplus plutonium) dilute and dispose program.

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Appendix A

Committee and Staff Biographies

Committee Chair

Robert C. Dynes (NAS) was the 18th president of the University of California (UC) and is now an emeritus professor of physics at UC San Diego, where he directs a laboratory that focuses on superconductivity. Dr. Dynes served as chancellor of UC San Diego from 1996 to 2003 after 6 years in the physics department, where he founded an interdisciplinary laboratory in which chemists, electrical engineers, and private industry researchers investigated the properties of metals, semiconductors, and superconductors. Prior to joining the UC faculty, he had a 22-year career at AT&T Bell Laboratories, where he served as department head of semiconductor and material physics research and director of chemical physics research. Dr. Dynes received the 1990 Fritz London Award in Low Temperature Physics, was elected to the National Academy of Sciences in 1989, and is a fellow of the American Physical Society, the Canadian Institute for Advanced Research, and the American Academy of Arts & Sciences. He is the current co-chair of the Intelligence Community Studies Board at the National Academies of Sciences, Engineering, and Medicine and has served on the executive committee of the U.S. Council on Competitiveness. He currently serves on the board of the La Jolla Institute of Allergy and Immunology and advises several technical startups in the San Diego area. A native of London, Ontario, Canada, and a naturalized U.S. citizen, Dr. Dynes holds bachelor’s degrees in mathematics and physics and an honorary doctor of laws degree from the University of Western Ontario, and master’s and doctorate degrees in physics and an honorary doctor of science degree from McMaster University. He also holds an honorary doctorate from L’Université de Montréal.

Committee Members

Lisa M. Bendixen is an expert in hazardous materials risk and safety and has addressed risk management, risk assessment, security, and resilience challenges across numerous industries, for fixed facilities as well as transportation systems. She is a vice president at ICF, consulting on critical infrastructure security and resilience, mission assurance, and other risk management issues with the Departments of Defense (DOD), Energy (DOE), and Homeland Security (DHS). She served on the Transportation Security Panel for the National Research Council’s (NRC’s) report *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* and was on the NRC committee that produced the report *Terrorism and the Chemical Infrastructure: Protecting People and Reducing Vulnerabilities* as well as several other national committees focusing on transportation risks, including spent fuel. She was the project manager and primary author of the *Guidelines for Chemical Transportation Risk Analysis*, published by the American Institute of Chemical Engineers’ Center for Chemical Process Safety, and served on the center’s technical steering committee. Her work with DHS has included long-term support on critical infrastructure security and resilience, including several versions of the National Infrastructure Protection Plan, development and implementation of the Chemical Facility Anti-Terrorism Standards, and strategic and policy support to the Office of Infrastructure Protection. She has supported DOE on work related to grid security, from natural hazards and adversarial threats. She is also actively supporting DOD on critical energy and communications infrastructure. She has played leading roles in several safety and risk associations. Ms. Bendixen holds a B.S. in applied mathematics and an M.S. in operations research from the Massachusetts Institute of Technology.

Appendix A

Michael S. Bronzini is the Dewberry Chair Professor Emeritus in the Volgenau School of Engineering at George Mason University, where he also served as chair of the Department of Civil, Environmental, and Infrastructure Engineering. He is principal and cofounder of 3 Sigma Consultants, LLC, based in Nashville, Tennessee. Dr. Bronzini has conducted research and authored more than 250 publications on innovative solutions to complex multimodal transportation systems problems with a focus on freight transportation. He was principal investigator of a project to develop model curricula for transportation of hazardous materials, for the National Academies' Hazardous Materials Cooperative Research Program (HMCRP). He led a study of the impacts on Tennessee and the nation of options for transportation of spent nuclear fuel to a geologic repository that would be located in the western United States. From 1990 to 1999, Dr. Bronzini was director of the Center for Transportation Analysis at Oak Ridge National Laboratory in Oak Ridge, Tennessee, and was responsible for overseeing its interdisciplinary transportation research program. He was professor and head of civil engineering at Pennsylvania State University and director of the Transportation Center and professor of civil engineering at the University of Tennessee. Dr. Bronzini is a National Associate of the National Academies and has held numerous leadership positions on the Transportation Research Board of the National Academies, including chair of the Inland Water Transportation Committee and chair of the Study Committee on Landside Access to U.S. Ports and inaugural member of the HMCRP Oversight Panel. He is currently a member of the TRB Committee on Transportation of Hazardous Materials. Dr. Bronzini has also served as a consultant and advisor to numerous private and public organizations, including the State of Nevada Nuclear Waste Project Office's Technical Review Committee for the proposed radioactive waste repository at Yucca Mountain. He received a B.S. in civil engineering from Stanford University and a Ph.D. in civil engineering from Pennsylvania State University.

George E. Dials resigned his executive position with Babcock & Wilcox Corporation in mid-2014 and returned with his wife Pamela to their home in Santa Fe, New Mexico. For several months, he served as a senior executive advisor to the director of Los Alamos National Laboratory in an established position as director of the Strategic Improvement Office, charged with enabling implementation of the recently published Los Alamos National Laboratory Strategic Plan. In May 2015, Mr. Dials accepted the position as president and chief executive officer (CEO) of Pajarito Scientific Corporation (PSC) in Santa Fe, New Mexico. Effective September 1, 2017, in order to focus on a number of other family and business interests, he resigned his position as president and CEO of PSC and accepted a role as senior advisor to and member of the board of directors of the company. Mr. Dials's career spans four decades in energy, national security, waste management, and nuclear technology programs. He has held leadership positions in national security and waste management corporations, and at the Department of Energy (DOE). Previously, Mr. Dials was president of B&W Conversion Services, LLC (BWCS), and served as project manager for the Depleted Uranium Hexafluoride (DUF_6) Conversion Operations, the first-of-its-kind nuclear operation in the United States. Mr. Dials directed the BWCS Lexington project office and is the day-to-day interface with DOE's federal project director. He also directed operations at the conversion plants in Piketon, Ohio, and Paducah, Kentucky. He joined the B&W Y-12 Nuclear Weapons Complex, LLC in 2006, serving as president and CEO, where he managed a $1.2 billion annual budget and more than 4,600 employees, leading Y-12 through a period of improvement initiatives' involving restorations and new builds, and restored the facilities to full production capabilities and operations. Previously, Mr. Dials held executive leadership positions at DOE's waste disposal facilities, which included the Waste Isolation Pilot Plant (WIPP) and Yucca Mountain—locations designed to safely manage waste from nuclear operations. He was president and chief operating officer of the privately owned Waste Control Specialists, LLC, operating the hazardous waste disposal facility, and managing licensing of a low-level radioactive waste treatment and storage facility. Formerly, he oversaw design, engineering, and scientific studies of the Yucca Mountain Project as president and general manager of TRW Environmental Safety Systems, Inc., a DOE management and operating contractor. As a member of DOE's Senior Executive Service, Mr. Dials was manager, Carlsbad Area Office, responsible for WIPP and the National

Transuranic Waste Program. He also served as Idaho Operations Office assistant manager in Idaho Falls. Career awards include the DOE Exceptional Service Medal, 1998; New Mexico Distinguished Public Service Award, 1998; American Nuclear Society Fellow, 2006; Waste Management Symposia Wendell D. Weart Life Time Achievement Award, 2012; Worldwide Who's Who Executive; and Nuclear Fuel Cycle, 2013. During his military career, Mr. Dials served in multiple leadership roles, including an assignment as a Military Research Associate to the Los Alamos National Laboratory; Special Weapons Plans Officer, United Nations Command/U.S. Forces Korea, South Korea; and company commander of a combat infantry company, South Vietnam. Military decorations include a Silver Star, four Bronze Stars, and two Air Medals awarded for combat operations in Vietnam. Mr. Dials holds a B.S. in engineering from the U.S. Military Academy at West Point and an M.S. in nuclear engineering and an M.S. in political science from the Massachusetts Institute of Technology.

Leonard W. Gray retired from E.O. Lawrence Livermore National Laboratory (LLNL) in 2005, and has 50 years of experience in the chemistry, engineering, and physics of plutonium processing. He began his career in 1966 at the Savannah River Site with assignments in both H Canyon (highly enriched uranium-235, neptunium, and low assay plutonium-238 recovery) and F Canyon (solvent extraction of uranium and plutonium), F B-Line (plutonium finishing), H B-Line (neptunium and plutonium-238 finishing), and F A-Line (uranium finishing). After an educational leave of absence to obtain his Ph.D., he was assigned to the Savannah River Laboratory with assignments in the Analytical Chemistry Section where he was the lead chemist for chemical forensics of process upsets and then in the Separations Chemistry Section where he was responsible for developing processes for reactor spent fuels labeled as nonprocessable. He then was the lead chemist for the aqueous recovery of many tons of plutonium scrap residues that had collected at the Rocky Flats Site; this was a multisite program that assigned various Rocky Flats plutonium scraps to Los Alamos, Hanford, Savannah River, and Rocky Flats where these scraps best fit into their respective plutonium recovery operations. He was then transferred to the Savannah River Plant Site to oversee the Separations Technology Laboratory with responsibilities over all chemical unit operations (highly enriched uranium, neptunium, low assay plutonium-238, americium-241, curium-244, weapons-grade plutonium, and depleted uranium) in F and H Canyons; here he continued to work with the Rocky Flats Plant Site to develop a process for the recovery of plutonium and americium from chloride-containing aged plutonium scraps. In 1988, he transferred to LLNL to lead the chemical processing portion of the Laser Special Isotope Separations Program. His previous chemical forensic work at the Savannah River Laboratory resulted in an invitation to visit the Russian Tomsk-7 Processing site to aid in the investigation of an accident similar to one that had occurred at Savannah River. Before retirement he was the chief scientist for the U.S.-Russian Plutonium Disposition Program; this played a major role in the United States-Russian Agreement for each country to dispose of approximately 34 metric tons of excess weapons-grade plutonium in methods that would prevent their return to a weapons program. His assignments have taken him to nuclear facilities in Australia, China, England, France, Russia, and Scotland. He has won numerous awards for his work in chemical forensics and plutonium processing science. These include Award of Excellence for Significant Contributions to the Nuclear Weapons Program (his team was the first team at Savannah River to be awarded the Award of Excellence by the director of Military Applications) and he is the only recipient from LLNL to be awarded the Glenn T. Seaborg Actinide Separation Award. He also served on the Chemical Safety Committee of the American Chemical Society. Dr. Gray remains active in retirement, continuing to mentor young scientists, having served as chief scientist for the safe de-inventory and shutdown of the LLNL Heavy Element Facility and having authored the recent Official Use Only publication "Worldwide Plutonium Production and Processing." He presently serves as chairman of the Plutonium Experts Panel for the National Technical Nuclear Forensics Center of the Department of Homeland Security. Dr. Gray received his Ph.D. in inorganic chemistry from the University of South Carolina in 1972, his M.S. in chemistry from Texas Technological College in 1967, and his B.S. in chemistry from the New Mexico Institute of Mining and Technology in 1964, and his A.A. from Middle Georgia College in 1961.

Michael R. Greenberg studies environmental health and risk analysis. He is the Distinguished Professor of the Edward J. Bloustein School of Planning and Public Policy, Rutgers University. He has written more than 30 books and more than 300 articles. His most recent books are *Protecting Seniors Against Environmental Disasters: From Hazards and Vulnerability to Prevention and Resilience* (Earthscan, 2014), *Explaining Risk Analysis* (Earthscan, 2017), *Urban Planning and Public Health* (American Public Health Association, 2017), and *Siting Noxious Facilities* (Earthscan, 2018). He has been a member of National Research Council committees that focus on the destruction of the U.S. chemical weapons stockpile and nuclear weapons; chemical waste management; degradation of the U.S. government physical infrastructure; and sustainability and the Environmental Protection Agency. He chaired the committee for the appropriations committees of the U.S. Senate and House to determine the extent that the Department of Energy emphasizes human health and safety in its allocations for remediating former nuclear weapons sites. He served as area editor for social sciences and then editor-in-chief of *Risk Analysis: An International Journal* during the period 2002-2013 and continues as associate editor for environmental health for the *American Journal of Public Health*. Professor Greenberg graduated with a B.A. from Hunter College with concentrations in math and history and an M.A. in urban geography and a Ph.D. in environmental and medical geography from Columbia University.

David W. Johnson, Jr. (NAE), is the retired director of materials research at Bell Laboratories, Lucent Technologies, a retired editor-in-chief for the *Journal of the American Ceramic Society* and former adjunct professor of materials science at Stevens Institute of Technology. His research activities included fabrication and processing of glass and ceramics with emphasis on materials for electronic and photonic applications. He is a member of several professional societies, including a fellow, distinguished life member, and past president of the American Ceramic Society. Dr. Johnson won the Taylor Lecture Award and the Distinguished Alumni Award from Pennsylvania State University, the Ross Coffin Purdy Award for the best paper in ceramic literature, the Fulrath Award, the John Jeppson Award, the Orton Lecture Award from the American Ceramic Society, and the International Ceramics Prize for Industrial Research from the World Academy of Ceramics. He is a member of the National Academy of Engineering and the World Academy of Ceramics. He holds 46 U.S. patents and has published numerous papers on materials sciences. He earned a B.S. in ceramic technology and a Ph.D. in ceramic science from Pennsylvania State University.

Annie B. Kersting is an expert on the environmental behavior of actinides with a particular focus on plutonium. She works at the Lawrence Livermore National Laboratory (LLNL) where she manages an active research group in environmental radiochemistry focused on understanding the biogeochemical processes that control actinide (uranium, plutonium, neptunium, and americium) transport in the environment. In particular, she is interested in identifying the processes that control actinide interactions on the molecular scale with inorganic, organic, and microbial surfaces in the presence of water with the goal to reliably predict and control the cycling and mobility of actinides in the environment. Dr. Kersting's research interests include the fields of radiochemistry, isotope geochemistry, and environmental chemistry. She is currently director of University Relations and Science Education at LLNL, where she oversees a broad range of educational science and technology programs and initiatives that advance the mission and vision of the laboratory. She works with the laboratory's senior leadership to develop and execute strategies, build strategic partnerships, and foster collaborative research and education initiatives to ensure a workforce pipeline of top-tier science and technology talent. Dr. Kersting previously served as the director of the Glenn T. Seaborg Institute at LLNL for more than 10 years, where she focused on collaborative research between LLNL and the academic community in nuclear forensics, super heavy element discovery, and environmental radiochemistry. Through the institute, she managed a yearly summer program for graduate students in nuclear forensics and environmental radiochemistry. Dr. Kersting was a member of the Nuclear and Radiation Studies Board of the National Research Council from 2010 to 2014, and a member of the Committee for the Technical Assessment of Environmental Programs at the Los Alamos National Laboratory of the National Research Council from 2006 to 2007.

She served on the Environmental Management Sciences Program Review Panel of the Department of Energy's (DOE's) Office of Science in 2006 and served as a scientific advisor on the Actinide Migration Committee for Rocky Flats from 2000 to 2003. Since 2013, she has served as an associate editor of *Geochimica et Cosmochimica Acta*. She has been an active member of the Environmental Protection Agency's Radiation Advisory Board since 2014. In 2016, she was awarded the Francis P. Garvan–John M. Olin Medal from the American Chemical Society for excellence in chemistry, leadership, and service. In 2017, she was awarded the Secretary of Energy's Achievement Award for contributions to DOE and the nation for serving on the technical Assessment Team. She holds a B.S. in geology and geophysics from the University of California, Berkeley, and an M.S. and a Ph.D. in geology and geophysics from the University of Michigan. She was a postdoctoral fellow in the Institute of Geophysics and Planetary Physics at LLNL from 1992 to 1995.

M. David Maloney is technology fellow, emeritus, at Jacobs Engineering Group (formerly CH2M), Aerospace-Technology-Environment-Nuclear business line, providing support to operations at Department of Energy (DOE) nuclear sites by identifying, developing, and deploying new technologies—including waste, nuclear material, and used fuel management—to reduce the costs and schedule of decommissioning, remediation, and closure. At Rocky Flats and Hanford, both plutonium mission sites, he partnered with DOE's Office of Environmental Management (DOE-EM) Science and Technology Program to create a risk/cost-shared approach that became a model and a congressional line item for the weapons complex that saved more than $350 million. This work involved waste material conditioning/treatment, packaging, assay, certification, and shipping to other sites for future processing and to the Waste Isolation Pilot Plant for disposal. Dr. Maloney participated in workshops on total system performance assessment models for the U.S. High Level Waste repository and on the UK Radioactive Waste Management Directorate waste form/package/near-geoenvironment integration for the UK High-Level Waste/Intermediate-Level Waste Repository. He also managed the 5-year National Nuclear Security Administration (NNSA) Initiatives for Proliferation Prevention project with the Russian Academy of Sciences and the PA Mayak production and storage site investigating ceramics for waste form and cask applications. For 2 years he served as assistant to the general manager, Energy and Environment Programs, at Argonne National Laboratory where he focused on technology transfer to industry. He has participated in several National Academies' study panels from 1997 to date supporting DOE EM and NNSA inquiries. Dr. Maloney has a Ph.D. in physics from Brown University. His research associate work was at the Institute for Experimental Nuclear Physics, Karlsruhe Institute of Technology and Kernforschungszentrum, Germany.

S. Andrew Orrell joined the Idaho National Laboratory (INL) in September 2019, where he currently works as an R&D technical consultant, supporting INL initiatives concerning transportation, storage, and disposal of commercial and Department of Energy spent nuclear fuel and high-level waste. Prior to joining the INL, he served 5 years as the section head for Waste and Environmental Safety at the International Atomic Energy Agency (IAEA) where he was responsible for the development and promulgation of internationally accepted standards, requirements, and guides for the safe management of radioactive waste and spent fuel, decommissioning, remediation, and environmental monitoring. In addition, Mr. Orrell oversaw the planning and execution of support to the IAEA Member States for the implementation of the IAEA Safety Standards, and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Prior to joining IAEA, Mr. Orrell was the director of Nuclear Energy Programs for Sandia National Laboratories, where he was responsible for laboratory development initiatives involving all facets of the nuclear fuel cycle. He provided executive leadership for Sandia's Lead Laboratory for Repository Systems program, managing the completion of the post-closure performance assessment and safety case for a license to construct the nation's first geological repository for high level nuclear waste at Yucca Mountain. Before working on Yucca Mountain, he managed site characterization programs for a deep geological repository for transuranic waste at the Waste Isolation Pilot Plant, and developed transportation optimizations for the National Transuranic

Waste Management program. With 30 years of professional experience in nuclear fuel cycle and radioactive waste management for the United States and several international programs, Mr. Orrell is versed in the complex interdependencies between nuclear energy development, waste management, decommissioning, remediation, and disposal. Mr. Orrell routinely advises government and industry leaders on the technical implications concerning radioactive waste management, including national policy development and regulation, geological repository development and licensing, safety case development, interim storage, stakeholder engagement, and public risk perception.

William C. Ostendorff (U.S. Navy retired) joined the Naval Academy's Political Science Department as the Class of 1960 Distinguished Visiting Professor in National Security in August 2016. Captain Ostendorff has been confirmed by the U.S. Senate on three occasions to serve in senior administration posts in both Republican and Democratic administrations. He served as principal deputy administrator at the National Nuclear Security Administration (NNSA) in the Bush administration (2007-2009) and as a commissioner at the U.S. Nuclear Regulatory Commission (U.S. NRC, 2010-2016) in the Obama administration prior to joining the Naval Academy faculty. At the U.S. NRC, Commissioner Ostendorff was a strong proponent of regulatory technical competence. He was considered by many to be a key leader on the Commission in the areas of post-Fukushima regulatory decision making and in both physical and cyber security of commercial nuclear facilities. During his more than 6 years as a commissioner, he testified before Congress on 26 occasions and gave more than 180 speeches in the United States and abroad on nuclear safety and security. At NNSA, Captain Ostendorff served as central technical authority for nuclear safety and as chief operating officer of the agency. He played a significant leadership role in developing the future vision for the nation's national security laboratories and in evaluating options for nuclear weapons complex modernization. From 2003 to 2007, he was a member of the staff of the House Armed Services Committee. There, he served as counsel and staff director for the Strategic Forces Subcommittee with oversight responsibilities for the Department of Energy's Atomic Energy Defense Activities as well as the Department of Defense's space, missile defense, and intelligence programs. He served as staff chair for dozens of hearings at both the subcommittee and full committee level including highly visible hearings on the 9/11 Commission, the Weapons of Mass Destruction Commission, and other hearings associated with U.S. strategic forces. Captain Ostendorff was an officer in the U.S. Navy from 1976 until he retired in 2002. Entering the Rickover Nuclear Navy, he served on six submarines. During his naval career, he commanded a nuclear attack submarine and a nuclear attack submarine squadron and served as director of the Division of Mathematics and Science at the U.S. Naval Academy. His military decorations include four awards of the Legion of Merit and numerous unit and campaign awards. He earned a bachelor's degree in systems engineering from the U.S. Naval Academy, a law degree from the University of Texas, and a master's in international and comparative law from Georgetown University. He is a member of the State Bar of Texas.

Tammy C. Ottmer is a nationally recognized expert in nuclear waste transportation safety. She was appointed to her position as Colorado Waste Isolation Pilot Plant (WIPP) program manager of the Hazardous Materials Section by the governor of Colorado. In addition, she was delegated additional responsibility as manager over Nuclear Materials Transportation Oversight by Colorado State Patrol, including collaborative planning with shippers and carriers intending to move radioactive materials and nuclear waste through Colorado, the western region, and across the nation. She continues to design, develop, implement, and oversee nuclear materials transportation for new transportation campaigns utilizing the WIPP program as a model. A primary focus area continues to be the full implementation of the Western Governors' Association/Department of Energy (DOE) Cooperative Agreement for the Transportation of Transuranic Wastes. She works at regional and national levels to innovate approaches to ensure the safe transportation of transuranic materials, highway route-controlled quantities, high-level radioactive waste, and commercial spent nuclear fuel shipments in the distant future, whether to interim storage or permanent disposal. Ms. Ottmer has chaired committees chartered to update internal DOE manuals and then integrate them into the internal DOE Order system. These Orders have a direct correlation to safe transportation when they are incorporated into DOE Requests for Proposal for new contracts across the nation. Ms. Ottmer serves as advisor to the governor on nuclear transportation matters including the spent commercial nuclear fuel stored at the Fort Saint Vrain Independent Spent Fuel Storage Installation in northern Colorado. Ms. Ottmer has had an opportunity to serve in an international capacity. The International Atomic Energy Agency in Vienna, Austria, asked specifically for Ms. Ottmer to serve as a consultant. The mission of this consultancy was to review and evaluate international radiological transportation safety guides. The guides concerned transportation accidents involving radioactive materials as well as associated emergency response. She provided recommendations for the revisions of these transportation safety guides. Ms. Ottmer received a B.A. from the University of Colorado Boulder.

Cecil V. Parks's career has spanned 41 years at Oak Ridge National Laboratory (ORNL), where he is currently director of the Nuclear Nonproliferation Division. Prior to this assignment, he served as director for the former Nuclear Security and Isotope Technology Division, director of the Reactor and Nuclear Systems Division, and director for the former Nuclear Science and Technology Division. In these senior leadership positions, Dr. Parks has been responsible for line management, strategic planning, and mission execution for diverse research and development organizations engaged in basic and applied science and technology for the nuclear fuel cycle, isotope production, and nuclear nonproliferation and safeguards. He has extensive experience in programmatic business development and execution with a wide range of government agencies including the Department of Energy (DOE), the National Nuclear Security Administration (NNSA), and the U.S. Nuclear Regulatory Commission (U.S. NRC). From 1980 to 2014, Dr. Parks had project or line responsibility for development of the SCALE code system, which is used worldwide to solve challenging problems in reactor physics and depletion, criticality safety, and radiation transport. For 36 years, Dr. Parks has consulted on technical and safety issues associated with transport and storage of fissile and radioactive material. From 1992 to 2012, he supported the U.S. NRC and the Department of Transportation as the U.S. technical expert to the International Atomic Energy Agency on packaging requirements and transport controls for fissile material. Dr. Parks has been active in professional societies and has been a member, facilitator, or leader of various review teams chartered by NNSA, DOE, or the U.S. NRC. Dr. Parks is the author or co-author of more than 150 technical papers, ORNL or U.S. NRC reports, and journal articles, and has been engaged in standards development related to nuclear criticality safety. Dr. Parks has a Ph.D. in nuclear engineering from the University of Tennessee and M.S. and B.S. degrees in nuclear engineering from North Carolina State University (NCSU). He also has a B.S. in mechanical engineering from NCSU. Dr. Parks is a fellow of the American Nuclear Society.

Matthew K. Silva served for 10 years as the chemical engineer and 4 years as the director of the New Mexico Environmental Evaluation Group until its closure in 2004. As mandated by federal law, the organization provided an independent technical evaluation of the Waste Isolation Pilot Plant project to ensure the protection of the safety and health of the people of New Mexico. He holds a B.S. in basic science and an M.S. in petroleum engineering from the New Mexico Institute of Mining and Technology. Additionally, he holds a Ph.D. in chemical engineering from the University of Kansas.

Staff

Jennifer Heimberg has been a senior program officer at the National Academies of Sciences, Engineering, and Medicine since 2011. She has directed studies within the Division on Earth and Life Studies (DELS) and Division of Behavioral and Social Sciences and Education (DBASSE). Her work within DELS' Nuclear and Radiation Studies Board focuses on nuclear security, non-proliferation, and nuclear environmental cleanup. Reports include *Reducing the Use of Highly Enriched Uranium in Civilian Research Reactors*; *Performance Metrics for the Global Nuclear Detection Architecture*; and *Best Practices for Risk-Informed Decision Making Regarding Contaminated Sites: Summary of a Workshop*. Within DBASSE, she directed two separate studies resulting in the reports *Valuing Climate*

Damages: Updating the Estimation of the Social Cost of Carbon Dioxide and *Reproducibility and Replicability in Science.* Prior to coming to the National Academies, she worked as a program manager at the Johns Hopkins University Applied Physics Laboratory (APL) for nearly 10 years. While at APL she established and grew its nuclear security program with the Department of Homeland Security's Domestic Nuclear Detection Office. She received a B.S. cum laude in physics from Georgetown University, a B.S.E.E. from Catholic University of America, and a Ph.D. in physics from Northwestern University.

Kevin D. Crowley has been an advisor to the Nuclear and Radiation Studies Board (NRSB) at the National Academies of Sciences, Engineering, and Medicine in Washington, DC, since entering phased retirement in August 2017. His professional interests focus on the application of science and technology to improve societal well-being, advance public policy making, and enhance international cooperation, particularly with respect to the safety, security, and efficacy of nuclear and radiation-based technologies and applications. He previously held several positions at the National Academies, including senior board director of the NRSB (2005-2017), director of the Board on Radioactive Waste Management (1996-2005), and principal investigator for a long-standing cooperative agreement between the National Academy of Sciences and the Department of Energy to provide scientific support to the Radiation Effects Research Foundation in Hiroshima, Japan (2010-2017). Before joining the National Academies staff in 1993, Dr. Crowley held teaching/research positions at Miami University of Ohio, the University of Oklahoma, and the U.S. Geological Survey. He holds M.A. and Ph.D. degrees, both in geology, from Princeton University.

Richard "Dick" Rowberg is currently on phased retirement and is a senior advisor for the Division on Engineering and Physical Sciences of the National Academies of Sciences, Engineering, and Medicine. Prior to retirement from the National Academies, he was deputy executive director of its Division on Engineering and Physical Sciences. He has served at the National Academies since 2002. From 1985 to 2001, he worked for the Congressional Research Service of the Library of Congress. From 1994 to 2001, Dr. Rowberg was a senior specialist in science and technology with the Resources, Science, and Industry Division, and from 1985 to 1994, he was chief of the Science Policy Research Division. From 1975 to 1985, Dr. Rowberg worked for the Congressional Office of Technology Assessment (OTA). From 1975 to 1979 he served as an analyst in and deputy manager of the OTA Energy Program, and from 1979 to 1985, he was manager of the OTA Energy and Materials Program. From 1969 to 1974, Dr. Rowberg was a research engineer and adjunct assistant professor in the Department of Electrical Engineering of the University of Texas at Austin. He received a B.A. in physics from the University of California, Los Angeles (UCLA), in 1961 and a Ph.D. in plasma physics from UCLA in 1968. In 2010, Dr. Rowberg was elected a fellow of the American Physical Society.

Appendix B

Meetings

Disposal of Surplus Plutonium in the Waste Isolation Pilot Plant

MEETING #1: NOVEMBER 28-30, 2017

The Keck Center
500 Fifth Street, NW, Washington, DC 20001

TUESDAY, NOVEMBER 28, 2017

DATA-GATHERING SESSION OPEN TO THE PUBLIC
Keck Room 208

1:00 PM **Call to Order and Welcome, Brief Introductions by the Committee**
Bob Dynes, Committee Chair

1:15 PM **National Nuclear Security Administration (NNSA) Overview of the Material Management and Minimization Program and the Committee's Tasking**
Peter Hanlon, NNSA, Assistant Deputy Administrator for Material Management and Minimization

1:40 PM **Plutonium Dilute and Dispose Program Scope and Status**
Sachiko McAlhany, NNSA, Senior Technical Advisor

2:40 PM **BREAK**

3:00 PM **The Waste Isolation Pilot Plant (WIPP) and Disposal of Surplus Plutonium**
Betsy Forinash, Director, National Transuranic Waste Program—Headquarters, Department of Energy's Office of Environmental Management (DOE-EM)

3:45 PM **Environmental Protection Agency's (EPA's) Activities Related to the Plutonium Dilute and Dispose Program**
Thomas Peake, EPA Radiation Protection Division, Director for the Center for Waste Management and Regulations

4:45 PM **Opportunity for Public Comment**

5:00 PM **End Data-Gathering Session**

WEDNESDAY, NOVEMBER 29, 2017

DATA-GATHERING SESSION OPEN TO THE PUBLIC
Keck Room 208

9:00 AM **Call to Order and Welcome, Open Session Reminder**
Bob Dynes, Committee Chair

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9:10 AM **New Mexico Stakeholder Perspectives: Southwest Research and Information Center**
Don Hancock, Director, via Webcast

9:40 AM **Dilute and Dispose: The Best Available Approach for Excess Plutonium Disposition**
Ed Lyman, Senior Scientist, Global Security Program, Union of Concerned Scientists

10:30 AM **BREAK**

10:45 AM **Perspectives from the U.S. Government Accountability Office (U.S. GAO)**
David Trimble, Director, Natural Resources and Environment, U.S. GAO
Eli Lewine, Senior Analyst, Natural Resources and Environment, U.S. GAO

11:30 AM **Historical Perspectives and Congressional Authorities**
James Werner, Congressional Research Service

12:15 PM **BREAK for LUNCH,** catered for committee members

1:00 PM **Plutonium Disposal Considerations**
Matthew Bunn, Professor of Practice, Harvard Kennedy School, Belfer Center for Science and International Affairs

1:40 PM **Opportunity for Public Comment**

2:00 PM **End Public Session**

THURSDAY, NOVEMBER 30, 2017

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC
Department of Energy, Forrestal Building

8:30 AM **Meet at the Forrestal Building for Check-in, Badging, and Security Check**

9:00 AM **Welcome and Introductions, Review Security Procedures, Briefings**

12:45 PM **Wrap-up**

1:00 PM **ADJOURN**

Note: The data-gathering session of this meeting to be held on November 30, 2017, from 9:00 AM to 1:00 PM, EST, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open this session to the public would disclose information described in 5 U.S.C. § 552(b).

MEETING #3[1]: FEBRUARY 12-13, 2018

Gressette Senate Office Building—Committee Room 105
South Carolina Capitol Complex
1101 Pendleton Street, Columbia, SC 29201

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC
Gressette Senate Office Building—Committee Room 105,
South Carolina Capitol Complex, Columbia, SC

MONDAY, FEBRUARY 12, 2018

5:00 PM **Call to Order and Welcome**

- Brief introductions of committee and staff
- Review of the meeting agenda and objectives
- Overview of SRS Site Tours
  Robert (Bob) Dynes, Committee Chair
  Jennifer (Jenny) Heimberg, Study Director

Perspectives, Concerns, and Questions About DOE Plans to Dilute and Dispose of Surplus Plutonium at WIPP

5:15 PM *Rick Lee, Chair of the Governor's Nuclear Advisory Council*
Charles W. Hess, Vice President, High Bridge Associates

5:45 PM *James Marra, Director, Citizens for Nuclear Technology Awareness*

6:15 PM *Gil Allensworth, Chair, Savannah River Site (SRS) Citizens Advisory Board (CAB)*

6:45 PM *Christopher Wells, Assistant Director of Nuclear Programs, Southern States Energy Board*

7:05 PM **Public Comments**
The committee will listen to comments from the public. Each comment period will be limited to 3 minutes. Note that the committee accepts written comments at any time during the study. Please send written comments to Plutonium_Disposition@nas.edu.

7:30 PM **ADJOURN Day One**

Note: The data-gathering sessions of this meeting to be held on February 12, 2018, from 10:00 AM to 11:00 AM, EST, and February 13, 2018, from 9:00 AM to 1:30 PM, EST, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open these sessions to the public would disclose information described in 5 U.S.C. § 552(b).

[1]Meeting #2 was a closed committee-only session.

Appendix B

MEETING #4: MARCH 12-14, 2018

New Mexico trip:
Los Alamos, Albuquerque, Carlsbad, and the Waste Isolation Pilot Plant (WIPP)

MONDAY, MARCH 12, 2018[2]

The classified subgroup will visit Los Alamos National Laboratory (LANL) in the morning of March 12.

SITE VISIT
Los Alamos National Laboratory, ARIES Facility

8:00 AM **Welcome and the Advanced Recovery and Integrated Extraction System (ARIES) Overview and Related Dilute and Dispose Activities (To Be Determined LANL Personnel)**

8:30 AM **Tour ARIES**

11:00 AM **LUNCH on-site, catered**
Meeting with dilute and dispose NNSA Staff

11:30 AM **End Tour**

DATA-GATHERING SESSION OPEN TO THE PUBLIC
Sheraton Albuquerque Airport Hotel, Gran Quivera Room, Albuquerque, NM

5:00 PM **Call to Order and Welcome**
- Brief introductions of committee and staff
- Review of the meeting agenda and objectives
  Robert (Bob) Dynes, Committee Chair
  Jennifer (Jenny) Heimberg, Study Director

5:15 PM **Perspectives, Concerns, and Questions About DOE Plans to Dilute and Dispose of Surplus Plutonium at WIPP**
George Anastas, retired, Past President of Health Physics Society

5:45 PM **Disposal of Plutonium at WIPP**
Don Hancock, Director of Nuclear Waste Programs, Southwest Research and Information Center

6:15 PM **Perspectives, Concerns, and Questions About DOE Plans to Dilute and Dispose of Surplus Plutonium at WIPP**
Lokesh Chaturvedi, Independent Consultant

6:45 PM **The Role of the Governor's Radioactive Waste Consultation Task Force**
Ken McQueen, Cabinet Secretary of New Mexico's Energy, Minerals, and Natural Resources Department

7:00 PM **Public Comments**

[2]All times shown below are Mountain Time.

The committee will listen to comments from the public. Each comment period will be limited to 3 minutes. Note that the committee accepts written comments at any time during the study. Please send written comments to Plutonium Disposition@nas.edu.

7:30 PM **ADJOURN Day One**

TUESDAY, MARCH 13, 2018

DATA-GATHERING SESSION OPEN TO THE PUBLIC
Skeen-Whitlock Building, Carlsbad, NM

4:00 PM **Call to Order and Welcome**

- Brief introductions of committee and staff
- Review of the meeting agenda and objectives
- Overview of the TRANSCOMM and Emergency Operations Center tours
  Robert (Bob) Dynes, Committee Chair

4:15 PM **WIPP Regulatory and Operations Overview**
Todd Shrader, Manager, Carlsbad Field Office
George Basabilvazo, Chief Scientist, Carlsbad Field Office

Perspectives, Concerns, and Questions About DOE Plans to Dilute and Dispose of Surplus Plutonium at WIPP

6:00 PM *Russell Hardy, Director, Carlsbad Environmental Monitoring & Research Center*

6:20 PM *John Heaton, Chairman of the Mayor's Nuclear Task Force*

6:40 PM *Cathrynn Brown, State Representative, and Susan Crockett, Eddy County Commissioner*

7:00 PM **Public Comments**
The committee will listen to comments from the public. Each comment period will be limited to 3 minutes. Note that the committee accepts written comments at any time during the study. Please send written comments to Plutonium_Disposition@nas.edu.

7:30 PM **ADJOURN Day Two**

Note: The data-gathering session of this meeting to be held on March 12, 2018, from 8:00 AM to 11:30 AM, MDT, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open this session to the public would disclose information described in 5 U.S.C. § 552(b).

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MEETING #7[3]: MAY 2-3, 2018

The Keck Center
500 Fifth Street, NW, Washington, DC 20001

WEDNESDAY, MAY 2, 2018

DATA-GATHERING SESSION OPEN TO THE PUBLIC **Keck Room 208**

2:30 PM **New Mexico's Agreements, Laws, and Regulations: Review of Potential Changes to the Land Withdrawal Act (LWA) and Consultation and Cooperation (C&C) Agreement**
Lindsay Lovejoy, Attorney

3:30 PM **Termination of Safeguards for the Surplus Plutonium in the Dilute and Dispose Option**
Debarah S. Holmer, Office of Environment, Health, Safety and Security (EHSS/AU), Department of Energy (DOE)

4:00 PM **Outline of the Dilute and Dispose Option Life-Cycle Cost Estimate (LCCE) Contents**
Virginia Kay, Deputy Director, Office of Material Disposition (NA-233), Office of Material Management and Minimization, National Nuclear Security Administration, DOE

4:30 PM **Public Comments**

4:45 PM **ADJOURN**

[3]Meetings #5 and #6 were committee-only sessions.

MEETING #8: JUNE 26, 2018

The Arnold and Mabel Beckman Center
100 Academy Drive, Irvine, CA 92617

TUESDAY, JUNE 26, 2018

All times shown below are Pacific Standard Time.

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC
Beckman Center, Board Room

12:00 PM **Welcome and Call to Order**
Robert (Bob) Dynes, Committee Chair

12:15 PM **Overview of Current Status and Next Steps of the Dilute and Dispose Program**
Pete Hanlon, Assistant Deputy Administrator, Defense Nuclear Nonproliferation, National Nuclear Security Administration (NNSA), Department of Energy (DOE)

12:45 PM **Surplus Plutonium Disposition Program**
Sachiko McAlhany, Senior Technical Advisor, NA-23
Todd Shrader, Manager, Carlsbad Field Office, Office of Environmental Management (DOE-EM)
Samuel Callahan, Director, Office of Security, AU-50

2:30 PM **BREAK in the Foyer**

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC
Beckman Center, Board Room

2:40 PM **Welcome**
Robert (Bob) Dynes, Committee Chair

2:45 PM **Planning, Inventory, and Capacity at the Waste Isolation Pilot Plant (WIPP)**
Todd Shrader, Manager, Carlsbad Field Office, DOE-EM

3:45 PM **End Data-Gathering Session Open to the Public**

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC
Beckman Center, Board Room

3:50 PM CONT'D (if needed) **Surplus Plutonium Disposition Program**

Sachiko McAlhany, Senior Technical Advisor, NA-23, NNSA
Todd Shrader, Manager, Carlsbad Field Office, DOE-EM
Samuel Callahan, Director, Office of Security, AU-50, NNSA

5:00 PM **NNSA's Quantities and Production Rates**
Sachiko McAlhany, Senior Technical Advisor, NNSA

6:00 PM **ADJOURN**

Note: The data-gathering sessions of this meeting to be held on June 26, 2018, from 12:00 PM to 2:30 PM and 3:45 PM to 6:00 PM, PDT, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open these sessions to the public would disclose information described in 5 U.S.C. § 552(b).

Appendix B

MEETING #9 CLASSIFIED SUBGROUP ONLY: AUGUST 23, 2018

Video Teleconference (VTC)

THURSDAY, AUGUST 23, 2018 (all times shown are Eastern)

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC
VTC: DOE-HQ, LLNL, and ORNL

12:00 PM *Sachiko McAlhany, Senior Technical Advisor, National Nuclear Security Administration (NNSA)*

1:45 PM **Move to Committee-Only Session**
Robert Dynes, Committee Chair, Committee on the Disposal of Surplus Plutonium

3:30 PM **ADJOURN**

Note: The data-gathering session of this meeting to be held on August 23, 2018, from 12:00 PM to 2:30 PM, EDT, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open this session to the public would disclose information described in 5 U.S.C. § 552(b).

MEETING #13[4]: APRIL 16-18, 2019

The Keck Center
500 Fifth Street, NW, Washington, DC 20001

TUESDAY, APRIL 16, 2019

DATA-GATHERING SESSION OPEN TO THE PUBLIC **Keck Room 201**

9:00 AM **Welcome and Meeting Overview**
Robert (Bob) Dynes, Committee Chair

9:15 AM **WIPP Compliance, Capacity, Storage, and Transportation**
George Basabilvazo, Chief Scientist, Carlsbad Field Office (CBFO), Department of Energy (DOE), and Gregory M. Sahd, Federal Security Officer, CBFO
30 min presentation, 30 min questions from committee

10:15 AM **Program Plan for Disposing of 6 MT of Surplus Plutonium**
Maxcine Maxted, Savannah River Nuclear Materials Program Manager, Office of the Assistant Manager for Nuclear Materials Stabilization, DOE-Environmental Management (EM)
45 min presentation, 30 min questions from committee

11:30 AM **LUNCH,** tickets for cafeteria for committee members

12:30 PM **Overview of Performance Assessments for Disposal of Surplus Plutonium**
Sean Dunagan, Manager of Special Projects and Remote Site Support, Sandia National Laboratories
Questions welcomed from committee throughout presentation

BREAK—at the discretion of the chair

3:45 PM **WIPP Compliance Recertification Process and Planned Change Notice Considerations**
Tom Peake, Director, Center for Waste Management and Regulations, Environmental Protection Agency
30 min presentation, 30 min questions from committee

4:45 PM **Feasibility and Risks of Human Intrusion in WIPP**
Cameron Tracy, Stanton Nuclear Security Postdoctoral Fellow, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University
30 min presentation, 30 min questions from committee

5:45 PM **Opportunity for Public Comments**
Each public comment will be limited to no more than 3 minutes' duration

6:00 PM **End Data-Gathering Session (no later than 6:00 PM, but potentially ending earlier if there are few public comments)**

[4]Meetings #10, #11, #12 were committee-only sessions.

WEDNESDAY, APRIL 17, 2019

DATA-GATHERING SESSION OPEN TO THE PUBLIC **Keck Room 201**

9:00 AM	**Call to Order and Welcome, Brief Introductions by the Committee** *Bob Dynes, Committee Chair*
9:15 AM	**NNSA Introduction** *Bill Kilmartin, Director, Office of Material Disposition, National Nuclear Security Administration (NNSA)* 5 minutes
9:20 AM	**Life-Cycle Cost Estimate Planning Documents: Risk and Opportunity Management Plan (ROMP) and the Risk and Opportunity Analysis Report (ROAR)** *Tom Cantey, Surplus Plutonium Disposition Program Manager, Office of Material Disposition, NNSA and Sterling Robertson, Surplus Plutonium Disposition Program Manager, Savannah River Nuclear Solutions* 30 min presentation, 30 min questions from committee
10:20 AM	**National Environmental Policy Act (NEPA) Strategy** *Paloma Richard, NEPA Document Manager, Office of Material Disposition, NNSA* 10 min presentation, 20 min questions from the committee
10:50 AM	**BREAK**
11:00 AM	**Engagement with IAEA for 6 MT** *Kevin Veal, Director, Office of International Nuclear Safeguards, NNSA* 5 min briefing, 20 min questions from committee
11:30 AM	**LUNCH**
12:30 PM	**Overview of Dilute and Dispose Waste Form Criticality Analysis for Disposal at the Waste Isolation Pilot Plant** *John Scaglione, Used Fuel Systems Group Leader, Oak Ridge National Laboratory* 45 min presentation, 30 min questions from committee
1:45 PM	**DOE (NNSA and EM) Follow-Up to Address Unanswered Questions from Day One**
2:15 PM	**Opportunity for Public Comments** Each public comment will be limited to no more than 3 minutes duration
2:30 PM	**End Data-Gathering Session (no later than 2:30 PM, but potentially ending earlier if there are few public comments)**

THURSDAY, APRIL 18, 2019

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC **Keck Center**

9:00 AM	**Welcome and Introductions** *Bob Dynes*

9:10 AM **NNSA Roundtable Discussions on Classified Aspects of Dilute and Dispose Plans and Updates to Security Planning**
Speaker to Be Determined

10:30 AM **Impacts of Dilute and Dispose Plans on Existing WIPP Security Processes**
Greg Sahd, CBFO

11:30 AM **End Data-Gathering Session**

Note: The data-gathering session of this meeting to be held on April 18, 2019, from 9:00 AM to 11:30 AM, EDT, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open this session to the public would disclose information described in 5 U.S.C. 552(b).

Appendix C

How Salt Repositories Work

DISPOSAL

All radioactive waste has the potential to present a hazard to people and to the environment and must be managed to reduce any associated risks to acceptable levels. The end state for radioactive waste is disposal. As noted in the International Atomic Energy Agency (IAEA) Safety Standards Series No. SSR-5 (IAEA, 2011, p. 3), the aim of disposal is

a) To contain the waste;
b) To isolate the waste from the accessible biosphere and to reduce substantially the likelihood of, and all possible consequences of, inadvertent human intrusion into the waste;
c) To inhibit, reduce, and delay the migration of radionuclides at any time from the waste to the accessible biosphere;
d) To ensure that the amounts of radionuclides reaching the accessible biosphere due to any migration from the disposal facility are such that possible radiological consequences are acceptably low at all times.

All radioactive waste disposal facilities including deep geological repositories share a basic objective in their design, operation, and closure: to provide reasonable assurance for the containment and isolation of the waste and limiting releases that would pose a threat to human health and the environment. Confidence in the containment and isolation performance is evaluated over timescales relevant to the risk posed by the hazard using models.

During the operational (pre-closure) phase of a disposal facility, such assurance of safety is intended to be provided by, for example, the waste container, waste acceptance criteria, and engineering and administrative controls. After repository closure (and any post-closure institutional control period), the assurance of safety should be provided by passive means, that is, characteristics inherent in the site, facility, the waste, and waste package that contribute to containment and isolation of the waste.

SALT

Commensurate with the generation of long-lived radioactive waste in the 1950s, several disposal concepts and sites have been the subject of considerable research and development, in many different geologies including crystalline rock, clays, and salt. In the United States and Germany, salt deposits (bedded and domal) have been explored for implementing deep geologic disposal concepts, particularly for heat-generating high level wastes or wastes otherwise contaminated with long-lived isotopes such as plutonium-239. There has been considerable research, development, and salt repository experience extending back many decades, not only for radioactive wastes but also for the strategic stockpiling of petroleum (NRC, 1957; Hansen and Leigh, 2011; Winterle et al., 2012; von Berlepsch and Haverkamp, 2016).[1]

Deep underground salt (rock salt, halite) deposits are easily mined and provide unique characteristics that are favorable to the long-term containment and isolation of radioactive waste:

[1]See, for example, https://www.energy.gov/fe/services/petroleum-reserves/strategic-petroleum-reserve (accessed February 19, 2020).

- Salt at depth is for all practical purposes essentially impermeable.
  - The impermeability of intact salt provides practically complete containment and isolation if undisturbed and precluding credible mechanisms or pathways for the transport of radionuclides.
- Salt is ductile under pressure and behaves much as a plastic. It is known to flow slowly under the pressure of the overlying strata.
  - "Salt creep" facilitates the entombment of the waste and the closure of openings.
- Fractures and openings in salt at depth are known to heal within a few decades.
  - The entombment of the waste by plastic flow and the subsequent healing of fractures fosters the return to the original salt impermeability.
- The presence of thick salt formations provides evidence that they are isolated from flowing or circulating waters of the accessible environment, because otherwise the salt would have been dissolved.
  - Although the water content is low and there is no circulating groundwater, brines do exist.
- Salt deposits that have existed underground for more than 200 million years are confidently thought to remain intact for thousands of years into the future.

Salt also exhibits a relatively high thermal conductivity, which can be important for the disposal of heat-generating waste (e.g., spent fuel or high level waste). Apart from the salt properties that are favorable to containment and isolation of radioactive waste, it is recognized that salt repositories do require sufficient overlying strata to protect the salt deposit from dissolution (salt deposits would fail if exposed to near-surface circulating groundwater). In addition, salt generally exhibits low radionuclide sorption (in contrast to, for example, clay), and thus provides little barrier to radionuclide migration *if* the salt barrier is otherwise compromised.

WIPP

With respect to the Waste Isolation Pilot Plant (WIPP), the bedded salt deposits of the Permian Salado Formation have been studied extensively, and in many ways typify the generic salt repository properties discussed above. In the simplest terms, the Salado salt formation of Permian age (~225 million years), at a depth of 2,150 feet, provides a geologic setting that is stable and absent flowing water. The Salado salt exhibits classic salt characteristics and behavior: the salt creep and healing of fractures, as well as the performance expected of the shaft closure seals, have been well established.

Decades of salt repository research and development at WIPP and elsewhere, several independent peer reviews, as well as the 5-year periodic compliance applications submitted by the Department of Energy (DOE) and certified by the Environmental Protection Agency (EPA) since 1996, continue to provide confidence in the long-term post-closure safety of WIPP.[2]

Undisturbed Scenario

Undisturbed performance refers to the cases or scenarios in which any releases of radionuclides to the accessible environment occur as the result of reasonably foreseeable natural processes. Releases due to human intrusion or from unlikely natural events (having less than a 1 in 10,000 chance of occurring in 10,000 years) are excluded from the undisturbed case.

Multiple post-closure performance assessments produced using computer models (and their subsequent contribution to EPA certification of WIPP compliance) have demonstrated that in the nominal undisturbed scenario (absent human intrusion by drilling), no releases of waste are expected in at least the

[2]See, for example, the agenda of a recent United States/German workshop on salt repository research, design, and operation (https://foundation.sdsmt.edu/file/foundation---documents/10th-US-German-Workshop---Draft-Agenda-Mar-7-2019.pdf, accessed March 22, 2020).

10,000-year performance period required by regulation. Confidence in the expectation of complete containment and isolation of the radioactive waste was a major factor in the 1996 Land Withdrawal Act amendment (Pub. L. No. 104-201) that uniquely exempts WIPP from the federal Resource Conservation and Recovery Act requirements that would otherwise prohibit the disposal of hazardous chemicals in WIPP without a no-migration variance. Furthermore, the complete containment provided by the salt obviates the need to take credit for the waste container during the 10,000-year post-closure evaluations.

Because, *in the undisturbed scenario*, total containment and isolation of the waste is expected, *the WIPP performance assessment results are insensitive to the emplaced inventory*. This has been demonstrated for the various projected inventories anticipated for WIPP, including the Sandia assessment of the substantial increase in long-term radioactivity (total curies) and additional plutonium-239 represented by the proposed diluted surplus plutonium transuranic (DSP-TRU) inventory (up to 48.2 metric tons [MT] of surplus plutonium).

This is a key aspect of WIPP: in the undisturbed scenario there are no releases expected within at least the 10,000-year regulatory performance period. The salt barrier (including the shaft and panel seals) provides complete containment and isolation of the waste inventory by the nature of the salt's creep closure and fracture healing to effectively entomb the waste.

Disturbed Scenario

The following discussion of the disturbed scenario is very simplistic and stylized to help illustrate the key factors affecting long-term performance of the repository. The committee notes that the Compliance Certification Application (CCA) and subsequent Compliance Recertification Applications (CRAs) provide detailed presentations of the performance assessment modeling and parameterization and urges the reader to consult those references. The committee was not charged to review the validity of the WIPP performance assessment, but rather to contemplate those aspects of the DSP-TRU inventory that could affect the WIPP post-closure safety and performance. For practical purposes, this can be rephrased as: "Are there aspects of the DSP-TRU inventory and emplacement that would affect the WIPP performance assessment and threaten noncompliance with the regulatory release limits?" See Chapter 5 for the committee's assessment.

In contrast to the undisturbed scenario, 40 CFR Part 191 also requires that releases of radionuclides resulting from drilling into the WIPP repository be considered. Performance assessments that consider inadvertent human intrusion into the repository are referred to as the disturbed scenario. Disturbed scenario via drilling intrusion has four release mechanisms that are modeled as

- **Cuttings and cavings,** which are the waste solids directly intersected by the drill;
- **Spallings,** which entrain solid materials pushed into the borehole with transport to surface;
- **Direct brine releases,** fluid that brings dissolved actinides to the surface; and
- **Long-term groundwater releases,** wherein radionuclides reach the Culebra aquifer and move past the compliance boundary.

The first three direct-release mechanisms dominate the total calculated release. The release paths are illustrated in Figure C-1. The relative contribution of the release mechanisms is illustrated in Figure C-2, as taken from results provided in the 2014 CRA (DOE, 2014).

As illustrated in Figures C-1 and C-2, drilling into the repository entrains a volume of waste (through cuttings and cavings, spallings, and direct brine release) and enables its release on the surface. In a solid competent mass, the volume is roughly that encountered by the drill head (see Figure C-3), and the radioactivity of that volume is dependent on the particular waste encountered by the drill.

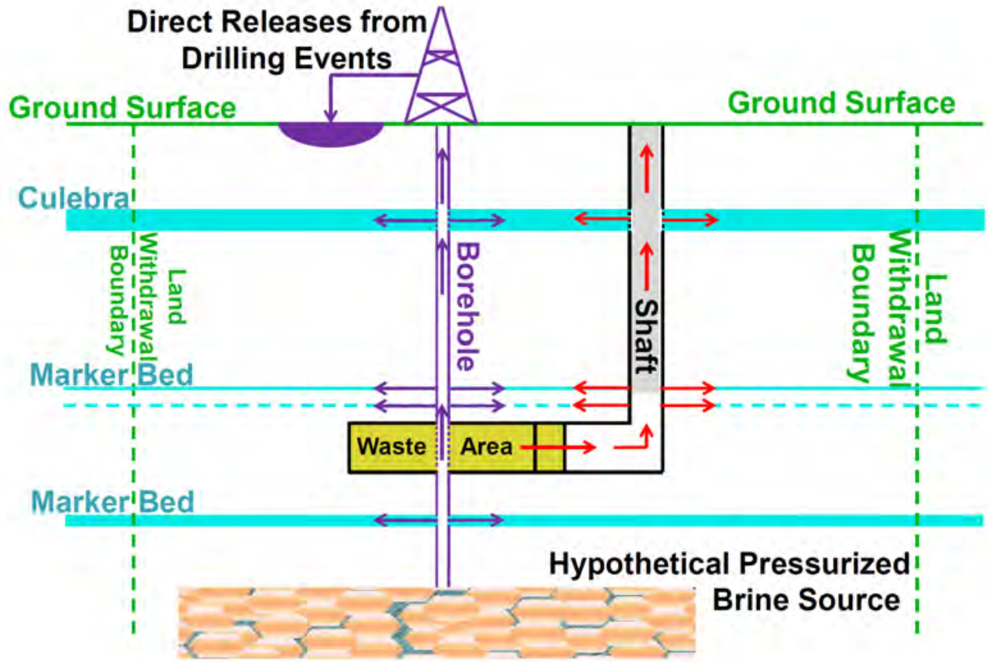

FIGURE C-1 Release mechanisms from inadvertent drilling intrusions. SOURCE: Dunagan et al., 2019, slide 10. Image provided by Sandia National Laboratories.

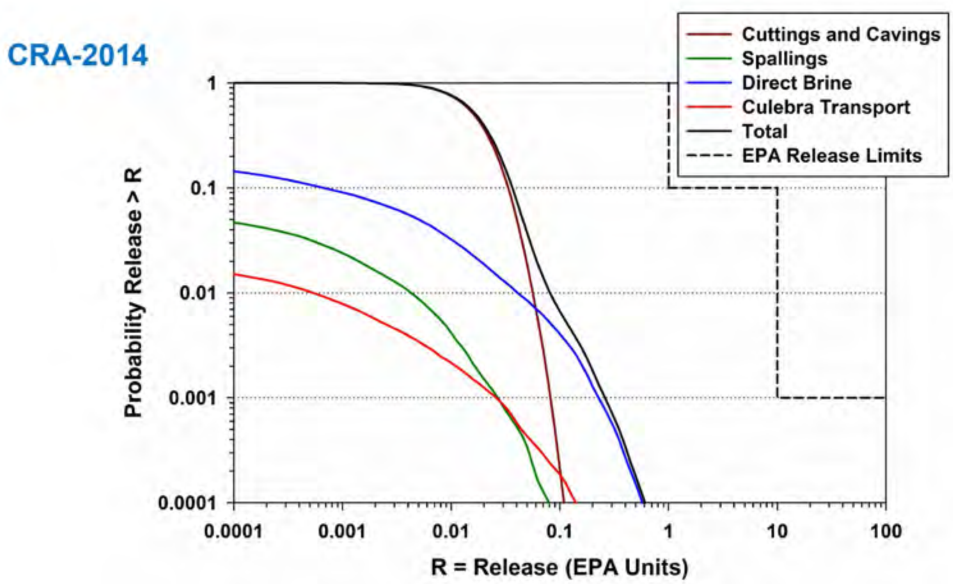

FIGURE C-2 Illustration of relative contributions to total release. SOURCE: Dunagan et al., 2019, slide 18. Image provided by Sandia National Laboratories.

A key element of the disturbed scenario is the presumption that inadvertent drilling will pass through the waste emplacement horizon and possibly intersect a pressurized brine pocket beneath the repository (see Figure C-1). This presumably floods and pressurizes the repository horizon, dissolves certain radionuclides, and facilitates transport to the surface.

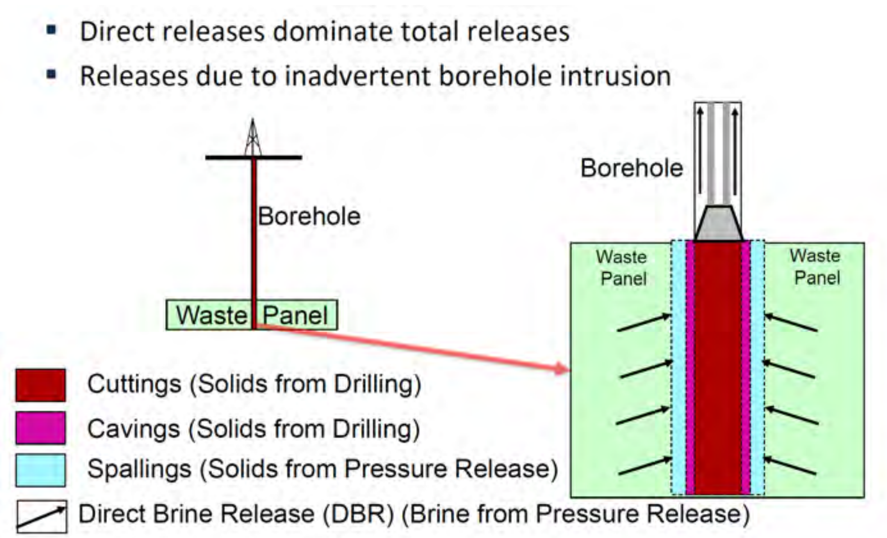

FIGURE C-3 Direct release mechanisms. SOURCE: Dunagan et al., 2019, slide 11. Image provided by Sandia National Laboratories.

Direct releases through inadvertent human intrusion require the presumption of drilling into the repository for the time after repository closure and the loss of institutional controls through the next 10,000 years. In this regard, 40 CFR Part 194 directs DOE to assume that the frequency of boreholes drilled into the WIPP site be based on the rate of drilling observed in the Delaware Basin during the 100 years prior to the time of the compliance application, and considering both deep and shallow drilling (i.e., boreholes that would and would not reach the depth of the WIPP repository). Owing to the increase in oil- and gas-related drilling around the WIPP site, the assumed performance assessment drilling rate has continued to increase, effectively doubling since the 1996 estimate to 99.0 boreholes per km^2 per 10,000 years in the 2019 CRA. This is equivalent to ~4,102 boreholes within the Land Withdrawal Boundary during the 10,000-year performance period (Dunagan et al., 2019). One might argue that direct releases from drilling into the repository are not just possible, but likely.

With the potential for direct releases through inadvertent human intrusion, concerns about long-term performance shift to those aspects of the waste and/or repository design that might inhibit or promote the postulated releases through drilling such as gas generation, radionuclide solubility, panel closures, waste emplacement, drilling rates, engineered barriers, or criticality. This is one reason for the WIPP waste acceptance criteria requirement to specify the waste and waste package characteristics for each waste stream, and noting not just the radionuclide inventory, but also the waste material parameters and waste packaging materials (e.g., sludge, cellulosic, rubber, metals, cement, organic and inorganic material, complexing agents, and oxyanion mass). Characteristics of the waste and packaging can affect the evolution of the emplaced waste volume over time and in the presence of brine by mechanisms that affect processes such as radiolysis and gas generation, colloid formation, plutonium oxidation state, or actinide solubility.

As an example of efforts to accommodate the waste and package constituents, DOE is emplacing magnesium oxide (MgO) among the emplaced waste to provide an engineered barrier that decreases the solubilities of the actinide elements (exacerbated by the presence of brine) by consuming all the carbon dioxide that would be produced by microbial activity should all the cellulosic, plastic, and rubber materials in the repository be consumed (DOE-CBFO, 2019).

This is the second key aspect of WIPP: in the disturbed scenario, releases due to human intrusion (drilling) are assumed within at least the 10,000-year regulatory performance period, and thus, properties of the waste and waste package that would inhibit or promote those releases become more important.

Compliance

A key aspect of Subpart B of 40 CFR Part 191 is that releases from the repository (by inadvertent drilling) are not measured as a dose, but as a quantity of radioactivity (EPA units) that are normalized to the total inventory emplaced at closure, with the EPA unit defined in part by the total inventory at the time of repository closure. Effectively, the more waste (greater radioactivity) emplaced, the more that can be released through inadvertent drilling without exceeding the compliance limits. While 40 CFR Part 191 requires that cumulative releases of radionuclides resulting from drilling into the WIPP repository be considered over the 10,000-year performance period, the regulation also specifies the compliance limits for those releases, and the means to normalize the releases against the total waste inventory.

The specifics of the probability-weighted release limits, the calculation of the EPA unit as a measure of inventory, and the calculations for computing the total release mean that the complementary cumulative distribution function curve are provided in the regulation (and discussed in the CCA), but the net effect is that the WIPP demonstration of compliance with regard to the calculated releases resulting from drilling over the 10,000-year period is largely insensitive to changes in inventory.

This leads to the third key aspect of WIPP: the regulatory framework is such that a greater initial inventory allows a greater radioactivity release in curies, as determined over the 10,000-year period.

Historically, WIPP performance assessment results have shown little difference in calculated releases solely as a result of inventory changes (see Figure C-4). Even with the substantially increased inventory of the DSP-TRU, and the latest drilling intrusion rates reflecting recent regional oil and gas drilling activity, a brief provided by DOE suggested that WIPP will continue to demonstrate compliance with the release limits of 40 CFR Part 191 (Dunagan et al., 2019).

SUMMARY POINTS

In the undisturbed scenario (absent any inadvertent human intrusion by drilling into the repository), the salt rock is expected to provide complete containment and isolation of the waste from the accessible environment, when evaluated over the 10,000-year compliance period. Indeed, all performance assessments to date including the Sandia assessment that includes up to 48.2 MT of additional diluted surplus plutonium (DSP-TRU waste) have shown no releases in the undisturbed scenario.

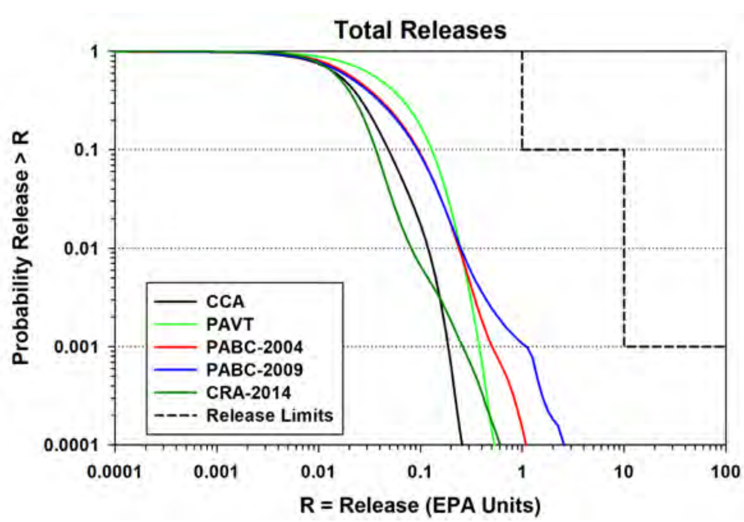

FIGURE C-4 Comparison of compliance calculation results. SOURCE: Dunagan et al., 2019, slide 19. Image provided by Sandia National Laboratories.

For the disturbed scenario, the WIPP performance assessment calculates releases mostly from the drilling intersection with the waste emplacement horizon and the encounter with possible pressurized brine pockets beneath the repository. But in general terms, WIPP is largely insensitive to changes in inventory when evaluated for the direct releases over the 10,000-year compliance period.

In the case of direct releases from drilling, some waste characteristics can potentially exacerbate the release. All changes in inventory are accompanied by waste characterization and waste packaging parameter data to enable a full examination of the potential factors that may contribute to release (e.g., enhanced actinide solubility). The DSP-TRU inventory, by nature of the substantial size of the inventory (potentially ~85 percent of the curie content at closure), the concentration of Pu-239 (nominal 300 g per drum, with ~166,000 drums), and the uncertain effects of the classified adulterant/diluent, raises concerns such as

- Understanding the effects of the DSP-TRU inventory on radiolysis and gas generation;
- Understanding the potential for criticality, pre- and post-10,000-year time frames;
- Understanding changes in the classified adulterant/diluent arising from the criticality evaluations (e.g., the addition of boron carbide);
- Understanding the effects of the classified adulterant/diluent material (described as a dry cement-like mixture) on WIPP chemistry, especially in the presence of brine, and effects on pH and plutonium solubility; and
- Understanding the presence of complexing agents, ligands, etc.

These concerns and others (e.g., unspecified changes in the WIPP underground configuration and the change to new code/model bases) represent substantial, simultaneous, and connected changes in the WIPP post-closure conceptualization. While there is reason for confidence in assuming that WIPP will continue to demonstrate regulatory compliance with the addition of the DSP-TRU inventory, the magnitude of these changes is at the crux of the recommendations to exercise prudence in pursuing the dilute and dispose concept (see, e.g., Recommendations 5-5 and 5-7).

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Appendix D

Legal and Regulatory Requirements for Transportation

In the course of writing this report, a number of references were examined including, but not limited to, the following, which guide both the Department of Energy's Office of Secure Transportation (DOE-OST) and DOE's Office of Environmental Management's Carlsbad Field Office (DOE-CBFO) in the transportation of radioactive materials, special nuclear materials, and nuclear waste.

Authoring Organization	Legal and Regulatory Requirements
Federal Regulations	US Department of Transportation, Title 49 Code of Federal Regulations (CFR) Parts 40, 100 -185, 382, 383, 385, 386, 387, 390-399
	Nuclear Regulatory Commission, Title 10 CFR Part 71 - Packaging and Transportation of Radioactive Material
	Pipeline and Hazardous Materials Safety Administration 2016 Emergency Response Guidebook
	Environmental Protection Agency, Title 40 CFR Part 263, Standards Applicable to Transporters of Hazardous Wastes
Memorandum of Understanding	Memorandum of Understanding between the Nuclear Regulatory Commission and the Department of Transportation that was published in the Federal Register on July 2, 1979 (44 FRN 38690)
US Dept. of Energy Directives, Guidance, and Delegations	• DOE Order 460.1D, Hazardous Materials Packaging and Transportation Safety, 2016 • DOE Order 460.2A, Departmental Materials Transportation and Packaging Management, 2004
States	Compliance with state hazardous materials, oversize overweight, radioactive materials, nuclear materials, nuclear waste statutes, regulations, and rules for Alabama, Georgia, Louisiana, Mississippi, New Mexico, South Carolina, Tennessee, and Texas, and any other state through which DOE-OST transits

Appendix D

References that guide **OST** in the transportation of special nuclear materials.

Authoring Organization	Legal and Regulatory Requirements
Public Law	ATOMIC ENERGY ACT OF 1954 [As Amended Through P.L. 115-439, Enacted January 14, 2019] including • Section 161 (i) – Declare a National Security Area • Section 161 (k) – Use of Firearms by Security Personnel
U.S. Code	U.S. Code Title 18. CRIMES AND CRIMINAL PROCEDURE Part I. CRIMES Chapter 44. FIREARMS Section 922. Unlawful acts
Federal Regulations	US Department of Energy, Title 10 Part 712 – Human Reliability Program including continuous monitoring, and training; 10 CFR 1047.7 – Use of Deadly Force
	Environmental Protection Agency, Title 40 CFR Part 263, Standards Applicable to Transporters of Hazardous Wastes
US Dept. of Energy Directives, Guidance, and Delegations	• DOE Order 251.D, Supplemental Directive NNSA S 251.1A, NNSA Directives Management, 2018 • DOE Order 461.1C, Packaging and Transportation for Offsite Shipment of Materials of National Security Interest, 2016 • DOE Order 461.2, Onsite Packaging and Transfer of Materials of National Security Interest, 2010 • DOE Order 474.2, Change Notice 4, DOE Order – Nuclear Material Control and Accountability, 2016 • DOE O 473.3A Chg 1 (MinChg), Protection Program Operations, 2018 • Archived JM DOE O 470,3B, Notice of Intent to Revise DOE Order 470.3B, Graded Security Protection (GSP) Policy, 2015 • Archived DOE O 470.3C, Design Basis Threat (DBT) Policy

References that guide **DOE-CBFO** in the transportation of transuranic waste.

Authoring Organization	Legal and Regulatory Requirements
Public Law	PUBLIC LAW 102-579 THE WASTE ISOLATION PILOT PLANT LAND WITHDRAWAL ACT as amended by Public Law 104-201 (H.R. 3230, 104th Congress), Section 16. Transportation
Executive Order	The provisions of Executive Order 12372 "Intergovernmental review of Federal programs", of July 14, 1982, appear at 47 FR 30959, 3CFR, 1982 Comp., p. 197.
Federal Regulations	49 CFR Parts 173.403, 385.4, 385.4(b), 385.415(b) refer to inspection requirements according to the Commercial Vehicle Safety Alliance handbook titled " North American Standard Out-of-Service Criteria and Level VI Inspection Procedures and Out-of-Service Criteria for Commercial Highway Vehicles Transporting Transuranics and Highway Route Controlled Quantities of Radioactive Materials as defined in 49 CFR part 173.403."
	Environmental Protection Agency, Title 40 CFR Part 262, Standards Applicable to Generators of Hazardous Waste
	Nuclear Regulatory Commission, Title 10 CFR Part 830.120 Quality Assurance Requirements
	US NRC Directory of Certificates of Compliance for Radioactive Materials Packages: Certificates of Compliance (NUREG-0383, Volume 2, Revision 27)
US Dept. of Energy Directives, Guidance, and Delegations	• DOE Order 151.1D, Comprehensive Emergency Management, 2016 • DOE Order 153.1, Departmental Radiological Emergency Response Assets, 2007 • DOE Order 200.1A, Information Technology Management, 2008 • DOE Order 231.1B, Admin Chg. 1, Environment, Safety and Health Reporting, 2012 • DOE Order 225.1B, Accident Investigations, 2011 • DOE Order 414.1D, Chg. 1 (Admin Chg), Quality Assurance, 2013 • DOE Order 435.1 Chg. 1, Radioactive Waste Management, 2001 • DOE Manual 460.2-1A, Radioactive Material Transportation Practices Manual, 2008
Federal Transportation Plan	TRU Waste Transportation Plan, Revision 4, Effective Date: December 2016, DOE/CBFO-98-3103

Appendix E

States' Active Partnership Role in Safe Transportation

States, whether point-of-origin, destination, or the Waste Isolation Pilot Plant (WIPP) transportation corridor, have additional responsibilities when transuranic and highway route controlled quantities of radioactive materials and waste transit their states. Many responsibilities are borne to meet state and federal laws; some responsibilities are specific to the WIPP transportation program. All of them are important in order to reinforce to the public that the transuranic waste shipments have been done and continue to be done safely and under the close scrutiny of the states that

- Maintain, enforce, and promote safety of the motoring public in order that commercial motor vehicles carrying hazardous materials as well as WIPP motor carriers may have safe passage.
- Secure regulatory compliance through roadside and on-site inspection of commercial motor vehicles hauling general freight, hazardous materials, and nuclear materials.
- Conduct en route inspections, including Commercial Vehicle Safety Alliance (CVSA) Level VI inspections, thus ensuring that the highest mechanical and radiation safety standards are maintained. This includes review of shipping papers (Environmental Protection Agency [EPA] Uniform Hazardous Waste Manifest [EPA Form 8700-22]) in order for the state inspector to verify the carrier and key information in the electronic log book, as well as the cargo details. Often, inspectors compare CVSA Level VI inspection forms from point of origin to the inspection forms that they are creating in order to verify radiation levels noted at point-of-origin versus en route readings done during inspections. These activities are done to ensure and maintain continuity of knowledge on hazardous and nuclear materials shipments.
- Collect state permit fees to pay for their specialized hazardous and nuclear materials programs.
- Serve as routing authorities for hazardous materials as well as radioactive and nuclear materials and waste.
- Perform motor carrier audits of commercial motor vehicles that list a particular state as their Department of Transportation–registered home.
- Monitor advance notification from the Department of Energy (DOE) in various forms:
  - Semi-Annual Notification letter;
  - Eight-Week Rolling Schedule updated weekly and more frequently as necessary in order to address changing needs such as highway closures, bad weather, road conditions, and large events;
  - Two-Week Notice of Intent to Ship along a new transportation corridor; and
  - Two-Hour Calls.
- Monitor the location of the WIPP motor carrier utilizing the TRANSCOM system and
  - Provide support to WIPP motor carriers in any unforeseen situation;
  - Report any unanticipated road conditions and closures or bad weather to the WIPP Central Monitoring Room to pass along to the drivers;
  - Respond and provide a law enforcement or radiation protection escort to the motor carrier if it must be routed off of the established route or be taken to safe parking; and
  - Respond to any incident or accident involving the WIPP motor carrier.

- Conduct needs assessments in order to design ongoing programmatic activities to meet the needs of emergency response personnel, public and elected officials, and the general public in the specialized areas of training, exercise, equipment, medical preparedness, security, routing, and public information.
- Respond to and mitigate hazmat incidents involving the potential or actual release of a hazardous or radioactive material; acquire immediate DOE telephonic technical guidance while awaiting arrival of federal response assets; formulate an action plan that anticipates continuously changing situations, and act to resolve the emergency. State and local response authorities participate in unified command along with federal response assets to provide technical assistance to the incident commander.

Appendix F

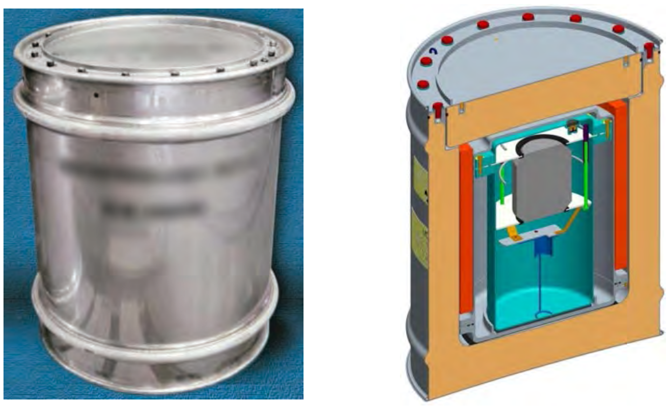
High-Risk Items Within the Risk and Opportunity Analysis Report

INTRODUCTION

The Risk and Opportunity Analysis Report (ROAR) (SRNS, 2018a) provides analyses by the Department of Energy's National Nuclear Security Administration (DOE-NNSA) of cost and schedule risks for the proposed dilute and dispose plan. Some risks may need continuous review as details of designs for the proposed facilities, equipment, processes, and operations are developed in preparation for a program Conceptual Design at stages CD-1 (approved in late 2019) and the start of construction activities after CD-3A approval (approved in early 2020, DOE-NNSA, 2018).

This committee has not reviewed the underlying operations data used by DOE-NNSA to conduct the ROAR and Life-Cycle Cost Estimate (LCCE) evaluations (SRNS, 2018a,b). That is, the committee did not independently verify the stated frequency of realized risks such as unplanned process excursions, equipment breakdowns, or accidents that were used by DOE-NNSA to determine programmatic risks to cost and schedule. The U.S. Army Corps of Engineers' review also did not investigate the underlying operations data. The operations data are based on experience at the sites or models developed in the course of the various dilute and dispose activities and trial runs to date.

Pantex's role is to provide 26.2 metric tons (MT) of pit material in classified amounts in a licensed Type B package under a classified schedule to the Los Alamos National Laboratory (LANL). This step is unchanged from the previous plan to dispose of surplus plutonium using irradiated mixed oxide fuel. Currently the FL-type Type B container is certified for transportation from Pantex; for the dilute and dispose plan, a new MD-2 container is expected to be certified and used (Whitworth, 2018). See Figure F-1.



(a) (b)

FIGURE F-1 MD-2 Type B container: (a) photo of the new MD-2 container, (b) cross section of the MD-2 container. The MD-2 containers, designed to be stronger and have improved ceramic insulation over the existing FL containers, were developed to support shipment of surplus pits for the Surplus Plutonium Disposition (SPD) Program in fiscal year (FY) 2021. SOURCE: Cantey and Robertson, 2019. Images provided by the Department of Energy.

DOE-NNSA plans to qualify and build the MD-2 container, which is stronger than the FL package and has an improved ceramic insulation formulation to pass drop and burn tests. The new MD-2 enables the pits to be kept in current sealed containers and is expected to be ready for use in FY 2021. In terms of Technology Readiness Level (TRL) the MD-2 is listed as TRL-7 (Cantey and Robertson, 2019) and should be able to come online well ahead of the time that it is needed for dilute and dispose operations ramp-up in 2023. Other plans related to improved containers for LANL operations are outlined in Box F-1.

ROAR REVIEW

The ROAR document identifies risks for the dilute and dispose program ranked low, moderate, and high. The ROAR also identifies a number of opportunities to offset the risks. Below, we provide an overview of the high risks and opportunities for the program.

BOX F-1 Plans for Improvements in Processes at LANL

Getting enough equipment and keeping it online is a scale-up risk but the type of equipment and processes for LANL activities is not an inherent risk to the plan. The plan calls for equipment and processes that utilize existing technology and bringing these up from current Technical Readiness Level-6 (TRL-6) and TRL-7 by FY 2023 to improve efficiencies in time for full ramp-up is not expected to be a problem. These are not flagged as risks in the ROAR.

For example, LANL plans to deploy several new and refurbished lathes and pit cutters to accomplish the needed size reduction throughput.[a] Pit cutter equipment is at TRL-7 and is expected to be available by the ramp-up date in 2023. LANL also plans to deploy several muffle furnaces and direct metal oxidation furnaces for the oxide production needed to meet the dilute and dispose plan throughput.[b]

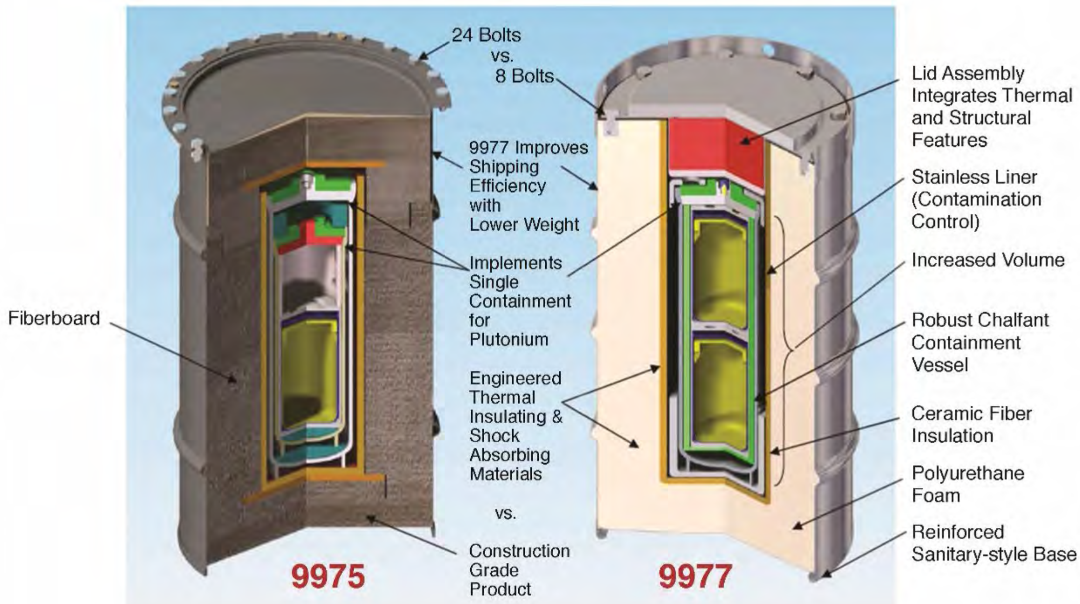
Efficiencies will also be gained by the use of new containers at LANL for shipment of the plutonium oxide to the Savannah River Site (SRS). The SAVY "twist-off can" is expected to be an efficiency improvement over the 3013 welded can, which might offset a current schedule risk and/or potential worker handling and safety risk in the committee's estimation. The dilute and dispose staffing and throughput plan assumes the SAVY container for cost and schedule purposes. Qualification of a SAVY container (Stone, 2012) to replace the 3013 container is needed by 2023 (see Box Figure 1). LANL also plans to qualify the 9977 container (2 × 5-kg capacity) to replace the current 9975 container (1 × 5-kg capacity) for shipping to and storage at SRS.[c] The use of the 9975 is a schedule risk not a scale-up risk; that is, the baseline assumes the 9977. The 9977 shipping package has been demonstrated through TRL-6 at this time (Cantey and Robertson, 2019). See Box Figure 2.

(a) (b)

BOX FIGURE 1 The dilute and dispose program plan includes a transition from the 3013 containers: (a) nested cans of the 3013 container (left to right, convenience can, inner welded can, and outer welded can) to (b) a SAVY container. The SAVY container is a reusable container that has locking tabs and O-ring seals to eliminate welding. SOURCE: Cantey and Robertson, 2019. Images provided by the Department of Energy.

continued

BOX F-1 Continued



BOX FIGURE 2 Comparison between the 9975 and 9977 shipping and storage containers. NOTE: 3013 containers shown in yellow. SOURCE: Cantey and Robertson, 2019, slide 6. Image provided by the Department of Energy.

[a]The size reduction by lathe or cutter machining is not identified as a throughput constraint in the ROAR.
[b]The planned numbers and types of equipment (SRNS, 2018a,c; Whitworth, 2018) are not final and not consequential to the dilute and dispose plan at this early stage.
[c]The 9975 is an existing multiuse package that is used by the SPD Program primarily to ship and store a single 3013 container. A loaded 9975/3013 can be stored at SRS for up to 20 years. The 9977 is an existing multiuse package that has the capability to hold two inner (presumably 3013) containers (Cantey and Robertson, 2019, slides 4 and 5).

Los Alamos National Laboratory

There are several scale-up risks for operations at LANL that are ranked as high risk to program schedule and cost.[1] These have to do with both equipment and operations:

- *Anomalous events causing delays.* These are unforeseen and known to occur; this is a matter of normal contingency planning. Such events must be accepted and accounted for in the program plan. Process upsets often result in major shutdowns. Background documentation for the program does not indicate how much time is built into the schedule for such anomalous events, although the ROAR does say that serious events can disrupt production for 1 year or more, stopping activity downstream at SRS and the Waste Isolation Pilot Plant. The documentation does not specify the nature of potential anomalous events.
- *Equipment installation schedule delays.* The program plan calls for efforts to mitigate this risk, presumably during the ramp-up phase of the program.

[1]In October 2019, the U.S. Government Accountability Office issued a report that examined DOE's capacity to produce plutonium oxide as DOE-NNSA begins to plan an expanded capability to produce pits (GAO, 2019).

- Inability to use a SAVY container for storing and shipping oxide product to SRS. The committee assumes that is a schedule risk but not a scale-up risk. That is, use of the 3013 instead of the SAVY container may slow down the operations, thus diminishing concerns about scale-up but extending program completion beyond the 2049-2056 time frame.
- *Lower than planned oxide production rate.* The ROAR document says that this can be mitigated at a cost of $150 million. Although the ROAR does not specify it, the committee assumes that these funds would be applied to increase the number of lines and/or shifts. The committee notes that the needed oxide production rate is much greater than previously demonstrated, a significant risk as noted in the ROAR.
- *Productivity impact of insufficient storage.* The ROAR document says this can be avoided for $10 million.

The opportunities to offset scale-up risks at LANL are

- *Install additional capacity at a cost of $67 million.* There is no detail as to how much schedule improvement would result with this expenditure.
- *Share with other installations at LANL in the proximity of the dilute and dispose operations.*
- *Maximize production prior to and/or during facility modifications.* This can be achieved for $22.3 million, according to the document.
- *Perform small in-line sample analysis.* An additional expenditure of $3.5 million is assumed by DOE-NNSA to facilitate the process throughout.

Savannah River Site

The ROAR document (SRNS, 2018a) identifies two risks at SRS that are ranked as high risk to program schedule and cost. These have to do with both equipment and operations:

- *Failure of characterization equipment.* The plans are to perform non-destructive assay (NDA), real-time radiography (RTR), and flammable gas analysis (FGA) without standby equipment. To mitigate this risk, the costs of purchasing spare NDA, RTR, and FGA equipment are included in the LCCE baseline.
- *Delay in K Area operations*. Savannah River Nuclear Solutions may not complete the necessary steps allowing K Area operation to begin. Even with mitigation efforts this risk remains high.

The ROAR document also identifies a number of SRS scale-up risks ranked as moderate or low in terms of cost and schedule and identifies a number of opportunities to offset risks at SRS:

- *Increase criticality control overpack (CCO) loading.* Increasing the loading of a CCO from 300 g Pu to 330 g Pu would decrease glovebox labor and reduce the number of containers, amount of container handling and storage, and the number of shipments. However, it would demand high-accuracy measurements in K Area with unacceptable third-party entrance into K Area. Therefore, this opportunity is deemed of low probability of success.
- *Optimize storage requirements.* Among the SRS requirements for ensuring safe storage of nuclear material in K Area are multiple mass measurements of incoming fissile materials for criticality analysis. Work is in progress to eliminate these multiple measurements at LANL by using multiple scales and independent verification, which would reduce cost and personnel exposure at LANL.

- *Streamline waste tracking methods.* Current waste characterization processes are designed for differing small-quantity wastes and necessitate significant effort. However, the dilute and dispose waste is uniform, and a streamlined waste tracking process in E Area is possible, leading to significant cost savings.
- *Treat E Area facility as contamination free.* Currently five or more radiological surveys are made when CCOs are moved before shipping. There is a potential to eliminate many of these surveys to be reflected in cost savings.

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Appendix G

Acronyms and Abbreviations

Am	americium
APCS	Abandonment of Panel Closures in the South
ARIES	Advanced Recovery and Integrated Extraction System
ATWIR	Annual Transuranic Waste Inventory Report
AU-50	Director of the Office of Security
B_4C	boron carbide
BRAGFLO	brine and gas flow modeling code
BRC	Blue Ribbon Commission on America's Nuclear Future
C&C	Consultation and Cooperation
CAB	Citizens Advisory Board (Savannah River Site)
CBFO	see DOE-CBFO
CCA	Compliance Certification Application
CCC	criticality control container; criticality control component
CCDF	complementary cumulative distribution function
CCO	criticality control overpack
CD	Critical Decision (e.g., CD-0 for Critical Decision 0)
CDF	cumulative distribution function
CFR	Code of Federal Regulations
CH	contact-handled
CH-TRU	contact-handled transuranic
Ci	curie
CID	Comprehensive Inventory Database
CRA	Compliance Recertification Application
CVSA	Commercial Vehicle Safety Alliance
CY	calendar year
DBFT	Deep Borehole Field Test
DOD	Department of Defense
DOE	Department of Energy
DOE-CBFO	Department of Energy's Office of Environmental Management's Carlsbad Field Office
DOE-CEPE	Department of Energy's Office of Cost Estimating and Program Evaluation
DOE-EM	Department of Energy's Office of Environmental Management
DOE-NNSA	Department of Energy's National Nuclear Security Administration
DMO	direct metal oxidation
DNFSB	Defense Nuclear Facilities Safety Board
DNN	Department of Energy's National Nuclear Security Administration, Office of Defense Nuclear Nonproliferation
DOS	Department of State
DOT	Department of Transportation
DSA	documented safety analysis

DSP	diluted surplus plutonium
DSP-TRU	diluted surplus plutonium transuranic
DWPF	Defense Waste Processing Facility
EEG	Environmental Evaluation Group
EIS	environmental impact statement
EM	see DOE-EM
EPA	Environmental Protection Agency
FEP	features, events, and processes
FGA	flammable gas analysis
FGE	fissile gram equivalent
FPEIS	final programmatic environmental impact statement
FTE	full-time equivalent
FY	fiscal year
g	gram
GAO	Government Accountability Office
GSP	graded security protection
GTCC	Greater-Than-Class-C
HalfPACT	half package transporter
HB-Line	chemical processing facility at Savannah River Site
HLW	high level radioactive waste
HQ	headquarters
HRCQ	highway route controlled quantities
HWDU	hazardous waste disposal unit
HWFP	Hazardous Waste Facility Permit
IAEA	International Atomic Energy Agency
IART	Incident/Accident Response Team
IDA	Institute for Defense Analyses
INL	Idaho National Laboratory
INV	inventory report
IPFM	International Panel on Fissile Materials
K	potassium
KAC	K-Area Complex
KIS	K Interim Surveillance
LANL	Los Alamos National Laboratory
LCCE	Life-Cycle Cost Estimate
LD	lethal dose
LWA	Land Withdrawal Act (Waste Isolation Pilot Plant)
LWR	light-water reactor
M^3	Material Management and Minimization (an office within the Department of Energy's National Nuclear Security Administration)
m^3	cubic meter
MAR	Material at Risk
MC&A	material control and accountability

MCL	maximum contaminant level
MD	materials disposition
MFFF	Mixed Oxide Fuel Fabrication Facility
MOA	memorandum of agreement
MOX	mixed oxide
MPa	megapascal
MRRC	Materials Risk Review Committee
MT	metric tons
MTHM	metric tons of heavy metal
NA-10	Office of Defense Programs (within the Department of Energy's National Nuclear Security Administration)
NA-80	Office of Defense Programs Counterterrorism and Counterproliferation (within the Department of Energy's National Nuclear Security Administration)
NDA	non-destructive assay
NDAA	National Defense Authorization Act
NEPA	National Environmental Policy Act
NMC&A	nuclear material control and accountability
NMED	New Mexico Environment Department
NNSA	see DOE-NNSA
NOI	notice of intent
Np	neptunium
NRC	National Research Council
NTP	National TRU Program
NUREG	Nuclear Regulatory Report
NWP	Nuclear Waste Partnership LLC
NWPA	Nuclear Waste Policy Act
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
OST	Department of Energy's Office of Secure Transportation
PA	performance assessment
PAIR	performance assessment inventory report
PARO	Public Access Records Office
PCN	planned change notice
PCR	planned change request
PDF	probability density function
PE-Ci	plutonium equivalent curies
PEIS	programmatic environmental impact statement
PFLOTRAN	petascale reactive multiphase flow and multicomponent transport code
PHMSA	Pipeline Hazardous Materials Safety Association
PMDA	Plutonium Management and Disposition Agreement
PMR	permit modification request
POC	pipe overpack container
PRA	performance risk assessment
Pu	plutonium
Pub. L.	public law
QA	quality assurance

RCRA	Resource Conservation and Recovery Act
RH	remote-handled
RH-TRU	remote-handled transuranic
ROAR	Risk and Opportunity Analysis Report
ROD	record of decision
ROMP	risks and opportunities management plan
RTR	real-time radiography
SEIS	supplemental environmental impact statement
SNL	Sandia National Laboratories
SNM	special nuclear material
SPD	surplus plutonium disposition
SPD INV	surplus plutonium disposition inventory report
SRNS	Savannah River Nuclear Solutions, LLC
SRS	Savannah River Site
SSEB	Southern States Energy Board
SST	Safe Secure Transport
STD	Department of Energy Standard
Sv	sievert
TBD	to be determined
TDOP	10-drum overpack
TMW	transuranic mixed waste
TRL	Technology Readiness Level (e.g., TRL-5)
TRU	transuranic
TRUPACT	TRansUranic Package Transporter
U	uranium
UO_2	uranium oxide
U.S. NRC	U.S. Nuclear Regulatory Commission
USACE	U.S. Army Corps of Engineers
VoR	volume of record
WAC	waste acceptance criteria
WDS/WWIS	Waste Data System/WIPP Waste Information System
WGA	Western Governors' Association
WIPP	Waste Isolation Pilot Plant
WRAC	waste removal after closure
WUF	waste unit factor
ZPPR	Zero Power Physics Reactor

Appendix H

Interim Report

Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant
Interim Report

Committee on Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant

Nuclear and Radiation Studies Board

Division on Earth and Life Studies

A Consensus Study Report of
The National Academies of
SCIENCES • ENGINEERING • MEDICINE

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Appendix H

Acknowledgments

A number of people and organizations contributed to the successful completion of this report. The committee wishes to thank the study sponsor, the U.S. Department of Energy's (DOE) National Nuclear Security Administration (NNSA), for supporting this project, and especially the following staff: William Kilmartin, Lyndsey Adams, Sachiko McAlhany, Virginia Kay, and Peter Hanlon. The committee also extends its thanks to Betsy Forinash, DOE's Office of Environmental Management, and Todd Shrader, DOE's Carlsbad Field Office (CBFO).

The committee also thanks the presenters and speakers who gave high-quality presentations during the public meetings as listed in Appendix B. In particular, the committee is thankful for the assistance provided for site visits and tours by the following individuals: Richard V. Lee, Jr., State of South Carolina Governor's Nuclear Advisory Council, for hosting a public session at the South Carolina State House in Columbia; Thomas Canty, Savannah River Site (SRS), for planning and coordinating the committee's site visit and tours at SRS, South Carolina; William Goodrum, Los Alamos National Laboratory (LANL), for planning and coordinating the committee's visit and tour at LANL, New Mexico; and Todd Shrader, CBFO manager, and George Basabilvazo, CBFO chief scientist, for planning and organizaing the committee's visit and tour at the Waste Isolation Pilot Plant and the public session in Carlsbad, New Mexico.

In addition, the committee is grateful for submitted public comments, which were useful in helping the committee better understand the public's concerns and views.

The committee is grateful for the outstanding assistance provided by the National Academies of Sciences, Engineering, and Medicine staff in preparing the report especially Toni Greenleaf, financial associate, for her assistance; Darlene Gros, senior program assistant, for logistical planning for all of the committee's meetings and project administration; Richard Rowberg, senior advisor, for his guidance and his participation in the classified meetings and tour; Kevin Crowley, technical editor, for his work negotiating and designing the study with DOE and for editing an early version of the interim report; and Jenny Heimberg, study director, for managing the study.

The chair is especially thankful for the opportunity to lead this distinguished committee. He would like to thank the members of the committee for their dedication, willingness to teach and to learn, and for their time and energy.

Reviewer Acknowledgments

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following individuals for their review of this report:

Mark D. Abkowitz, Vanderbilt University, Nashville, Tennessee
Lake H. Barrett, independent consultant, Venice, Florida
Craig H. Benson, University of Virginia, Charlottesville, Virginia
Matthew G. Bunn, Harvard University's John F. Kennedy School of Government, Cambridge, Massachusetts
Rodney C. Ewing, Stanford University, Stanford, California
Christine M. Gelles, Longenecker and Associates, Las Vegas, Nevada
Lindsay A. Lovejoy, Jr., attorney, Santa Fe, New Mexico
William H. Tobey, Harvard University, Cambridge, Massachusetts

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by Carloyn Huntoon, Consultant, Retired U.S. Government, and Chris Whipple, ENVIRON (Retired). They were responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

Appendix H

Contents[1]

[1]The page numbers shown here were revised for the placement of the Interim Report in the Final Report.

Summary

This report is the product of a congressional request[2] to the National Academies of Sciences, Engineering, and Medicine for an evaluation of the general viability of the U.S. Department of Energy's National Nuclear Security Administration's (DOE-NNSA's[3]) conceptual plans for disposing of 34 metric tons (MT) of surplus plutonium[4] in the Waste Isolation Pilot Plant (WIPP), a deep geologic repository near Carlsbad, New Mexico. Congress asked the National Academies to evaluate two issues:

- DOE-NNSA's plans to ship, receive, and emplace surplus plutonium in WIPP; and
- DOE-NNSA's understanding of the impacts of these plans on WIPP and WIPP-bound waste streams.

This report, the first of two to be issued during this study, provides a *preliminary assessment* of the general viability of DOE-NNSA's conceptual plans, focusing on some of the barriers to their implementation. The second report, to be issued after the committee receives additional planning documents from DOE-NNSA,[5] will address the Statement of Task in its entirety (see Box 1 in Chapter 1).

DISPOSITION OF U.S. SURPLUS PLUTONIUM

The U.S. government plans to disposition 34 MT of surplus weapons-grade plutonium under the Plutonium Management and Disposition Agreement (PMDA), which was signed by the United States and the Russian Federation in 2000 and amended in 2010, and the *Nonproliferation and Export Control Policy* issued by President Clinton in 1993 (DOS 2000, 2010; DOE 2018d).[6,7] The PMDA defines disposition requirements and methods to ensure the United States and the Russian Federation could not reintroduce surplus plutonium into the arsenals from which they came (i.e., diversion). The PMDA requirements also reduce the risk of access by unauthorized parties (i.e., theft) and strengthen arms control commitments. The amended PMDA in 2010 supersedes the earlier agreement and commits both countries to integrate surplus plutonium into mixed oxide (MOX) fuel[8] followed by irradiation. Immobilization of the plutonium is not a specified disposition method in the amended PMDA. Section 3.3 of this report discusses the PMDA and its current status in more detail.

[2]The mandate appears in House Report 114-532, Energy and Water Development Appropriations Bill, 2017.

[3]The committee refers to DOE's National Nuclear Security Administration as "DOE-NNSA," DOE's Office of Environmental Management as "DOE-EM," and to the broader Department of Energy as "DOE."

[4]Defined by DOE as plutonium that "has no identified programmatic use and does not fall into one of the national security reserves." DOE-NNSA is responsible for managing all U.S. surplus plutonium and DOE-EM is responsible for disposing of any quantities declared as waste.

[5]Release of these planning documents to the committee has been delayed by recent legal actions between South Carolina and DOE.

[6]One metric ton (MT), or 1000 kg, is equivalent to 2,205 pounds (lbs) or 1.1 U.S. tons.

[7]Dispositioning, disposal and storage are used throughout this report with the following definitions, as defined by the International Atomic Energy Agency (IAEA 2016): Dispositioning: Consigning of, or arrangements for the consigning of, radioactive waste for some specified (interim or final) destination, for example for the purpose of processing, disposal or storage. Disposal: Emplacement of waste in an appropriate facility without the intention of retrieval. Storage: The holding of radioactive sources, radioactive material, spent fuel or radioactive waste in a facility that provides for their/its containment, with the intention of retrieval.

[8]MOX fuel contains plutonium and uranium, both in oxide form.

DOE-NNSA issued a Record of Decision in 2000 to disposition weapons grade surplus plutonium by incorporating it into MOX reactor fuel followed by irradiation in commercial nuclear reactors. The United States began construction of a facility to manufacture MOX fuel, the Mixed Oxide Fuel Fabrication Facility ("MOX plant"), at the Savannah River Site in South Carolina in 2007. Construction has encountered substantial schedule delays and cost overruns. The Obama administration proposed to stop construction of this facility and instead use a "dilute and dispose process" to disposition this surplus plutonium in 2014. The Trump administration announced plans to cancel the MOX plant in May 2018 and declared the dilute and dispose process as the program of record.[9] The DOE issued a termination of the contract with CB&I AREVA MOX Services, the contractor managing the MOX program, in early October 2018 following several months of legal challenges between the state of South Carolina and the DOE.

DOE-NNSA asserts that through chemical (dilution) and physical (repository emplacement) barriers the end state of the dilute and dispose process would meet the intent of the PMDA for preventing plutonium recovery and reuse. The "dilute" portion of the dilute and dispose process entails the oxidization of surplus plutonium followed by dry blending with an adulterant to dilute the plutonium-239 content. Details of the adulterant composition and processing steps are classified. The "dispose" portion of the plan involves packaging, characterizing, and transporting the blended material to WIPP for final emplacement. The dilute and dispose process is not currently a PMDA-approved method for dispositioning U.S. surplus plutonium.

DOE-NNSA currently estimates that it will take 31 years to dilute and dispose of all 34 MT of surplus U.S. plutonium, beginning with conceptual process design in 2018 and ending with completion of emplacement of diluted plutonium at WIPP in 2049. Four DOE sites would be involved in implementing this process: the Pantex Plant in Texas, where 26.2 MT of surplus plutonium pits are stored; Los Alamos National Laboratory (LANL) in New Mexico, where the plutonium metal will be oxidized; Savannah River Site (SRS) in South Carolina, where the oxidized plutonium will be diluted and packaged for transport and disposal; and WIPP in New Mexico, where the diluted plutonium will be emplaced in the repository. An additional 7.8 MT of non-pit surplus plutonium stored in other locations throughout the DOE complex are also part of DOE-NNSA's conceptual plans and will be oxidized at LANL (if needed), diluted at SRS, and disposed of in WIPP.

COMMITTEE ASSESSMENT

The committee's preliminary assessment produced a set of findings, conclusions, and recommendations, provided below.

CONCLUSION 1: The dilute and dispose process has been demonstrated at a small scale by DOE-EM as it begins to process 6 MT of surplus plutonium, a quantity separate from the 34 MT associated with the Plutonium Management and Disposition Agreement (PMDA). The committee agrees with earlier assessments that the technical complexity of the dilute and dispose process is lower than that of the construction of a MOX fuel option. Because of lack of information, the committee makes no judgment in this interim report on the DOE's ability and the associated risks of scaling up the current infrastructure and processes to address the 34 MT. The committee has, however, identified several barriers that will need to be addressed by DOE-NNSA and others before the dilute and dispose conceptual plans can be implemented to support U.S. commitments under the PMDA.

FINDING 1: DOE-NNSA's dilute and dispose option, if implemented, is likely to face several challenges during its inception and lifetime of over three decades. These include potential changes to the intended

[9]On May 10, 2018, Secretary Perry issued a letter to Congress announcing DOE's decision to cancel the MOX plant and move to the dilute and dispose option for disposal of surplus plutonium citing a cost estimate that showed the cost of dilute and dispose was less than half of the projected cost of the MOX option (Demarest 2018). The authority for Secretary Perry to take such action was granted through the National Defense Authorization Act for Fiscal Year 2018 P.L. 115-91.

purpose, size, operations, and lifetime of WIPP; the lack of availability of other suitable repositories for disposing of diluted plutonium (i.e., Yucca Mountain or elsewhere); state, tribal, and local acceptance of diluted and packaged plutonium; transportation, and permanent disposal operations; changes in U.S. nuclear weapons programs (e.g., new pit production and associated waste streams); and funding availability. These challenges could lead to technological and/or programmatic changes to the current conceptual plans in order to achieve the DOE-NNSA's mission to dispose of 34 MT of surplus plutonium in an efficient, safe, and secure manner.

FINDING 2: The committee identified the following three barriers to implementation of DOE-NNSA's current conceptual plans:

- Insufficient current statutory and current physical capacity within WIPP for disposal of 34 MT of diluted plutonium throughout the lifetime of the dilute and dispose project.
- Unclear strategy for development of the National Environmental Policy Act (NEPA) environmental impact statement for disposing of 34 MT of surplus plutonium in WIPP using the dilute and dispose process.
- Lack of Russian Federation approval for dispositioning 34 MT of surplus plutonium using the dilute and dispose process to meet the requirements of the PMDA.

RECOMMENDATION 1: The remaining statutory capacity as defined in the Waste Isolation Pilot Land Withdrawal Act (P.L. 102-579, as amended by P.L. 104-201; LWA) and New Mexico Environment Department (NMED) permit at WIPP should be treated as a valuable and limited resource by DOE. DOE-EM and the Carlsbad Field Office should modify their current emplacement planning process to allow for guaranteed long-term allocation of disposal capacity for waste streams of highest priority to DOE.

FINDING 3: Shifting the plutonium disposition program of record to the dilute and dispose option will require detailed discussions between DOE and the states of New Mexico and South Carolina. Accommodating 34 MT of diluted plutonium and other planned and/or potential future DOE waste streams in WIPP will necessitate changes to state permits and possibly legislation requiring state cooperation, including public participation.

FINDING 4: DOE will need to determine which laws, regulations, and orders are applicable to the proposed dilute and dispose process and develop and implement a strategy to work with regulators to obtain the necessary changes.

RECOMMENDATION 2: DOE-NNSA should engage New Mexico and South Carolina as well as their congressional delegations prior to the public engagement required by the National Environmental Policy Act process to assess prospects for successfully amending the existing legal agreements to allow for the dilution and packaging of 34 MT of surplus plutonium at the Savannah River Site and its disposal in WIPP.

FINDING 5: The dilute and dispose option for surplus plutonium disposition is neither recognized nor approved by the existing PMDA. Irradiated MOX fuel containing the surplus plutonium is the currently approved disposition option for plutonium within the PMDA and is an option that is consistent with the standard established with commercial spent fuel (i.e., that the plutonium would be as inaccessible for recovery for reuse in weapons by the host state as if it were in spent fuel, or the "spent fuel standard"). Disposition options that use chemical barriers alone, such as dilution or combining plutonium with other elements, do not meet this standard. The physical barrier of deep geologic disposal is offered by the DOE-NNSA as a necessary barrier to meet the intent of the PMDA. However, emplacement of diluted plutonium in WIPP remains recoverable by the United States.

FINDING 6: Based on limited information regarding the NEPA strategy for the dilute and dispose program and the fact that DOE-NNSA's dilute and dispose plans derive from a similar program managed by DOE-EM to dilute and dispose of 6 MT of surplus plutonium, the committee finds that a full programmatic environmental impact statement (PEIS) of the dilute and dispose option, encompassing all sites, transportation, and activities involved in the dilute and dispose process rather than a supplemental EIS would help ensure the proper scope and scale of the proposed change. As much as 42.2 MT of surplus plutonium is being considered for disposal at WIPP, including 34 MT related to the PMDA. This represents the majority of the United States' declared excess plutonium and its processing would stress the sites, transportation, and activities well beyond the current disposition plans for 6 MT.

FINDING 7: DOE-NNSA does not have a well developed public outreach plan for the host sites for processes or for the transportation corridor states and tribes (i.e., the current plan is to follow public input require-ments defined by NEPA) for the dilute and dispose program.

CONCLUSION 2: Public trust will need to be developed and maintained throughout the lifetime of the dilute and dispose program because several permit modifications and potential changes to legislation will be required. These changes will require assuring the regulators and the public of the safety and security of the DOE plans. This is particularly challenging for the dilute and dispose program because of several factors: security classification of aspects of the planning (constituents of the adulterant, processing steps, security and safeguards assessments); early stage of program development with changes likely to occur as more information is known; and potential impacts that cross many states and DOE sites.

RECOMMENDATION 3: If the dilute and dispose option becomes the program of record, the committee strongly suggests that DOE consider re-initiating the Environmental Evaluation Group, as an independent technical review organization that can represent the concerns of the state of New Mexico, throughout the lifetime of the dilute and dispose program. Members of the technical review organization would need to be technically qualified to address the health and safety issues and a subset would need to have clearances or access authorizations that will allow thorough review of classified plans as they evolve and provide assessments of the dilute and dispose process.

RECOMMENDATION 4: In addition to and separate from the independent review organization representing the State of New Mexico described in Recommendation 3, periodic classified reviews for Congress by a team of independent technical experts should be required until classified aspects of the dilute and dispose plan, including the safety and security plans, are completed and implemented. Since DOE's plans and decisions are expected to mature and evolve, these independent reviews would provide a mechanism to review classified aspects of the program and would improve public trust in those decisions.

The committee's preliminary assessment also produced three sets of follow-up questions directed primarily to DOE-NNSA. In the final report, the committee may revisit and modify the findings, conclusions, and recommendations in this Interim Report based on DOE-NNSA's answers to these questions.

1. *WIPP Disposal Capacity:* Does DOE-NNSA agree that WIPP's current statutory and physical disposal capacity is a barrier to implementation of the dilute and dispose process for dispositioning 34 MT of surplus plutonium? If not, what data and analyses are DOE-NNSA using to support its alternative conclusion? If so, what are DOE-NNSA and the larger DOE planning or doing to ensure that there is available repository space to dispose of all 34 MT of diluted surplus plutonium and to avoid surface storage of diluted plutonium? What, if any, legal or legislative changes are required to ensure the availability of disposal space in WIPP for disposing of 34 MT of surplus plutonium? If WIPP becomes temporarily unavailable due to an unforeseen closure, what are the plans for the dilute and dispose program? How does the conceptual plan change if permit modifications (i.e.,

changes to the calculation of the volume of record, physical expansion of WIPP, or life extension of WIPP) are not approved?

2. *Environmental Impact Statements* (*EISs*)*:* How many and what kinds of environmental impact statements are currently associated with the dilute and dispose program? Which ones will need to be updated? And how will they be updated (i.e., supplemental EIS versus programmatic EIS)? What are the timeframes for completing these updates? Regardless of the type of EIS prepared, what are DOE-NNSA's plans to incorporate transportation safety and security risks into the NEPA process?
3. *WIPP Compliance:* Will the disposal of 34 MT of diluted plutonium in WIPP require changes to WIPP's Provisional Compliance Recertification Application or to the U.S. Environmental Protection Agency certification of WIPP? If so, what changes will be required, and how difficult (time, costs) will those changes be to implement? What is the timeframe for starting the application process?

1

Introduction

This report is the product of a congressional request[1] to the National Academies of Sciences, Engineering, and Medicine for an evaluation of the general viability of the U.S. Department of Energy's National Nuclear Security Administration's (DOE-NNSA's[2]) conceptual plans for disposing of 34 metric tons (MT) of surplus plutonium in the Waste Isolation Pilot Plant (WIPP) (DOS 2010). Congress asked the National Academies to evaluate two issues:

- DOE-NNSA's plans to ship, receive, and emplace surplus plutonium in WIPP; and
- DOE-NNSA's understanding of the impacts of these plans on WIPP and WIPP-bound waste streams.

See Box 1-1 for the full Statement of Task.

BOX 1-1 Statement of Task for This Study

The National Academies will evaluate the general viability of the U.S. Department of Energy National Nuclear Security Administration's (DOE-NNSA's) conceptual plans for disposing of surplus plutonium in the Waste Isolation Pilot Plant (WIPP) to support U.S. commitments under the Plutonium Management and Disposition Agreement, identify gaps, and recommend actions that could be taken by DOE-NNSA and others to address those gaps. This evaluation will specifically address the following issues:

1. DOE's plans to ship, receive, and emplace surplus plutonium in WIPP.
2. DOE's understanding of the impacts of these plans on the following:
   a. Transportation safety, security, and regulatory compliance.
   b. Current and future WIPP operations, including the need to construct additional waste disposal panels[a] and/or operate WIPP beyond its currently planned closure date.
   c. Disposal of other potential waste streams in WIPP, for example other plutonium wastes.
   d. Greater-than-Class-C-like wastes, and tank wastes.
   e. WIPP pre- and post-closure safety and performance.
   f. Compliance with WIPP waste acceptance criteria; Environmental Protection Agency disposal regulations; and the Land Withdrawal Act, National Environmental Policy Act, and Resource Conservation and Recovery Act requirements.

The National Academies may examine policy options but should not make policy recommendations that require nontechnical value judgments.

[a]WIPP's waste disposal area comprises multiple waste disposal panels. Currently, WIPP contains a total of eight panels; each panel contains seven disposal rooms. See Figure 2-2 in the main text of the report.

[1]The mandate appears in House Report 114-532, Energy and Water Development Appropriations Bill of Fiscal Year 2017 (U.S. Congress 2016).

[2]Throughout this report, the committee refers to DOE's National Nuclear Security Administration as "DOE-NNSA," the DOE's Office of Environmental Management as "DOE-EM," and to the broader Department of Energy as "DOE."

The National Academies appointed a committee of 13 technical experts to carry out this evaluation; their biographies are provided in Appendix A. The committee held eight meetings to gather information for this evaluation and prepare this Interim Report; agendas for the committee's information-gathering meetings are provided in Appendix B.

This report, the first of two to be issued during this study, was developed to provide initial input to Congress and advice to DOE-NNSA within the originally estimated timeline of the study. It provides an interim evaluation of the general viability and issues surrounding the DOE-NNSA's conceptual plans as assessed by the information provided to date. The committee's assessment for this Interim Report is a high-level review of the proposed diluted and dispose process, current WIPP capacity, and requirements of the PMDA. The second report, to be issued at the conclusion of the study, will address the entire Statement of Task (Box 1-1). Key documents and information such as National Environmental Policy Act (NEPA) strategies and decisions, criticality and performance assessments, plans for international monitoring and verification, and programmatic information contained within DOE's life-cycle cost estimate are not publicly available for the committee's review. Therefore, the viability of DOE-NNSA's conceptual plans on transportation safety, security, and regulatory compliance (Task 2.a), and pre- and post-closure safety and performance of WIPP (Task 2.d) are not addressed.

This report is organized into three chapters:

- Chapter 1 (this chapter) provides information about the tasking for this study.
- Chapter 2 describes the proposed disposition of surplus plutonium by the United States, including DOE-NNSA's conceptual plans for disposing of 34 MT of surplus plutonium in WIPP.[3]
- Chapter 3 provides committee interim findings, conclusions, and recommendations as well as questions on DOE-NNSA's conceptual plans.

The committee distinguishes between findings, conclusions, and recommendations using the following criteria:

- Findings: summary statements about the evidence with which no reasonable person could argue without rejecting the evidence—no judgment is involved,
- Conclusions: judgments based on one or more findings or analysis of the evidence—never contain the word "should,"
- Recommendations: proposed actions based on one or more conclusions—usually contain the word "should" and indicates an actor and an action.

[3]Dispositioning, disposal, and storage are used throughout this report with the following definitions, as defined by the International Atomic Energy Agency (IAEA 2016): Dispositioning: Consigning of, or arrangements for the consigning of, radioactive waste for some specified (interim or final) destination; for example, for the purpose of processing, disposal, or storage. Disposal: Emplacement of waste in an appropriate facility without the intention of retrieval. Storage: The holding of radioactive sources, radioactive material, spent fuel or radioactive waste in a facility that provides for their/its containment, with the intention of retrieval.

Appendix H

2

Disposition of Surplus Plutonium by the United States

The U.S. government defines surplus plutonium as plutonium that "is no longer needed for U.S. national security or programmatic purposes" (DOE 2015, p. S-1).[1] The U.S. stockpile of surplus plutonium currently exceeds 60 MT and exists in many forms, including reactor fuel, pits[2] from retired nuclear weapons, used nuclear fuel, and scraps and residues from nuclear weapons production (see Figure 2-1) (DOE 2015).

The disposition pathways for some stocks of U.S. surplus plutonium have already been determined by DOE-NNSA, as shown in Figure 2-1.[3] Of direct relevance to the present study is the proposed disposition pathway for 34 MT of pits and associated plutonium metals and oxides. These materials are being dispositioned by the DOE-NNSA under the Plutonium Management and Disposition Agreement (PMDA), which was signed by the United States and the Russian Federation in 2000 and amended in 2010. The intent of the PMDA is for both parties to convert surplus plutonium into forms unusable for nuclear weapons; specific methods of disposition are outlined within the PMDA.

The 2000 agreement commits both countries to the disposition of no less than 34 MT of weapons-grade[4] plutonium by one or both of two options: (1) incorporation of pit plutonium into mixed oxide (MOX) reactor fuel[5] followed by irradiation in nuclear reactors, or (2) immobilization of non-pit plutonium in glass or ceramic matrixes followed by encapsulation with high-level radioactive waste in a system suitable for geologic disposal.[6] The amended 2010 agreement recognized only irradiated MOX fuel as the disposition option of choice. Therefore, the committee did not include immobilization as an option for disposition in its assessments. The United States and the Russian Federation are required under the agreement to begin surplus plutonium disposition by 2018, with implementation to be verified by the International Atomic Energy Agency (DOS 2000, 2010). See Section 3.3 for more details on the PMDA, its technical and procedural requirements, and political statements regarding the current status of its implementation by both the United States and the Russian Federation.

Both of the PMDA surplus plutonium disposition options listed above, incorporation into MOX fuel followed by irradiation or immobilization with high-level radioactive waste, meet a set of criteria developed by a National Academy of Sciences committee in 1994 and commonly known as the "spent fuel standard" (NAS 1994). Written at the end of the Cold War and as nuclear materials were being declared as excess to weapons programs in the United States and the Russian Federation, approaches to characterize and evaluate options for plutonium management and disposition that would minimize the risk of plutonium recovery for reuse in weapons were presented:

> Options for the long-term disposition of weapons plutonium should seek to meet a "spent fuel standard"—that is, to make this plutonium roughly as inaccessible for weapons use as the much larger

[1]See also the first declaration of surplus (referred to as "excess") plutonium (DOE 1996b, Table 15, p. 76).

[2]A "pit" is the core of an implosion-type nuclear weapon (DOE 2015, p. S-1).

[3]Two entities within DOE are involved in the dilute and dispose conceptual plan. DOE-NNSA is responsible for development and execution of the plan for the disposition of 34 MT identified by the PMDA. DOE-EM is responsible for disposing of the surplus plutonium once it has been diluted and declared as waste.

[4]Defined in the PMDA as "plutonium with an isotopic ratio of plutonium 240 to plutonium 239 of no more than 0.10" (DOS 2000, p. 2).

[5]MOX fuel contains plutonium and slightly enriched uranium, both in oxide form (DOS 2000).

[6]A third option, any other methods that may be agreed to in writing by the Parties, is also included in both the original and amended PMDA.

> and growing stock of plutonium in civilian spent fuel. Options that left the weapons plutonium more accessible would mean that this material would continue to pose a unique safeguards problem indefinitely. Conversely, the costs, complexities, risks, and delays of going beyond the spent fuel standard to eliminate the excess weapons plutonium completely or nearly so would not offer substantial additional security benefits *unless society were prepared to take the same approach with the global stock of civilian plutonium.* (NAS, 1994, p. 36, emphasis original)

DOE has issued a series of environmental impact statements (EISs) and records of decision to shape and modify the disposition strategy for U.S. surplus plutonium (see Section 3.2 and Box 3-1). In 2000, DOE issued a Record of Decision (ROD) selecting the MOX fuel option using commercial nuclear reactors for dispositioning 34 MT of surplus plutonium under the 2000 PMDA and the immobilization option for dispositioning surplus plutonium that was not suitable for MOX fuel. In 2002, the George W. Bush administration cancelled the immobilization program citing budget constraints and the decision to support only one approach for plutonium disposal (see Box 2-1). This change was accounted for in the 2010 amended PMDA, as noted previously.

The MOX fuel option within the PMDA provides four barriers to recovery of the plutonium and is comparable to the spent fuel standard for the diversion, recovery, or theft of U.S. surplus plutonium (NAS 1994):

1. Chemical: The plutonium-239 in metal form is first oxidized and then chemically diluted by blending with uranium oxide (UO_2) to form MOX fuel.
2. Isotopic: The plutonium-239 isotopic composition is shifted during irradiation by the fission of plutonium-239 and -241 and by the transmutation of plutonium-239 to -240, plutonium -240 to -241, and plutonium -241 to -242.
3. Radiation: Irradiated MOX fuel creates a radiation barrier sufficient to be self-protecting for decades.
4. Physical: the weight and size of a nuclear fuel assembly are sufficient to require special handling equipment for processing.[7]

The United States began construction of a facility to manufacture MOX fuel, the Mixed Oxide Fuel Fabrication Facility ("MOX Plant"), at the Savannah River Site in South Carolina in 2007. Construction has encountered substantial schedule delays and cost overruns. The Obama administration proposed to stop construction of this facility and instead use a "dilute and dispose process" to disposition 34 MT of surplus plutonium (Goodson 2018). Congress provided $5 million to DOE-NNSA in fiscal year 2016 to begin planning and development of a conceptual design for the dilute and dispose process (see Box 2-1). In fiscal year 2017, Congress provided $15 million to DOE-NNSA to continue planning and development of the dilute and dispose option; it also mandated this National Academies of Sciences, Engineering, and Medicine evaluation (U.S. Congress 2016). In May 2018, the Trump administration announced plans to cancel the MOX plant and declared the dilute and dispose option as the program of record.[8] In October 2018, the DOE-NNSA issued a letter to CB&I AREVA MOX Services, the contractor of the MOX plant, directing them to terminate construction of the plant. DOE plans to convert the existing MOX infrastructure to a facility that would produce up to 50 plutonium pits per year by 2030.

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[7]The PMDA requirements do not include deep geologic disposal of the irradiated MOX fuel by either party, only irradiation to create a radiation barrier to recovery. If and when the irradiated MOX fuel were to be emplaced in a deep geologic repository, this would add a physical barrier to recovery, diversion, and theft.

[8]On May 10, 2018, Secretary Perry issued a letter to Congress announcing DOE's decision to cancel the MOX plant and move to the dilute and dispose option for disposal of surplus plutonium citing a cost estimate that showed the cost of dilute and dispose was less than half of the projected cost of the MOX option (Demarest 2018). The authority to take such action by Sec. Perry was granted through the National Defense Authorization Act for 2018 (H.R. 2810, 115th Cong. (2018).

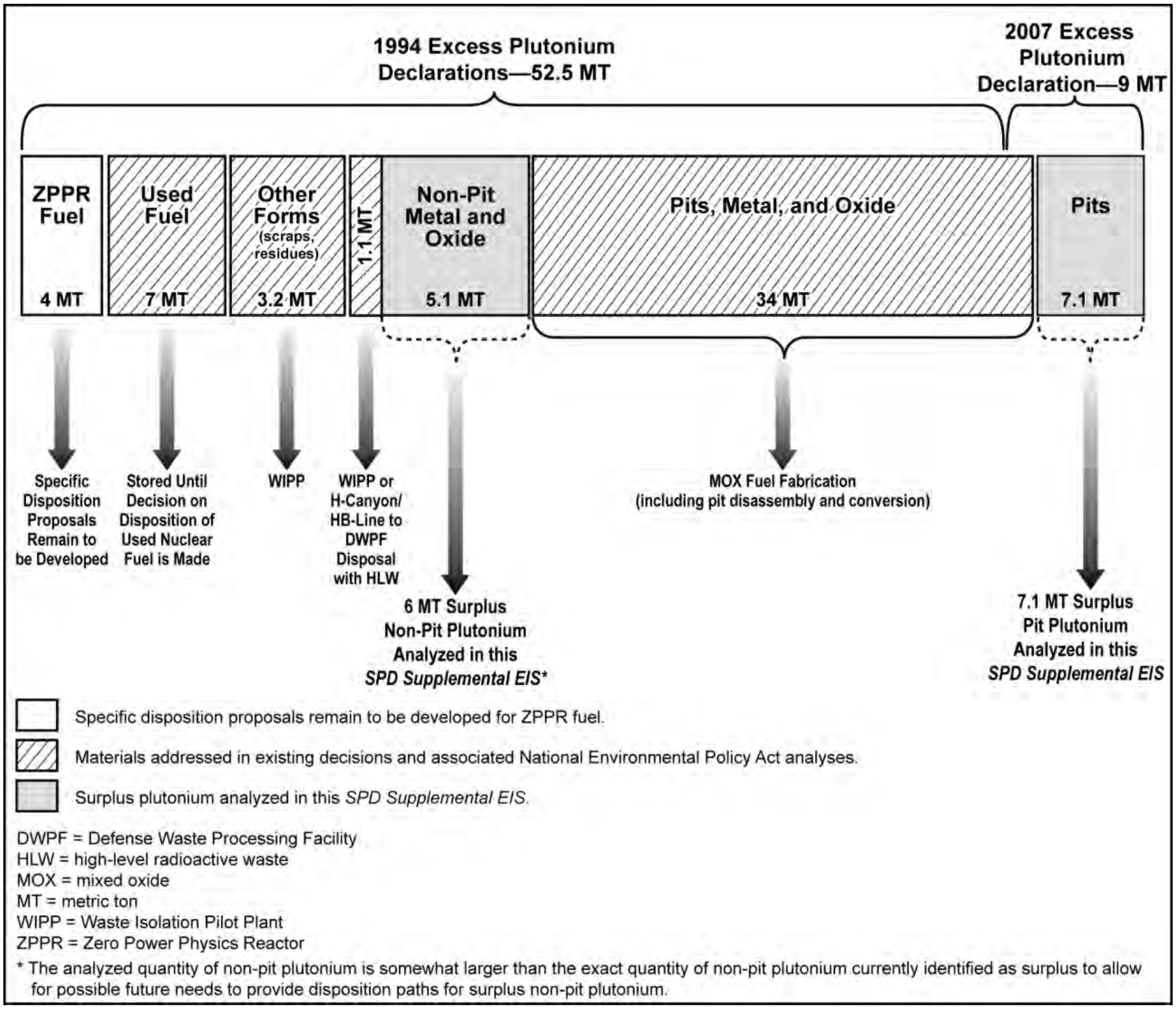

FIGURE 2-1 U.S. surplus plutonium quantities and disposition pathways. The total of 61.5 MT includes two declarations: the first in 1994 and another in 2007. A portion of the 2007 declaration is included in the 34 MT allocated to satisfy the Plutonium Management and Disposition Agreement (PMDA) shown with gray diagonal lines, labeled "MOX Fuel Fabrication (including pit disassembly and conversion)." The gray-shaded boxes highlight the quantities 5.1 MT of non-pit and 7.1 MT of pit surplus plutonium. The 5.1 MT (plus 0.9 MT of "possible future needs to provide disposition paths for surplus non-pit plutonium") are the focus of DOE-EM's current efforts to dispose of 6 MT of surplus plutonium using the dilute and dispose method as described in the Surplus Plutonium Disposition (SPD) Supplemental EIS. In April 2016, a Record of Decision was issued announcing the DOE's decision to dilute and dispose of the 6 MT of non-pit plutonium at the Waste Isolation Pilot Plant. NOTE: The 6 MT managed by DOE-EM is separate from the 34 MT associated with the PMDA. SOURCE: DOE 2015.

2.1 CONCEPTUAL PLANS FOR DILUTE AND DISPOSE

The dilution process entails first the oxidization of surplus plutonium metal and then the dry blending of the plutonium oxide with an adulterant to dilute the plutonium-239 content (see Figure 2-3a for additional process details). In the conceptual plan, the blended material will be packaged to make it suitable for transport to and disposal in WIPP, a deep geologic repository located within a bedded salt formation near Carlsbad, New Mexico. After approximately 20 years of testing and development, the WIPP opened in

1999 to dispose of defense-generated transuranic (TRU) waste created by the U.S. government (see Figure 2-4) (GAO 2017).[9] TRU waste emplaced in WIPP will eventually be encased in salt as the salt formation naturally creeps to close voids and reconsolidates, making the TRU waste isolated from the environment. The dilute and dispose process has been demonstrated at a small scale by DOE-EM as it begins to process 6 MT of surplus plutonium (Figure 2-1). Additionally, DOE reports that 4.8 MT of plutonium similarly processed is emplaced at WIPP.

DOE-NNSA asserts that the end state of the dilute and dispose process would introduce sufficient chemical and physical barriers to meet the intent of the PMDA for preventing plutonium recovery and reuse. DOE-NNSA states that the barriers include: oxidation and dilution of plutonium with an adulterant ("chemical") and disposal of the packaged and diluted plutonium in a deep geologic repository ("physical"). The term "end state" refers to the state of the surplus plutonium after both dilution and disposal. However, the dilute and dispose process is not currently a PMDA-approved method for dispositioning U.S. surplus plutonium.

A conceptual flowsheet for the dilute and dispose process is shown in Figure 2-2; four DOE sites would be involved in the implementation of this process: Pantex Plant in Texas; Los Alamos National Laboratory in New Mexico; Savannah River Site (SRS) in South Carolina; and WIPP in New Mexico. The front end of the dilute and dispose process is identical to that for the MOX process until the process converges on "**Dilute**" in Figure 2-2.

Beginning with the box labelled, **Surplus Pit Management**, a total of 26.2 MT of pits from disassembled nuclear weapons (labelled "surplus pits") will be shipped from the Pantex Plant to Los Alamos National Laboratory via Office of Secure Transportation (OST).

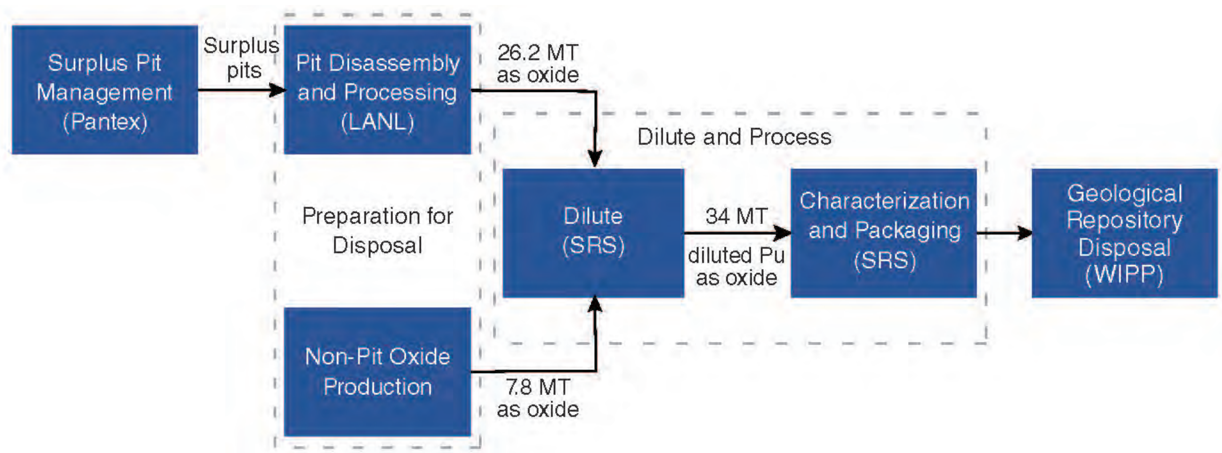

FIGURE 2-2 Conceptual flowsheet for the DOE-NNSA dilute and dispose processes. The process is described in the text. The combined amount of pit and non-pit plutonium is 34 MT. SOURCE: Modified from image provided by the U.S. Department of Energy (Kay 2018).

[9]The term "transuranic waste" is defined in the Waste Isolation Pilot Plant Withdrawal Act 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 has determined, with the concurrence of the Administrator, 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." Waste Isolation Pilot Plant Withdrawal Act, Pub. L. No. 102-579, 106 Stat. 4777, 4779 (1992).

The **Pit Disassembly and Processing** step is the disassembly and conversion of the pits into plutonium oxide, which will take place at Los Alamos National Laboratory. This oxidized material will be packaged for transportation and storage (placed into a DOE-STD-3013 container) and shipped via OST to the Savannah River Site for further processing.

Non-Pit Oxide Production indicates a total of 7.8 MT of non-pit plutonium that is stored in different DOE sites; a portion of the non-pit plutonium is oxidized and will be sent directly to the Savannah River Site for further processing, the remaining portion of non-pit plutonium will be shipped first to Los Alamos National Laboratory to be oxidized before being shipped to and processed at the SRS.[10] All shipments described in this step are shipped via OST.

During the **Dilute and Process** and **Geological Repository Disposal** steps, the oxidized plutonium is processed, packaged, and emplaced in WIPP. When the plutonium oxide reaches the SRS, it will follow a different processing path than that proposed for the MOX process. Figures 2-3a and 2-3b provide details on the dilution, packaging, and characterization steps that will take place at SRS.

The process outlined in the detailed but unclassified flow sheet (Figure 2-3a) for the dilute process was shown to the committee at a mock-up unclassified glovebox at SRS. The "radiological barrier" in the figure refers to a can/bag/can barrier put in place to protect workers from contamination of the diluted plutonium. It does not refer to additional radioactive material added to the diluted plutonium, or a "radiation barrier," as used previously in this report.

The dilution processing steps are as follows:

- The 3013 canisters containing the oxidized plutonium will be opened at SRS in a glovebox, and dry-blend the plutonium oxide with a multicomponent adulterant[11] to dilute the plutonium-239 content. The diluted plutonium oxide will be placed into new cans (can/bag/can); the final assembly is then assayed and packaged into a stainless steel pipe, the Criticality Controlled Component (CCC). Two can/bag/can assemblies are placed into a single CCC. The CCC is placed inside of a Criticality Controlled Overpack (CCO). The CCO is a 55-gallon drum. CCOs are placed in approved containers for transport, TRUPACT-II, for shipment to WIPP. The dilution process at SRS is currently being carried out at a small-scale in order to process 6 MT of surplus non-pit plutonium for dilution and disposal (Gunter Decl.[12]) (see Figure 2-1 and Box 3-1).
- Not shown in the processing steps in Figure 2-3a is the termination of safeguards. The current status and plans for the removal of safeguards and an assessment of the security of the diluted plutonium are under development so the committee makes no assessment of this step in this Interim Report.
- If safeguards are terminated and the diluted plutonium[13] is certified to meet WIPP's waste acceptance criteria (WAC), the packaged plutonium waste form will be organizationally transferred to DOE-EM, which will ship it to WIPP and emplace it in the repository as contact-handled transuranic (CH-TRU) waste (DOE 2016d). See Figure 2-4.

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[10]The quantities of pit and non-pit surplus plutonium for disposition are listed in Section I – Quantities and Methods of Disposition in the PMDA as amended in 2010. The location and proportion of oxidized/non-oxidized non-pit plutonium is classified by the U.S. government.

[11]As noted previously, the properties of the adulterant are classified by the U.S. government.

[12]South Carolina v. U.S. Department of Energy, No. 1:16-cv-00391-JMC (D.S.C. 2017).

[13]The oxidized plutonium is considered "material" as it enters the process at SRS and the packaged and diluted plutonium is considered "waste" after it is determined to meet the WIPP WAC (GAO 2017). Plutonium is handled as accountable material until it is diluted and declared to be waste.

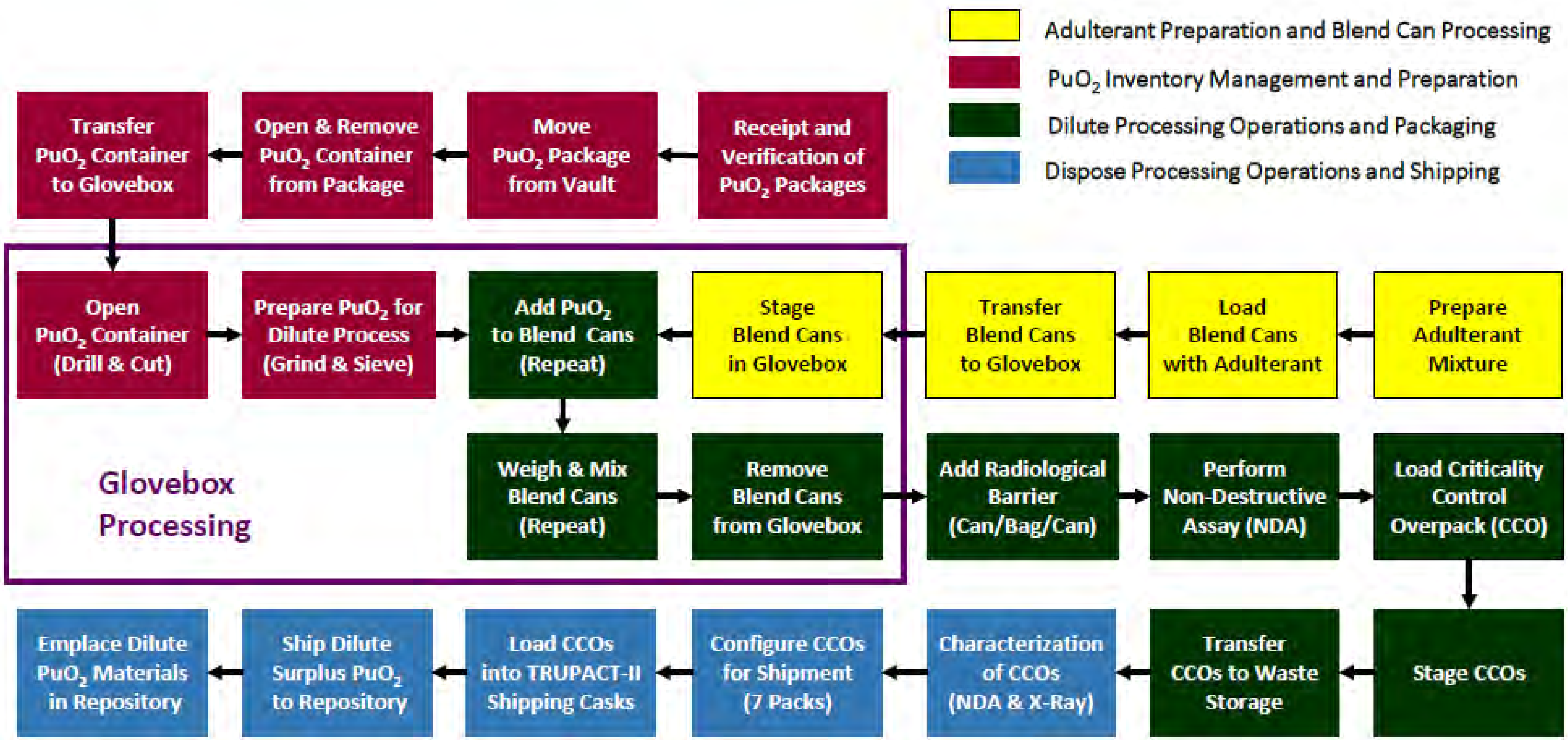

FIGURE 2-3a Block diagram of the "Dilute and Processing" and "Geological Repository Disposal" steps shown in Figure 2-2, beginning with receipt of the oxidized plutonium at the Savannah River Site (Receipt and Verification of the PuO_2 [plutonium oxide] Packages) and ending with emplacement in WIPP. As the final diluted product is prepared to be removed from the glovebox, no more than 150 fissile gram equivalents (FGE) of plutonium-239 is placed inside an inner can, which is then placed inside a plastic bag, which is placed into another can ("Can/Bag/Can"). A cross section of the can/bag/can assembly is shown in Figure 2-3b. SOURCE: Image provided by the U.S. Department of Energy (McAlhany 2017).

Appendix H

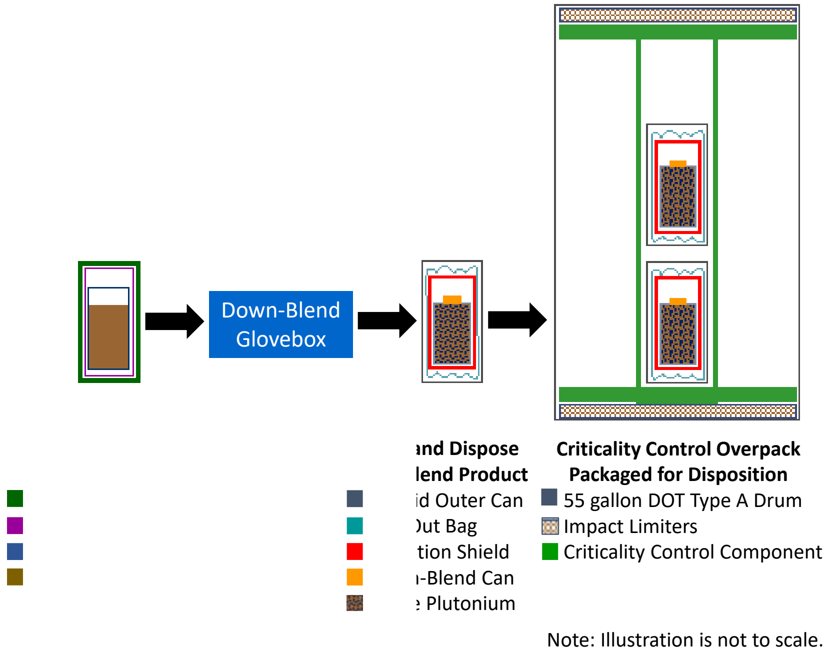

FIGURE 2-3b Cross sections of the plutonium containers used in the process outlined in Figure 2-3a. At Los Alamos National Laboratory, the oxidized plutonium is placed into DOE-STD-3013 containers. Upon arrival at the Savannah River Site, the same containers are used to store the plutonium oxide until it is introduced into the glovebox. The can/bag/can assembly described and shown in Figure 2-3a is shown here as "Dilute and Dispose Down-Blend Product." Two of these assemblies are placed within a stainless steel pipe, the Criticality Controlled Component (CCC). A single CCC is placed inside a Criticality Controlled Overpack (CCO). The CCO is a 55-gallon drum. SOURCE: Adapted from image provided by the U.S. Department of Energy (McAlhany 2017).

The dilute and dispose process will require extensive interstate truck transportation over a projected period of about 25 years.[26] The DOE OST[27] will be responsible for shipping undiluted plutonium materials from the Pantex Plant to Los Alamos and from Los Alamos to Savannah River following safety, security, and safeguarding protocols that have been in use for many decades. The packaged diluted plutonium waste will be shipped from Savannah River to the WIPP site by DOE-EM using existing TRU waste shipping casks and resources. DOE-EM plans to rely on the present set of rules and procedures, which have been used successfully to transport over 12,000 TRU waste shipments to WIPP, to ensure the safety and security of the proposed dilute and dispose TRU shipments (DOE-EM 2017).

A 2015 DOE red team review compared the MOX and dilute and dispose options and concluded that the latter process was technically viable and could be implemented at about half the cost of the former (Mason 2015). The red team also concluded in the executive summary (Mason 2015, p. xi) that the "risks associated with the Dilute and Dispose option are far lower than the MOX approach, since both the technology and the disposition process associated with Dilute and Dispose are far simpler."[28] The review also identified regulatory and other issues, including WIPP capacity, that "are not insurmountable" but should be addressed as early as possible during the planning phase. Although the committee has not yet seen risk assessments or program documents associated with the life-cycle cost estimate and cannot comment on risk, the committee notes that the technical complexity of the dilute and dispose option is lower than that of the MOX option.

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[26]WIPP does not accept waste via rail (WIPP n.d.).

[27]See https://www.energy.gov/nnsa/office-secure-transportation (accessed September 10, 2018).

[28]The type of risk quoted above refers to the assessment of programmatic and technical risks (see Mason 2015, p. 34 for more discussion).

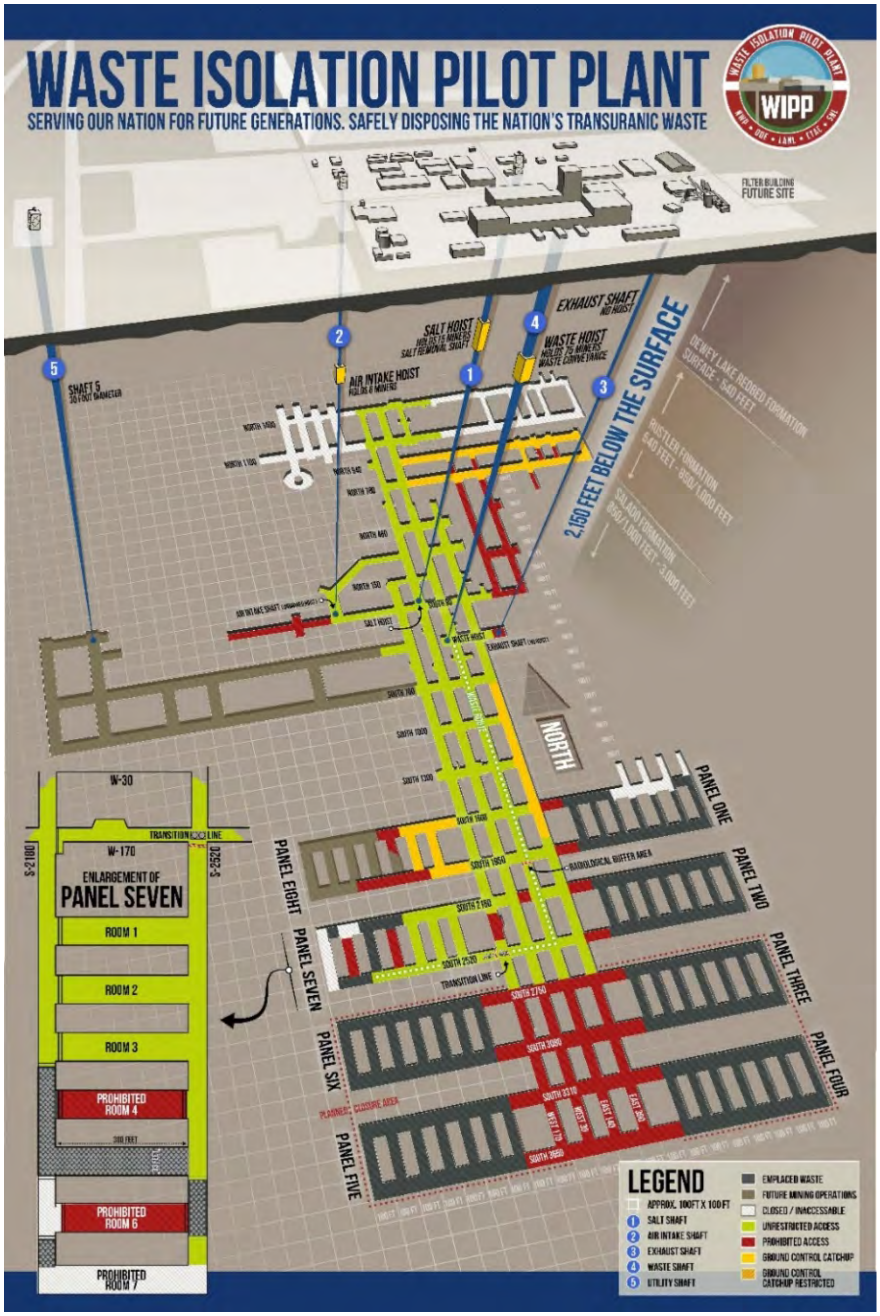

FIGURE 2-4 Schematic layout of the Waste Isolation Pilot Plant, which is located in southeastern New Mexico near Carlsbad. WIPP began accepting defense-generated transuranic (TRU) waste in 1999. The location of the emplaced TRU waste is about 2,150 feet (655 meters) below the surface within a salt formation (the Salado Formation, as indicated in the figure). WIPP's original design has eight waste panels, shown in the lower third of the figure. Panels One through Six have been closed. Panels Seven and Eight will continue to accept TRU waste although Panel Seven has been radiologically contaminated due to an exploding waste drum in 2014. A new ventilation shaft, Shaft 5, is being constructed which will allow WIPP to expand current operations and increase emplacement rates matching those before the 2014 accident. The ventilation shaft required a permit modification from the State of New Mexico. SOURCE: Todd Shrader, DOE-EM.

2.2 CURRENT STATUS OF DOE-NNSA DILUTE AND DISPOSE PLANNING EFFORT

DOE-NNSA received funding from Congress to begin planning for the dilute and dispose process in 2016, following the completion of the red team review referenced in the previous Section 2.1 (GAO 2017) (see Box 2-1). A high-level schedule of the dilute and dispose plan is shown in Figure 2-5. The planning effort is being managed under DOE Order 413.3B and has passed Critical Decision-0 (CD-0), Approve Mission Need (DOE 2010).[29]

BOX 2-1 Federal Decisions and Appropriations Related to the Dilute and Dispose Alternative to MOX

Below is a short chronology of congressional decisions and appropriations related to the dilute and dispose program. Prior to fiscal year (FY) 2016, there was no specified amount of money allocated to the dilute and dispose program. The program is also referred to as "downblend and dispose" in the text below.

FY 2015

In the Explanatory Statement for the Consolidated Appropriations Act, 2015, Congress requested a comparison of life-cycle cost estimates:

"NNSA is directed to submit to the Committees on Appropriations of the House of Representatives and the Senate not later than 120 days after enactment of this Act an independently-verified lifecycle cost estimate for the option to complete construction and operate the MOX facility and the option to downblend and dispose of the material in a repository."[a]

FY 2016

Congress approved use of $5 million to the conceptual design of dilute and dispose option

In the Explanatory Statement for the Consolidated Appropriations Act, 2016, Congress approved use of $5 million to the conceptual design of dilute and dispose option:

"[T]he Department [of Energy] may use up to $5,000,000 to advance planning, to resolve regulatory and other issues, to complete conceptual design activities for the dilute and dispose alternative to the Mixed Oxide (MOX) Fuel Fabrication Facility, and to develop and submit to the Committees on Appropriations of both Houses of Congress a report that includes an evaluation of program risks and a lifecycle cost estimate and schedule for the alternative. The agreement prohibits funds from being used to dilute plutonium that could otherwise be used for MOX feedstock or used to meet U.S. commitments under the Plutonium Management and Disposition Agreement. The Department shall ensure any proposed solution will continue to meet current transuranic waste disposal commitments."[b]

FY 2017

In the Explanatory Statement for the Consolidated Appropriations Act, 2017, Congress approved use of $15 million with the following explanation:

"The NNSA may use up to $15,000,000 to advance planning, to resolve regulatory and other issues, and to complete conceptual design activities for the dilute and dispose alternative to the Mixed Oxide (MOX) Fuel Fabrication Facility."[c]

continued

[29]Order 413.3B outlines an internal DOE process for reviewing and approving large acquisition programs through Critical Decision milestones. After reaching CD0, DOE program managers may proceed with conceptual planning. See DOE 2010 (Table 2.0, p. A-5).

BOX 2-1 Continued

FY 2018

In the Explanatory Statement for the Consolidated Appropriations Act, 2018, Congress approved funding for planning for dilute and dispose:

"Within Material Disposition, the agreement includes funding to advance planning for the dilute and dispose alternative to the Mixed Oxide Fuel Fabrication Facility."[d]

A pathway was created to move from MOX to dilute and dispose as the program of record was issued in section 3121(b)(1) of the National Defense Authorization Act for Fiscal Year 2018 (P.L. 115-91; 131 Stat. 1892) (emphasis added):

(i) an alternative option for carrying out the plutonium disposition program for the same amount of plutonium as the amount of plutonium intended to be disposed of in the MOX facility exists, meeting the requirements of the Business Operating Procedure of the National Nuclear Security Administration entitled ''Analysis of Alternatives'' and dated March 14, 2016 (BOP–03.07); and

(ii) the remaining lifecycle cost, determined in a manner comparable to the cost estimating and assessment best practices of the Government Accountability Office, as found in the document of the Government Accountability Office entitled ''GAO Cost Estimating and Assessment Guide'' (GAO–09–3SP), for the alternative option ***would be less than approximately half of the estimated remaining lifecycle cost of the mixed oxide fuel program***; and

(C) The ***details of any statutory or regulatory changes necessary to complete the alternative option***.

FY 2019

Congress approved use of $25 million with the following explanation:

"Provided, That of such amount, $25,000,000 shall be made available for design activities supporting the dilute and dispose strategy for plutonium disposition: Provided further, That none of the funds made available under this heading shall be made available for the construction activities or acquisition of equipment for the Surplus Plutonium Disposition Project."

[a] See https://docs.house.gov/billsthisweek/20141208/113-HR83sa-ES-D.pdf.
[b] See https://docs.house.gov/meetings/RU/RU00/20151216/104298/HMTG-114-RU00-20151216-SD005.pdf.
[c] See https://rules.house.gov/sites/republicans.rules.house.gov/files/115/OMNI/DIVISION%20D%20-%20E%26W%20SOM%20FY17OCR.pdf.
[d] See https://docs.house.gov/billsthisweek/20180319/DIV%20D%20EW%20SOM%20FY18-OMNI.OCR.pdf.

The process outlined in the National Environmental Policy Act (NEPA) requires DOE to obtain public comments and inputs for decisions and actions. The NEPA schedule for dilute and dispose in Figure 2-5 shows that a Notice of Intent (NOI) will be issued in late FY 2018 and a final EIS in mid FY 2020. Although requested, the committee has not yet seen a detailed NEPA strategy for the conceptual plan or details on what constitutes a final EIS, and the NOI had not been issued as of the writing of this Interim Report.

Also seen in Figure 2-5 is the planned duration of the dilute and dispose process. DOE-NNSA currently estimates that the effort to dilute and dispose of 34 MT of surplus plutonium will take 31 years to complete, beginning with conceptual design in 2018 and ending with emplacement of all 34 MT of diluted plutonium at WIPP in 2049.

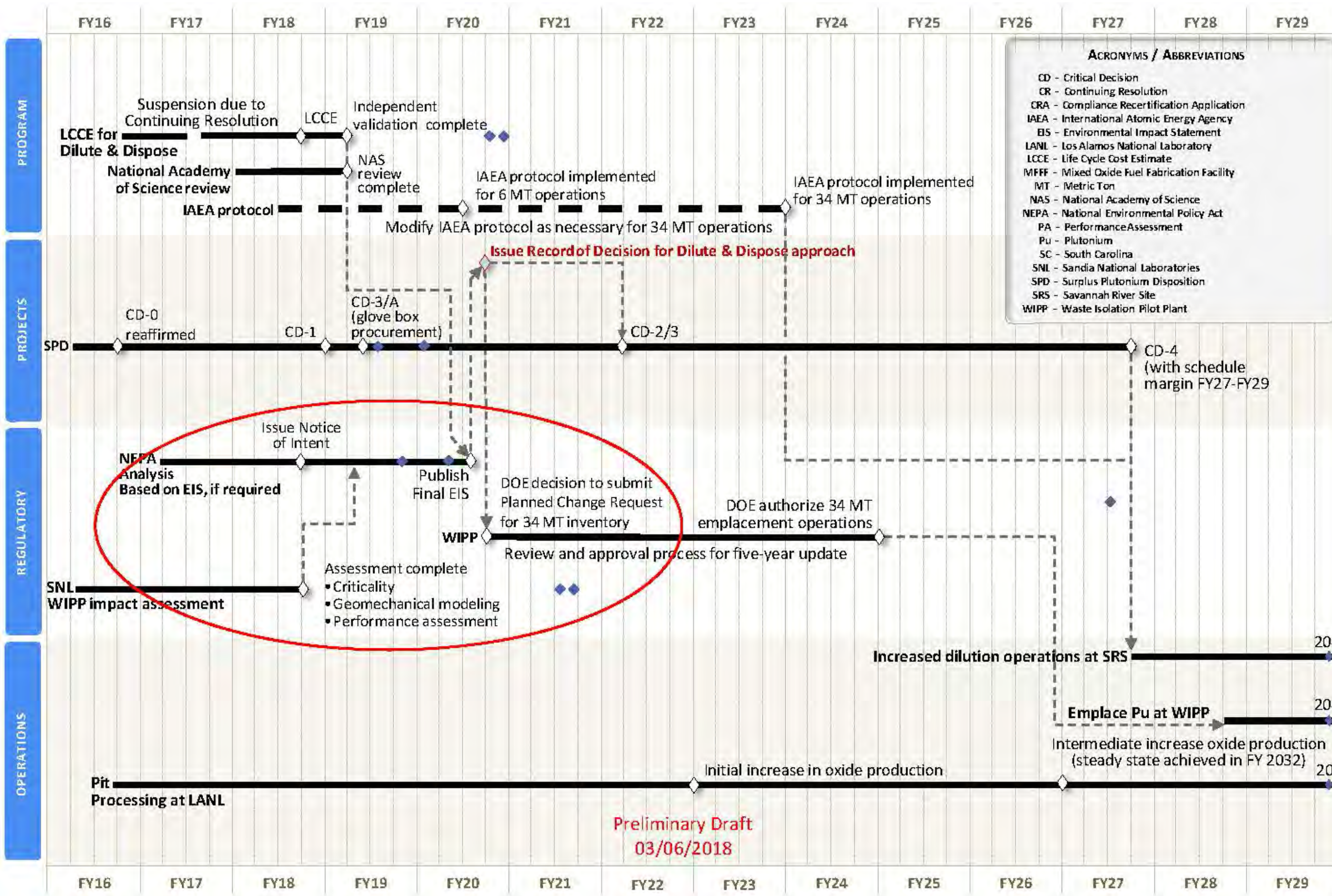

FIGURE 2-5 High-level schedule for the dilute and dispose conceptual plan, developed in March 2018 and considered preliminary. Some of the information and analysis expected by this committee are shown in the red circle: WIPP Impact Assessment (criticality, geomechanical, and performance assessments), life-cycle cost estimate (which contains scheduling and program planning details), and the Notice of Intent. SOURCE: Kay 2018.

3

Committee Assessment of DOE-NNSA'S Conceptual Plans for Dilute and Dispose Process

The release of several key DOE-NNSA dilute and dispose planning documents to the committee has been delayed due to recent legal actions between the State of South Carolina and DOE.[1] These documents, which include DOE-NNSA's life-cycle cost estimates and other planning details, an initial assessment of the long-term performance assessment of emplacing 34 MT of diluted plutonium in WIPP, newly updated system planning documents, and a criticality safety assessment of the emplaced waste are needed by the committee to fully address the committee's tasking of assessing the viability of DOE-NNSA's conceptual plans. Consequently, in this Interim Report the committee is able to provide only a *preliminary assessment* which focuses on potential barriers to implementation of DOE-NNSA's conceptual plans.

The committee's preliminary assessment produced seven findings, two conclusions, and four recommendations, and a series of follow-up questions directed primarily at DOE-NNSA. The findings, conclusions, recommendations and questions are presented and discussed in this section.

> **CONCLUSION 1:** The dilute and dispose process has been demonstrated at a small scale by DOE-EM as it begins to process 6 MT of surplus plutonium, a quantity separate from the 34 MT associated with the Plutonium Management and Disposition Agreement (PMDA). The committee agrees with earlier assessments that the technical complexity of the dilute and dispose process is lower than that of the construction of a MOX fuel option. Due to lack of information, the committee makes no judgment in this Interim Report on the DOE's ability and the associated risks of scaling-up the current infrastructure and processes to address the 34 MT. The committee has, however, identified several barriers that will need to be addressed by DOE-NNSA and others before the dilute and dispose conceptual plans can be implemented to support U.S. commitments under the PMDA.

The dilute and dispose process is not technically challenging; in fact, the process has already been implemented at a small scale to disposition up to 6 MT of non-pit plutonium in WIPP (DOE 2016d, also see Figure 2-1 and Section 3.2 for additional discussion) (Forinash 2017).[2] DOE-NNSA is planning to build on this previous experience and infrastructure to scale-up existing processes and achieve the higher throughputs needed to dispose of the additional 34 MT of surplus plutonium (see Figure 2-5).

Nevertheless, DOE-NNSA's dilute and dispose process faces a number of barriers, some of which are discussed in subsequent sections of this report. The process, if implemented, would involve a large number of sites, organizations, and stakeholders. DOE-NNSA must scale-up its prototypic systems and storage capacity at Pantex, Los Alamos, and Savannah River (Figure 2-2) for packaging, shipping, disassembling, oxidizing, diluting, assaying, repackaging and transporting the plutonium oxide, and it must operate that system safely and securely for 31 years or longer. Although a system plan for the dilute and dispose option

[1]South Carolina filed a lawsuit against DOE over its decision to stop work on the MOX Plant at Savannah River. A U.S. District Court issued a preliminary injunction against DOE's stop-work order on July 8, 2016, State of South Carolina v. U.S. Department of Energy, No. 1:18-cv-01431-JMC (D.S.C. 2018). On July 16, 2018, the district court put South Carolina's lawsuit on hold pending a review by the appellate court.

[2]DOE has disposed of approximately 4.8MT of plutonium residues at WIPP including residues that resulted from cleanup of the Hanford site in Washington and the Rocky Flats site (now named Rocky Flat Environmental Technology Site) in Colorado. However, the committee did not review the processes used for disposal of these wastes.

has been developed (Surplus Plutonium Disposition System Plan, SRNS-TR-2016, 00136, Rev. 0[3]), the formal coordination required across DOE offices to make decisions that affect the different offices' priorities is not clearly described or acknowledged in the documentation.

DOE-NNSA will have to develop a progressively improved understanding of the operational and transportation risks and uncertainties for each process step as its moves through the DOE Order 413.3B planning process into full-scale operations. DOE-NNSA can learn from DOE-EM's ongoing efforts to dispose of 6 MT of plutonium in WIPP,[4] and it will also have to incorporate stakeholder feedback into its own planning efforts.

FINDING 1: DOE-NNSA's dilute and dispose option, if implemented, is likely to face several challenges during its inception and lifetime of over three decades. These include potential changes to the intended purpose, size, operations, and lifetime of WIPP; the lack of availability of other suitable repositories for disposing of diluted plutonium (i.e., Yucca Mountain or elsewhere); state, tribal, and local acceptance of diluted and packaged plutonium; transportation, and permanent disposal operations; changes in U.S. nuclear weapons programs (e.g., new pit production and associated waste streams); and funding availability. These challenges could lead to technological and/or programmatic changes to the current conceptual plans in order to achieve the DOE-NNSA's mission to dispose of 34 MT of surplus plutonium in an efficient, safe, and secure manner.

The committee observed over the course of its data collection that some improvements are being made to conceptual planning as process knowledge is gained with the prototype systems installed at Los Alamos and the Savannah River Site. Additionally, DOE-NNSA continues to evaluate potential security risks associated with shipment of diluted plutonium to WIPP and has indicated to the committee that it will implement mitigation strategies as needed. Evidence of the changing nature of the program is a recently updated version of the Dilute and Dispose System Requirements document received by the committee during the writing of this report (DOE 2018d).[5]

FINDING 2: The committee identified the following three barriers to implementation of DOE-NNSA's current conceptual plans:

- Insufficient current statutory and current physical capacity within WIPP for disposal of 34 MT of diluted plutonium throughout the lifetime of the dilute and dispose project.
- Unclear strategy for development of the National Environmental Policy Act (NEPA) environmental impact statement for disposing of 34 MT of surplus plutonium in WIPP using the dilute and dispose process.
- Lack of Russian Federation approval for dispositioning 34 MT of surplus plutonium using the dilute and dispose process to meet the requirements of the PMDA.

These issues are discussed in the following subsections.

3.1 AVAILABILITY OF WIPP FOR DISPOSAL OF 34 MT OF DILUTED PLUTONIUM

DOE-NNSA asserts that the intent of the PMDA to disposition 34 MT of surplus plutonium cannot be met without *both* diluting this material *and* disposing of by emplacing it in a deep geological repository such as WIPP. Access to WIPP's capacity is an essential and critical requirement for the success of DOE-NNSA's conceptual plans (see Section 3.3 for further analysis and discussion on the relative barriers of the

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[3]An updated version of the Surplus Plutonium Disposition System Plan has been created but has not yet been shared with the committee.

[4]Indeed, DOE-NNSA told the committee that it intends to incorporate the lessons learned from DOE-EM's plutonium disposal program into its own planning efforts.

[5]The Configuration Control Log included the following description of the changes made: "Complete Update. Updated to incorporate revised assumptions and requirements."

dilution and disposal process). WIPP's current statutory and physical capacity is potentially problematic for four reasons:

1. WIPP is the only deep geologic repository currently available in the United States for surplus plutonium disposal.
2. Demand for future defense-generated transuranic (TRU) waste disposal capacity at WIPP for this program and others presently exceeds its congressionally legislated capacity under the Land Withdrawal Act.
3. Access to WIPP is controlled by DOE-EM and the state of New Mexico, which have different legal obligations and programmatic priorities than DOE-NNSA.
4. WIPP operations are scheduled to end in 2034,[6] well before the scheduled 2049 end date for a DOE-NNSA dilute and dispose campaign.

The following barriers require resolution through permit modifications with the state of New Mexico and/or changes to legislation through congressional action in order for DOE-NNSA's conceptual plans for dilute and dispose to be viable:

1. Increasing statutory capacity at WIPP through a recalculation of existing and future "volumes of record" through a permit modification (or through a change of the TRU waste capacity limits in the LWA, see discussion later in this report),
2. Increasing physical capacity at WIPP by adding more disposal room requiring a permit modification,
3. Extending the end date of WIPP to 2050 or later requiring a permit modification.

Some of these actions may be required for future TRU waste streams absent the disposal of 34 MT of diluted plutonium; regardless, the approval of the permits is necessary for DOE-NNSA's conceptual plan. Further discussion of these four potential barriers to WIPP access is provided in the following subsections.

3.1.1 WIPP is the only deep geologic repository currently available in the United States for surplus plutonium disposal.

Other potentially suitable disposal options for surplus plutonium—for example, Yucca Mountain in Nevada or deep boreholes in as-yet unspecified locations—are not presently being pursued by the U.S. government.[7] Development and licensing of alternative disposal options would likely take decades. Based on the difficulty of establishing a single repository for spent nuclear fuel in the United States, it is hard to see how an alternative repository could be planned, developed, and implemented in that timeframe.

[6]The closure date can be found in Permit Attachment G the WIPP Hazardous Waste Permit (June 2018; see Schedule for Final Facility Closure (NMED 2018b, p. G-6): "For the purpose of establishing a schedule for closure, an operating and closure period of no more than 35 years (25 years for disposal operations and 10 years for closure) is assumed. This operating period may be extended or shortened depending on a number of factors, including the rate of waste approved for shipment to the WIPP facility and the schedules of TRU mixed waste generator sites, and future decommissioning activities."

[7]U.S. surplus plutonium was included in the inventory for the environmental assessments of Yucca Mountain. From the Final Supplemental Environmental Impact Statement (June 2008) DOE/EIS-0250F-S1 SUMMARY, emphasis added: MATERIALS CONSIDERED FOR DISPOSAL The NWPA [Nuclear Waste Policy Act] limits how much spent nuclear fuel and high-level radioactive waste DOE could emplace in the first geologic repository to 70,000 MTHM [metric tons of heavy metal] until a second repository is in operation. The materials proposed for disposal under the Proposed Action would include about 63,000 MTHM of commercial spent nuclear fuel and high-level radioactive waste. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel (including naval spent nuclear fuel) and the equivalent of 4,667 MTHM of DOE high-level radioactive waste. This inventory could include surplus weapons-usable plutonium, which DOE could immobilize and dispose of as part of the high-level radioactive waste inventory, or use to produce mixed uranium and plutonium oxide fuel (called mixed-oxide fuel).

Exclusive reliance on WIPP for disposal is a single-point failure risk for the success of the dilute and dispose program. Any unplanned shutdowns or suspensions of disposals at WIPP—such as the shutdown that occurred between February 2014 and December 2016[8] as the result of a truck fire and an unrelated radiation release or the much shorter suspension in late May 2018 to address a misaligned drum—could delay, disrupt, and potentially derail and increase the costs of DOE-NNSA's efforts to dispose of 34 MT of surplus plutonium (Barber 2018, DOE n.d.).

3.1.2 Demand for disposal capacity at WIPP for this program and others presently exceeds its congressionally legislated capacity under the Land Withdrawal Act.

WIPP's disposal capacity is defined by the Waste Isolation Pilot Plant Land Withdrawal Act to be 6.2 million ft^3 (175,564 m^3) of defense-generated TRU waste. The 1988 Consultation and Cooperation Agreement between DOE and New Mexico further limits the amount of remote-handled (RH) TRU in WIPP to 250,000 ft^3 (7,079 m^3), leaving 5,950,000 ft^3 (168,485 m^3) of disposal space for CH-TRU waste[9] (DOE 1988).

A special 2017 TRU waste inventory analysis, *NNSA Surplus Plutonium Disposition Performance Assessment Inventory Report 2017*, was produced by Los Alamos National Laboratory in response to a request by Sandia National Laboratories (LANL 2017). The inventory report included future wastes from the generating sites, was extended through 2050, and included 42.2 MT of surplus plutonium for disposal in WIPP. The inventory analysis notes that WIPP does not have sufficient statutory disposal capacity for all of DOE's surplus plutonium given the volume of TRU waste already emplaced or likely to be emplaced in the repository (LANL 2017).[10]

The currently available physical capacity in WIPP is limited by the number of panels in its original design. A Government Accountability Office (GAO) report from 2017 concluded that WIPP would reach current available physical capacity by 2026 and that an additional two panels would be needed to accommodate future TRU waste. The GAO further estimated that an additional one-and-a-half rooms would be needed to emplace 34 MT of diluted surplus plutonium (GAO 2017). Its assessment did not include the 8.2 MT (from the 42.2 MT) reported in the 2017 special inventory report noted above. The GAO report further notes that a new mathematical modelling tool will be required to assess WIPP's regulatory performance necessary for the design of new panels. The committee has requested further but has not yet received information about the modelling efforts including the plans and schedule for model verification and validation. The committee will discuss the modelling effort further in its final report.

Based on the current inventory of surplus plutonium and with limited other disposition options, it is foreseeable that at least 48.2 MT of surplus plutonium could be requested to be disposed of in WIPP in the future, consisting of the following (see Figure 2-1):

- 6 MT of plutonium currently being disposed of in WIPP by DOE-EM (see Section 3.2 in this report);[11]
- 34 MT of surplus plutonium planned to be disposed of under the PMDA; and
- 7.1 MT of surplus pit plutonium and 1.1 MT of plutonium in "other forms" for which disposition pathways are currently undecided by DOE.

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[8]Waste shipments to WIPP did not resume until April 2017.

[9]CH-TRU is defined in the WIPP Land Withdrawal Act as "transuranic waste with a surface dose rate not greater than 200 millirem per hour." RH-TRU is defined in the Act as "transuranic waste with a surface dose rate of 200 millirem per hour or greater." Waste Isolation Pilot Plant Withdrawal Act, P.L. 102-579, 106 Stat. 4777, 4778 (1992).

[10]This analysis was based on actual and projected waste inventories as of the end of calendar year 2015. The committee has not verified the content of the Los Alamos analysis but has no reason to question its accuracy.

[11]The volume for the 6 MT of surplus plutonium is included in the Annual Transuranic Waste Inventory Report – 2016. It is not explicitly shown but is included in the INV-SPD-17 estimated volumes (LANL 2017).

The Los Alamos inventory report concluded that the disposal of the proposed surplus plutonium would exceed the repository's legislated capacity by about 17,700 m^3 (LANL 2017) but it is clear that disposal of that waste would also exceed its current physical capacity as well.

A committee-generated estimate of planned and potential waste disposal volumes in WIPP as requested in its tasking (see task 2.c in Box 1-1) is shown in Figure 3-1. This analysis includes additional potential sources of TRU waste not shown in the 2017 Inventory Report. The committee estimate shows that:

- An estimated 156,000 m^3 of emplaced and WIPP-bound waste will be disposed of in WIPP from current and planned DOE-site cleanup activities through 2050 (LANL 2017).
- Disposal of about 48.2 MT of surplus plutonium in WIPP would require about 34,000 m^3 of disposal space (assuming 300g of plutonium per 55-gallon drum or Criticality Controlled Overpack [CCO]).
- DOE has not made a decision to dispose of tank waste in WIPP but the volumes have been included in future estimates of WIPP waste. Disposal of some TRU waste stored in tanks at Idaho and Hanford would require 3,187 m^3 based on recent estimates. However, the tank waste estimates vary by year. For example, earlier estimates of tank wastes from Hanford indicate up to 8,400 m^3 of disposal space, not including the volume of tank waste solidifier (DOE 2014a, Section 24.5.1.7).

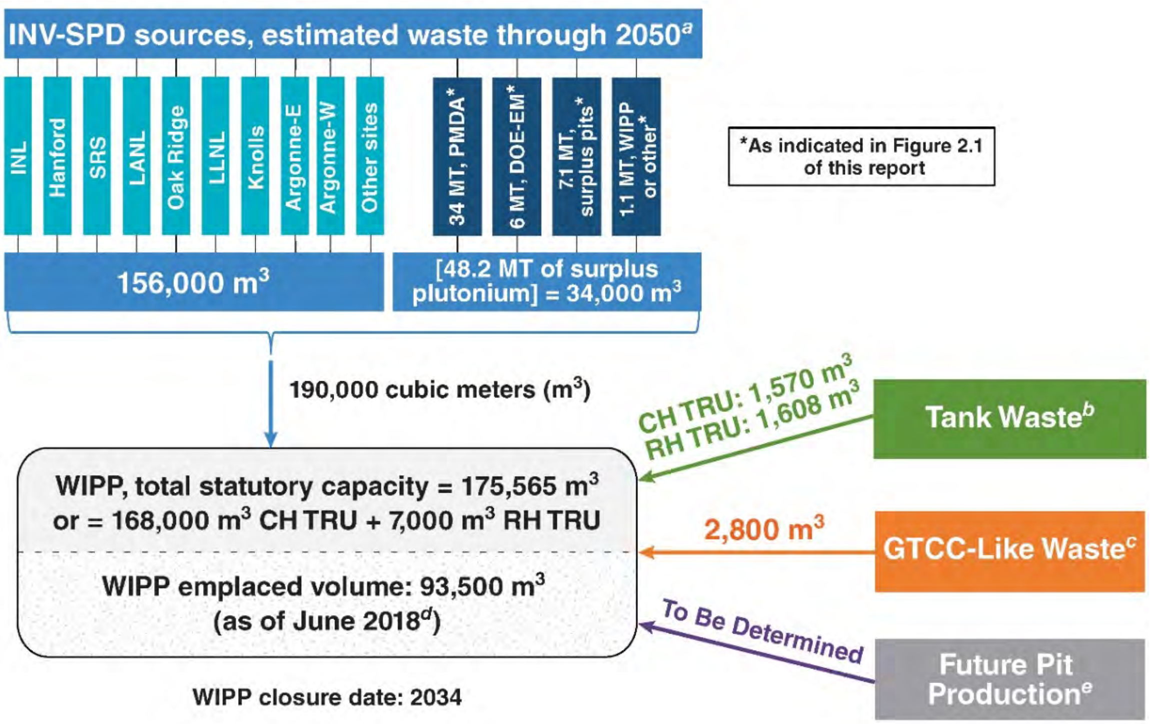

FIGURE 3-1 Committee-generated estimate of the volume required for disposal of various waste streams in WIPP. SOURCES: (a) LANL 2017; (b) DOE written responses to NAS Question Set Two (received on September 28, 2018), available by request through the National Academies' Public Access Records Office at paro@nas.edu; (c) DOE 2016b; (d) Todd Shrader, presentation to committee, 2018; (e) Request for data to DOE, submitted August 8, 2018.

- Disposal of Greater-Than-Class-C (GTCC) waste and GTCC-like[12] waste in WIPP was identified as one of several preferred alternatives in the Final EIS for GTCC and GTCC-like Waste. The volume of DOE-owned and generated GTCC-like waste is 2,800 m^3 as shown in Figure 3-1.[13] The total volume of both GTCC and GTCC-like waste would require about 12,000 m^3 of disposal space.
- Estimated volumes for TRU waste generated from future pit production have been requested but not yet received from DOE-NNSA.

The total disposal space required to accommodate all of these waste streams is about 196,000 m^3, which exceeds WIPP's legislated capacity by over 20,400 m^3. Any current or future unanticipated amounts would add to this excess amount.

DOE-EM is attempting to change the accounting of the "waste volume of record" through a permit modification request to the New Mexico Environment Department.[14] If approved, this modified calculation would change the way that DOE-EM reports waste volumes for compliance with the WIPP Land Withdrawal Act waste volume limit, and "free up" about 30 percent of waste capacity. This increase could postpone but may not eliminate WIPP's capacity problem.

The volume of emplaced waste in WIPP is currently accounted for by the volume of the outermost waste container (e.g., a 55-gallon drum or 0.2 m^3 as shown in Figure 2-3b). The same volume is accounted and reported for both the NMED permit (i.e., the state of New Mexico's Underground Hazardous Waste Disposal Unit limits[15]) and the LWA (i.e., the congressional limits).

The permit modification proposes to change the volume accounting basis for reporting against the LWA limits only. DOE proposes to create a "Land Withdrawal Act TRU Waste Volume of Record" to refer to the volume of TRU waste inside a disposal container. The permit modification request proposes to track the "LWA TRU Waste Volume of Record" separately from the NMED Permit "TRU Mixed Waste Volume."

DOE notes in the permit request that the volume of emplaced contact-handled TRU (CH-TRU) mixed waste as of December 6, 2017, based on the outermost container volumes is 91,709 m^3 while the volume based on the innermost container volumes is 65,347 m^3. This represents a recovery of ~28 percent of the currently available volume. The committee notes that the DOE retrospective capacity analysis appears to be based on only "overpack disposal containers." The DOE reported to the committee that the LWA Volume of Record would only be applied to the inner container volumes of overpacked waste containers, for example, 10-drum overpack containers (TDOP, designed to contain older deteriorating drums), or pipe overpack containers, (including the CCC/CCO which consists of a inner pipe with the TRU waste contained within a larger 55-gallon drum, as shown in Figure 2-3b), as opposed to the "fill factor" of direct-loaded containers. The permit request itself is not explicit on this detail.

As shown schematically in Figure 2-3b, an inner pipe, referred to as a Criticality Control Container (CCC), contains the diluted surplus plutonium. A single CCC with dimensions of 6 inch diameter, 26.875 length is nested within a 55-gallon-drum-sized CCO. Each CCC has a limit of no more than 300 fissile

[12]"Greater-than-Class-C" or GTCC is a Nuclear Regulatory Commission (NRC) designation for low-level radioactive waste that exceeds the concentration limits of radionuclides established for Class C waste in NRC's Code of Federal Regulations 10. CFR § 61.55. Although the NRC classification system does not apply to DOE (DOE 2016b, p. S-10): "the DOE owns or generates both low level radioactive waste and non-defense-generated TRU waste which have characteristics similar to those of GTCC and for which there may be no path for disposal. DOE has included these wastes, otherwise known as 'GTCC-like waste.'"

[13]Disposal of this material in WIPP is one of several of DOE's preferred disposition alternatives; the others are generic commercial low-level waste disposal facilities (see DOE 2016b). A record of decision has not yet been issued by DOE.

[14]The state of New Mexico ruled in June 2018 that DOE's request should be treated as a Class 3 modification (DOE proposed a Class 2 modification) given the significant public interest in this issue. A Class 3 modification allows for public input to the permit modification process (ENV 2018a).

[15]A typical disposal panel holds approximately 18,000 m^3. See Table J-3 in the WIPP Permit: https://hwbdocuments.env.nm.gov/Waste%20Isolation%20Pilot%20Plant/170900/170900%20WIPP%20Permit%20PDF/Attachment%20J%2004-15-2011.pdf.

gram equivalents (FGE) of surplus plutonium. The number of CCC/CCOs needed to dispose of 34 MT is easily calculated; 34,000,000 g divided by 300 g, resulting in 113,333 containers.

Under the present accounting, this equates to ~23,800 m^3 for both the LWA volume and NMED volume reporting. If the "LWA TRU Waste Volume of Record" permit request is approved, the accounting would be ~23,800 m^3 for the NMED hazardous waste disposal unit (HWDU) and ~1,405 m^3 for the LWA reporting, providing a 94 percent recovery of the available volume needed for disposition of the 34 MT.

As indicated by the LANL inventory estimate, DOE is analyzing the case of up to 42.2 MT (34 MT of the PMDA plus 7.1 MT and 1.1 MT as shown in Figure 2-1) of surplus plutonium in WIPP in addition to the 6 MT currently being processed. Based on current plans, the 6 MT and 34 MT portions of this total will be disposed of using the CCC/CCO disposal containers. It is reasonable to assume the remaining 8.2 MT would be disposed of in a similar manner. Using the same calculations above, this would amount to 33,740 m^3 for the NMED HWDU reporting and 1,992 m^3 for the LWA reporting, a difference of 31,748 m^3.

The combination of reduction in the "LWA TRU Waste Volume of Record" for already emplaced waste plus the potential disposal of 48.2 MT surplus plutonium would provide 58,110 m^3 additional capacity under current LWA limits.

The United States will continue to generate defense TRU waste through its weapons programs. It is likely to have more defense TRU waste than deep geologic disposal capacity, even if the LWA volume of record is allowed to be recalculated. This puts inordinate pressure on WIPP to accommodate all federal needs for disposal of TRU wastes for decades to come.

The remaining capacity at WIPP is a limited resource and is allocated based on many different priorities. One way to mitigate the risk to the dilute and dispose program would be to reserve space at WIPP. However, this is not being considered under the current processes. Space management (i.e., planned location for the emplacement of the waste as it arrives at WIPP) is currently designed to take waste as it is prepared for shipment to WIPP. In response to a committee question about emplacement procedures (i.e., identifying location within the repository for emplacement) at WIPP, DOE responded that its long-term and mid-term planning is based on estimates from the defense TRU waste generating sites. For decisions on emplacement location, the Carlsbad Field Office manager uses an 8-weeks shipping projection. There appear to be no mechanisms for prioritizing waste for disposal space years in advance (as would be needed for the diluted plutonium) or reserving space in WIPP for high-priority waste streams (DOE 2018b).

RECOMMENDATION 1: The remaining statutory capacity as defined in the Waste Isolation Pilot Plant Land Withdrawal Act (P.L. 104-201; LWA) and New Mexico Environment Department (NMED) permit at WIPP should be treated as a valuable and limited resource by DOE. DOE-EM and the Carlsbad Field Office should modify their current emplacement planning process to allow for guaranteed long-term allocation of disposal capacity for waste streams of highest priority to DOE.

3.1.3 Access to WIPP is controlled by DOE-EM and the State of New Mexico, which have different legal obligations and programmatic priorities than DOE-NNSA.

WIPP is a DOE-EM-managed facility and is being operated for the benefit of DOE-EM's cleanup program, which operates under legally enforceable schedules and agreements with several states and the U.S. Environmental Protection Agency. A DOE-NNSA campaign to dispose of diluted surplus plutonium in WIPP would compete with DOE-EM for access to WIPP's waste receipt and emplacement facilities.[16] It is not clear to the committee which entity within DOE would be responsible for resolving scheduling conflicts between the two offices or the process by which those conflicts would be resolved.

There are several legally binding agreements related to WIPP operations, including:

[16]There are limits to the number of waste shipments that can be received and emplaced in WIPP each week. A DOE-EM representative told the committee in November 2017 that current rates of emplacing waste in WIPP allow five to six shipments per week but that emplacement rates were expected to ramp up in the future due to operational efficiencies and added ventilation (Forinash 2017).

1. The Waste Isolation Pilot Plant Land Withdrawal Act (P.L. 102-579, 106 Stat. 4777-4796 [1992]).
2. Stipulated Agreements and Consultation and Cooperation ("C&C") Agreement between New Mexico and DOE (DOE 1988).
3. WIPP waste acceptance criteria (WIPP WAC) (DOE 2016d).

Additionally, there are a number of legal/political/policy issues associated with DOE-NNSA's dilute and dispose program that cut across various levels of New Mexico government—local (county), state (legislature and governor), and the New Mexico congressional delegation.

There is a complex set of laws, regulations, and orders applicable to the proposed dilute and dispose process. These could also include agreements with South Carolina, tribal nations, and southern states along the transportation routes in addition to New Mexico. There is a long history of commitments, some of which are legally binding, made by DOE related to radioactive waste removal from specific states. Delays in implementing the dilute and dispose process could result in fines and/or affect DOE's ability to import or remove waste into or out of South Carolina.[17]

FINDING 3: Shifting the plutonium disposition program of record to the dilute and dispose option will require detailed discussions between DOE and the states of New Mexico and South Carolina. Accommodating 34 MT of diluted plutonium and other planned and/or potential future DOE waste streams in WIPP will necessitate changes to state permits and possibly legislation requiring state cooperation including public participation.

FINDING 4: DOE will need to determine which laws, regulations, and orders are applicable to the proposed dilute and dispose process and develop and implement a strategy to work with regulators to obtain the necessary changes.

RECOMMENDATION 2: DOE-NNSA should engage New Mexico and South Carolina as well as their congressional delegations prior to the public engagement required by the National Environmental Policy Act process to assess prospects for successfully amending the existing legal agreements to allow for the dilution and packaging of 34 MT of surplus plutonium at the Savannah River Site and its disposal in WIPP.

3.1.4 WIPP operations are scheduled to end in 2034, well before the scheduled 2049 end date for a DOE-NNSA dilute and dispose campaign.

WIPP has been operational for more than 19 years and parts of the facility and underground access ways are approaching 30 years old.[18] Extending WIPP's projected life from 2034 (the currently planned closure date[19]) to 2049 (the projected end of the DOE-NNSA's dilute and dispose campaign) would add another minimum of 16 years to the life of the facility. Extending WIPP life beyond 2034 will require approvals from New Mexico (through permit modification requests by DOE) and most certainly will require additional appropriations from Congress. There will likely be additional costs for maintaining WIPP's systems, structures, and components in a safe and secure condition during this life extension, and the entire cost of running and maintaining WIPP could fall on DOE-NNSA once the DOE-EM TRU waste mission has ended. DOE-NNSA has yet to issue a life-cycle cost estimate for the dilute and dispose option, and so the committee is unable to evaluate whether the additional costs noted above have been included in that estimate.

[17] See 50 U.S.C. §2566 (2010).

[18] Note that parts of the underground have been accessible since 1988.

[19] The original closure date for WIPP was 2018; an extension to 2034 more than doubles the originally planned lifetime of the facility.

3.2 UNCLEAR STRATEGY FOR DEVELOPMENT OF THE NEPA ENVIRONMENTAL IMPACT STATEMENT

DOE has issued a number of environmental impact assessments (EISs), supplemental EISs, and records of decision (RODs) for dispositioning surplus plutonium (see Box 3-1). The final programmatic EIS, FPEIS-0229, evaluated strategies and locations for storing and dispositioning weapons-usable[20] fissile materials (DOE 1996a); the associated ROD selected MOX and immobilization as the preferred options for surplus plutonium disposition. The Surplus Plutonium Disposition EIS-0283 (tiered from the FPEIS-0229, DOE 1996a) evaluated site-specific alternatives for the construction and operation of facilities for disposition of up to ~45 MT of surplus plutonium (DOE 1999). The associated ROD in 2000 identified immobilization and irradiation of MOX fuel as the preferred dual alternatives for surplus plutonium disposal. Two years later, the immobilization program was cancelled due to budget constraints and MOX was selected as the only method for plutonium disposal for the United States (DOE 2002). The PMDA was later renegotiated (DOS 2010). Immobilization was removed from the listed disposal options; some of the material selected for immobilization was to be processed at the MOX plant to make it useable in MOX fuel.

In 2015, dilute and dispose was specifically considered as one of the disposition options for non-pit surplus plutonium (referred to as "WIPP Disposal") in the Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement (DOE 2016c).[21] Under this disposition option, plutonium oxide would be "mixed/blended with inert material …. Inert material would be added to dilute the plutonium-239 content and inhibit plutonium recovery and could include dry mixtures of commercially available materials" (DOE 2015, p. S-31). The subsequent April 2016 ROD selected WIPP disposal for dispositioning 6 MT of diluted non-pit plutonium.

It is DOE policy to follow NEPA and to apply the NEPA review process early in program development.[22] Requirements for a programmatic (including sitewide) NEPA document are outlined in the Code of Federal Regulations, 10 CFR Part 1021. Programmatic NEPA documents are required to support a DOE programmatic decision. Programmatic decisions are defined as:

> *Major Federal action includes actions with effects that may be major and which are potentially subject to Federal control and responsibility. … Actions include the circumstance where the responsible officials fail to act and that failure to act is reviewable by courts or administrative tribunals under the Administrative Procedure Act or other applicable law as agency action…*
> *(b) Federal actions tend to fall within one of the following categories:*
> *(3) Adoption of programs, such as a group of concerted actions to implement a specific policy or plan; systematic and connected agency decisions allocating agency resources to implement a specific statutory program or executive directive. (10 CFR 1508.18((b)3))*

DOE has not yet issued a Notice of Intent (NOI), an EIS, or ROD for dispositioning 34 MT of pit and non-pit surplus plutonium using the dilute and dispose process. At the very least, DOE will need to issue a supplemental EIS and ROD for this disposition alternative. A programmatic environmental impact assessment might be required because

1) the quantities of surplus plutonium being considered for disposal at WIPP are much larger than those assessed in the 2015 Supplemental EIS and represent the majority of the United States excess plutonium (i.e., as much as 42.2 MT versus 6 MT); and

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[20]A fissionable nuclear material such as uranium-235 or plutonium-239 that is pure enough to be usable in a nuclear weapon.

[21]DOE/EIS-0283-S2 evaluates environmental impacts for disposition of 13.1 MT of surplus plutonium, including 6 MT of surplus non-pit plutonium (managed by DOE-EM) as well as 7.1 MT of plutonium from pits shown in Figure 2-1 of this report (DOE 2015).

[22]See https://www.ecfr.gov/cgi-bin/text-idx?SID=a4e055019b59e975ce6b588a419d7b2d&mc=true&node=pt10.4.1021&rgn=div5.

Appendix H

BOX 3-1 Timeline of Actions and Decisions for Disposal of Surplus Plutonium

Below is a timeline for major actions and decisions relevant to the dilution and disposal of surplus plutonium. Items in italics are events relevant to the surplus plutonium disposition program but are not environmental impact statements or records of decision.

1993	*President Clinton issues policy on Nonproliferation and Export Control, a key element of which states that the United States is, "committed to eliminating, where possible, the accumulation of stockpiles of highly enriched uranium and plutonium and to ensure that where these materials already exist, they are subject to the highest standards of safety, security, and international accountability. . . ."* (DOE 1996b, p. 75)
1995	*DOE declares excess weapons-grade plutonium and identifies plutonium waste throughout the DOE complex (DOE 1996b, p. 76) 38.2 MT plutonium in various forms (metals, oxides, reactor fuel, irradiated fuel, and other forms) is identified as excess and 3.4 MT of plutonium is identified as waste.*
1996	**Storage and Disposition Final Programmatic EIS, FPEIS–0229, 1996** Considered 37 alternatives for "the disposition of up to 50 metric tons of plutonium that has been or in the future may be declared surplus to national security needs;"[a]
1997	**Record of Decision (ROD), FPEIS-0229** Decision to implement immobilization and MOX for disposal of surplus plutonium. Decision to use Safe Secure Transport (now called the Office of Secure Transportation, OST) to transport all plutonium-bearing materials between sites including unirradiated MOX fuel. (DOE 1997)
1999	**Surplus Plutonium Disposition, SPD EIS-0283** Focus on disposition of surplus plutonium. Tiered from FPEIS-0229 (DOE 1999b)
2000	**ROD SPD EIS-0283** "[T]o provide for the safe and secure disposition of up to 50 metric tons of surplus plutonium… the Department has decided to use a hybrid approach…[using] **immobilization …** and … **MOX fuel**. The Department has selected the Savannah River Site in South Carolina as the location for all three disposition facilities." (DOE 2000, p. 1608)
2000	*United States and the Russian Federation sign the PMDA.*
2002	**ROD SPD EIS-0283** Cancelation of the immobilization program due to budget constraints and assumptions that a single focus on MOX would save time and money over the previous hybrid strategy. Part of the rationale for the decision to cancel immobilization was the expectation that Russia would not agree to an immobilization only program: DOE-NNSA has evaluated its ability to continue implementing two disposition approaches and has determined that in order to make progress with available funds, only one approach can be supported. (DOE 2002, p. 19434)
2003	**Savannah River Site, Interim Management of Nuclear Materials, Amended ROD, EIS-0220** "The program will dispose of 34 MT of surplus plutonium, including approximately 6.5 MT of the 17 MT of surplus plutonium originally intended for immobilization…" and stored at SRS. (DOE 2003, p. 20134)
2007	*DOE Secretary Bodman declares an additional 9 MT of Pu as surplus.*

continued

BOX 3-1 Continued

2010 *United States and the Russian Federation sign the PMDA as amended by the 2010 Protocol, immobilization is removed as an option for U.S. disposition of surplus plutonium.*

2014 *Disposition of Surplus Pu Working Group report (DOE 2014b)*
Reviewed options for plutonium disposal as the costs of the MOX plant were increased significantly. Five options were evaluated:

Option 1: Irradiation of MOX Fuel in Light Water Reactors (LWRs);
Option 2: Irradiation of Plutonium Fuel in Fast Reactors;
Option 3: Immobilization (Ceramic or Glass Form) with High-Level Waste;
Option 4: Dilute [Downblending] and Disposal; and,
Option 5: Deep Borehole Disposal.

A Key Point Summary listed Option 4 as the least expensive and having the least risk as compared to the other alternatives. The assessment acknowledged that the PMDA would need to be renegotiated and the capacity and scope of the mission at WIPP would need to be expanded.

2015 *AeroSpace and Red Team Reports, independent review of April 2014 Working Group's assessment with a focus on Options 1 and 4 (MOX and Dilute and Dispose)*

2015 **Supplemental EIS-0283-S2**[b]
Final supplemental SPD EIS considered disposal options for non-pit surplus plutonium

2016 **ROD SPD EIS-0283**
Decision to dispose of 6 MT non-pit surplus plutonium through dilute and dispose at WIPP

"Blending for disposal at WIPP is a proven process that is ongoing at SRS for disposition of plutonium material… ." (DOE 2016c, p. 19591)

CH-TRU volume is estimated to be between 15,000 and 17,000 m^3.

2016 Russian Federation President Vladimir Putin announces suspension of the PMDA

[a] "Discarding Plutonium to WIPP" was rejected in this analysis due to lack of capacity at WIPP, (see DOE 1996a, summary table).
[b] DOE has issued two supplements to SPD EIS-0283: SPD EIS-0283-S1 identified a set of six reactors that would use MOX fuel, SPD EIS-0283-S2 assessed disposal options for *non-pit* surplus plutonium and added two more reactors that could potentially use MOX fuel.

2) it is not clear whether the processing plans and facilities to be used for dispositioning 34 MT of surplus plutonium are similar enough to those for the 6 MT considered in the 2015 Supplemental EIS.
3) the assumptions that were made, the preferred alternatives identified, and the facilities at which the processes would take place when the original PEIS (DOE 1996a, see Box 3-1) have changed significantly.

Additionally, there may be other EISs and RODs tied to the facilities to be used for the DOE-NNSA dilute and dispose process that might also need to be updated or created.

FINDING 6: Based on limited information regarding the NEPA strategy for the dilute and dispose program and the fact that DOE-NNSA's dilute and dispose plans derive from a similar program managed by DOE-EM to dilute and dispose of 6 MT of surplus plutonium, the committee finds that a full programmatic environmental impact statement (PEIS) of the dilute and dispose option, encompassing all sites, transportation, and activities involved in the dilute and dispose process rather than a supplemental EIS would help ensure the proper scope and scale of the proposed change. As much as 42.2 MT of surplus plutonium is being considered for disposal at WIPP, including 34 MT related to the PMDA. This represents the majority of the United States' declared excess plutonium and its processing would stress the sites, transportation, and activities well beyond the current disposition plans for 6 MT.

3.3 DILUTE AND DISPOSE IS NOT AN APPROVED METHOD FOR ELIMINATING SURPLUS PLUTONIUM IN THE PMDA

The committee was asked to evaluate the viability of DOE-NNSA's dilute and dispose conceptual plans to support U.S. commitments under the PMDA. In its assessment, the committee compared both the technical and procedural requirements of the amended PMDA (DOS 2010).

In its technical assessment, barriers to plutonium recovery were considered by the committee and referencing the 1994 NAS report which developed the "spent fuel standard" (see Chapter 2). The current PMDA-approved method of disposition is the MOX fuel option that includes irradiation in a reactor would provide the following barriers for reuse in weapons:

1) **Chemical:** Oxidation of the plutonium metal, and dilution of the oxidized plutonium with uranium oxide (UO_2) to form MOX fuel.
2) **Isotopic:** The plutonium-239 isotopic composition is shifted during irradiation by the fission of plutonium-239 and -241 and by the transmutation of plutonium-239 to -240, plutonium-240 to -241, and plutonium-241 to -242. The ratio of plutonium-240/plutonium-239 would be increased to at least 0.1 giving an increase in neutron generation making the plutonium much more difficult to use for production of normal weapons.
3) **Radiation:** Irradiation in a reactor creates a radiation barrier sufficient to be self-protecting for decades.
4) **Physical:** The weight and size[23] of a nuclear fuel assembly is sufficient to require special-handling equipment for processing.

The dilute and dispose option provides the following barriers:

1) **Chemical:** Oxidation of the plutonium metal and dilution of the plutonium-239 with a classified dry-blended adulterant using classified methods, and
2) **Physical:** Packaged into a stainless steel pipe within a 55-gallon drum (see Figure 2-3b) and disposed of in a deep geologic repository (WIPP).

As compared to the MOX option, the dilute and dispose option does not require additional processing steps and remote and special handling equipment to recover the plutonium due to the lack of isotopic, radiation, and physical (i.e., due to weight and size of the waste) barriers.

A 1994 NAS report which outlined the spent fuel standard makes two statements relevant to the dilute and dispose approach. An assessment of the chemical barrier is provided (NAS 1994, p. 148):

> Chemical barriers alone, such as diluting the plutonium or combining it chemically with other elements, will not be sufficient to match [the combination of] chemical, radiological, and isotopic barriers, and therefore cannot meet the spent fuel standard.

[23]A fuel assembly consisting of ~200 rods and 12 feet long is over 2 MT (https://www.nrc.gov/materials/fuel-cycle-fac/fuel-fab.html for LWR fuel assemblies).

And its assessment of the physical barrier of deep geologic storage through boreholes (NAS 1994, p. 16):

> Plutonium in such boreholes would be extremely inaccessible to potential proliferators, but would be recoverable by the state in control of the borehole site.

The 1994 committee assessed disposition options for meeting the spent fuel standard that included both chemical and radiological barriers or chemical and substantial physical barriers but does not review a dilute and dispose option as proposed by DOE-NNSA.

The PMDA does not reference the 1994 NAS report but the means for dispositioning the surplus plutonium outlined in the agreement, irradiation of MOX fuel in nuclear reactors, met the spent fuel standard. As discussed below, there is no indication that the process for modifying the current PMDA has not been initiated so there is no official response by the Russian Federation. However, the Russians expressed concerns over an "immobilization only" approach for the 34 MT as discussed in the ROD which moved the U.S. program to a MOX only disposition approach:

> Russia does not consider immobilization alone to be an acceptable approach because immobilization, unlike the irradiation of MOX fuel, fails to degrade the isotopic composition of the plutonium. Russia has contended that the United States could easily obtain plutonium by removing it from the immobilized waste form in the event of a desire to reuse the plutonium for nuclear weapons. Because selection of an immobilization only approach would lead to loss of Russian interest in and commitment to surplus plutonium disposition, DOE is of the view that if only one disposition approach is to be pursued, the MOX approach rather than the immobilization approach is the preferable one. (DOE 2002, p. 19434)

The committee also reviewed the procedural requirements of the PMDA. Article III of the PMDA Additional Protocol 2010 specifies the means that are to be used by the United States and the Russian Federation for dispositioning 34 MT of surplus plutonium:

> *Disposition shall be by irradiation of disposition plutonium as fuel in nuclear reactors; or any other methods that may be agreed by the Parties in writing.* (DOS 2010, p. 4, Article III)

Article XIII of the PMDA Additional Protocol 2010 also specifies how the agreement can be amended:

> *This Agreement may only be amended by written agreement of the Parties, except that the Annex on Key Program Elements may be updated as specified in paragraph 5 of that Annex.* (DOS 2010, p. 10, Article XIII)

To the committee's knowledge, the United States has not notified the Russian Federation in writing about its plans to pursue the dilute and dispose process in place of MOX. However, the Russian Federation government is aware of DOE's desire to use dilute and dispose to disposition 34 MT of surplus plutonium. Russian Federation President Vladimir Putin raised concerns in an April 2016 meeting with journalists about the United States' use of the dilute and dispose process for dispositioning surplus plutonium under the PMDA:

> *[...] [B]ack in the early 2000s, the Americans and we agreed on destroying weapons-grade plutonium. [...] Each side had 34 tonnes. We signed this agreement and settled on the procedures for the material's destruction, agreed that this would be done on an industrial basis, which required the construction of special facilities. Russia fulfilled its obligations in this regard and built these facilities, but our American partners did not.*
>
> *Moreover, only recently, they announced that they plan to dispose of their accumulated highly enriched nuclear fuel by using a method other than what we agreed on when we signed the corresponding agreement, but by diluting and storing it in certain containers. This means that they preserve what*

> *is known as the breakout potential, in other words it can be retrieved, reprocessed and converted into weapons-grade plutonium again. This is not what we agreed on. Now we will have to think about what to do about this and how to respond to this. [...] [O]ur partners should understand that [...] serious issues, especially with regard to nuclear arms, are [where] one should be able to meet one's obligations.* (IPFM Blog 2016)

President Putin subsequently suspended Russian implementation of the PMDA in October 2016. The U.S. response to the Russian Federation's actions are summarized in the State Department's 2018 Report on Adherence to and Compliance with Arms Control, Nonproliferation, and Disarmament Agreements and Commitments:

> *Despite Russia's assertion, the PMDA allows either side to utilize any disposition method that is agreed by the Parties in writing (Article III.1). Neither side is in violation of the PMDA and neither side has begun implementation of its disposition program. Changing the U.S. method to dilution-burial, however, would allow the United States to begin fulfilling the goals of the agreement more quickly.* (DOS 2018, p. 14)

Based on President Putin's comments above and the stated reluctance of the Russian Federation to agree to an immobilization only option (DOE 2002), it could be difficult for the United States to get written approval from the Russian Federation for implementing the dilute and dispose process in place of MOX. Of course, the United States could, as a matter of policy, pursue dilute and dispose outside of the PMDA framework.

In the context of current events including uncertainty about the future of the Intermediate-Range Nuclear Forces (INF) Treaty between the U.S. and the Russian Federation, a renegotiation of the PMDA may not be a reasonable near-term expectation. The committee recognizes that changing United States-Russian Federation relations may de facto alter the applicability of the PMDA's plutonium disposition criteria to the proposed dilute and dispose method. However, the committee does not see any evidence that the PMDA criteria are not applicable to the proposed dilute and dispose method and notes that the existing PMDA does not recognize dilute and dispose as an acceptable method of disposition. Notably, DOE-NNSA recently revised the dilute and dispose program requirements document; the updated text no longer mentions the PMDA as justification for the program (DOE 2018d).

FINDING 5: The dilute and dispose option for surplus plutonium disposition is neither recognized nor approved by the existing PMDA. Irradiated MOX fuel containing the surplus plutonium is the currently approved disposition option for plutonium within the PMDA and is an option that is consistent with the standard established with commercial spent fuel (i.e., that the plutonium would be as inaccessible for recovery for reuse in weapons by the host state as if it were in spent fuel or the "spent fuel standard"). Disposition options that use chemical barriers alone such as dilution or combining plutonium with other elements do not meet this standard. The physical barrier of deep geologic disposal is offered by the DOE as a necessary barrier to meet the intent of the PMDA. However, emplacement of diluted plutonium in WIPP remains recoverable by United States.

3.4 ASSESSMENT OF CONCEPTUAL PLANS AND PUBLIC OUTREACH

The DOE-NNSA is in the early stages of development for a proposed 30-year program. Congress has appropriated funds only for initial planning and cost estimation activities. DOE-NNSA aims to advance from Critical Decision-0 (CD-0) to CD-1 by 2019 (see Figure 2-5) where CD-1 "marks the completion of the project definition phase and the conceptual design" (DOE 2010, p. A-5). Therefore, a large number of details and risks of the dilute and dispose plan are yet to be determined, many of which are too early to accurately estimate or identify. Additionally, the decision to move to dilute and dispose for the 34 MT under the PMDA is politically charged. It is coupled to the decision to cancel the MOX plant. Moreover, Russian Federation concurrence with this change has not been resolved.

Although some details may be undetermined at the early stage of program development, it is clear that public and state-level engagement will be important to the success of the program (see Finding 3 and Recommendation 2). The dilute and dispose conceptual plans rely on significant permit modifications for WIPP operations to be approved by the State of New Mexico. The process is likely to require periods of public comments. Also, the large number of transports of weapons-grade material and diluted plutonium waste between New Mexico and South Carolina are likely to raise public concern. The changing mission of WIPP, if the dilute and dispose option were to be fully implemented, has also been raised as a concern by the public (Anastas 2018, Chaturvedi 2018). Finally, a significant portion of the proposed program relies on access to classified information, material, and assessments, many of which are under development at this early stage of the program.[24] For these reasons—the continued evolution of the classified plans and the classified list of the constituents of the adulterant—this committee was unable to judge the whether the adulterant would add any additional hazards to WIPP.[25]

FINDING 7: DOE-NNSA does not have a well developed public outreach plan for the host sites for processes or for the transportation corridor states and tribes (i.e., the current plan is to follow public input requirements defined by NEPA) for the dilute and dispose program.

CONLUSION 2: Public trust will need to be developed and maintained throughout the lifetime of the dilute and dispose program because several permit modifications and potential changes to legislation will be required. These changes will require assuring the regulators and the public of the safety and security of the DOE plans. This is particularly challenging for the dilute and dispose program because of several factors: security classification of aspects of the planning (constituents of the adulterant, processing steps, security and safeguards assessments); early stage of program development with changes likely to occur as more information is known; and potential impacts that cross many states and DOE sites.

Independent technical review of DOE's plans could improve DOE's plans, actions, and decisions while increasing public trust. In 1981, the establishment of an independent technical review group, Environmental Evaluation Group (EEG), was required as a result of a Stipulated Agreement between the State of New Mexico, DOE, and the Department of the Interior. EEG was disbanded in 2004 due to lack of funding.[26]

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[24]A subgroup of this committee with the appropriate clearances has been briefed on the classified draft dilute and dispose assessments and plans but the assessments and plans are not yet final.

[25]The 2017 special inventory report includes the constituents of the adulterant and is presumably part of Sandia National Laboratories' performance assessment (LANL 2017).

[26]The EEG was established with federal funding in 1978 to provide an independent technical review of the nuclear waste repository proposed for salt beds in New Mexico. In 1981, the State and DOE settled the lawsuit filed by then Attorney General Jeff Bingaman. This set the stage for the Stipulated Agreement, and accompanying documents, to respect New Mexico's concerns. The Stipulated Agreement makes reference to the Consultation and Cooperation (C&C) Agreement. Article X of the C&C Agreement states:

The parties recognize that in order for the State to comment and make recommendations under this Agreement it must have adequate resources to carry out an independent review of WIPP. DOE shall continue to assist the State in obtaining the resources necessary for the State to undertake a meaningful independent review of the public health and safety aspects of WIPP. (DOE 1988, p. 12)

The DOE recognizes the State's desire to continue the State review capability and further agrees to negotiate for an appropriate State review capability independent of D.O.E. beyond 1985 for the full operational life of WIPP through and including the decontamination and decommissioning stages and post-operational stages of WIPP (DOE 1988, p. 29).

Appendix H

The Supplemental Stipulated Agreement that established EEG was clear that an independent technical review group be created for "the full operational life of WIPP through and including the decontamination and decommissioning" (DOE 1988, p. 29). Section 1433 of the National Defense Authorization Act for Fiscal Year 1989, as originally written, identified the roles and responsibilities of the organization and provided New Mexico with assurance of the independence of the group.[27] Recently, the Energy and Water Development Appropriations Bill for Fiscal Year 2019[28] has language calling for independent technical review. Since New Mexico will be the recipient of the diluted plutonium waste and New Mexico's Environmental Department will review DOE's permit modification requests, an independent technical review organization representing New Mexico's concerns could increase the robustness of DOE plans as well as increase public trust in them.

RECOMMENDATION 3: If the dilute and dispose option becomes the program of record, the committee strongly suggests that DOE consider reinitiating the Environmental Evaluation Group, as an independent technical review organization that can represent the concerns of the state of New Mexico, throughout the lifetime of the dilute and dispose program. Members of the technical review organization would need to be technically qualified to address the health and safety issues and a subset would need to have clearances or access authorizations that will allow thorough review of classified plans as they evolve and provide assessments of the dilute and dispose process.

As noted above, the dilute and dispose plan has many critical components that could affect public health, safety, and security but are classified including: details on the chemical nature of the adulterant, evaluations necessary to terminate safeguards of the diluted plutonium oxide, analysis of the criticality risks, and security planning for the transportation of diluted plutonium oxide waste across much of the southern United States. In particular, the transportation plans could affect members of the public outside of New Mexico. As the classified aspects of the dilute and dispose program plans mature, an independent technical group with appropriate clearances could improve the planning and increase trust across the southern states including South Carolina where the diluted plutonium waste will be stored until it is shipped to WIPP for disposition.

The classified aspect of the adulterant leads to other complications. Negotiating a new method of disposal with the Russian Federation is likely to be hampered or at least complicated by the use of a classified adulterant. Further, WIPP operations are not designed to handle classified information although the committee was told that small volumes of classified TRU waste have been disposed previously. The precedent set could have larger policy concerns when and if other countries agree to disposition plutonium using dilute and dispose.

RECOMMENDATION 4: In addition to and separate from the independent review organization representing the State of New Mexico described in Recommendation 3 periodic classified reviews for Congress by a team of independent technical experts should be required until classified aspects of the dilute and dispose plan including the safety and security plans are completed and implemented. Since DOE's plans and decisions are expected to mature and evolve these independent reviews would provide a mechanism to review classified aspects of the program and would improve public trust in those decisions.

[27]National Defense Authorization Act for Fiscal Year 1988, P.L. 100-456, 102 Stat. 1918-2124 (1988).

[28]S.R. 115-258, 115th Cong (2018) requires DOE to submit a report in early 2019 to include "acquiring independent scientific and technical review of dilute and dispose processes and waste forms to ensure compliance with waste acceptance criteria…" (p. 111). The bill has been approved by the Senate Appropriations committee but not the broader Senate or House.

3.5 QUESTIONS FOR DOE-NNSA

The present committee was charged by the U.S. Congress with evaluating DOE-NNSA's plans for disposing of 34 MT of surplus plutonium to support the requirements of the PMDA. The committee is still gathering information to complete this task. The committee's comments, observations, and findings in this Interim Report led the committee to develop the following three question sets, directed primarily at DOE-NNSA. Answers to these questions may result in changes in the committee's final report to the preliminary findings, conclusions, and recommendations.

1. *WIPP Disposal Capacity:* Does DOE-NNSA agree that WIPP's current statutory and physical disposal capacity is a barrier to implementation of the dilute and dispose process for dispositioning 34 MT of surplus plutonium? If not, what data and analyses are DOE-NNSA using to support its alternative conclusion? If so, what are DOE-NNSA and the larger DOE planning/doing to ensure that there is available repository space to dispose of all 34 MT of diluted surplus plutonium and to avoid surface storage of diluted plutonium? What, if any, legal or legislative changes are required to ensure the availability of disposal space in WIPP for disposing of 34 MT of surplus plutonium? If WIPP becomes temporarily unavailable due to an unforeseen closure, what are the plans for the dilute and dispose program? How does the conceptual plan change if permit modifications (i.e., changes to the calculation of the volume of record, physical expansion of WIPP, or life extension of WIPP) are not approved?
2. *Environmental Impact Statements:* How many and what kinds of environmental impact statements are currently associated with the dilute and dispose program? Which ones will need to be updated? How will they be updated (i.e., supplemental EIS versus programmatic EIS)? What are the timeframes for completing these updates? Regardless of the type of EIS prepared, what are DOE-NNSA's plans to incorporate transportation safety and security risks into the NEPA process?
3. *WIPP Compliance:* Will the disposal of 34 MT of diluted plutonium in WIPP require changes to WIPP's Provisional Compliance Recertification Application or to the EPA certification of WIPP? If so, what changes will be required, and how difficult (time, costs) will those changes be to implement? What is the timeframe for starting the application process?

The committee hopes to obtain detailed answers to these questions from DOE-NNSA prior to the completion of the final report from this study.

Appendix H

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Appendix A

Committee and Staff Biographies

Committee Chair

Robert C. Dynes (NAS) was the 18th president of the University of California (UC) and is now an emeritus professor of physics at UC San Diego, where he directs a laboratory that focuses on superconductivity. Dr. Dynes served as chancellor of UC San Diego from 1996 to 2003 after 6 years in the physics department, where he founded an interdisciplinary laboratory in which chemists, electrical engineers, and private industry researchers investigated the properties of metals, semiconductors, and superconductors. Prior to joining the UC faculty, he had a 22-year career at AT&T Bell Laboratories, where he served as department head of semiconductor and material physics research and director of chemical physics research. Dr. Dynes received the 1990 Fritz London Award in Low Temperature Physics, was elected to the National Academy of Sciences in 1989, and is a fellow of the American Physical Society, the Canadian Institute for Advanced Research, and the American Academy of Arts & Sciences. He is the current cochair of the Intelligence Community Studies Board at the National Academies of Sciences, Engineering, and Medicine and has served on the executive committee of the U.S. Council on Competitiveness. He currently serves on the Board of the La Jolla Institute of Allergy and Immunology and advises several technical startups in the San Diego area. A native of London, Ontario, Canada, and a naturalized U.S. citizen, Dr. Dynes holds a bachelor's degree in mathematics and physics and an honorary doctor of laws degree from the University of Western Ontario, and master's and doctorate degrees in physics and an honorary doctor of science degree from McMaster University. He also holds an honorary doctorate from L'Université de Montréal.

Committee Members

Lisa M. Bendixen is an expert in hazardous materials risk and safety and has addressed risk management, risk assessment, security, and resilience challenges across numerous industries, for fixed facilities as well as transportation systems. She is a vice president at ICF, consulting on critical infrastructure security and resilience, mission assurance, and other risk management issues with the Departments of Defense, Energy, and Homeland Security. She served on the Transportation Security Panel for the National Research Council's (NRC) report *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* and was on the NRC committee that produced the report *Terrorism and the Chemical Infrastructure: Protecting People and Reducing Vulnerabilities* as well as several other national committees focusing on transportation risks, including spent fuel. She was the project manager and primary author of the Guidelines for Chemical Transportation Risk Analysis, published by the American Institute of Chemical Engineers' Center for Chemical Process Safety and served on the center's technical steering committee. Her work with DHS has included long-term support on critical infrastructure security and resilience, including several versions of the National Infrastructure Protection Plan, development and implementation of the Chemical Facility Anti-Terrorism Standards, and strategic and policy support to the Office of Infrastructure Protection. She has supported DOE on work related to grid security, from natural hazards and adversarial threats. She is also actively supporting DOD on critical energy and communications infrastructure. She has played leading roles in several safety and risk associations. Ms. Bendixen holds a S.B. in applied mathematics and an M.S. in operations research from the Massachusetts Institute of Technology.

Michael S. Bronzini is Dewberry Chair Professor Emeritus in the Volgenau School of Engineering at George Mason University, where he also served as Chair of the Department of Civil, Environmental, and Infrastructure Engineering. He is principal and cofounder of 3 Sigma Consultants, LLC, based in Nashville, Tennessee. Dr. Bronzini has conducted research and authored more than 250 publications on innovative solutions to complex multimodal transportation systems problems with a focus on freight transportation. He was principal investigator of a project to develop model curricula for transportation of hazardous materials, for the National Academies' Hazardous Materials Cooperative Research Program (HMCRP). He led a study of the impacts on Tennessee and the nation of options for transportation of spent nuclear fuel to a geologic repository that would be located in the western United States. From 1990 to 1999, Dr. Bronzini was director of the Center for Transportation Analysis at Oak Ridge National Laboratory in Oak Ridge, Tennessee, and was responsible for overseeing its interdisciplinary transportation research program. He was professor and head of Civil Engineering at Pennsylvania State University and director of the Transportation Center and professor of Civil Engineering at the University of Tennessee. Dr. Bronzini is a National Associate of the National Academies and has held numerous leadership positions on the Transportation Research Board of the National Academies, including chair of the Inland Water Transportation Committee and chair of the Study Committee on Landside Access to U.S. Ports and inaugural member of the HMCRP Oversight Panel. He is currently a member of the TRB Committee on Transportation of Hazardous Materials. Dr. Bronzini has also served as a consultant and advisor to numerous private and public organizations, including the State of Nevada Nuclear Waste Project Office's Technical Review Committee for the proposed radioactive waste repository at Yucca Mountain. He received a B.S. in civil engineering from Stanford University and an M.S. and a Ph.D. in civil engineering from Pennsylvania State University.

George E. Dials resigned his executive position with Babcock & Wilcox Corporation in mid-2014 and returned with his wife Pamela to their home in Santa Fe, New Mexico. For several months, he served as a senior executive advisor to the director of Los Alamos National Laboratory in an established position as director of the Strategic Improvement Office, charged with enabling implementation of the recently published Los Alamos National Laboratory Strategic Plan. In May 2015, Mr. Dials accepted the position as president and CEO of Pajarito Scientific Corporation (PSC) in Santa Fe, New Mexico. Effective September 1, 2017, in order to focus on a number of other family and business interests, he resigned his position as president and CEO of PSC and accepted a role as senior advisor to and member of the board of directors of the company. Mr. Dials' career spans four decades in energy, national security, waste management, and nuclear technology programs. He has held leadership positions in national security and waste management corporations, and at the Department of Energy. Previously, Mr. Dials was president of B&W Conversion Services, LLC (BWCS), and served as project manager for the Depleted Uranium Hexafluoride (DUF_6) Conversion Operations, the first-of-its-kind nuclear operation in the United States. Mr. Dials directed the BWCS Lexington project office and is the day-to-day interface with the Department of Energy's (DOE) federal project director. He also directed operations at the conversion plants in Piketon, Ohio, and Paducah, Kentucky. He joined B&W Y-12 Nuclear Weapons Complex, LLC in 2006, serving as president and CEO, where he managed a $1.2 billion annual budget and more than 4,600 employees, leading Y-12 through a period of improvement initiative's restorations and new builds, restored the facilities to full production capabilities and operations. Previously, Mr. Dials held executive leadership positions at DOE's waste disposal facilities, which included WIPP and Yucca Mountain—locations designed to safely manage waste from nuclear operations. He was president and COO of the privately owned Waste Control Specialists, LLC, operating the hazardous waste disposal facility, and managing licensing of a low-level radioactive waste treatment and storage facility. Formerly, he oversaw design, engineering, and scientific studies of the Yucca Mountain Project as president and general manager of TRW Environmental Safety Systems, Inc., a DOE management and operating contractor. As a member of DOE's Senior Executive Service, Mr. Dials was manager, Carlsbad Area Office, responsible for WIPP and the National Transuranic Waste Program.

He also served as Idaho Operations Office Assistant Manager in Idaho Falls. Career awards include the U.S. DOE Exceptional Service Medal, 1998; New Mexico Distinguished Public Service Award, 1998; American Nuclear Society Fellow, 2006; Waste Management Symposia Wendell D. Weart Life Time Achievement Award, 2012; Worldwide Who's Who Executive; and Nuclear Fuel Cycle, 2013. During his military career, Mr. Dials served in multiple leadership roles, including an assignment as a Military Research Associate to the Los Alamos National Laboratory; Special Weapons Plans Officer, United Nations Command/U.S. Forces Korea, South Korea; and company commander of a combat infantry company, South Vietnam. Military decorations include a Silver Star, four Bronze Stars, and two Air Medals awarded for combat operations in Vietnam. Mr. Dials holds a B.S. in engineering from the U.S. Military Academy at West Point, an M.S. in nuclear engineering and an M.S. in political science from the Massachusetts Institute of Technology.

Leonard W. Gray retired from E.O. Lawrence Livermore National Laboratory (LLNL) in 2005, has 50-years' experience in the chemistry, engineering, and physics of plutonium processing. He began his career in 1966 at the Savannah River Site with assignments in both H-Area Canyon (high enriched uranium-235, neptunium, and low-assay plutonium-238 recovery) and F-Area Canyons (solvent extraction of Uranium and plutonium), F-B-Line (Plutonium Finishing), H-B Line (neptunium and plutonium-238 finishing) and F-A-Line (Uranium Finishing). After an educational leave-of-absence to obtain his Ph.D., he was assigned to the Savannah River Laboratory with assignments in the Analytical Chemistry Section where he was the lead chemist for chemical forensics of process upsets and then in the Separations Chemistry Section where he was responsible for developing processes for reactor spent fuels labelled as non-processable. He then was the lead chemist for the aqueous recovery of many tons of plutonium scrap residues which had collected at the Rocky Flats Site; this was a multi-site program which assigned various Rocky Flats plutonium scraps to Los Alamos, Hanford, Savannah River and Rocky Flats where these scraps best fit into their respective plutonium recovery operations. He was then transferred to the Savannah River Plant Site to oversee the Separation Technology Laboratory with responsibilities over all chemical unit operations (HEU, Np, low assay Pu-238, Am-241, Cm-244, WG-Pu, depleted U) in F- and H-Areas; here he continued to work with the Rocky Flats Plant Site to develop a process for the recovery of plutonium and americium from chloride-containing aged plutonium scraps. In 1988, he transferred to the Lawrence Livermore National Laboratory to lead the chemical processing portion of the Laser Special Isotope Separations Program. His previous chemical forensic work at Savannah River Laboratory resulted in an invitation to visit the Russian Tomsk-7 Processing site to aid in the investigation of an accident similar to one that had occurred at Savannah River. Before retirement he was the chief scientist for the U.S.-Russian Plutonium Disposition Program; this played a major role in the US-Russian Agreement for each country to dispose of approximately 35 metric tons of excess weapons-grade plutonium in methods that would prevent their return to a weapons program. His assignments have taken him to nuclear facilities in Australia, China, France, England, Russia, and Scotland. He has won numerous awards for his work in chemical forensics and plutonium processing science. These include Award of Excellence for Significant Contributions to the Nuclear Weapons Program (his team was the first team at Savannah River to be awarded the Award of Excellence by the director of Military Applications) and he is the only recipient from LLNL to be awarded the Glenn T. Seaborg Actinide Separation Award. He also served on the Chemical Safety Committee of the American Chemical Society. Dr. Gray remains active in retirement, continuing to mentor young scientists, having served as chief scientist for the safe de-inventory and shutdown of the LLNL Heavy Element Facility and having authored the recent Official Use Only publication "Worldwide Plutonium Production and Processing." He presently serves as chairman of the Plutonium Experts Panel for the National Technical Nuclear Forensics Center of the Department of Homeland Security. Dr. Gray received his Ph.D. in inorganic chemistry from the University of South Carolina in 1972, his M.S. in chemistry from Texas Technological College in 1967, and his B.S. in chemistry from the New Mexico Institute of Mining and Technology in 1964, and his A.A. from Middle Georgia College in 1961.

Michael R. Greenberg studies environmental health and risk analysis. He was interim dean and is Distinguished Professor of the Edward J. Bloustein School of Planning and Public Policy, Rutgers University. He has written more than 30 books and more than 300 articles. His most recent books are *Protecting Seniors Against Environmental Disasters: From Hazards and Vulnerability to Prevention and Resilience* (Earthscan, 2014), *Explaining Risk Analysis* (Earthscan, 2017), *Urban Planning & Public Health* (APHA 2017), and *Siting Noxious Facilities* (Earthscan, 2018). He has been a member of National Research Council committees that focus on the destruction of the U.S. chemical weapons stockpile and nuclear weapons; chemical waste management; degradation of the U.S. government physical infrastructure; and sustainability and the U.S. Environmental Protection Agency. He chaired the committee for the appropriations committees of the U.S. Senate and House to determine the extent that the U.S. DOE emphasizes human health and safety in its allocations for remediating former nuclear weapons sites. He served as area editor for social sciences and then editor-in-chief of *Risk Analysis: An International Journal* during the period 2002-2013 and continues as associate editor for environmental health for the *American Journal of Public Health*. Professor Greenberg graduated with a B.A. from Hunter College with concentrations in math and history and an M.A. in urban geography and a Ph.D. in environmental and medical geography from Columbia University.

David W. Johnson, Jr., is the retired director of materials research at Bell Laboratories, Lucent Technologies, a retired editor-in-chief for the *Journal of the American Ceramic Society* and former adjunct professor of materials science at Stevens Institute of Technology. His research activities included fabrication and processing of glass and ceramics with emphasis on materials for electronic and photonic applications. He is a member of several professional societies, including a fellow, distinguished life member, and past president of the American Ceramic Society. Dr. Johnson won the Taylor Lecture Award and the Distinguished Alumni Award from Pennsylvania State University, the Ross Coffin Purdy Award for the best paper in ceramic literature, the Fulrath Award, the John Jeppson Award, the Orton Lecture Award from the American Ceramic Society, and the International Ceramics Prize for Industrial Research from the World Academy of Ceramics. He is a member of the National Academy of Engineering and the World Academy of Ceramics. He holds 46 U.S. patents and has published numerous papers on materials sciences. He earned a B.S. in ceramic technology and a Ph.D. in ceramic science from Pennsylvania State University.

Annie Kersting is director of University Relations and Science Education at the Lawrence Livermore National Laboratory (LLNL). She develops and oversees a broad range of university research collaborations and technology programs and initiatives that advance the mission and vision of LLNL. Dr. Kersting's research interests include the fields of radiochemistry, isotope geochemistry, and environmental chemistry. She manages an active research group in environmental radiochemistry focused on understanding the biogeochemical processes that control actinide (U, Pu, Np, Am) transport in the environment. In particular, she is interested in identifying the processes that control plutonium interactions on the molecular scale with inorganic, organic, microbial surfaces in the presence of water with the goal to reliably predict and control the cycling and mobility of actinides in the environment. Dr. Kersting previously served as the director of the Glenn T. Seaborg Institute in the Physical and Life Sciences Directorate, where she focused on developing research collaborations between LLNL and the academic community in environmental radiochemistry, nuclear forensics, and super heavy element discovery. Dr. Kersting was a board member of the Nuclear and Radiation Studies Board, National Research Council, 2010-2014, and a committee member of the Committee for the Technical Assessment of Environmental Programs at the Los Alamos National Laboratory, National Research Council, from 2006 to 2007. She served on the Environmental Management Sciences Program Review Panel of the U.S. Department of Energy's Office of Science in 2006, and as a scientific advisor on the Actinide Migration Committee for Rocky Flats from 2000 to 2003. Since 2013, she has served as an associate editor of *Geochimica et Cosmochimica Acta* since 2013. She currently chairs the Environmental Protection Agency's SAB Radiation Advisory Committee. In 2016, she was awarded the

Francis P. Garvan-John M. Olin Medal from the American Chemical Society for excellence in chemistry, leadership, and service. In 2017, she was awarded the Secretary of Energy's Achievement Award for contributions to the department and the nation for serving on the Technical Assessment Team. She holds a B.S. in geology and geophysics from the University of California, Berkeley, and an M.S. and Ph.D. in geology and geophysics from the University of Michigan. She was a postdoctoral fellow in the Institute of Geophysics and Planetary Physics at LLNL from 1992 to 1995.

M. David Maloney is Technology Fellow, Emeritus, at Jacobs Engineering Group (formerly CH2M), Aerospace-Technology-Environment-Nuclear business line, providing support to operations at DOE nuclear sites by identifying, developing, and deploying new technologies—including waste, nuclear material, and used fuel management—to reduce the costs and schedule of decommissioning, remediation, and closure. At Rocky Flats and Hanford, both plutonium mission sites, he partnered with the Department of Energy, Office of Environmental Management (DOE-EM) Science and Technology Program to create a risk/cost-shared approach that became a model and a congressional line item for the weapons complex that saved over $350 million. This work involved waste material conditioning/treatment, packaging, assay, certification, and shipping to other sites for future processing and to WIPP for disposal. Dr. Maloney participated in workshops on Total System Performance Assessment models for the U.S. High-Level Waste (HLW) repository and on the UK Radioactive Waste Management Directorate waste form/package/near-geoenvironment integration for the UK High-Level Waste/Intermediate-Level Waste Repository. He also managed the 5-year National Nuclear Security Administration (NNSA) Initiatives for Proliferation Prevention project with the Russian Academy of Sciences and the PA Mayak production and storage site investigating ceramics for waste form and cask applications. For 2 years he served as assistant to the general manager, Energy and Environment Programs, at Argonne National Laboratory where he focused on technology transfer to industry. He has participated in several National Academies of Science study panels from 1997 to date supporting DOE-EM and NNSA inquiries. Dr. Maloney has a Ph.D. in Physics from Brown University. His research associate work was at the Institute for Experimental Nuclear Physics, Karlsruhe Institute of Technology and Kernforschungszentrum, Germany.

S. Andrew Orrell is the section head for Waste and Environmental Safety at the International Atomic Energy Agency (IAEA) where he is responsible for the development and promulgation of internationally accepted standards, requirements, and guides for the safe management of radioactive waste and spent fuel, decommissioning, remediation, and environmental monitoring. In addition, Mr. Orrell oversees the planning and execution of support to the IAEA Member States for the implementation of the IAEA Safety Standards, and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Prior to joining the IAEA, Mr. Orrell was the director of Nuclear Energy Programs for Sandia National Laboratories, where he was responsible for laboratory development initiatives involving all facets of the nuclear fuel cycle. He provided executive leadership for Sandia's Lead Laboratory for Repository Systems program, managing the completion of the post-closure performance assessment and safety case for a license to construct the nation's first geological repository for high-level nuclear waste at Yucca Mountain. Prior to working on Yucca Mountain, he managed site characterization programs for a deep geological repository for transuranic waste at the Waste Isolation Pilot Plant, and developed transportation optimizations for the National Transuranic Waste Management program. With over 25 years of professional experience in nuclear fuel cycle and radioactive waste management for the United States and several international programs, Mr. Orrell is versed in the complex interdependencies between nuclear energy development, waste management, decommissioning, remediation, and disposal. Mr. Orrell routinely advises government and industry leaders on the technical and policy implications of radioactive waste management, including repository development and licensing, national policy development and regulation, site characterization, and safety case development, storage, transportation, and the securing of public confidence.

William C. Ostendorff (U.S. Navy retired) joined the Naval Academy's Political Science Department as the Class of 1960 Distinguished Visiting Professor in National Security in August 2016. Captain Ostendorff has been confirmed by the U.S. Senate on three occasions to serve in senior administration posts in both Republican and Democratic administrations. He served as principal deputy administrator at the National Nuclear Security Administration (NNSA) in the Bush administration (2007-2009) and as a commissioner at the U.S. Nuclear Regulatory Commission (U.S. NRC, 2010-2016) in the Obama administration prior to joining the Naval Academy faculty. At the U.S. NRC, Commissioner Ostendorff was a strong proponent of regulatory technical competence. He was considered by many to be a key leader on the Commission in the areas of post-Fukushima regulatory decision making and in both physical and cyber security of commercial nuclear facilities. During his more than 6 years as a commissioner, he testified before Congress on 26 occasions and gave over 180 speeches in the United States and abroad on nuclear safety and security. At NNSA, Captain Ostendorff served as central technical authority for nuclear safety and as chief operating officer of the agency. He played a significant leadership role in developing the future vision for the nation's national security laboratories and in evaluating options for nuclear weapons complex modernization. From 2003 to 2007, he was a member of the staff of the House Armed Services Committee. There, he served as counsel and staff director for the Strategic Forces Subcommittee with oversight responsibilities for the Department of Energy's Atomic Energy Defense Activities as well as the Department of Defense's space, missile defense, and intelligence programs. He served as staff chair for dozens of hearings at both the subcommittee and full committee level including highly visible hearings on the 9/11 Commission, the Weapons of Mass Destruction Commission, and other hearings associated with U.S. strategic forces. Captain Ostendorff was an officer in the U.S. Navy from 1976 until he retired in 2002. Entering the Rickover Nuclear Navy, he served on six submarines. During his naval career, he commanded a nuclear attack submarine and a nuclear attack submarine squadron and served as director of the Division of Mathematics and Science at the U.S. Naval Academy. His military decorations include four awards of the Legion of Merit and numerous unit and campaign awards. He earned a bachelor's degree in systems engineering from the U.S. Naval Academy, a law degree from the University of Texas, and a master's in international and comparative law from Georgetown University. He is a member of the State Bar of Texas.

Tammy C. Ottmer is a nationally-recognized expert in nuclear waste transportation safety. She was appointed to her position as Colorado Waste Isolation Pilot Plant (WIPP) program manager by the Governor of Colorado. In addition, she was delegated additional responsibility as manager over Nuclear Materials Transportation Oversight by Colorado State Patrol, including collaborative planning with shippers and carriers intending to move radioactive materials and nuclear waste through Colorado, the western region, and across the nation. She continues to design, develop, implement, and oversee nuclear materials transportation for new transportation campaigns utilizing the WIPP program as a model. A primary focus area continues to be the full implementation of the Western Governors' Association/U.S. Department of Energy (DOE) Cooperative Agreement for the Transportation of Transuranic Wastes. She works at regional and national levels to innovate approaches to ensure the safe transportation of transuranic materials, highway route controlled quantities, high-level radioactive waste as well as commercial spent nuclear fuel shipments in the distant future, whether to interim storage or permanent disposal. Ms. Ottmer has chaired committees chartered to update internal DOE manuals and then integrate them into the internal DOE Order system. These Orders have a direct correlation to safe transportation when they are incorporated into DOE Requests for Proposal for new contracts across the nation. Ms. Ottmer serves as advisor to the governor on nuclear transportation matters including the spent commercial nuclear fuel stored at the Fort Saint Vrain Independent Spent Fuel Storage Installation in northern Colorado. Ms. Ottmer has had an opportunity to serve in an international capacity. The International Atomic Energy Agency in Vienna, Austria, asked specifically for Ms. Ottmer to serve as a consultant. The mission of this consultancy was to review and evaluate international radiological transportation safety guides. The guides concerned transportation accidents involving radioactive materials as well as associated emergency response. She provided recommendations for the revisions of these transportation safety guides. Ms. Ottmer received a B.A. from the University of Colorado at Boulder.

Cecil V. Parks' career has spanned 40 years at Oak Ridge National Laboratory (ORNL) where he is currently director of the Nuclear Nonproliferation Division. Prior to this assignment, he served as director of the Nuclear Security and Isotope Technology Division, director of the Reactor and Nuclear Systems Division and director of the former Nuclear Science and Technology Division. In these senior leadership positions, Dr. Parks has been responsible for line management, strategic planning, and mission execution for diverse R&D organizations engaged in basic and applied science and technology for the nuclear fuel cycle, isotope production, and nuclear nonproliferation and safeguards. He has extensive experience in programmatic business development and execution with a wide range of government agencies including the Department of Energy (DOE), the National Nuclear Security Administration (NNSA), and the Nuclear Regulatory Commission (U.S. NRC). From 1980 to 2014, Dr. Parks had project or line responsibility for development of the SCALE code system, which is used worldwide to solve challenging problems in reactor physics and depletion, criticality safety, and radiation transport. For 36 years, Dr. Parks has consulted on technical and safety issues associated with transport and storage of fissile and radioactive material. From 1992 to 2012, he supported the U.S. NRC and the U.S. Department of Transportation as the U.S. technical expert to the International Atomic Energy Agency on packaging requirements and transport controls for fissile material. Dr. Parks has been active in professional societies and a member, facilitator, or leader of various review teams chartered by the NNSA, DOE, or the U.S. NRC. Dr. Parks is the author or co-author of over 150 technical papers, ORNL or U.S. NRC reports, and journal articles, and has been engaged in standards development related to nuclear criticality safety. Dr. Parks has a Ph.D. in nuclear engineering from the University of Tennessee and M.S. and B.S. degrees in nuclear engineering from North Carolina State University. He also has a B.S. in mechanical engineering from North Carolina State University. Dr. Parks is a fellow of the American Nuclear Society.

Matthew K. Silva served 10 years as the chemical engineer and 4 years as the director of the New Mexico Environmental Evaluation Group until its closure in 2004. As mandated by federal law, the organization provided an independent technical evaluation of the WIPP project to ensure the protection of the safety and public health of the people of New Mexico. He holds a B.S. in basic science and an M.S. in petroleum engineering from the New Mexico Institute of Mining and Technology. Additionally, he holds a Ph.D. in chemical engineering from the University of Kansas.

Staff

Jennifer Heimberg (study director) has been a senior program officer at the National Academies of Sciences, Engineering, and Medicine since 2011. She has directed studies within the Divisions of Earth and Life Studies (DELS) and Behavioral and Social Sciences and Education (DBASSE). Her work within DELS' Nuclear and Radiation Studies Board focuses on nuclear security, nonproliferation, and nuclear environmental cleanup. Reports include *Reducing the Use of Highly Enriched Uranium in Civilian Research Reactors*; *Performance Metrics for the Global Nuclear Detection Architecture*; and *Best Practices for Risk-Informed Decision Making Regarding Contaminated Sites: Summary of a Workshop*. Within DBASSE, she has worked with the Boards on Environmental Change and Society (BECS) and Behavioral, Cognitive, and Sensory Sciences (BBCSS). For BECS, she directed a high-profile study resulting in the report *Valuing Climate Damages: Updating the Estimation of the Social Cost of Carbon Dioxide*, for which she won the 2017 National Academies Staff Award "Best in a Leading Role." For BBCSS, she is leading a large group of Academies staff to manage the new study, *Reproducibility and Replicability in Science*. Prior to coming to the National Academies, she worked as a program manager at the Johns Hopkins University Applied Physics Laboratory for nearly 10 years. While at APL she established and grew its nuclear security program with the Department of Homeland Security's Domestic Nuclear Detection Office. She received a B.S. cum laude in physics from Georgetown University, a B.S.E.E. from Catholic University of America, and a Ph.D. in physics from Northwestern University.

Kevin D. Crowley has been an advisor to the Nuclear and Radiation Studies Board (NRSB) at the National Academies of Sciences, Engineering, and Medicine in Washington, DC, since entering phased retirement in August 2017. His professional interests focus on the application of science & technology to improve societal wellbeing, advance public policymaking, and enhance international cooperation, particularly with respect to the safety, security, and efficacy of nuclear and radiation-based technologies and applications. He previously held several positions at the National Academies, including senior board director of the NRSB (2005-2017), director of the Board on Radioactive Waste Management (1996-2005), and principal investigator for a long-standing cooperative agreement between the National Academy of Sciences and the U.S. Department of Energy to provide scientific support to the Radiation Effects Research Foundation in Hiroshima, Japan (2010-2017). Before joining the National Academies staff in 1993, Dr. Crowley held teaching/research positions at Miami University of Ohio, the University of Oklahoma, and the U.S. Geological Survey. He holds M.A. and Ph.D. degrees, both in geology, from Princeton University.

Richard “Dick” Rowberg is currently on phased retirement and is a senior advisor for the Division of Engineering and Physical Sciences (DEPS) of the National Academies of Sciences, Engineering, and Medicine (NASEM). Prior to retirement from the National Academies, he was Deputy Executive Director of DEPS. He has served at the National Academies since 2002. From 1985 to 2001, he worked for the Congressional Research Service of the Library of Congress. From 1994 to 2001, Dr. Rowberg was a senior specialist in science and technology with the Resources, Science, and Industry Division, and from 1985 to 1994, he was chief of the Science Policy Research Division. From 1975 to 1985, Dr. Rowberg worked for the Congressional Office of Technology Assessment (OTA). From 1975 to 1979 he served as an analyst in and deputy manager of the OTA Energy Program, and from 1979 to 1985, he was manager of the OTA Energy and Materials Program. From 1969 to 1974, Dr. Rowberg was a research engineer and adjunct assistant professor in the Department of Electrical Engineering of the University of Texas at Austin. He received a B.A. in physics from University of California, Los Angeles (UCLA) in 1961, and a Ph.D. in plasma physics from UCLA in 1968. In 2010, Dr. Rowberg was elected a fellow of the American Physical Society.

Appendix B

Information-Gathering Sessions

DISPOSAL OF SURPLUS PLUTONIUM IN THE WASTE ISOLATION PILOT PLANT

MEETING #1: NOVEMBER 28-30, 2017

The Keck Center
500 Fifth Street NW
Washington, DC 20001

<u>Tuesday, November 28, 2017</u>

DATA-GATHERING SESSION OPEN TO THE PUBLIC
Keck Room 208

1:00 PM **Call to order and welcome, brief introductions by the committee**
Bob Dynes, Committee Chair

1:15 PM **National Nuclear Security Administration (NNSA) Overview of the Material Management and Minimization Program and the Committee's Tasking**
Peter Hanlon, NNSA, Assistant Deputy Administrator for Material Management and Minimization

1:40 PM **Plutonium Dilute and Dispose Program Scope and Status**
Sachiko McAlhany, NNSA, Senior Technical Advisor

2:40 PM **BREAK**

3:00 PM **The Waste Isolation Pilot Plant (WIPP) and Disposal of Surplus Plutonium**
Betsy Forinash, Director, National Transuranic Waste Program-HQ, DOE-EM

3:45 PM **Environmental Protection Agency's Activities Related to the Plutonium Dilute and Dispose Program**
Thomas Peake, EPA Radiation Protection Division, Director for the Center for Waste Management and Regulations

4:45 PM **Opportunity for Public Comment**

5:00 PM **End Data-Gathering Session**

<u>Wednesday, November 29, 2017</u>

DATA-GATHERING SESSION OPEN TO THE PUBLIC
The Keck Center, Room 208

9:00 AM	**Call to order and welcome, open session reminder** *Bob Dynes, Committee Chair*
9:10 AM	New Mexico Stakeholder Perspectives: Southwest Research and Information Center *Don Hancock, director,* via Webcast
9:40 AM	Dilute and Dispose: The Best Available Approach for Excess Plutonium Disposition *Ed Lyman, Senior Scientist, Global Security Program, Union of Concerned Scientists*
10:30 AM	**BREAK**
10:45 AM	Perspectives from the U.S. Government Accountability Office *David Trimble, Director, Natural Resources and Environment, U.S. GAO* *Eli Lewine, Senior Analyst, Natural Resources and Environment, U.S. GAO*
11:30 AM	Historical Perspectives and Congressional Authorities *James Werner, Congressional Research Service*
12:15 PM	BREAK for LUNCH, catered for committee members
1:00 PM	Plutonium Disposal Considerations *Matthew Bunn, Professor of Practice, Harvard Kennedy School, Belfer Center for Science and International Affairs*
1:40 PM	**Opportunity for Public Comment**
2:00 PM	**End public session**

<u>Thursday, November 30, 2017</u>

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC
Department of Energy, Forrestal Building

8:30 AM	**Meet at the Forrestal Building for check-in, badging, and security check**
9:00 AM	**Welcome and Introductions, Review Security Procedures** **Briefings**
12:45 PM	**Wrap-up**
1:00 PM	**ADJOURN**

Note: The data-gathering session of this meeting to be held on November 30, 2017, from 9:00 AM to 1:00 PM, EST, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open this session to the public would disclose information described in 5 U.S.C. § 552(b).

MEETING #3: FEBRUARY 12-13, 2018

Gressette Senate Office Building - Committee Room 105
South Carolina Capitol Complex
1101 Pendleton Street
Columbia, SC 29201

Monday, February 12, 2018

DATA-GATHERING SESSION OPEN TO THE PUBLIC
Gressette Senate Office Building – Committee Room 105,
South Carolina Capitol Complex, Columbia, SC

5:00 PM **Call to order and welcome**

- Brief introductions of committee and staff
- Review of the meeting agenda and objectives
- Overview of SRS Site Tours
  Robert (Bob) Dynes, committee chair
  Jennifer (Jenny) Heimberg, study director

Perspectives, Concerns, and Questions About DOE Plans to Dilute and Dispose of Surplus Plutonium at WIPP

5:15 PM *Rick Lee, Chair of the Governor's Nuclear Advisory Council*
Charles W. Hess, Vice President, High Bridge Associates

5:45 PM *James Marra, Director, Citizens for Nuclear Technology Awareness*

6:15 PM *Gil Allensworth, Chair, SRS Citizens Advisory Board (CAB)*

6:45 PM *Christopher Wells, Assistant Director of Nuclear Programs, Southern States Energy Board*

7:05 PM **Public Comments**
The committee will listen to comments from the public. Each comment period will be limited to 3 minutes. Note that the committee accepts written comments at any time during the study. Please send written comments to Plutonium_Disposition@nas.edu.

7:30 PM **ADJOURN Day One**

Note: The data-gathering sessions of this meeting to be held on February 12, from 10:00 AM to 11:00 PM, EST, and February 13, 2018, from 9:00 AM to 1:30 PM, EST, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open these sessions to the public would disclose information described in 5 U.S.C. § 552(b).

Appendix H

MEETING #4: MARCH 12-14, 2018

New Mexico trip:
Los Alamos, Albuquerque, Carlsbad,
and the Waste Isolation Pilot Plant (WIPP)

Monday, March 12, 2018

The classified subgroup will visit Los Alamos National Laboratory (LANL) in the morning of March 12.

SITE VISIT
Los Alamos National Laboratory, ARIES Facility

8:00 AM **Welcome and the Advanced Recovery and Integrated Extraction System (ARIES) Overview and Related Dilute and Dispose Activities (To Be Determined LANL Personnel)**

8:30 AM **Tour ARIES**

11:00 AM **LUNCH on-site, catered**
Meeting with dilute and dispose NNSA Staff

11:30 AM **End Tour**

DATA-GATHERING SESSION OPEN TO THE PUBLIC
Sheraton Albuquerque Airport Hotel, Gran Quivera Room, Albuquerque, NM

5:00 PM **Call to order and welcome**
- Brief introductions of committee and staff
- Review of the meeting agenda and objectives
  Robert (Bob) Dynes, Committee Chair
  Jennifer (Jenny) Heimberg, Study Director

5:15 PM **Perspectives, Concerns, and Questions About DOE Plans to Dilute and Dispose of Surplus Plutonium at WIPP**
George Anastas, retired, Past President of Health Physics Society

5:45 PM **Disposal of Plutonium at WIPP**
Don Hancock, Southwest Research and Information Center, Director of Nuclear Waste Programs

6:15 PM **Perspectives, Concerns, and Questions About DOE Plans to Dilute and Dispose of Surplus Plutonium at WIPP**
Lokesh Chaturvedi, Ph.D., Independent Consultant

6:45 PM **The Role of the Governor's Radioactive Waste Consultation Task Force**
Ken McQueen, Cabinet Secretary of New Mexico's Energy, Minerals, and Natural Resources Department

7:00 PM **Public Comments**
The committee will listen to comments from the public. Each comment period will be limited to 3 minutes. Note that the committee accepts written comments at any time during the study. Please send written comments to Plutonium_Disposition@nas.edu.

7:30 PM **ADJOURN Day One**

Tuesday, March 13, 2018

DATA-GATHERING SESSION OPEN TO THE PUBLIC
Skeen Whitlock Building, Carlsbad, NM

4:00 PM **Call to order and welcome**
- Brief introductions of committee and staff
- Review of the meeting agenda and objectives
- Overview of the TRANSCOMM and EOC tours
  Robert (Bob) Dynes, Committee Chair

4:15 PM **WIPP Regulatory and Operations Overview**
Todd Shrader, Manager, Carlsbad Field Office
George Basabilvazo, Chief Scientist, Carlsbad Field Office

Perspectives, Concerns, and Questions About DOE Plans to Dilute and Dispose of Surplus Plutonium at WIPP

6:00 PM *Russell Hardy, Director, Carlsbad Environmental Monitoring & Research Center*

6:20 PM *John Heaton, Chairman of the Mayor's Nuclear Task Force*

6:40 PM *Cathrynn Brown, State Representative and Susan Crockett, Eddy County Commissioner*

7:00 PM **Public Comments**
The committee will listen to comments from the public. Each comment period will be limited to 3 minutes. Note that the committee accepts written comments at any time during the study. Please send written comments to Plutonium_Disposition@nas.edu.

7:30 PM **ADJOURN Day Two**

Note: The data-gathering session of this meeting to be held on March 12, 2018 from 8:00 AM to 11:30 AM, MDT, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open this session to the public would disclose information described in 5 U.S.C. § 552(b).

Appendix H

MEETING #7: MAY 2-3, 2018

The Keck Center
500 Fifth Street NW
Washington, DC 20001

<u>Wednesday, May 2, 2018</u>

DATA-GATHERING SESSION OPEN TO THE PUBLIC
The Keck Center, K208

2:30 PM **New Mexico's Agreements, Laws, and Regulations: Review of Potential Changes to the Land Withdrawal Act (LWA) and Consultation and Cooperation (C&C) Agreement**
Lindsay Lovejoy, Attorney

3:30 PM **Termination of Safeguards for the Surplus Plutonium in the Dilute and Dispose Option**
Debarah S. Holmer, Office of Environment, Health, Safety and Security (EHSS/AU), Department of Energy (DOE)

4:00 PM **Outline of the Dilute and Dispose Option Life Cycle Cost Estimate (LCCE) Contents**
Virginia Kay, Deputy Director, Office of Material Disposition (NA-233), Office of Material Management and Minimization, National Nuclear Security Administration, DOE

4:30 PM **Public Comments**

4:45 PM **ADJOURN**

MEETING #8: JUNE 26, 2018

The Arnold and Mabel Beckman Center
100 Academy Drive
Irvine, CA 92617

Tuesday, June 26, 2018

All times shown below are Pacific Standard Time.

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC
Beckman Center, Board Room

12:00 PM **Welcome and Call to Order**
Robert (Bob) Dynes, Committee Chair

12:15 PM **Overview of Current Status and Next Steps of the Dilute and Dispose Program**
Pete Hanlon, Assistant Deputy Administrator, Defense Nuclear Nonproliferation, National Nuclear Security Administration (NNSA)

12:45 PM **Surplus Plutonium Disposition Program**
Sachiko McAlhany, Senior Technical Advisor, NA-23
Todd Shrader, Manager, Carlsbad Field Office, DOE-EM
Samuel Callahan, Director, Office of Security, AU-50

2:30 PM **BREAK in the Foyer**

DATA-GATHERING SESSION: OPEN TO THE PUBLIC
Beckman Center, Board Room

2:40 PM **Welcome**
Robert (Bob) Dynes, Committee Chair

2:45 PM **Planning, Inventory and Capacity at the Waste Isolation Pilot Plant (WIPP)**
Todd Shrader, Manager, Carlsbad Field Office, Department of Energy,
Office of Environmental Management (DOE-EM)

3:45 PM **End Data-Gathering Session Open to the Public**

DATA-GATHERING SESSION: NOT OPEN TO THE PUBLIC
Beckman Center, Board Room

3:50 PM CONT'D (if needed) **Surplus Plutonium Disposition Program**

Sachiko McAlhany, Senior Technical Advisor, NA-23
Todd Shrader, Manager, Carlsbad Field Office, DOE-EM
Samuel Callahan, Director, Office of Security, AU-50

5:00 PM **NNSA's Quantities and Production Rates**
Sachiko McAlhany, Senior Technical Advisor, NNSA

6:00 PM **ADJOURN**

Note: The data-gathering sessions of this meeting to be held on June 26, 2018, from 12:00 noon to 2:30 PM and 3:45 PM to 6:00 PM, PDT, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open these sessions to the public would disclose information described in 5 U.S.C. § 552(b).

CLASSIFIED SUBGROUP ONLY: AUGUST 23, 2018

Video Teleconference (VTC)

DRAFT AGENDA

Thursday, August 23, 2018 (all times shown are Eastern)

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC
VTC: DOE-HQ, LLNL, and ORNL

12:00 PM **Sachiko McAlhany, National Nuclear Security Administration (NNSA)**

1:45 PM **Move to Committee-Only session**
Robert Dynes, Chair, Committee on the Disposal of Surplus Plutonium

3:30 PM **ADJOURN**

Note: The data-gathering session of this meeting to be held on August 23, 2018, from 12:00 noon to 2:30 PM, EDT, will not be open to the public under Subsection 15(b)(3) of the Federal Advisory Committee Act, 5 U.S.C. App. The Academy has determined that to open this session to the public would disclose information described in 5 U.S.C. § 552(b).