Final Report of the Plutonium Disposition Red Team

Date: 13 August 2015

Oak Ridge, Tennessee

Thom Mason, Chair

If DOE chooses to pursue this opportunity, it will be important to assess implications to the NRC license and fuel quality to define an efficient path forward and maximize potential savings.

3. Dilute and Dispose, and Similar Options

For purposes of considering alternatives that have not already been screened out as impractical, the Red Team articulated a guiding principle to use as a framework for examining alternative approaches:

> "Develop an alternative disposition pathway that can be executed at an affordable cost, with an acceptable schedule and risk profile, using an approach that has a reasonable probability of achieving Russian concurrence on a revised PMDA."

Having screened out all previously considered alternatives to MOX other than Dilute and Dispose, the Red Team attempted a systematic approach to developing practical variations to this remaining alternative using this guiding principle. A broad definition of the possible approaches is shown in Figure 4 with five different levels of options possible (A through E). The options span a spectrum from the minimum condition (do nothing), up to and including the current approach, with the baseline MOX approach shown as option E for the sake of comparison. Based on sponsor input and collected information, the first filter that the Red Team applied towards the range of remaining options was the desire to minimize the proliferation risk associated with disposition. Options A and B from Figure 4 were eliminated from further consideration since the disposition form is an intact pit that fails to provide adequate protection against proliferation. So the remaining option categories were C) the sterilization option, D) the Dilute and Dispose option, and E) the MOX approach. The MOX approach was evaluated previously in this document, and the sterilization approach will be discussed later, in Section 3.2. Section 3.1 evaluates alternative category D (Dilute and Dispose) from Figure 4. For purposes of this report, the downblending option as described in the PWG report is considered a "base" concept for the Red Team's Dilute and Dispose option (alternative D), takes the path of D2 in Figure 4, and is the subject of Section 3.1.1. Opportunities to improve upon that base approach, including the path represented by D1 in Figure 4, are addressed in Section 3.1.2.

3.1 The Dilute and Dispose Option

3.1.1 The Base Case (D2 from Figure 4)

3.1.1.1 Description of the Basic Dilute and Dispose Option

This option would involve the dilution of 34 MT of excess plutonium oxide material with inert materials at SRS, packaging the diluted material into approved shipping containers, and transporting the shipping containers to WIPP where they would be placed in the underground panels for permanent disposal. The D2 base option shows pits being shipped from Pantex to LANL where they would be disassembled, the plutonium metal converted to plutonium oxide as in the MOX option (except to a lower acceptance standard than MOX feedstock), and the plutonium oxide transported to SRS for dilution prior to disposition to WIPP. The system diagram for this option is given in Figure 5.

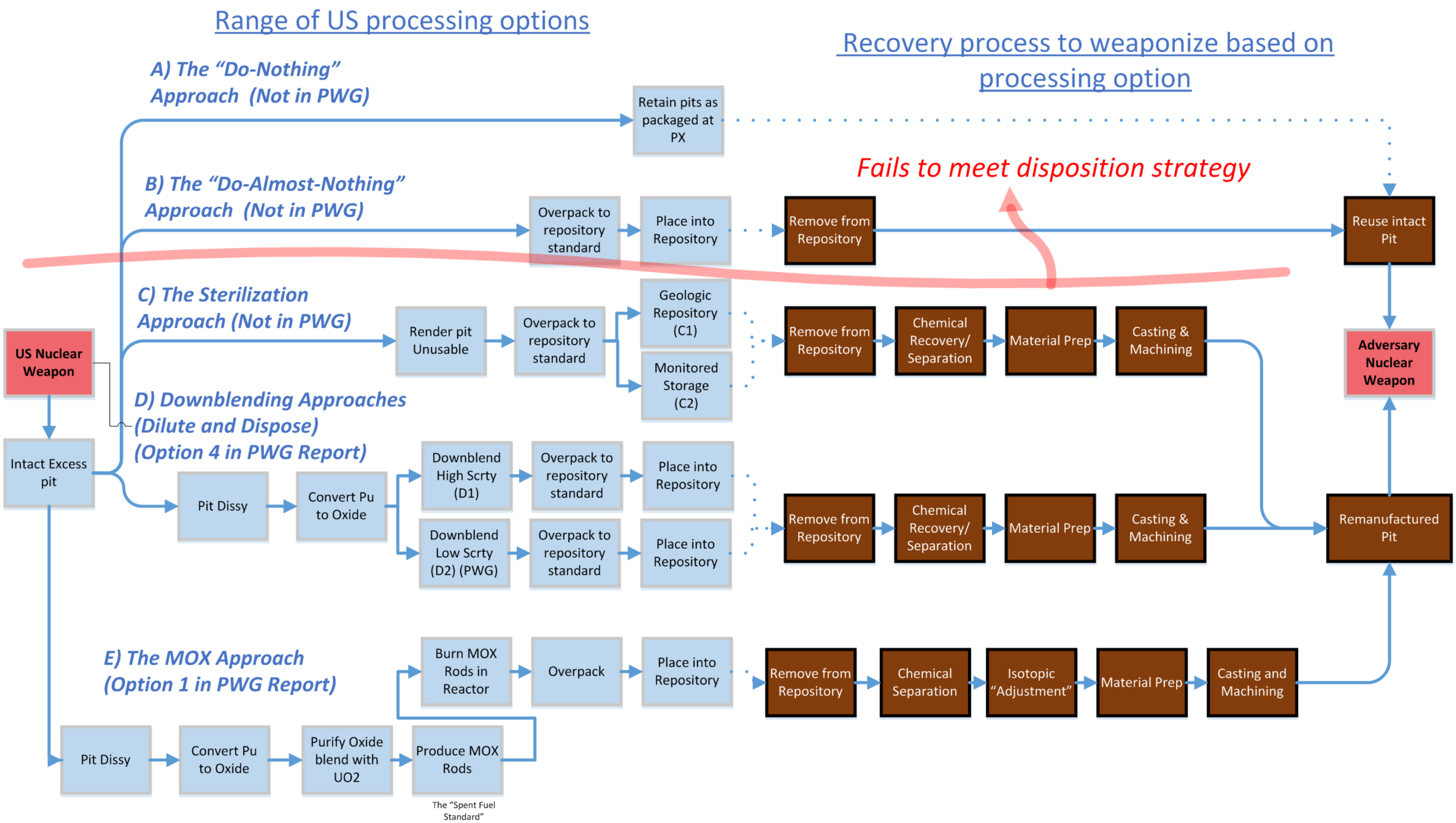

Figure 4. Remaining Practical Approaches to Pu Disposition

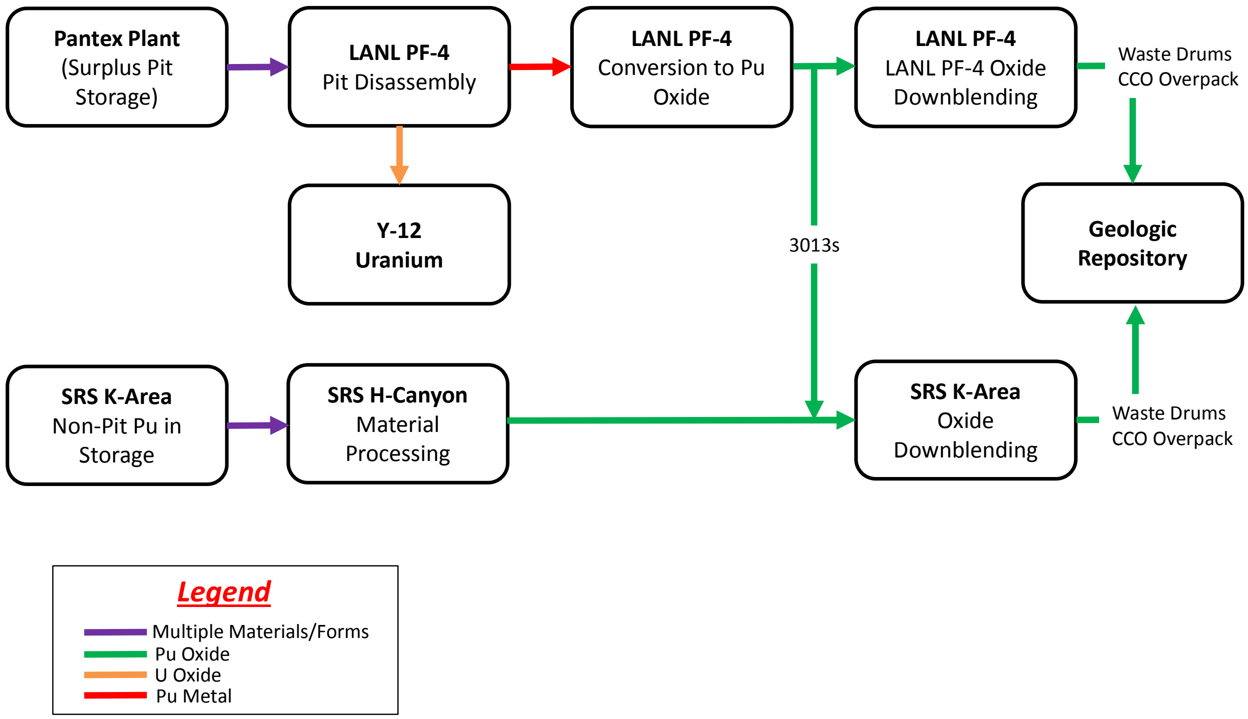

Figure 5. Basic Flow Diagram for the Dilute and Dispose Approach: This figure shows the major material flows for the base Dilute and Dispose approach as well as one variant, described later. Under this variant, LANL also dilutes material as a second production site, working in parallel with SRS.

The plutonium oxide would be diluted with an adulterant mixture that serves to reduce the attractiveness level of the plutonium oxide by yielding a mixture that: 1) has a reduced plutonium concentration; and 2) requires extensive processing to achieve a purified material. As such, the diluted plutonium oxide material would meet a Safeguards and Security Attractiveness Level D, and safeguards could be terminated on the material so that it could be disposed at the WIPP.

3.1.1.2 Technical Viability of Dilution and Disposal

To assess this option, the Red Team toured the SRS K-Area facility, the LANL PF-4 facility, and WIPP, and held multiple discussions with facility and Program personnel. Based on these inputs, and the fact that this approach for dispositioning excess plutonium oxide materials has already been used at several DOE sites in the past (the Rocky Flats Environmental Technology Site, the Hanford Site, and SRS), the Red Team judges that:

- The dilution of plutonium oxide with an inert adulterant is a low complexity technology;
- There are no real technical challenges to the successful implementation of this option, given the systems already in place to produce oxide for MFFF; and
- The primary risks with this approach would be regulatory and stakeholder issues.

As mentioned above, all of the dilution activities for the base version of this option would be done at SRS. Specifically, the dilution activities would occur in the K-Area Material Storage (KAMS) facility. Initially, the dilution activities would be conducted in the current KAMS glovebox, referred to as the K-Area Interim

Surveillance glovebox. The anticipated throughput of this glovebox is 400-500 kg of plutonium per year. To increase the throughput up to about 1,500 kilograms of plutonium per year, this option includes the installation of two additional gloveboxes into KAMS at an unofficial estimated cost of up to $240 million. That installation not only includes the two gloveboxes but also non-destructive assay equipment and changes to the KAMS documented safety analysis to allow for increased throughput, as well as support systems such as ventilation systems, fire suppression systems, staging rooms, electrical upgrades, and installation of several instrument and monitoring systems. The Red Team believes that the $240M estimate is conservative when compared to the much less expensive installation cost of the very similar, existing glovebox.

The diluted plutonium oxide material would be packaged in product cans, removed from the glovebox in bag-out sleeves, and packaged into a slip-lid can. That can-bag-can configuration would be loaded into a Criticality Control Overpack (CCO) that will be used to ship material to WIPP in a TRUPACT II. The average plutonium loading of the CCO is anticipated to be about 300 grams.

The disposition of the 34 MT of plutonium in this manner will be subject to international observation and remote monitoring by the IAEA. Therefore, some equipment would need to be installed in KAMS to support the IAEA activities. It should be noted that KAMS already has some SNM under international safeguards, so facility operators are familiar with the IAEA requirements.

The SRS activities for this option also include the conversion of a fraction of AFS metal to oxide using the H-Canyon for dissolution of the metal, with the purification, oxalate precipitation, and oxide conversion in the HB-Line. These activities are anticipated to be completed in 2022-2024 and are also required for the MOX Program to provide feed for the MFFF.

The Red Team toured the KAMS on July 28, 2015. Based on that tour, the Red Team judges that:

- There is sufficient footprint in KAMS facility available for dilution activities and associated storage and staging; and
- The previous experience in repurposing the KAMS facility for other purposes gives confidence in the viability of this approach.

The LANL activities for this option would essentially be the same as for the MOX Program. Specifically:

- All pit disassembly and oxidation of pit material would be done at LANL; and
- All oxidized plutonium pit material would be sent to SRS for dilution under the base approach.

However, there are three scope changes to the LANL activities relative to the MOX program, all of which effectively reduce the relative cost and risk of feed production for the Dilute and Dispose option as compared to MOX:

- No analysis of the product plutonium oxide would be necessary to show that the material meets the MOX feed specifications;
- Major elements of the LANL program (e.g., most QA and quality control requirements) intended to produce "certified" oxide would not be necessary since oxide production specifications would only be driven by transportation requirements and the WIPP waste acceptance criteria; and

- The milling/blending operation would be eliminated and other process equipment would be simplified throughout the manufacturing flowsheet.

With respect to facility modifications and/or equipment, there is an apparent synergy between existing equipment that would be removed and new equipment that would need to be added for capacity. After the tour of the PF-4 facility at LANL on July 16, 2015, the Red Team judges that:

- LANL has the technical capability needed to prepare plutonium oxide from pit plutonium metal, and has in fact demonstrated this capability at a pilot scale, producing oxide with a more demanding specification than would be needed for the Dilute and Dispose option;
- There is sufficient space available in the PF-4 facility to perform this scope without undue interference from existing and planned missions. While PF-4 is used for other missions and customers, and risk exists that other missions could impact Dilute and Dispose operations, the Red Team judges the probability of that occurring as low and concludes that the impacts of interruption are more severe to the MOX approach than to the Dilute and Dispose option.; and
- Resumption of operations will be a factor in PF-4 planning through 2016 for either the MOX approach or the Dilute and Dispose approach.

In this option all diluted plutonium oxide materials would be sent to WIPP for disposition. As previously discussed, WIPP has already received and disposed of such materials in the past. Thus, the receipt of similarly diluted materials is not expected to pose technical problems; but there are regulatory issues that would need to be addressed to allow the disposition of all 34 MT of plutonium (see Section 3.1.1.4). To accommodate the number of CCO packages anticipated for this option, at least one additional panel would need to be mined at a cost of about $8-10 million/panel, but it is not clear that this would be an NNSA cost. The scope of this option would also include the termination of the MFFF project; in fact this represents the largest cost element for the Dilute and Dispose option. The Red Team has assumed based on input from MOX Services that between $200M and $350M per year will be needed over the first three years to fund the MFFF project termination if the Dilute and Dispose option is selected for future execution.

In summary, the Dilute and Dispose approach uses simple, robust technological elements to produce a product suitable for disposal at WIPP. All of the processes necessary to produce, pack and ship diluted plutonium have been demonstrated in a production environment at multiple sites. The process requires no unique machine tools, gages or instruments that are not already a part of the process for making oxide and disposing of waste for the MOX approach. It also utilizes transportation techniques that are well established and proven. Stated another way, all of the technology required to produce a blended can of oxide is a subset of the technology required to produce certified oxide for the MOX approach. Thus, the technology is assessed to be mature having been demonstrated in a production environment.

These same processes will need to be scaled up to achieve a higher throughput capacity, but this scaling involves essentially no unique technical risk as it represents replication of existing equipment and relatively simple footprint expansion within existing facilities. In an effort to reduce dose, some of these processes may eventually be automated in the future, but initial operations are perfectly suited to manual activities to produce suitable product. Perhaps the greatest technical risk during full-scale operations will be the standard challenge of managing tightly controlled material movement logistics within a high security nuclear facility. Ultimately, the rate of oxide production at LANL is expected to control the maximum rate of diluted plutonium drums sent to WIPP each year.

Regardless, there is a stark contrast in the required technology for the MOX approach versus the Dilute and Dispose approach. Each involves the usual supporting technology required for safe and secure plutonium operations such as a complex facility ventilation system, airlocks, nuclear material control and accountability, etc., but the technology comparison is between the highly automated process equipment in a newly constructed, highly controlled MFFF on the cutting edge of integrated manufacturing technology, versus the simple mixing and measuring technology of the Dilute and Dispose approach.

3.1.1.3 Ability to Meet International Commitments

While the NAS report adopted a SFS as discussed at the beginning of this report, and the irradiation component of the PMDA requires spent MOX fuel to no longer be weapon-grade (i.e, the ^{240}Pu to ^{239}Pu ratio should be greater than 10%), it was also clear in the NAS report that similar chemical, physical, and radiological barriers to proliferation should be acceptable as well. Consistent with this, the Russians agreed in the original PMDA to allow the U.S. to use immobilization for a portion of the inventory, which involves no isotopic dilution but achieves all three of the barriers discussed by NAS. As pointed out in the PWG report, the Dilute and Dispose option would implement two of these three barriers (chemical and physical).

Much has been, and will continue to be, said about the risk of unacceptability of this option from the standpoint of meeting the letter and intent of the PMDA. However, as discussed in Executive Considerations, the Red Team believes that based on the history of modifications negotiated to date under the framework of the PMDA it is reasonable to conclude that a new modification could be successfully negotiated on the basis of a Dilute and Dispose approach, provided a strong U.S. commitment is maintained with regard to timely disposition. The Red Team conclusion is supported by the following considerations:

- Article III of the PMDA allows for modification to the disposition approach if agreed in writing.
- The U.S. has previously accommodated Russian national interests in an amendment to the PMDA.
- International circumstances have changed, such that it now appears appropriate to credit engineering and institutional measures, such as physical security, disposal site characteristics, and safeguards, as essentially equivalent to the barriers provided by SFS. Indeed, the Surplus Pu Disposition SEIS Scoping Comment Summary stated that Dilute and Dispose is “akin” to the SFS, which implies that the U.S. has already made a “sufficiently equivalent” determination.
- Regardless of any path forward, PMDA negotiations must be renewed with the Russians. In the case of the MOX approach, it is already too late to achieve the agreed timeline for disposition of the 34 MT. Based on interviews conducted by the Red Team, the Russians may consider the agreement abrogated on this basis alone, but will nevertheless proceed with Pu disposition as part of their overall nuclear energy strategy (although they may hold weapons grade material aside and use recycled reactor grade MOX). Regardless, the proliferation risk of Russian held material has changed substantially since the PMDA was first negotiated, as previously discussed. This leaves room for negotiation, assuming that overall relations allow cooperative exchange.
- The U.S. has already successfully disposed of non-MOXable weapons grade Pu at WIPP via a Dilute and Dispose approach, although none of this material can count toward the 34 MT commitment since it was not independently verified by the IAEA. DOE has determined that the blending technique utilized for this material achieves the reduction of attractiveness required to eliminate safeguards as discussed in DOE Order 474.2. Thus, the U.S. will have a reasonable position to enter into negotiations of the PMDA.

It is the Red Team's opinion that the federal government has a reasonable position with which to enter PMDA negotiations when a negotiating process emerges as a natural outcome of a final decision on the path forward. In any event, the Red Team offers a brief alternative approach in Appendix D to address concerns that the Dilute and Dispose option inadequately complies with the PMDA.

3.1.1.4 Regulatory and Other Issues

Most of the regulatory issues identified for this option by the Red Team involve WIPP. Of first concern is the timely resumption of WIPP operations, which have been suspended since the two February 2014 incidents (vehicle fire and radioactive material release). As previously discussed, WIPP is the only repository for TRU waste, and as such is a critical asset both for completion of the EM mission (cleanup of the nation's nuclear weapons production legacy), and for continued support of DOE's weapons and other programs. Thus, an inability to resume operations at WIPP is not considered by the Red Team to be a credible risk to the Dilute and Dispose option. WIPP is simply too important to the nation. As reaffirmed in her NY Times quote on August 8, New Mexico Governor Susana Martinez believes WIPP and LANL are "*critical assets to our nation's security, our state's economy, and the communities in which they operate."*

Rather, the protracted resumption of operations at WIPP poses a risk to the assumed startup date for the Dilute and Dispose option. A conservative assumption for the full-scale resumption of WIPP operations would be five years. During the first three years of this assumed WIPP recovery period, DOE would need to spend a significant fraction of the expected available annual funding (as much as 75%, assuming annual budgets remain at current levels) on MFFF cessation anyway, and could spend the rest on development of a detailed baseline program plan and funding-capped pursuit of the relatively small capital investments at LANL and SRS needed to support an optimized version of the Dilute and Dispose option. As the relatively small capital projects are completed, DOE could ramp up oxide production capacity and produce a feedstock backlog to ensure that LANL does not become an unacceptable production limiter. The primary impact due to delayed start, therefore, would be escalation of present-day dollars, but the Red Team asserts that an accurate baseline plan for Dilution and Disposal would involve a relatively long ramp up period anyway, which would prevent WIPP restart from appearing as the critical path.

Second, the WIPP LWA restricts the total TRU waste volume to 176,000 cubic meters, and to date, 91,000 cubic meters have already been emplaced. Of the remaining 85,000 cubic meters, only about 19,000 cubic meters are considered "unsubscribed", and as previously discussed, the Red Team believes this number may be over-estimated (depending of course, on value judgements related to disposal priority). The base Dilute and Dispose option would require a considerably larger volume allowance, perhaps as much as 34,000 cubic meters. Unless some of the subscribed capacity is re-directed toward support of the Pu Disposition Program, an increase in the volume allowance would require action by the U.S. Congress. But the Red Team posits that the eventual expansion of WIPP capacity will be necessary anyway from the emerging recognition of other TRU waste sources that are not included in the current DOE-EM baseline, irrespective of the needs of the Plutonium Disposition Program, although any such expansion would be subject to cooperation and regulation from the State of New Mexico regardless of the source of waste.

In any event, well over half of the entire duration of a Dilute and Dispose operation could be completed before facility expansion would be needed. This leaves adequate time to address the national imperative for additional capacity at WIPP (subject to concurrence from the State of New Mexico) without it becoming a critical path item on the Dilute and Dispose schedule, and there are opportunities for mitigating the residual risk discussed below in Section 3.1.2. Similar to the WIPP restart risk, the Red Team does not consider WIPP expansion to be a catastrophic risk to the base Dilute and Dispose approach, even ignoring the potential enhancements (discussed below) which may obviate the need for any legislative or regulatory action to expand WIPP specifically to support a Dilute and Dispose approach. The Red Team notes that long-term WIPP operation and available capacity is also a requirement for the MOX Fuel approach since the WSB would generate TRU Waste as a consequence of MFFF Operations.

A third regulatory risk relates to the Resource Conservation and Recovery Act (RCRA) Permit for hazardous wastes from the New Mexico Environment Department under which WIPP operates. Based on discussions with personnel at WIPP during the July 13, 2015 visit, large-scale support of the Pu Disposition Program would require one or more Class III permit modifications, which are subject to public involvement. Although such revisions to the permit have been made in the past rather routinely, the recent incidents at WIPP may stimulate heightened public interest, and non-governmental organizations may mobilize in an attempt to prevent the large-scale disposal of excess weapon-grade plutonium at WIPP. Ultimately, any such permit modifications would be subject to State of New Mexico approval and regulation.

The updating of National Environmental Policy Act (NEPA) documentation to support this alternative will present a similar opportunity for public input. The current NEPA action governing the plutonium oxide dilution effort at SRS is an Interim Action which allows for a limited amount of material to be diluted and sent to the WIPP. The Surplus Plutonium Disposition SEIS allows for a larger amount of plutonium oxide to be diluted and shipped to WIPP, but the Record of Decision for that NEPA action has not been issued. To cover the full scope of diluting 34 MT plutonium oxide and shipping it to the WIPP for disposition would require additional NEPA review.

3.1.2 Potential Enhancements to the Base Dilute and Dispose Option

The Red Team spent considerable time evaluating the Dilute and Dispose option as an alternative means for Pu Disposition. This involved trips to LANL, WIPP, and SRS locations in order to walk the spaces intended for use in this option. During the course of this effort, several possible enhancements were identified that offered potential improvements to the base approach. These enhancements included the broad goals of:

- Possible cost and schedule savings;
- Improvements to reduce execution, regulatory and security risks;
- Changes in the approach to simplify logistics; and
- Changes in the approach to facilitate successful negotiations on any necessary PMDA modification.

While all of the following opportunities are expected to be technically feasible, none are needed to initiate the Dilute and Dispose process and the removal of plutonium from current locations. These enhancements can be developed and added in parallel with ongoing operations. It is important to note that the Dilute and Dispose option can be started early at a lower throughput during the modification process to install new gloveboxes in the baseline case. It is during this transition period that the following enhancement opportunities could be developed and implemented.

3.1.2.1 Increased Pu Loading Per Container

Increasing the plutonium amount per container would have a direct impact on LCCs of the Dilute and Dispose option because of the reduction in processing time, and the reduction in drums, shipments, and other logistics associated with the campaign. This opportunity would incur increases in cost from enhanced security requirements consistent with the approach in the PWG report variant to the Option 4 Downblending approach, as depicted as path D1 on Figure 4. One possible benefit of this approach is the volume reduction needed for the final disposal in WIPP. It may be possible to increase loading to a level that negates the need LWA changes to accept the waste from 34 MT of surplus plutonium.

3.1.2.2 Accurate Volume Accounting at WIPP

The Red Team was surprised to learn that the WIPP RCRA permit requires that the volume considered utilized at WIPP is based on the volume of the external container rather than the volume of the TRU waste within. Thus, it is estimated that 30-50% of the 176,000 cubic meters at WIPP may eventually be consumed by empty space within outer containers. In the limited time available for this study, the Red Team identified no basis for this accounting method in worker or environmental protection or regulatory compliance. Likewise, the total volume restriction that appears in both the RCRA permit and the LWA is not rooted in WIPP's performance assessment. As discussed in our Executive Considerations, the treatment of WIPP as a valuable national asset requires addressing these limitations in cooperation with the State of New Mexico. In combination with enhanced Pu loading discussed in Section 3.1.2.1, proper waste volume accounting may obviate the need for any changes to the LWA.

3.1.2.3 LANL and SRS Cooperative Hybrid

This approach would help optimize Office of Secure Transport, TRUPACTs, and other logistical resources by performing some Dilute and Dispose scope at both LANL and SRS, in an optimized configuration yet to be determined through detailed study. This approach may have LANL perform some dilution and direct shipments to WIPP as an add-on to the LANL oxide production scope. This approach would increase the number of glovebox lines at LANL for oxide blending, but the small number required would be readily available since they are basic gloveboxes that do not require customization. WIPP-compliant characterization and TRUPACT loading and shipping equipment are already available to support existing operations.

An optimized approach also may also require modifications to the scope at SRS. Increasing the amount of metal to be converted to oxide at SRS is one option, either using a process similar to existing processing of AFS material or through the installation of muffle furnaces at KAMS. Another option is the use of HB-Line for dilution to supplement operations in KAMS and potentially at LANL. During the lifecycle of H-Canyon operations for EM's spent nuclear fuel processing at SRS, the support infrastructure (HVAC, etc.) remains viable for HB-Line Phase 1 and/or Phase 3 gloveboxes to be used to augment Pu dilution within H area security constraints. HB-Line Phase 1 was used in 2012/2013 to dilute the initial EM plutonium for WIPP.

The H-Canyon life expectancy is dependent on EM funding and decisions on duration of Spent Fuel processing missions. Currently, H-Canyon is expected to remain operational into FY24, although recent EM budget constraints have called this into question. The cost to extend this Phase 1 operation until 2024 is expected to be bounded by the annual cost for AFS-2 processing because of the less demanding sample analyses and operations to meet WIPP criteria compared to MFFF specifications. After that, there will be serious issues regarding the responsibility for funding infrastructure.

An optimized hybrid approach to oxide production and blending would increase overall throughput and reliability through a parallel processing approach. Cost savings relative to the base approach would be manifested in terms of reduced LCC. Also, the risk of one site losing operational status would be partially mitigated by the presence of duplicative capability and complimentary capacity. The Red Team notes that initial investments into hybrid capability might have a higher return at LANL in the event of severe funding restrictions, since pit conversion must occur there anyway.

3.1.2.4 Use of a Planned Future Glovebox in KAMS for Dilution

This opportunity would utilize a new glovebox that is anticipated (pending NEPA) for processing in KAMS. This glovebox is expected to include furnace capability and could augment metal conversion to oxide as well as dilution. Physical modifications are not expected to be significant to replace minor hardware elements in the glovebox to allow bulk dilution. The glovebox is being installed for a different program, and is expected to only be utilized for this purpose for 2-3 years.

3.1.2.5 Addition of More Gloveboxes in KAMS

Determining the optimum number of glovebox lines to be added to KAMS may result in more than the two currently envisioned in the base Dilute and Dispose approach in order to reduce project duration and LCC. However, the utility of such an investment requires an understanding of limiting conditions, which is likely to be oxide production at LANL, where limited capital investment may have a greater benefit. If the addition of more than two gloveboxes at KAMS makes sense, the Red Team notes that such an addition of scope should be made early in the design phase to take advantage of economies of scale. Installation of new gloveboxes may be difficult once the supporting infrastructure is installed, and especially after the existing gloveboxes become contaminated. Contracting strategies that incentivize building additional glovebox lines within a defined total project cost may be effective, given that a large fraction of the capital cost will likely be devoted to design and safety analysis as opposed to procurement.

3.1.2.6 Alternative Downblending Technologies

Other potential approaches exist which would require technology maturation to blend the Pu for disposal in different ways to achieve different objectives. Appendix D offers a description of one such approach related to specific risk mitigation. There are others which could be analyzed within a value engineering context. In addition, automation of portions of the Dilute and Dispose option could be explored to minimize labor and personnel exposure and to accelerate portions of the overall flowsheet. All such options are viewed as continuing improvement techniques and opportunity challenges for the management team of the Dilute and Dispose approach, and should only be pursued if a business case can be made for return on investment.

3.2 The Sterilization Approach (Option C on Figure 4)

As presently defined, the Dilute and Dispose approach was intended to meet the established requirements for shipping and disposal. Although far more efficient than the MOX approach, these requirements result in limitations that cause considerable expense, lengthen the time for program execution, and require frequent transportation of nuclear material. Option C from Figure 4 illustrates a potentially simpler option. Under this option, two major changes occur relative to the “base” Dilute and Dispose option. First, instead of transporting pits to LANL for disassembly and the plutonium to either SRS or LANL for processing, the pits would be processed at Pantex to “sterilize” them to the extent necessary to achieve disposition. Second, instead of transportation to a geologic repository, the sterilized pits would remain at Pantex under monitored storage (Variant C1 in Figure 4). Variant C2 would have the sterilized pits transported to WIPP for permanent disposal, thus achieving equivalency to the Dilute and Dispose alternative.

A sterilization approach (particularly if enhanced by monitored storage at Pantex in lieu of WIPP disposal) could result in the following improvements relative to the dilute and dispose option:

- Using this approach would dramatically improve the processing rate to convert starting material into a “dispositionable” product;
- Would reduce nuclear material shipments by 90% ;
- The end product could be monitored to ensure that theft and diversion does not occur;
- The packages prepared for monitored storage could be monitored in-situ, and could always be transported to a geologic repository at a later date;
- Eliminates the non-value added work associated with complete pit processing.

However, there are also significant challenges to this approach:

- The sterilization approach, although viewed by the Red Team as essentially equivalent to Dilute and Dispose (under variant C2), may not be viewed by the Russian Federation as sufficiently compliant with the PMDA;
- Under Variant C1, Pantex storage capacity may be insufficient to support this approach absent a capital investment;
- Under Variant C2, the acceptability of this material form as a waste that can be transported and disposed at WIPP is not clear. At a minimum, it may require exemptions to obtain safeguards termination, and there may be challenges related to compliance with WIPP waste acceptance criteria.

The pursuit of this option would require a separate feasibility study and detailed planning. As discussed for the Dilute and Dispose optimization opportunities listed in Section 3.1.2, this alternative could be implemented after the dilution and disposal approach is underway, as a means of truncating LCC.

4. Comparative Analysis

This section provides a summary-level comparative examination for purposes of aiding DOE in a path forward decision. Section 4.1 summarizes the attributes of the two options relative to the criteria utilized by the Red Team, and Section 4.2 provides conclusions from the Red Team on relative cost and risk.

4.1 Attribute Comparison Summary

The various attributes of the retained options (technical viability, ability to meet international commitments, and regulatory and other issues) are discussed in detail in previous sections, and briefly summarized in the table below. While it may appear from Table 5 that the Red Team considers the two options to be roughly equivalent overall when assessed against the criteria specified in the Charge memo from the Secretary, the Red Team has concluded that the nature of the risks associated with the two options puts the MOX approach at greater risk of cost growth throughout its life cycle. Since the technology for Dilute and Dispose is so much simpler, and the overall disposition process so much less complex, the most significant risks associated with this approach could be retired early, as issues associated with WIPP restart and potential expansion and the PMDA are strategized and addressed during a protracted planning phase, while small-scale Pu dilution proceeds using the existing glovebox, NNSA is installing two additional gloveboxes, and the MOX approach is being discontinued.