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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

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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.

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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:

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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.

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Contents

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Summary

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[3] 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,[4] 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).[5,6] 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

[1]The mandate appears in House Report 114-532, Energy and Water Development Appropriations Bill, 2017.

[2]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."

[3]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.

[4]Release of these planning documents to the committee has been delayed by recent legal actions between South Carolina and DOE.

[5]One metric ton (MT), or 1000 kg, is equivalent to 2,205 pounds (lbs) or 1.1 U.S. tons.

[6]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.

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

plutonium into mixed oxide (MOX) fuel[7] 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.

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.[8] 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

[7]MOX fuel contains plutonium and uranium, both in oxide form.

[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 for Secretary Perry to take such action was granted through the National Defense Authorization Act for Fiscal Year 2018 P.L. 115-91.

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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 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

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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 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

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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?

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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 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."

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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.

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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:

---

[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.

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> 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 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.

[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).

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

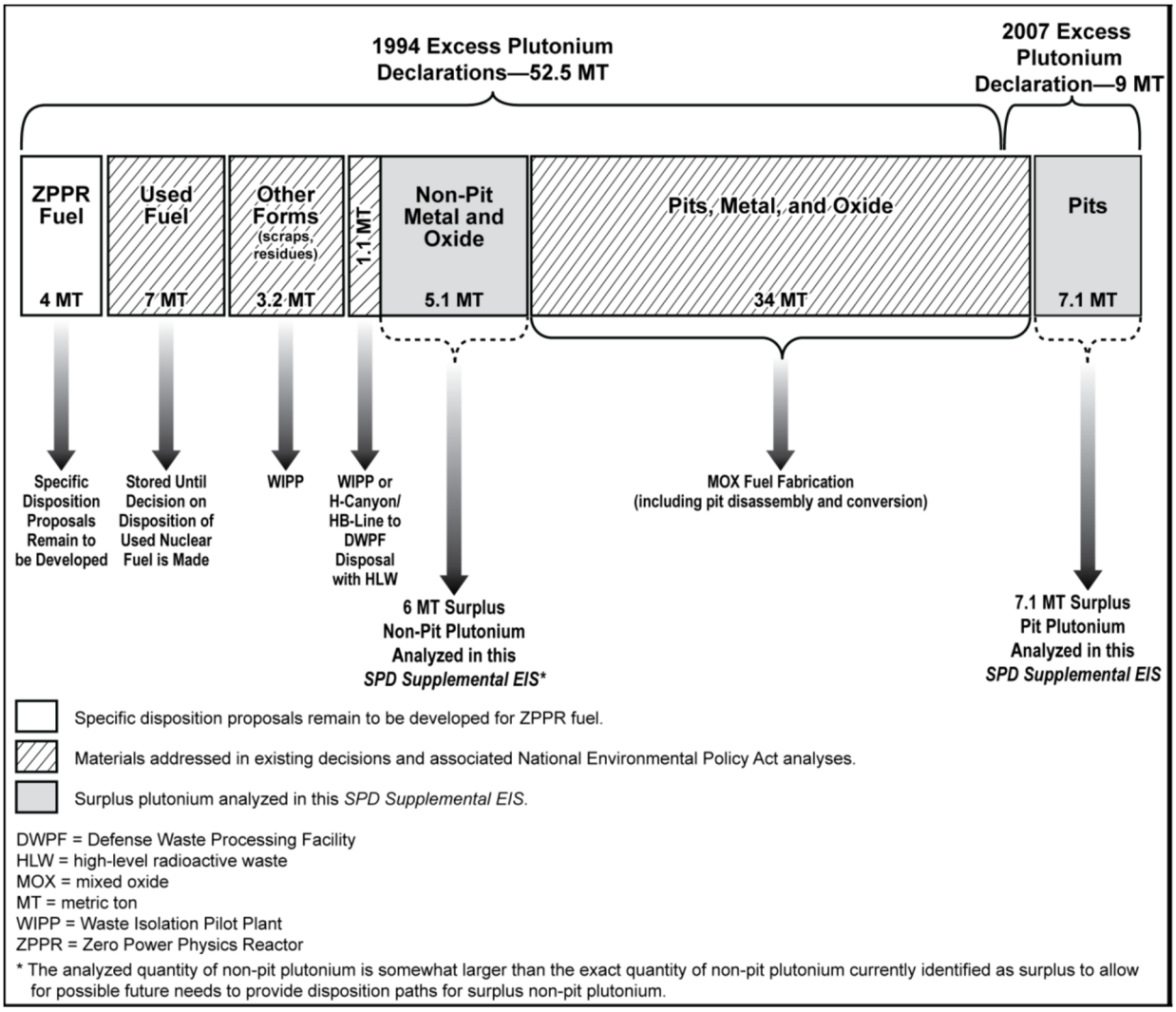

FIGURE 2-1 U.S. surplus plutonium quantities and disposition pathways. The total of 61.5 MT includes two declarations: the first in 1994 and another in 2007. A portion of the 2007 declaration is included in the 34 MT allocated to satisfy the Plutonium Management Disposition Agreement (PMDA) shown with 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.

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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.

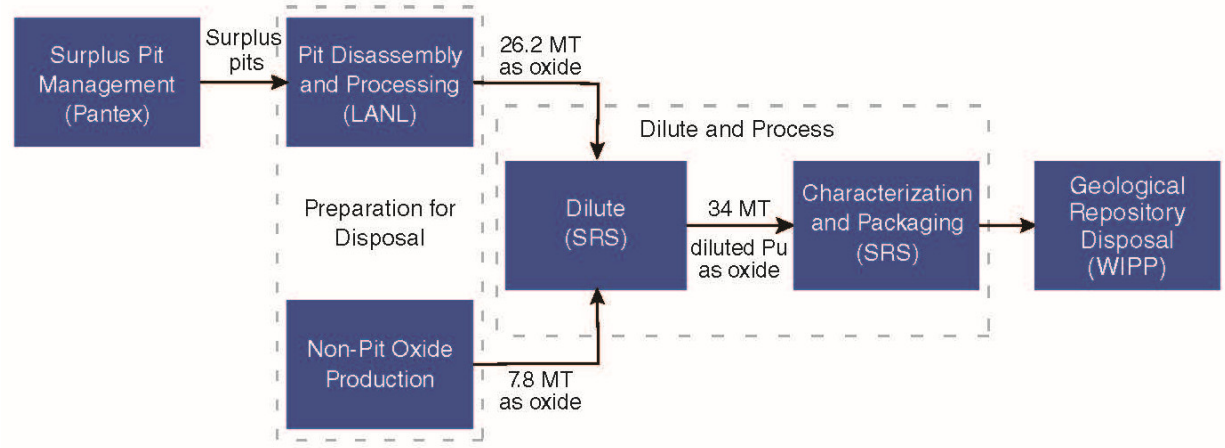

FIGURE 2-2 Conceptual flowsheet for the DOE-NNSA dilute and dispose processes. The process is described in the text. The combined amount of pit and non-pit plutonium is 34 MT. SOURCE: Modified from image provided by the U.S. Department of Energy (Kay 2018).

[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)

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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 Transport (OST).

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.

[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.

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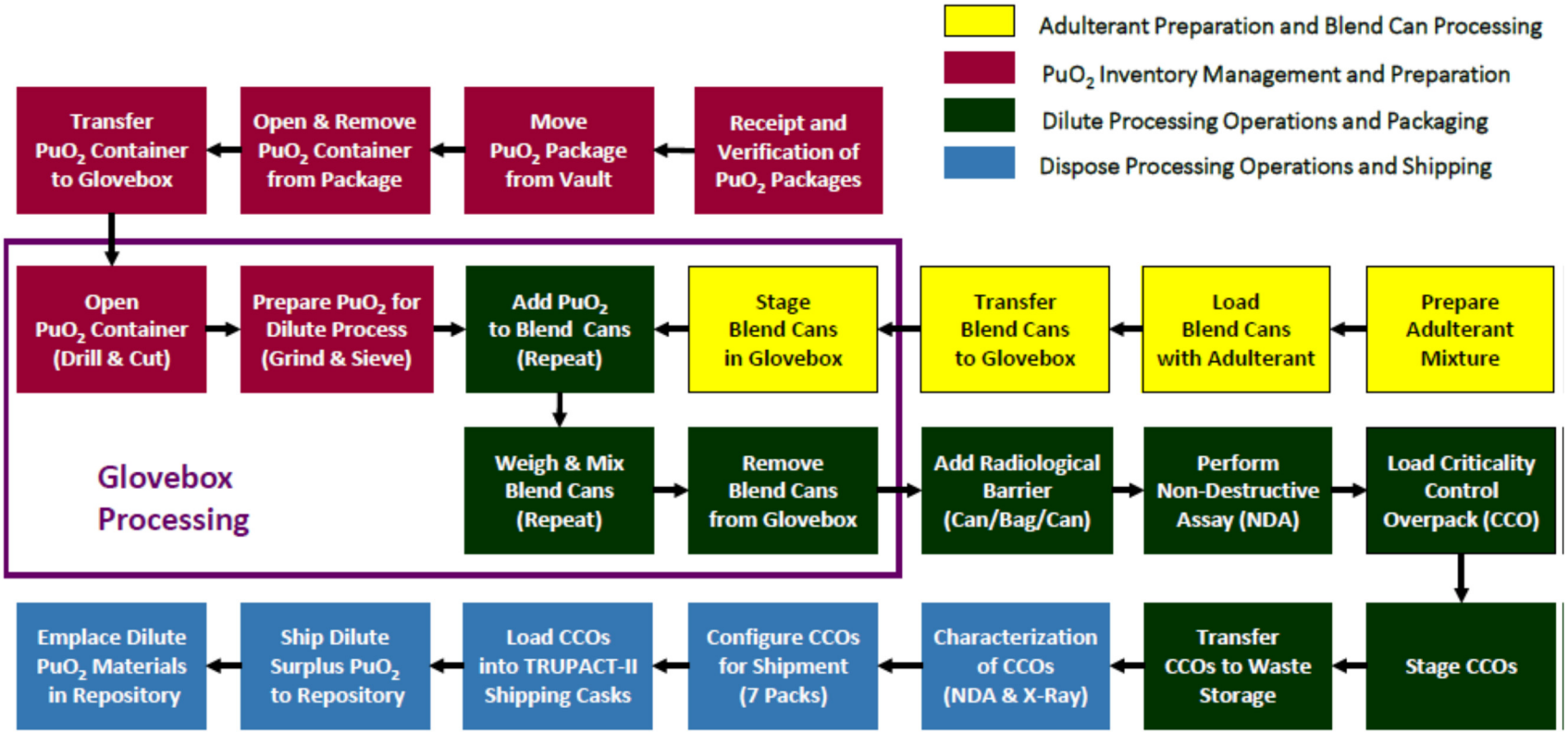

FIGURE 2-3a Block diagram of the "Dilute and Processing" and "Geological Repository Disposal" steps shown in Figure 2-2, beginning with receipt of the oxidized plutonium at the Savannah River Site (Receipt and Verification of the PuO_2 [plutonium oxide] Packages) and ending with emplacement in WIPP. As the final diluted product is prepared to be removed from the glovebox, no more than 150 fissile gram equivalents (FGE) of plutnoium-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).

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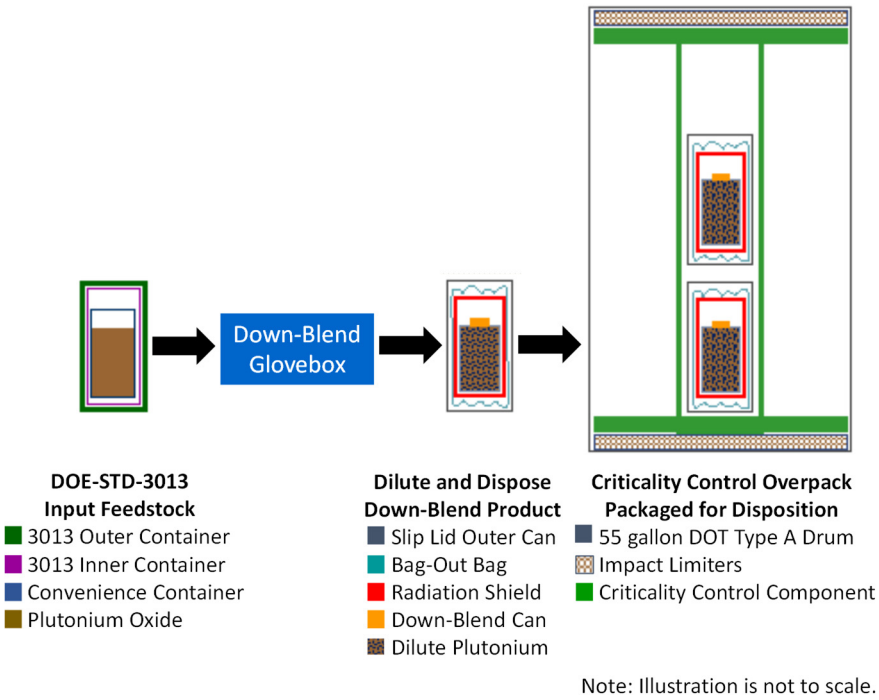

FIGURE 2-3b Cross sections of the plutonium containers used in the process outlined in Figure 2-3a. At Los Alamos National Laboratory, the oxidized plutonium is placed into DOE-STD-3013 containers. Upon arrival at the Savannah River Site, the same containers are used to store the plutonium oxide until 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.[14] The DOE OST[15] 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."[16] 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.

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

[15]See https://www.energy.gov/nnsa/office-secure-transportation (accessed September 10, 2018).

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

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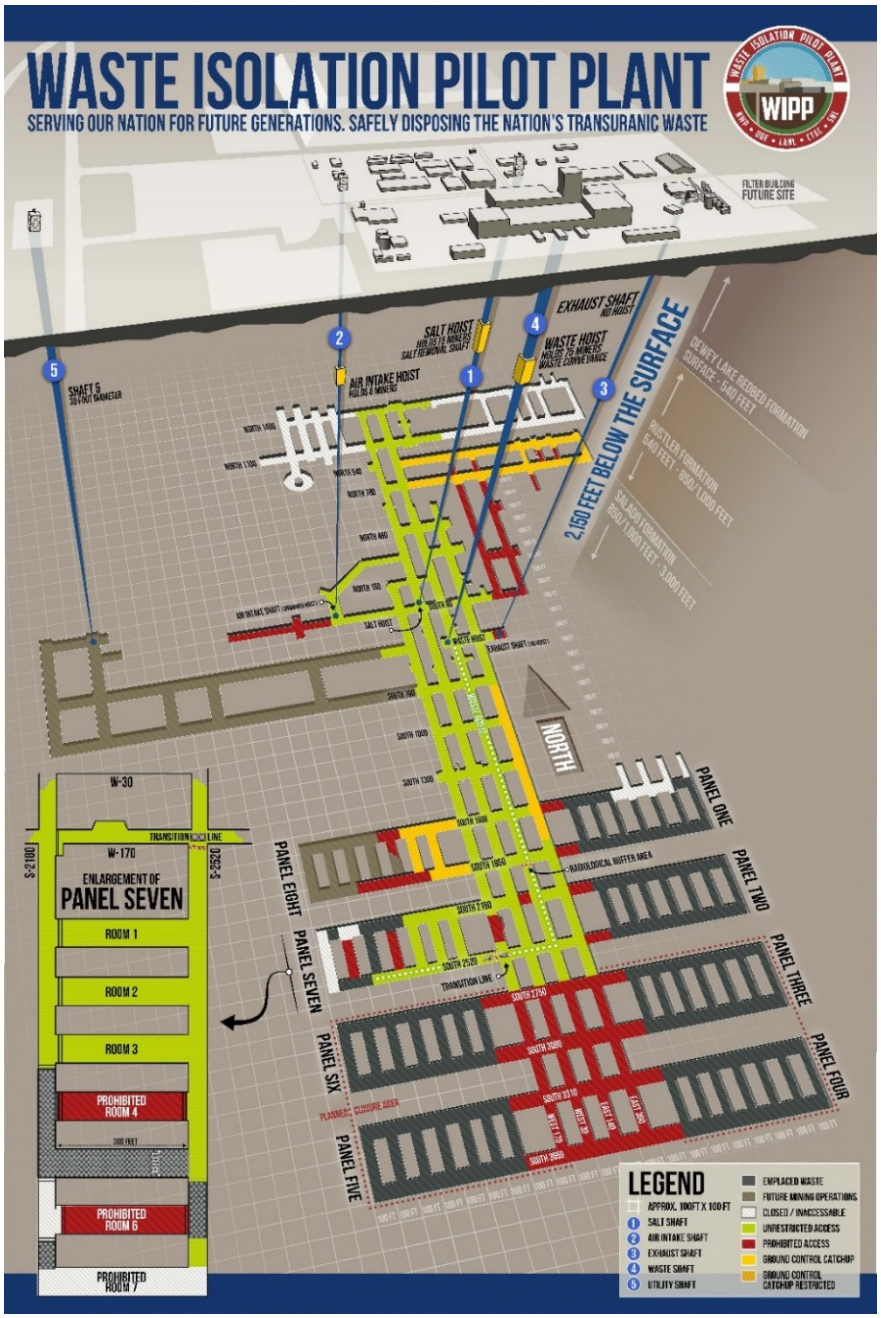

FIGURE 2-4 Schematic layout of the Waste Isolation Pilot Plant, which is located in southeastern New Mexico near Carlsbad. WIPP began accepting defense-generated transuranic (TRU) waste in 1999. The location of the emplaced TRU waste is about 2,150 feet (655 meters) below the surface within a salt formation (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.

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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).[17]

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 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)

[17]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).

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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***.

FY2019

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.

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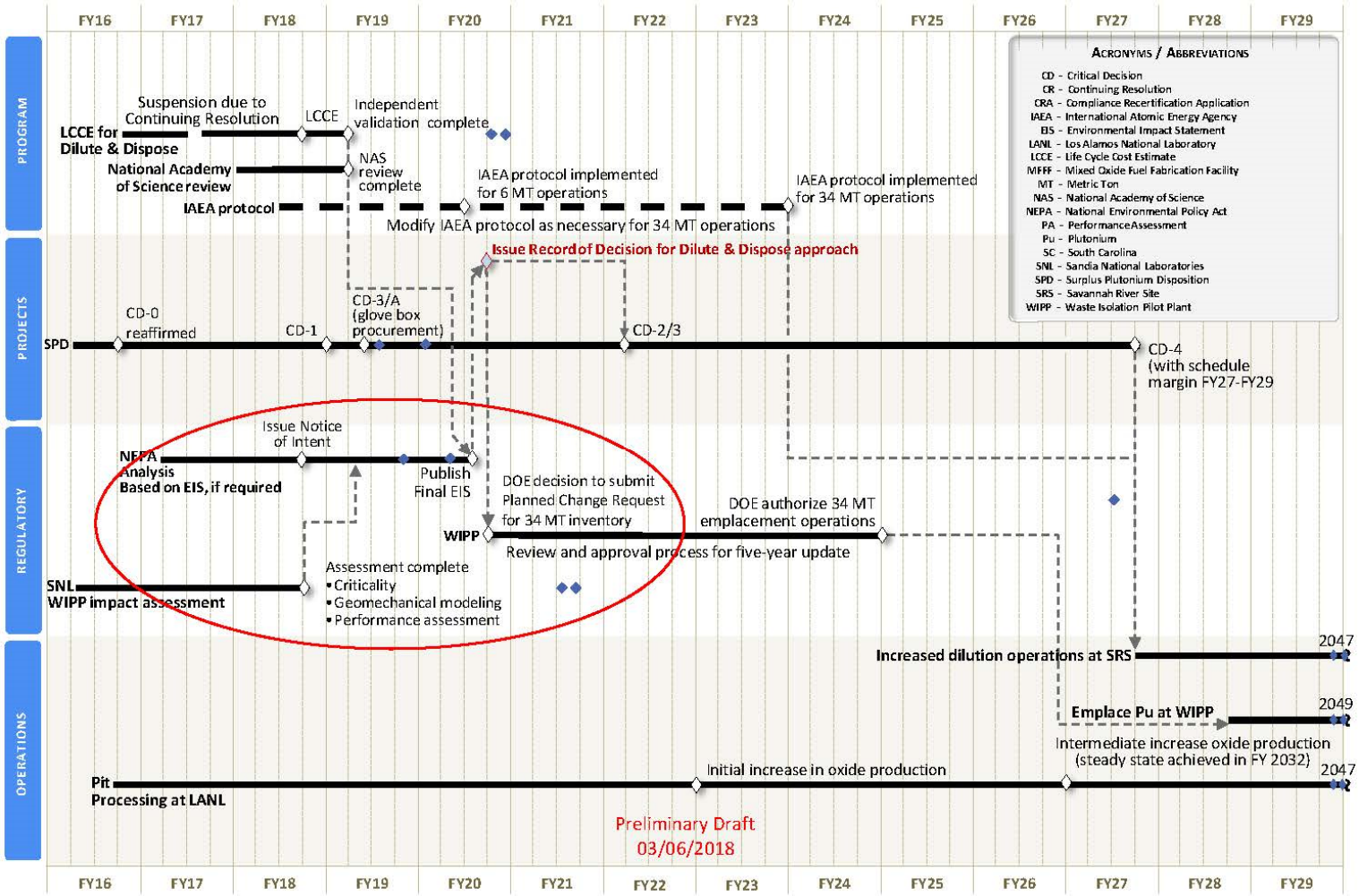

FIGURE 2-5: High-level schedule for the dilute and dispose conceptual plan, developed in March 2018 and considered preliminary. Some of the information and analysis expected by this committee are shown in the red circle: WIPP Impact Assessment (criticality, geomechanical, and performance assessments), life-cycle cost estimate which contains scheduling and program planning details), and the Notice of Intent. SOURCE: Kay 2018.

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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

[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.

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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 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]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."

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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 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

[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.

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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.

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). Their 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]

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).

[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).

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- 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.

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]).

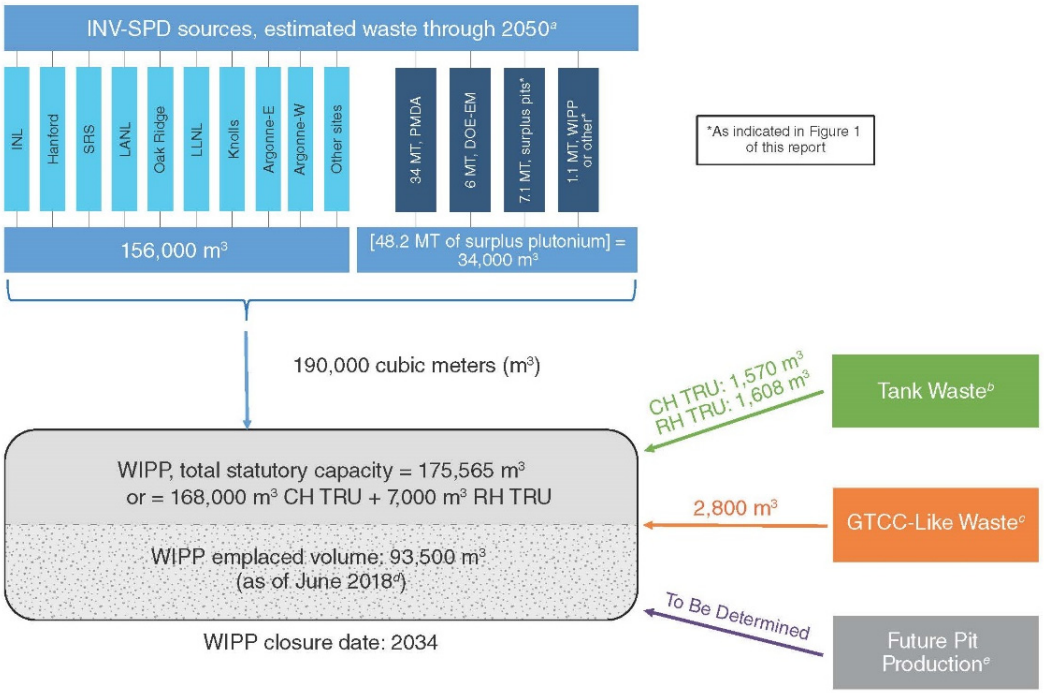

FIGURE 3-1 Committee-generated estimate of the volume required for disposal of various waste streams in WIPP. SOURCES: (a) LANL 2017; (b) DOE written responses to NAS Question Set Two, prepared by the Committee on the Disposal of Surplus Plutonium in the Waste Isolation Pilot, unpublished manuscript (last modified June 6, 2018, received on September 28, 2018); (c) DOE 2016b; (d) Todd Shrader, presentation to committee, 2018; (e) Request for data to DOE, submitted August 8, 2018.

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

- 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).
- 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 innermost container volumes is 91,709 m^3 while the volume based on the innermost container volumes, 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

[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 facility (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.

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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 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 appears 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.

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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:

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 isolation pilot plant (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.

[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).

[17]See 50 U.S.C. §2566 (2010).

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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.

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.

[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.

[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).

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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 Transport, 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)

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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.

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:*

[22] See https://www.ecfr.gov/cgi-bin/text-idx?SID=a4e055019b59e975ce6b588a419d7b2d&mc=true&node=pt10.4.1021&rgn=div5.

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

> *(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
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.

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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.

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:

[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).

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

> *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.

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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]

[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).

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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]

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.

[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).

[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.

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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 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.

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.,

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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.

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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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 LaJolla 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.

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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; and American Nuclear Society Fellow, 2006; Waste Management Symposia Wendell D. Weart Life Time

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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.

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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

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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.

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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.

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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 Behavioural, 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.

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Kevin D. Crowley has been an advisor to the Nuclear and Radiation Studies Board (NRSB) at 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.

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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

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-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**

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Wednesday, November 29, 2017

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**

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

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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).

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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

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

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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).

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MEETING #7: 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
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)

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Disposal of Surplus Plutonium at the Waste Isolation Pilot Plant: Interim Report

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).

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Appendix 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).

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