AEROSPACE REPORT NO.
TOR-2015-01848

Plutonium Disposition Study Options Independent Assessment Phase 1 Report
Option 1: MOX Fuel
Option 4: Downblend

April 13, 2015

Matthew J. Hart[1], Nichols F. Brown[2], Mark J. Rokey[1], Harold J. Huslage[3], Denise J. Castro-Bran[4], Norman Y. Lao[5], Roland J. Duphily[5], Vincent M. Canales[2], Joshua P. Davis[6], Whitney L. Plumb-Starnes[7], Jya-Syin W. Chien[5]
[1]Civil Applications Directorate, Civil and Commercial Programs Division
[2]Schedule and Cost Analysis Department, Acquisition Analysis and Planning Subdivision
[3]Nuclear Security Programs, Civil Applications Directorate
[4]Systems and Operations Assurance Department, Mission Assurance Subdivision
[5]Acquisition Risk and Reliability Engineering Department, Mission Assurance Subdivision
[6]Vehicle Conceptual Design Section, Architecture and Design Subdivision
[7]Systems Performance Estimation and Algorithms Department, Architecture and Design Subdivision

Prepared for:

National Nuclear Security Administration
1000 Independence Avenue S.W.
Washington, DC 20585

Contract No. FA8802-14-C-0001

Authorized by: Civil and Commercial Programs Division

AEROSPACE
Assuring Space Mission Success

Contents

Figures

Tables

1. Charter

Within its mission to reduce global danger from weapons of mass destruction, the Defense Nuclear Nonproliferation Program through the Office of Material Management and Minimization is responsible for the implementation of the U.S.–Russia Plutonium Management and Disposition Agreement (PMDA), which commits both countries to dispose of at least 34 metric tons (MT) of weapon-grade plutonium each by irradiating it as mixed oxide (MOX) fuel or any other methods that may be agreed by the Parties in writing.

Unanticipated cost increases for the MOX fuel approach prompted the Department of Energy, National Nuclear Security Administration (DOE/NNSA) to assess plutonium disposition strategies in 2013 and identify options for the out years. The Secretary of Energy formed the Plutonium Disposition Working Group (PWG) to critically examine costs of other potential options to complete the plutonium disposition mission. In April 2014 the working group released its findings in "Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon- Grade Plutonium Disposition Options." This report discussed five options for disposal, including the current program of record:

1. Convert the Plutonium to MOX fuel for use in commercial reactors (program of record)
2. Irradiation of plutonium in fast reactors
3. Immobilization with high level waste
4. Downblend the plutonium with inert material and disposition in a geologic repository
5. Deep borehole disposal

Congress directed DOE/NNSA to task a Federally Funded Research and Development Center (FFRDC) to conduct an independent review of the PWG report. In December 2014, The Aerospace Corporation (Aerospace) was approached by DOE/NNSA to perform this review. Aerospace was asked to assess and validate the report's analysis and findings, and independently verify lifecycle cost estimates for the construction and operation of the MOX facility (Option 1) and the option to downblend and dispose of the material in a repository (Option 4). Aerospace was asked to assess programmatic factors affecting cost and schedule relating to areas of technical uncertainty and risk, including areas of technical readiness and the systems operations concept; accreditation/certification of new facilities and technologies to transition or dispose of weapon-grade plutonium and disposal execution processes and documentation; compliance with existing / potential future environmental regulations and modifications to international agreements; oversight and governance, agencies external to DOE which may affect certification, facilities construction, regulations to support monitoring; and issues regarding implementation of such selected alternatives, including regulatory and public acceptance issues, and interactions with affected states.

This report addresses the independent assessments of Option 1 and Option 4. The independent assessments of Options 2, 3, and 5 will be covered in a subsequent report to be submitted to NNSA.

The Aerospace Corporation maintains capabilities in building architecture, civil, structural, mechanical, and electrical engineering as applied to facilities concept development, planning (including cost), construction and operations. Aerospace regularly performs technical and risk assessments of large scale complex facilities developments for use for civil, commercial, and national security programs.

2. Executive Summary

Aerospace assembled a team of knowledgeable experts in facilities development, cost and schedule, programmatic and technical risk assessment, nuclear power industry experience, and prior nuclear weapons complex experience to review the NNSA plans and infrastructure associated with Option 1, MOX Fuel and Option 4, Downblend.

The assessment approach for this study is illustrated in Figure 1. The assessment started by first examining the 2014 PWG estimate. The Aerospace team examined in detail, through presentations and discussions with NNSA and contractor personnel, all elements of the PWG 2014 cost estimate, considering use of best practices and industry standard approaches to cost estimating, including cost-risk. Aerospace assessed the quality and completeness of the individual program element cost estimating products for the defined scope of work at the time of the 2014 PWG Estimate, relative to other program experience in facilities development. Aerospace reviewed data provided by the NNSA used in the grass-roots estimates, analogy based estimates, and prior independent cost assessments.

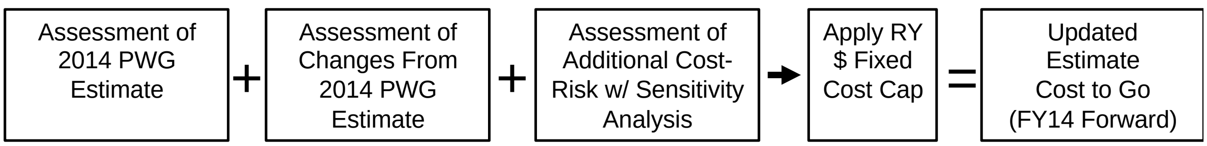

Figure 1. Four-step approach used to develop estimates.

Next, Aerospace made an assessment of changes that have occurred since the 2014 PWG estimate was completed in 2013. This included examination of missing cost elements, changes in work scope, and updates to the project element estimates since the time of the 2014 PWG estimate. Cost increases due to known delays in the program and the associated cost escalation due to inflation in the out-years were also estimated. These changes were then added to the original 2014 PWG estimate to create a new "baseline" from which to assess programmatic risk.

In the third step of the assessment process, Aerospace performed a cost-risk assessment of the work scope associated with options 1 and 4, including the changes noted above. Risks were identified for both the capital and construction projects associated with the Mixed Oxide Fuel Fabrication Facility (MFFF) or downblending facility, and other key program elements, such as the MOX Fuel Irradiation, Feedstock, and Transportation Program (MIFT). Cost–risk drivers were identified in terms of likelihood, range of potential consequence (cost impact), and the time-frame relative to the program lifecycle when the risk could be realized. Aerospace performed a probabilistic cost risk sensitivity analysis to assess the potential impact to the life cycle cost-to-go, and developed an estimate of the program cost contingency going forward, at the 85th percentile confidence level.

In the final step of the assessment process, Aerospace applied fixed real-year cost-caps to capital and construction elements of the program in order to assess impacts of a constrained budget on the program timeline. Two scenarios were assessed: the 2014 PWG estimate, which used 500M RY$/year, and an estimate of the minimum cost cap needed to complete the program. Application of the cost caps resulted in delays to the completion of construction and operations, and resulting cost escalation, relative to the 2014 PWG estimate.

Aerospace also conducted a qualitative assessment of other relevant factors that discriminate between options. These factors include accreditation/certification of new facilities and technologies to transition or dispose of weapons grade Pu, and disposal execution processes and documentation; compliance with existing and potential future environmental regulations and modifications to international agreements;

oversight / governance, agencies external to DOE which may affect certification, facilities construction, regulations to support monitoring; and regulatory and public acceptance issues regarding implementation of such selected alternatives, including interactions with affected States.

Table 1 summarizes the results of the cost assessment. For the MOX Fuel Option, the 2014 PWG report estimate cost-to-go is 25.1B RY$ (18.6B FY14$). Adding known changes to the program since the time of the estimate, which include the costs of program delays, results in 30.7 $B (21.3B FY14$) cost-to-go. Additional cost contingency determined through the risk-sensitivity analysis and application of the $500M RY$/year cost cap used in the 2014 PWG estimate increases the total lifecycle cost-to-go to 47.5B RY$ (27.2B FY14$). In a similar fashion, for the Downblend Option, the total lifecycle cost-to-go with identified changes to the 2014 PWG estimate and risk sensitivity analysis is 17.2B RY$ (13.1B FY14$).

Table 1 includes costs for the capital and construction projects associated with options 1 and 4, and other key program elements needed to complete the plutonium disposition mission, such as MIFT. MIFT cost-to-go over the lifecycle of the program is 16.5B RY$.

Application of the cost cap results in increased time to compete MFFF construction and an increase in cost-to-go in real year dollars. This is due to additional costs for maintaining the Waste Solidification Building (WSB) and program management and integration functions during the additional years required to complete MFFF construction, and escalation over the lifecycle of the program due to inflation.

It was determined that the minimum cost cap on capital and construction to complete the MFFF construction was approximately 375M RY$/year. In FY14, the MFFF construction was funded at ~350M RY$/year. The application of a 375M RY$/year cost cap increases the total lifecycle cost-to-go to 110.4B RY$ (29.8B FY14$).

Table 1. Summary Cost-To-Go Estimate for Options 1 and 4

	Plutonium Working Group (PWG) 2014 Report Estimate	Assessment of Changes Since PWG 2014 Report Estimate	Assessment of Cost-Risk Drivers Through Sensitivity Analysis (85th Percentile Confidence)	
	Cost-to-Go FY14 Forward	+ Changes	+ Cost Risk = Updated Estimate	
			500M RY$/Yr Cap on Construction/Capital	**~375M RY$/Yr Cap** on Construction/Capital
Option 1: MOX Fuel	25.1B RY$ 18.6B FY14$	30.7 B RY$ 21.3B FY14$	47.5B RY$ 27.2B FY14$	110.4B RY$ 29.8B FY14$
Option 4: Downblend	10.3B RY$ 8.2B FY14$	13.2 B RY$ 10.1 B FY14$	17.2B RY$ 13.1B FY14$	

Note that for the MOX Fuel Option, costs for MFFF shutdown to a safe state at end of operations are included in this assessment. However, this study did not assess MFFF decommissioning and demolition (D&D) and return to green field.

Section 3 of this report provides an overview of Options 1 and 4. Section 4 describes the review of the 2014 PWG estimate and associated findings. Section 5 documents the assessment of the changes to the program since the time of the 2014 PWG estimate, and quantifies those in terms of cost. Section 6 provides a discussion of the risk sensitivity analysis process, identified risks and their cost impacts.

Section 7 presents the effects on overall lifecycle cost-to-go as influenced by cost caps, and includes cost profiles for option 1 and 4. Section 8 provides the updated estimate of the cost-to-go. Section 9 discusses the qualitative assessment factors, and Section 10 provides summary findings of the study.

Summary findings of the study are:

- Under the 500M RY$ / year cost cap on the Mixed Oxide Fuel Fabrication Facility (MFFF) capital and construction assumed in the 2014 PWG estimate, the total cost-to-go for the MOX Fuel Option is 47.5B RY$ (85% confidence cost contingency). The MOX Fuel Irradiation, Feedstock, and Transportation Program (MIFT) and other costs are 400-500M RY$ / year, including cost contingency starting in FY2017. MFFF operations costs are 1100-1300 M RY$ / year, starting in 2044. The MOX Fuel Program completion is ~ FY2059.
- The MFFF construction cannot be completed at current (FY14) funding level (350M RY$ / year cost cap on construction/capital) and the assumed escalation rates (4% construction and capital, 2% labor). The minimum cost cap on capital and construction to complete the MFFF construction is approximately 375M RY$/year, and results in completion of construction in FY2100, and a total cost-to-go of 110.4B RY$ (85% confidence cost contingency) for the MOX Fuel Program. Annual operations costs are > 3.0B RY$ / year. The MOX Fuel Program completion is in ~ FY2115.
- The Downblend Option project cost-to-go is 17.2B RY$ (85% confidence cost contingency). Downblend construction and operations costs are 100-200 M RY$ / year, under the timeline assumed in the 2014 PWG estimate. MIFT and other costs are 400-500 M RY$ / year, with cost contingency, during feedstock production. Program completion is ~ FY2049.
- In comparing MOX Fuel and Downblend Options, there is a large difference in total lifecycle cost-to-go at any cost-risk confidence level. There is no cost-risk confidence level in the assessment where the MOX Fuel Option lifecycle cost-to-go is less than the Downblend Option.
- 2014 PWG cost estimates were done in a manner consistent with best practices and industry standards for cost estimating.
- Program-level cost contingency in the 2014 Plutonium Working Group (PWG) estimate is underestimated. Contingencies are based on lower level technical risks, and do not consider program element dependencies and interactions. There is uncertainty in the remaining work scope.
- Program delays to the MOX Fuel Program, realized thus far, result in ~ 4.3 $B RY increase from 2014 PWG estimate.
- Program delays to MIFT, realized thus far, result in ~ 1.5 $B RY increase from 2014 PWG estimate.
- For the MOX Fuel Option, the majority of risk is related to the uncertainties in MFFF construction, start of operations, and feedstock and MOX Fuel production rates.
- The Downblend Option is lower in risk than the MOX Fuel Option. The largest risk is the uncertainty in the feedstock production rate.
- An opportunity exists to reduce cost and program complexity for Option 1 or 4 by consolidating the steady state feedstock production into a single product line.

3. Disposition Options Overview

Top-level program work flow diagrams were constructed in order to organize the quantification process for each option and assist the process of assessing and quantifying risk. The MOX Fuel program workflow (Figure 2) starts with plutonium pits being transferred from the Pantex (PTX) facility to Los Alamos National Laboratory (LANL) for disassembly. At that point, the conversion of the material to a mixed oxide is divided into three separate product lines:

- Plutonium is packaged in dissolvable containers at LANL and shipped to Savannah River Site (SRS) for dissolution in the H-Canyon facility. The plutonium is then extracted from the solution as an oxide in the HB-Line facility. Non-pit plutonium stored in K-area is also processed through the H-Canyon dissolution and HB-Line oxidation processes.
- Plutonium metal is converted to a mixed oxide at the LANL PF-4 facility using muffle furnaces or specialized direct metal oxide (DMO) furnaces and then shipped to SRS for entry into the MOX fuel fabrication process.
- Plutonium metal is prepared and shipped to SRS for oxidation in specialized DMO furnaces to be installed in the MFFF facility, once complete.

The three product lines converge in MFFF, where it then undergoes aqueous processing, and is combined with depleted uranium oxide and fabricated into fuel pellets and ultimately fuel assembly rods for use in commercial nuclear reactors. Waste products from the MFFF processing are transferred to the Waste Solidification Building (WSB) for conversion to a form suitable for disposal. The MOX Fuel Option fulfills its mission when the fabricated fuel rods are burned in commercial reactor such that the residual plutonium is difficult to recover.

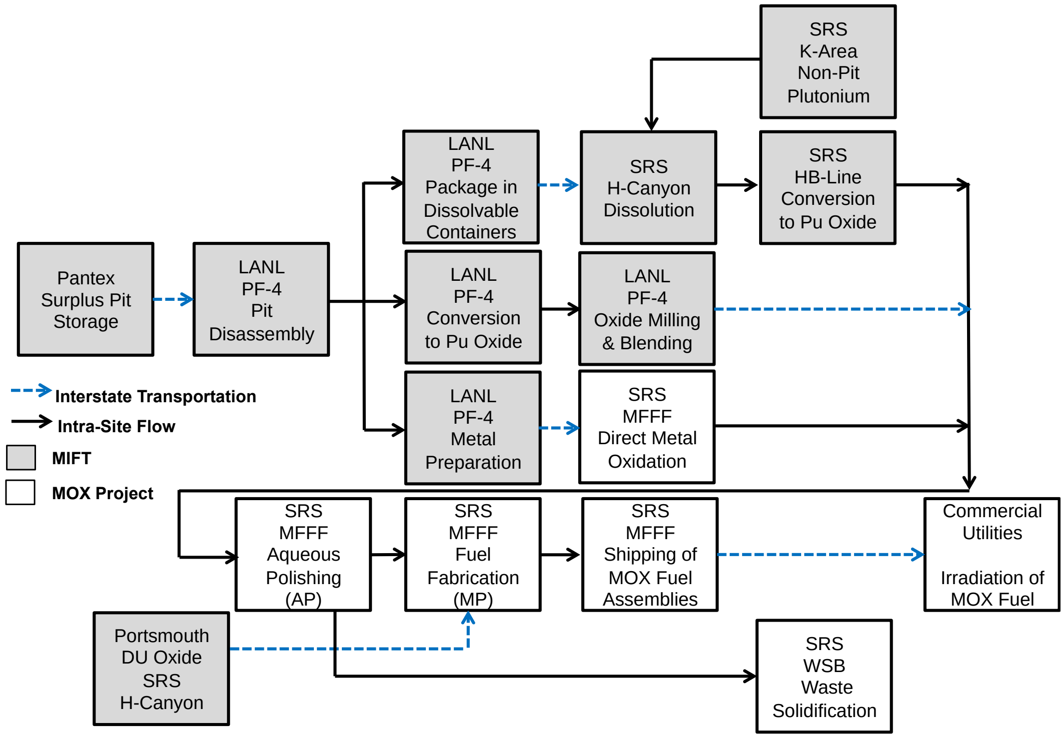

Figure 2. MOX fuel program workflow.

The Downblend program workflow (Figure 3) starts with plutonium pits transferred from PTX to LANL where they are disassembled and divided into two product lines:

- Packing plutonium in dissolvable containers at LANL for dissolution at SRS H-Canyon and conversion to an oxide with the existing supply of non-pit plutonium stored in K-area.
- Conversion of plutonium to mixed oxide at LANL using muffle furnaces and/or specialized DMO furnaces.

The two product lines converge at SRS, where the mixed oxide is combined in small amounts with a large amount of inert material, significantly reducing the mass and volumetric fraction of plutonium in the downblended material. The downblended material is then packaged and transported to a geologically stable underground repository for disposition.

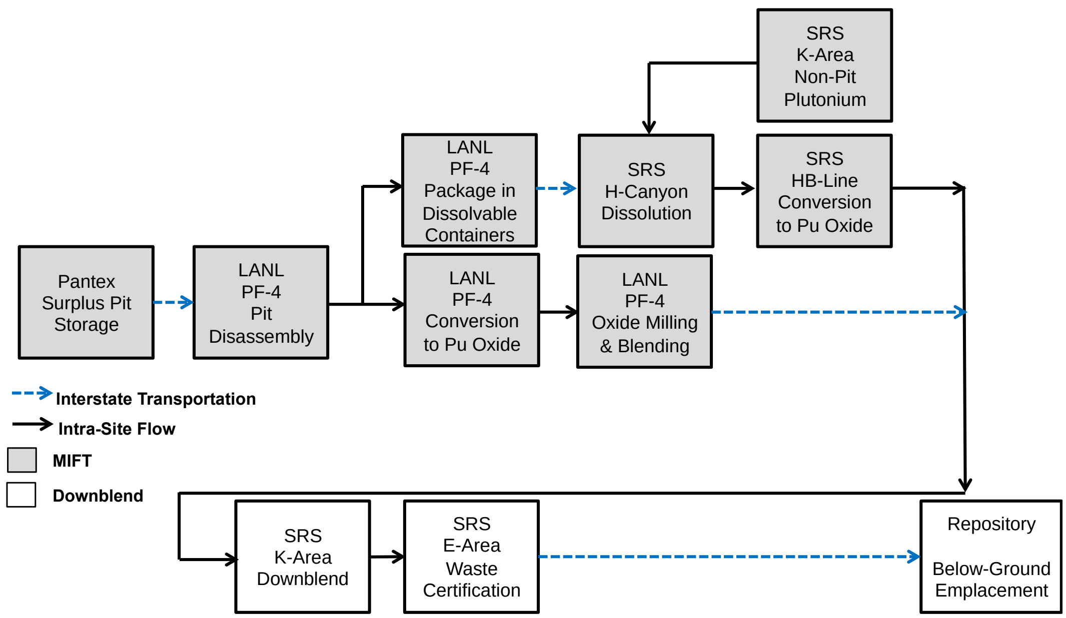

Figure 3. Downblend program workflow.

4. Assessment of the PWG 2014 Cost Estimate

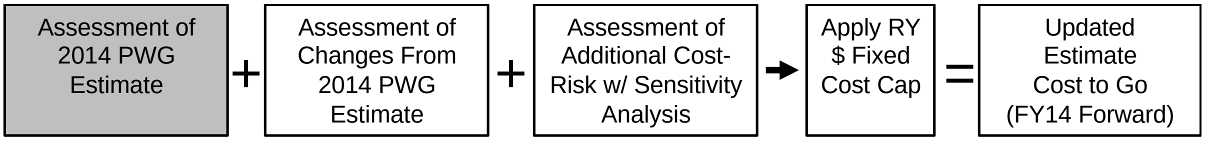

Figure 4. Step 1 of four-step approach, assessment of 2014 PWG estimate.

The first step in the evaluation process was to assess the existing estimate in the 2014 PWG report. On January 13-15, 2015, NNSA's Office of Material Management and Minimization (NA-23) organized a series of briefings for the team at NNSA Headquarters, detailing the options with supporting cost and technical data. Mr. William Kilmartin, Director, Office of Material Disposition, and his staff provided a detailed overview on the MOX Fuel Irradiation, Feedstock, and Transportation (MIFT) lifecycle. Ms. Sachiko McAlhany, Senior Technical Advisor, Office of Material Management and Minimization, gave a program overview and discussed the Plutonium Disposition Infrastructure Program (PDIP) costs. Richard Person, Office of Enterprise Project Management, Project Planning and Execution, discussed cost modeling of the MOX project. Mr. Matt Crozat, Senior Policy Advisor, Office of Nuclear Energy, presented materials on the Advanced Disposition Reactor (ADR), and Dr. John Herczeg, Deputy Assistant Secretary for Fuel Cycle Technologies, Office of Nuclear Energy discussed ongoing R&D efforts for deep borehole disposal option.

On January 27-29, 2015, NA-23 organized a series of briefings and tours at Savannah River Site. Ms. Jean Ridley, Director of Waste Disposition Programs Division, Savannah River Operations Office, led the team on a tour of the Defense Waste Processing Facility (DWPF). Mr. James Dollar, Program Manager, Savannah River Nuclear Solutions (SRNS), presented an overview of Alternate Feed Stock 2 (AFS-2) program. Ms. Terri Williams, Environmental Management Operations, SRNS, provided a cost overview of H-Canyon and HB-line. Ms. Janice Lawson, Manager of L-Area and K-Area Project Operations, SRNS, led the team on a tour of K-Area. Mr. H Allen Gunter, DOE Senior Technical Advisor, Nuclear Materials Stabilization, briefed the downblending and disposal option. Terri Williams of SRNS provided a cost overview of K-Area, and Mr. William Bates of Nuclear Materials Management Programs, SRNL presented material on the ADR option. Security overviews and force cost estimates were presented, including vulnerability upgrades. Mr. Scott Cannon, Federal Project Director for the MFFF Facility, led a tour of the MFFF. A tour of the Waste Solidification Building (WSB) was led by Mr. Thomas Cantey, Federal Project Director, WSB. Ms. Sue King, Vice President of Project Operations, MOX Services LLC, presented the MOX operations cost basis, current MFFF project status, and a summary of MFFF technical and cost risks. A VTC was held with Carlsbad Field Office and EM-HQ.

On February 10-11, 2015, NA-23 organized a series of briefings and tours over a two-day period at Los Alamos National Laboratory. Ms. Julia Whitworth, Acting Program Manager for the LANL Oxide Production Program, presented an overview of the ARIES plutonium disposition project. Mr. Mark Dinehart, Program Director, Plutonium Facility-4 Readiness, presented an overview of the Steady State Feedstock Project, and Dr. Drew Kornreich, LANL Process Modeling and Analysis Group, presented an accompanying briefing on steady state facility approach and associated cost estimates. A detailed tour of Plutonium Facility-4 (PF-4) was organized, showing equipment and facilities used/to be used by the Advanced Recovery and Integrated Extraction System (ARIES) and the Steady State Feedstock Project (SSFP). Dr. Judy Eglin, Program Director, Plutonium Science and Manufacturing Directorate, presented the PF-4 facility cost recovery model, and Dr. James Ostic, Program Director, Integrated Program Management Office, gave an overview of programs using PF-4.

Reports and other documentation provided to Aerospace as part of this assessment are documented in Appendix A of this report. The Aerospace team first reviewed the high-level, time phased cost estimating data from the 2014 PWG estimate which integrated individual program element cost estimates from the MOX construction Project, and other on-going programs necessary for the MOX Fuel or Downblend Options to execute. These included funding lines for PDIP, MIFT, and Waste sustainment for the MOX Fuel program, as well as estimates for K-Area new facilities at SRS, for the Downblend Option. Data was traced from the top level integrated estimate to the individual program element costs estimates. Those estimates were reviewed by Aerospace cost and facilities development experts and assessed for quality, completeness, inclusion of cost-risk analysis where applicable, and use of industry standards and best practices in development of the estimates. Related analogy estimates and other independent estimates were also reviewed as part of this assessment.

The assessment described herein falls within the description of the Type IV independent cost estimate (Sampling Approach) as described in the Department of Energy (DOE) Independent Cost Review (ICR) and Independent Cost Estimate (ICE) Standard Operating Procedures (SOP) Revision 1. The assessment begins with the activities needed for a reasonableness review, and also includes the identification of the key cost-risk drivers, which are defined as elements in the estimate whose sensitivity significantly impacts the total lifecycle cost-to-go. Assessments of cost-risk were conducted using the Aerospace Project Risk Evaluation Process (PREP), which is described in Section 6 of this report. Program level cost-risks that significantly influence the estimate are captured and discussed in section 6.

Aerospace did not assess the scientific and technical aspects of the physics, chemistry, and metallurgy processes used in the conversion of pit and non-pit plutonium to an oxide feedstock, the MOX fuel fabrication process, or the downblend process. Aerospace did not assess the adequacy of the existing and proposed facilities to support the physics, chemistry, and metallurgy processes required by the MOX Fuel and Downblend Options. Aerospace did not conduct an independent grass-roots, parametric, or analogy based cost estimate on the individual project elements in the time available for this study. The updated cost estimate has not been reconciled with other estimates at the time of this report.

Aerospace used cost estimating experts and published GAO cost estimating guidelines[1] in the assessment of the quality of the cost estimates in the 2014 PWG estimate. Based on the expert review, the individual cost estimates developed for the program elements were done in a manner consistent with best practices for grass-roots cost estimating and/or parametric and analogy-based cost estimating. The methodologies applied were appropriate based on the maturity of the elements being estimated. Several of the estimates were formally documented to include the purpose, description of the work scope to be estimated, ground rules and assumptions, along with a description of the point estimate and a risk analyses. Other estimates were provided in the form of briefing charts and spreadsheets, which when discussed with the authors were determined to be sufficiently complete for the purposes of this study. There were a number of omissions from the original 2014 PWG estimate, including funding to support the depleted uranium supply, full understanding of the MFFF prime contractor scope of work going forward, and costs for completing systems and operational processes for WSB. These items and others were carried forward in the study and addressed later as risks. Specific cost elements that were preliminary at the time of the 2014 PWG estimate were known by the NNSA and were identified to the team. The information provided addressed all but a small fraction of the cost items for the program.

With respect to the fully integrated program estimate, individual program-element cost estimates were appropriately integrated into the program estimate. Multiple estimates were integrated and correctly phased in time, and all major cost elements for each option were captured.

[1] GAO Cost Estimating and Assessment Guide Twelve Steps of a High-Quality Cost Estimating Process

While some of the program element estimates incorporated into 2014 PWG estimate included cost-risk reported at the 85th percentile confidence level, the integrated program estimate as a whole is underestimated. Cost contingency was identified primarily at lower program element-levels, but interdependencies and impacts on other program elements were not considered in the cost-risk analysis. Additionally, the remaining work scope associated with the project and program continues to be more fully defined since the time of the 2014 PWG estimate and several program elements have been updated. Therefore, the completeness of the work scope identified for each project/program element remains uncertain. Sufficient detail, however, is available in the 2014 PWG estimate for use as a point of departure in assessing changes since the original estimate and for performing a sensitivity analysis to assess program risk.

5. Assessment of Changes since Publication of the 2014 Report

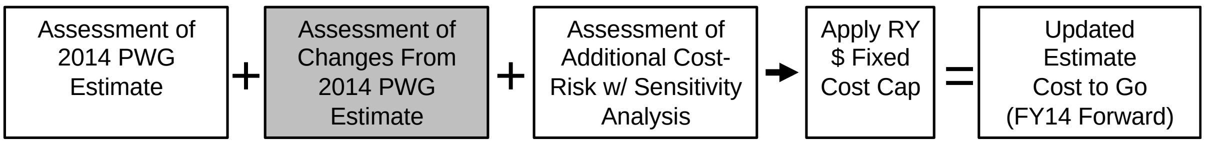

Figure 5. Step 2 of four-step approach, assessment of changes from 2014 PWG estimate.

Next, changes that have occurred to the program since the completion of the 2014 PWG estimate in 2013 were assessed. Known updates to individual program elements' cost estimates were accounted for. The time required for decision-making, program re-baselining and ramp up for full MFFF construction were assessed to be no less than two years, with authorization to proceed assumed at the start of FY2016. This resulted in either a ramp up to the MFFF construction or starting the Downblend project no earlier than the start of FY2018. The team assessed separately that the earliest restart for MIFT was the start of FY17. The overall duration of construction, capital improvements and operations times for either option were held constant from the 2014 PWG estimate, which resulted in essentially extending the entire program schedule to the right by three years for MIFT for both options, and four years for MFFF and WSB re-start in the MOX Fuel Option. Costs associated with maintaining workforce, technical readiness and continuing MFFF construction at 2014 levels during these delays were included. Escalation costs in out-years associated with the delays were also included.

Figure 6 illustrates the schedule shifts for both the MOX Fuel and Downblend Options. Table 2 and Table 3 capture the cost changes for the MOX Fuel Option and Downblend Option, respectively. Updated program element estimates for MIFT-related functions included H-Canyon Lifecycle Cost Estimate, the LANL Steady State Feedstock Production Program, and upgrades to the shipping and receiving facilities at PF-4. Changes due to program delays were by far the largest contributing cost factor, adding approximately 4.3B RY$ to MOX Fuel and 1.5B RY$ to the Downblend Option cost-to-go.

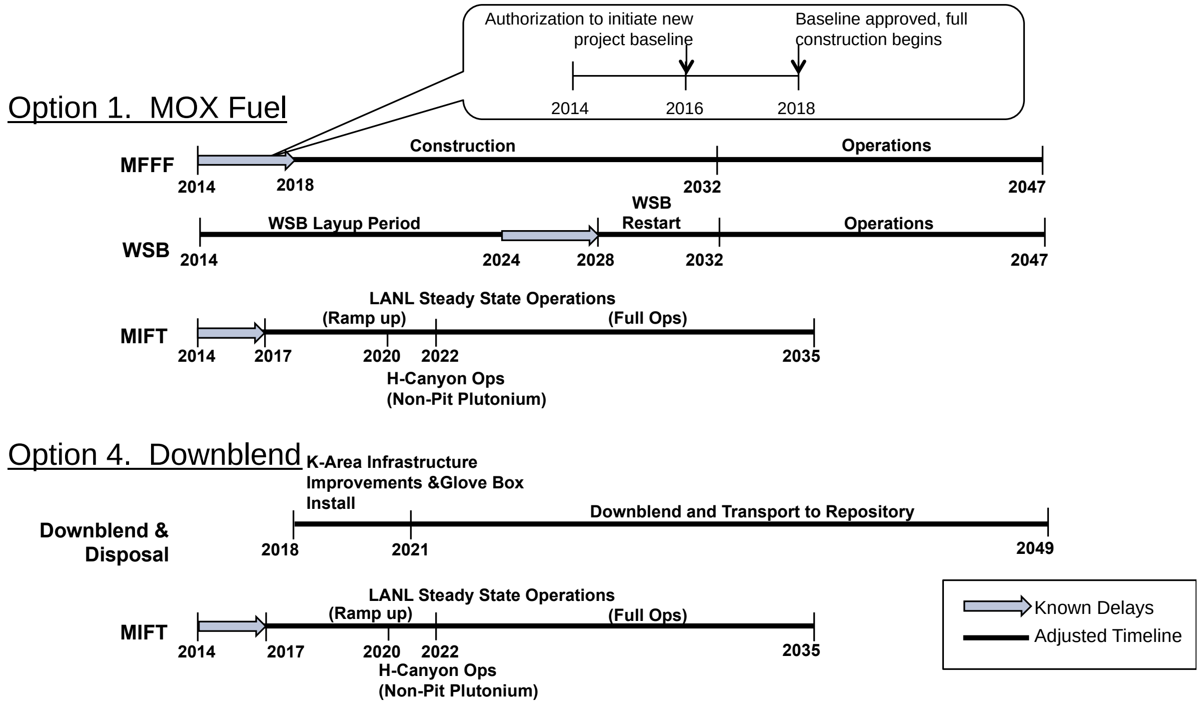

Figure 6. Program timelines with changes since the 2014 PWG estimate.

Table 2. Updates to 2014 PWG Estimate for MOX Fuel Option

2014 PWG Estimate (Cost to Go FY14 Forward)	**25.1 B RY$**

STEP 1: Incorporate Identified Changes Since Original 2013 Estimate
• H-Canyon Cost Updates
  • H-Canyon Lifecycle Cost Analysis Preliminary Update, SRS, 1/25/15
• LANL Steady State Feedstock Program Cost Updates
  • Steady State Planning Summary Document, LA-CP-13-00980, 8/1/13
  • MIFT Lifecycle Costs for U.S. Plutonium Disposition, File name "MIFT Cost MOX Option.pdf," 11/2013
  • Summary Document August 1 Deliverable, File name "2- Slides for Sep Briefing NNSA HQ.pdf," Slide 56, 9/13
  • LANL Steady State Feedstock Program Independent Review, p.88, 9/17/13
  • SSFP Oxide Production LCCE, File name "SSFP FY WBS Cost Estimate 08_21_2013 - Rev F.pdf," August 21, 2013
• PF-4 Shipping and Receiving Facility Upgrade
	1.23 B RY$

STEP 2: Include Escalation Due to Program Delays • 4%/year for construction, 2%/year for MIFT and Operations	2.56 B RY$
STEP 3: Include Projected Annual Program Costs During Delay, in RY$ • MFFF 4 years, MIFT: 3 years, WSB Layup: 4 years, PM & Integration: 4 years	1.78 B RY$
Changes from PWG 2014 Estimate (Cost to Go FY14 Forward)	**30.7 B RY$**

Table 3. Updates to 2014 PWG Estimate for Downblend Option

2014 PWG Estimate (Cost to Go FY14 Forward)	**10.3 B RY$**

STEP 1: Incorporate Identified Changes Since Original 2013 Estimate
• H-Canyon Cost Updates
    • H-Canyon Lifecycle Cost Analysis Preliminary Update, SRS, 1/25/15
• LANL Steady State Feedstock Program Cost Updates
    • Steady State Planning Summary Document, LA-CP-13-00980, 8/1/13
    • MIFT Lifecycle Costs for U.S. Plutonium Disposition, File name "MIFT Cost MOX Option.pdf," 11/2013
    • Summary Document August 1 Deliverable, File name "2- Slides for Sep Briefing NNSA HQ.pdf," Slide 56, 9/13
    • LANL Steady State Feedstock Program Independent Review, p.88, 9/17/13
    • SSFP Oxide Production LCCE, File name "SSFP FY WBS Cost Estimate 08_21_2013 - Rev F.pdf," August 21, 2013
• PF-4 Shipping and Receiving Facility Upgrade
	1.23 B RY$

STEP 2: Updated Capital Cost Estimate for New Glove Boxes	0.090 B RY$
STEP 3: Include Escalation Due to Program Delays • 4%/year for capital, 2%/year for MIFT and Operations	0.744 B RY$
STEP 4: Include Projected Annual Program Costs During Delay, in RY$ • MIFT: 3 years, PM & Integration: 3 years	0.803 B RY$
Changes Since PWG 2014 Estimate (Cost to Go FY14 Forward)	**13.2 B RY$**

6. Identification and Quantification of Risks through Sensitivity Analysis

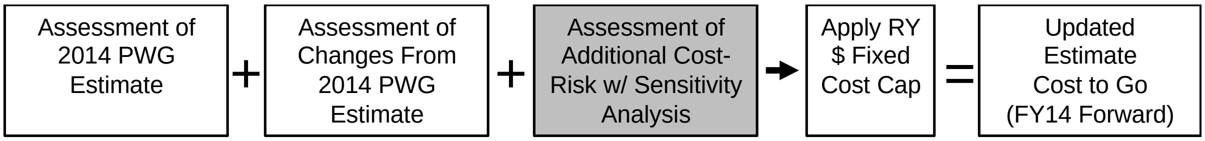

Figure 7. Step 3 of four-step approach, assessment of additional cost-risk with sensitivity analysis.

6.1 Risk Identification and Quantification Process

Technical and programmatic risks for each option were identified, quantified, and converted to cost-risk using the Project Risk Evaluation Process (PREP) methodology developed by The Aerospace Corporation to independently assess program risks on complex space programs. PREP is used to assess the cost-risk of a space missions and facilities at various points in their development lifecycle, and to identify and assess the total cost impacts associated with technical and programmatic risks to a program.

The PREP process utilizes expert assessment informed with technical data and analytical tools to estimate the likelihood and impact (range of cost threat) associated with a given risk, should it be realized. Typical technical inputs include concept and/or detailed design information, concepts of operation, system complexity descriptions, and materials and equipment lists. Typical programmatic inputs include work breakdown structure, cost profiles, and an integrated master schedule. Risks are “monetized” through evaluating their cost to specific program elements and applying an appropriate range of labor and/or hardware costs.

Technical and programmatic risks associated with interdependencies of the program elements in the MOX Fuel and Downblend options were identified and common risks were grouped together. Likelihoods were designated based on the level of maturity of the program element to which the risk applied, information on historical program performance, and technical information from the documents supplied at the site visits.

The risk consequence was developed as a three-point range estimate, which included a lower bound minimum value, most likely (or average) value, and an upper bound maximum value. Values were selected as a fraction of the total cost associated with the program elements impacted by the risk. The values were based on expert assessment of operational, and programmatic factors, such as planned production durations and rates vs. realized production durations and rates, planned funding vs. realized budgets, and the range of uncertainty in facility availability estimates. Technical factors, such as construction and operations complexity, the degree of uncertainty in the number and cost materials, and degree of uncertainty in the remaining work scope to complete the program elements, were also used in determining the range of consequences.

The range of consequences were considered within the constraints of the construction and operations durations assumed in the 2014 PWG estimate. Consequences were estimated in terms of the additional time duration needed to complete the activity. The time impacts were then converted to dollars by assessing the resources needed to recover the additional time needed, and complete the activity within the original duration of the activity. These estimates were determined using the annual per year costs associated with the affected program elements from the 2014 PWG estimate.

6.2 Cost Contingency Confidence Level

Estimating uncertainty is a function of, but not limited to, the quality of the project scope definition, the current project life-cycle status, and the degree to which the project team uses new or unique technologies. Government agency cost estimating guidance was reviewed in order to determine the appropriate confidence level for reporting cost-contingency and total cost-to-go on DOE programs. DOE order 413.3b Appendix C states that risks for all capital asset projects should be analyzed using a range of 70-90% confidence level upon baselining at CD-2, but if the project undergoes a baseline change, risks should be reanalyzed at a higher confidence level[2,3].

GAO cost estimating guidance[4,5] points to 70-80% confidence on cost contingency as typical, but does not prescribe a fixed level, and leaves it to the discretion of the agency and the nature of the program being estimated. Air Force and DOD/OSD cost estimating guidance is similar[6,7], with many DOD programs using 65% confidence level as a guideline in reporting cost contingency. NASA[8] typically uses 70% for estimating purposes and funds cost contingency at the 50% confidence level.

A number of the elements in the 2014 PWG estimate were reported at an 85% confidence level. Therefore, for purposes of this report, and in order to remain consistent with the original 2014 PWG estimate, cost contingency is reported at the 85% confidence level, unless otherwise noted.

6.3 Summary of Top Risk Drivers for the MOX Fuel Option

The risk assessment process for the MOX Fuel Option resulted in 14 risks and one opportunity, listed in Appendix B. Figure 8 summarizes the relative ranking of each of the risks, in terms of their mean value, which is defined as the product of the risk likelihood and average cost impact from the three-point range estimate. All risks and opportunities were probabilistically combined through a Monte-Carlo process to provide a total risk-based cost contingency in dollars. At 85% confidence, total cost contingency is $11.1B RY$. The 2014 PWG estimate includes 2.5B RY$ in cost contingency for the MOX Fuel Option, so the addition of the risk factors increases the cost-to-go estimate of Option 1 by $8.6B.

[2] DOE G 413.3-21 U.S. DEPARTMENT OF ENERGY Cost Estimating Guide Draft 6, 1-24-2011.
[3] Independent Cost Review (ICR) and Independent Cost Estimate (ICE) Standard Operating Procedures (SOP) Revision 1, Department of Energy.
[4] GAO 13-510T, Observations on Project and Program Cost Estimating in NNSA and the Office of Environmental Management.
[5] GAO Cost Estimating and Assessment Guide Twelve Steps of a High-Quality Cost Estimating Process.
[6] Operating and Support Cost-Estimating Guide, Office of the Secretary of Defense Cost Assessment and Program Evaluation, March 2014 (OSD CAPE).
[7] U. S. Air Force Cost Risk and Uncertainty Analysis Handbook, 2009.
[8] NASA Program Requirements (NPR 7120.5E).

The following eight risks are responsible for 95% of the total mean cost risk assessed for Option 1:

1. Fuel Production Rate Lower Than Expected: *IF MOX Fuel production goals are not met during MFFF steady state operations, THEN additional resources will be required to maintain the planned fuel production schedule*. Likelihood: Highly Likely (75%). There are a number of events that could result in this risk being realized. Different fuel types will be required by different commercial utilities, and uncertainty exists in the associated requirements and production work scope to accommodate multiple fuel types. It is not clear to what extent this has been factored into the layout, equipment, workforce size, training, and operations for MFFF. Another concern is the potential for continued changes to the safety basis, or other policy and regulatory requirements, which may, over time, impact staffing levels, use automation, and facility certification. Uncertainty exists in the complexity and extent of automated production support systems and the associated uncertainty in staffing to operate and maintain these systems. There is also a dependency on the WSB operations to support steady state fuel production rates, and difficulties in WSB could impact production goals. Production target rates have not been previously demonstrated domestically. Uncertainty also exists in demonstrating MFFF fuel production processes, which are to be validated for the first time through initial hot operations. Uncertainty in the funding of out-year operations for MFFF may impact the ability to maintain production rates and adequately staff the facility. In recent years funding has been less than requested for both MFFF construction and the Feedstock Pilot Program, and therefore steady state fuel production rates may not be able to be realized.
2. Feedstock Production Rate Lower Than Expected: *IF steady state feedstock production goals are not met during steady state operations, THEN additional resources will be required to maintain the planned feedstock production schedule*. Likelihood: Highly Likely (75%). There are a number of events that could result in this risk being realized. Competition from other programs for physical space and shared infrastructure in PF-4 may affect material storage, staging, material processing and material transportation throughout the facility. There is also uncertainty in the operational availability for the PF-4 facility, and actual availability rates to forecasts going forward. Changes to the safety basis, policy, and regulatory requirements may impact staffing levels and operational processes. Uncertainty exists in the planning to transition to steady state production, which is a several-fold increase from the current target production rates in the feedstock production pilot program. Uncertainty also exists in the ability to validate steady state production processes and throughput rates through the feedstock pilot program. Uncertainty in the funding of out-year operations may impact the ability to adequately staff and maintain steady state production goals.
3. MFFF Construction Cost Estimate Uncertainty and Cost Growth: *IF the current MOX services construction costs increase beyond the point estimate, THEN additional resources will be required*. Likelihood: Highly Likely (75%). Cost increases could come from several sources. Uncertainty in the remaining design work to go results in uncertainty in the remaining construction work scope to complete the project. Uncertainty exists in the number, unit cost, and availability of specialized materials and hardware. The level of complexity in construction activities associated with the remaining 40-60% of the work is greater than the work accomplished to date. Finish work on plumbing systems and equipment installation has to be done within fine tolerances and requires specialized trades skills, which may require additional time, workforce, and result in the need for re-work. Uncertainty exists in the work scope for the integration of automated systems, control systems, and software. Workforce attrition may occur for both general and specialized construction skills due to competition in the labor market.

4. MFFF Temporary Suspension of Operations: *IF a determination is made to suspend operations at MFFF, THEN additional resources will be required due to a delay in completion of MOX fuel production*. Likelihood: Near Certainty (90%). The potential for adverse consequences associated with operations on hazardous materials drives a strong culture of safety around nuclear operations. Operations may be temporarily suspended for a variety of reasons, as the safety oversight process continually evaluates the effectiveness of process and safety controls across the spectrum of operational activities in MFFF. The use of automation in the facilities adds a layer of safety at the expense of added complexity of the hardware used in performing the operations. This, combined with the length of duration of the production operations at steady state rates, may result in at least one temporary suspension of operations during the production period.

5. MFFF Full Construction Restart Delay: *IF the decision is not made by start of FY16 or other complications delay re-start of full MFFF construction, THEN additional resources will be required due to a delay in the first year of re-start execution*. Likelihood: Likely (50%). Uncertainty exists in the replanning and rehiring ramp-up schedule until the program is reauthorized. The resource pool of qualified contractors, vendors, and other resources is already constrained, due to the skill level required for nuclear operations and competition from other nuclear project in the region. A further delay could see a further diminished resource pool.

6. Feedstock Temporary Suspension of Operations: *IF a determination is made to suspend operations in facilities supporting feedstock production (PANTEX, LANL, SRNS, and the Portsmouth Facility), THEN additional resources will be required due to a delay in completion of the feedstock production program.* Likelihood: Near Certainty (90%). Feedstock production operations may be temporarily suspended for a variety of reasons, as the safety oversight process continually evaluates the effectiveness of process and safety controls across the spectrum of operational activities in all facilities required for feedstock production, transportation, and storage prior to conversion to MOX fuel. This, combined with the length of duration of the feedstock production operations at steady state rates, may result in at least one temporary suspension of operations during the production period.

7. SRS Overhead Cost Increases: *IF overhead costs for MOX Fuel Production at SRS are higher than anticipated, THEN additional resources will be required*. Likelihood: Highly Likely (75%). Uncertainty in the out-year costs to maintain shared services and infrastructure at SRS may result in increased costs to MFFF and WSB operations.

8. Facilities and Infrastructure Lifecycle Sustainment (Recapitalization): *IF start of operations is delayed, THEN facilities, such as WSB, K-Area, and Portsmouth, may require additional resources to maintain their readiness or lay-up status, to replace aging or obsolete equipment, and to complete necessary preparations for startup*. Likelihood: Near Certainty (90%). Uncertainty in WSB start-up costs and the year of startup are the primary drivers for this risk, however recapitalization will be required at Portsmouth and possibly K-Area as delays to the start of operations continue. In addition, there is some concern regarding equipment obsolescence at MFFF and in the MIFT program if MFFF construction delays continue and there is need for recapitalization prior to completion of construction and facility startup.

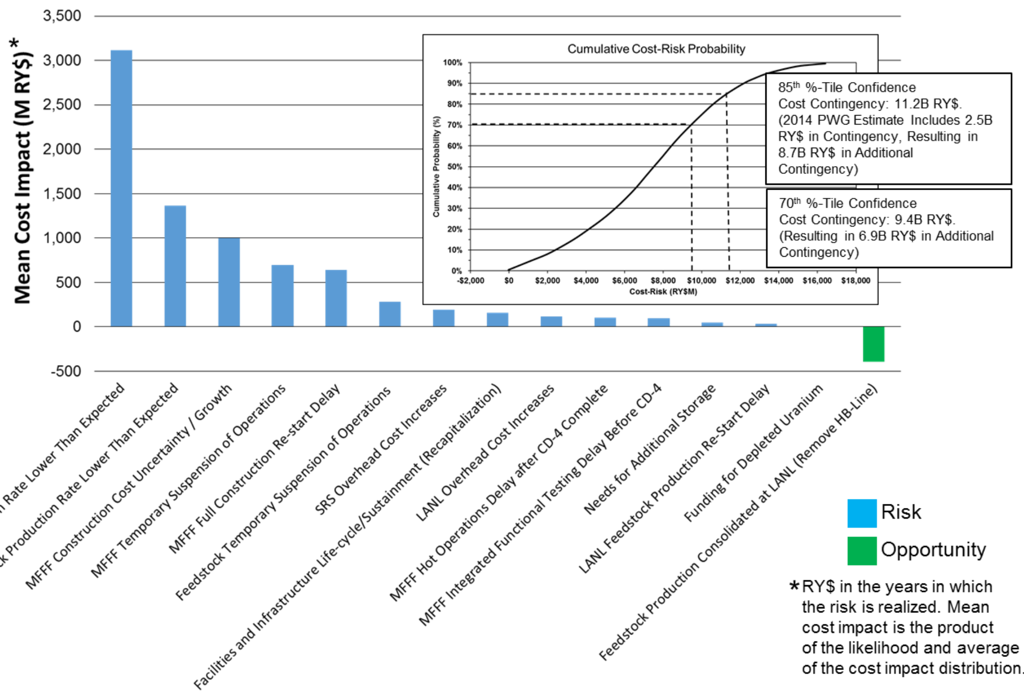

Figure 8. Cost-risk sensitivity drivers, option 1: MOX fuel.

6.4 Summary of Top Risk Drivers for the Downblend Option

The risk and identification process for the Downblend Option resulted in 14 risks and two opportunities, listed in Appendix B. Figure 9 summarizes the relative ranking of each of the risks, in terms of their mean values. These items were probabilistically combined through a Monte-Carlo process to provide total risk exposure in dollars. At 85% confidence, cost contingency is $3.6B RY$. The following eight risks are responsible for 95% of the total mean cost risk assessed for Option 4:

1. Feedstock Production Rate Lower Than Expected: *IF feedstock production goals are not met during steady state operations, THEN additional resources will be required to maintain the planned feedstock production schedule*. Likelihood: Highly Likely (75%). There are a number of events that could result in this risk being realized. Competition from other programs for physical space and shared infrastructure in PF-4 may affect material storage, staging, material processing and material transportation throughout the facility. There is also uncertainty in the operational availability for the PF-4 facility, and actual availability rates to forecasts going forward. Changes to the safety basis, policy, and regulatory requirements may impact staffing levels and operational processes. Uncertainty exists in the planning to transition to steady state production, which is a several-fold increase from the current target production rates in the feedstock production pilot program. Uncertainty also exists in the ability to validate steady state production processes and throughput rates through the feedstock pilot program. Uncertainty in the funding of out-year operations may impact the ability to adequately staff and maintain steady state production goals.

2. SRS Downblend Facility Start Delay: *IF program decision is not made by start of FY16 or discussions on changes to the PMDA extend beyond 2018, THEN additional resources will be required due to the delay.* Likelihood: Unlikely (25%). Uncertainty exists in the re-planning and rehiring ramp-up schedule until reauthorization of the program. Further, uncertainty exists in PMDA discussion depth and timeline required to adopt the Downblend Option.

3. Feedstock Temporary Suspension of Operations: *IF a determination is made to suspend operations in facilities supporting feedstock production (PANTEX, LANL, SRNL, and the Portsmouth Facility), THEN additional resources will be required due to a delay in the completion of the feedstock production program.* Likelihood: Near Certainty (90%). Feedstock production operations may be temporarily suspended for a variety of reasons, as the safety oversight process continually evaluates the effectiveness of process and safety controls across the spectrum of operational activities in all facilities required for feedstock production, transportation, and storage prior to conversion to MOX fuel. This, combined with the length of duration of the feedstock production operations at steady state rates, may result in at least one temporary suspension of operations during the production period.

4. Downblend Production Rate is Lower than Expected: *IF the downblend production goals are not met during steady state operations, THEN additional resources will be required to complete the downblend production on schedule*. Likelihood: Unlikely (25%). Changes to the safety basis, policy, or regulatory requirements, over time, may impact staffing levels, automation requirements, and facility certification. Uncertainty in the availability date for the disposition repository for the downblended material may impact the lblend production rate, however, K-Area may be available for temporary storage of the downblended material. Uncertainty in out-year operations funding may impact ability to adequately staff and maintain production rates.

5. Downblend Facility Temporary Suspension of Operations: *IF a determination is made to suspend operations at Downblend facility, THEN additional resources will be required due to a delay in completion of the downblend production program.* Likelihood: Near Certainty (90%). Downblend material production operations may be temporarily suspended for a variety of reasons, as the safety oversight process over the downblend production line, and the K-Area facility continually evaluates the effectiveness of process and safety controls. Aside from the downblend production line itself, a decision to temporarily suspend other program activities in K-Area may result in suspension of the downblend production line.

6. Downblend Construction Cost Estimate Uncertainty and Cost Growth: *IF the complexity of the glove boxes and other infrastructure to support the Downblend Option in K-area increase, THEN additional capital resources and staffing may be required to support design, installation, maintenance and production operations*. Likelihood: Highly Likely (75%). Immaturity in the design and associated costs of downblend-option equipment and infrastructure in K-Area may result in cost growth.

7. LANL Overhead Cost Increase: *IF overhead costs for feedstock production at LANL are higher than anticipated, THEN additional funding will be needed*. Likelihood: Unlikely (25%). Uncertainty in the out-year utilization for PF-4 space may result in increased costs (facility price per square foot) for programs using the facility.

8. MFFF Project Termination Cost Uncertainty: *IF MFFF contract termination and program close out costs exceed funds allocated in the 2014 PWG Estimate, THEN additional resources may be required*. Likelihood: Unlikely (25%). Legal challenges and economic and political impacts may result in delays in terminating the MOX Fuel program, as well as uncertainty in subcontract penalties, damage payments, and payments for long-lead items.

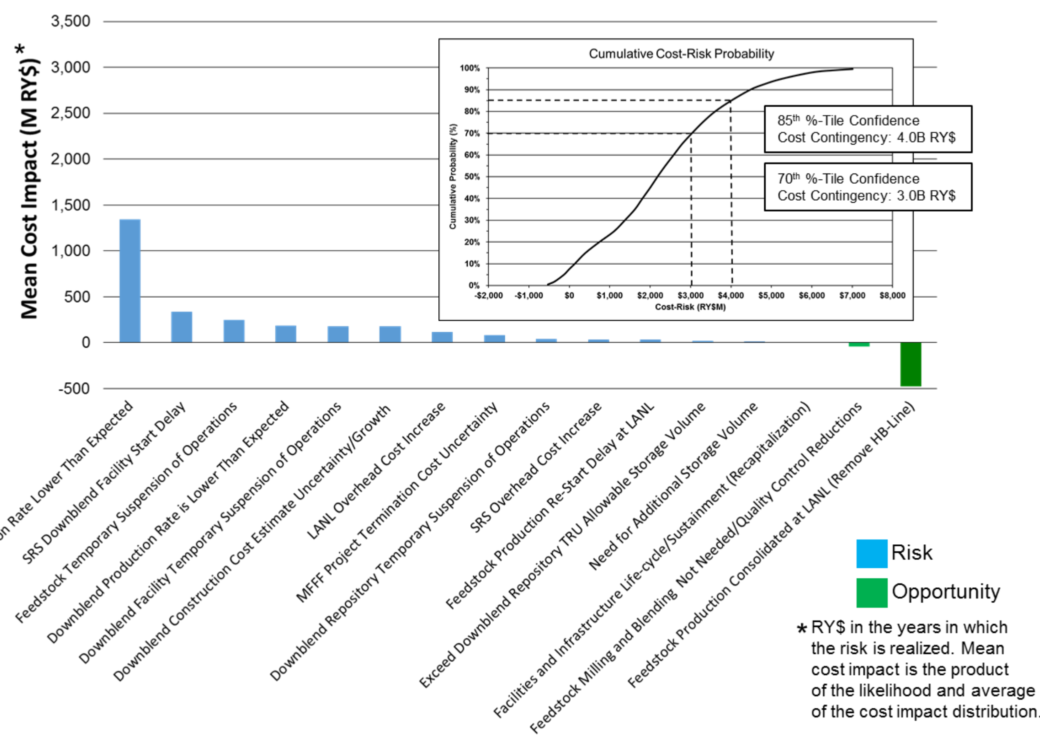

Figure 9. Cost-risk sensitivity drivers, option 4: downblend.

6.5 Opportunities

Earlier in the MOX Fuel program, plutonium oxide feedstock production was thought to be on the critical path, lagging behind MFFF construction. In order to regain schedule, three different feedstock production processes were planned (shown in Figure 2). With the current delays to MFFF construction, feedstock production is no longer a critical path item, which creates an opportunity to consolidate the steady state feedstock production into a single oxide production line at LANL after the completing the dissolution and oxidation of non-pit plutonium in storage in K-area at SRS. This opportunity for cost savings was included in the PREP analysis for both the MOX Fuel Option (Figure 8) and the Downblend Option (Figure 9).

A second opportunity exists for the Downblend Option to save costs associated with the milling, blending and assay of the feedstock batch lots produced at LANL. Since the feedstock in the Downblend Option is no longer destined for MOX fuel fabrication, the level of quality control rigor and documentation on each batch lot can be significantly relaxed. This opportunity for cost savings was included in the analysis for the Downblend Option.

6.6 Cost Risk

Risks are probabilistically combined through a Monte-Carlo process to provide total risk exposure to the program in dollars. Each risk is considered to be independent from the others. For each risk, the first draw in the Monte-Carlo process is on likelihood. If the draw is successful then the second draw, on impact, is done by randomly sampling a triangular probability density function defined by the three-point range estimate described above for the given risk. The results are summed across all risks and then binned by likelihood. 10,000 draws are made on each risk in the Monte-Carlo process to produce the cumulative cost-risk distribution function or “S-curve.” The S-curve is then summed with the changes identified in original 2014 PWG estimate, accounting for contingency already included in the original estimate.

The results of the cost-risk sensitivity analysis are shown in Figure 10 for MOX Fuel and Downblend Options. The numbers in this figure do not include the cost increases associated with the application of cost caps to MFFF construction, which will be addressed in the next section of this report. The figure shows cost-to-go for cost confidence levels associated with (1) updates due to changes since 2014 PWG Estimate (in the ~10^{th} %-tile), (2) 70%-tile confidence cost contingency, and (3) 85%-tile confidence cost contingency. 85% confidence cost contingency results in 36% cost contingency for MOX Fuel and 27% for Downblend on the total lifecycle cost-to-go, including operations. The initial 2014 PWG estimate carried 10% cost contingency on MOX Fuel Program. In comparing the MOX Fuel and Downblend Options, Figure 10 illustrates the large difference between the options at any cost-risk confidence level. There is no cost-risk confidence level in the assessment where MOX Fuel program lifecycle cost-to-go is less than the Downblend Option.

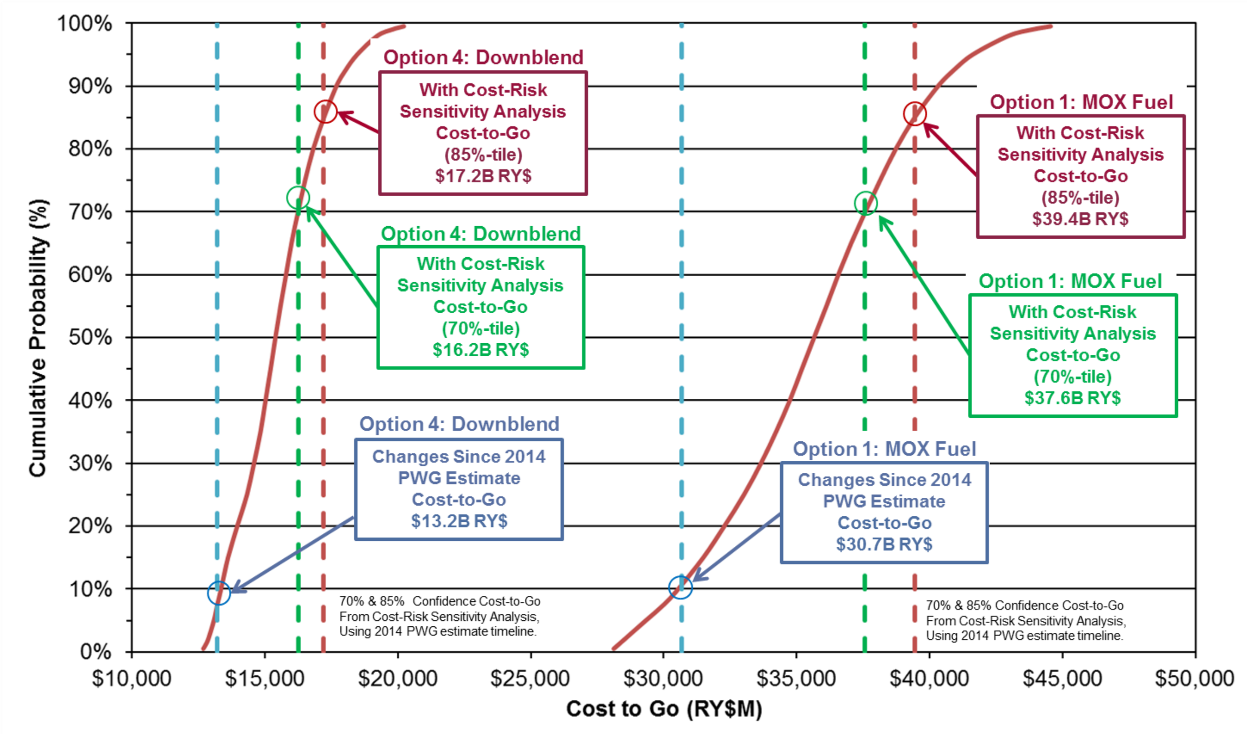

Figure 10. Comparison of total lifecycle cost-to-go before application of cost caps to MFFF construction.

7. Assessment of Cost Caps on Cost Profile

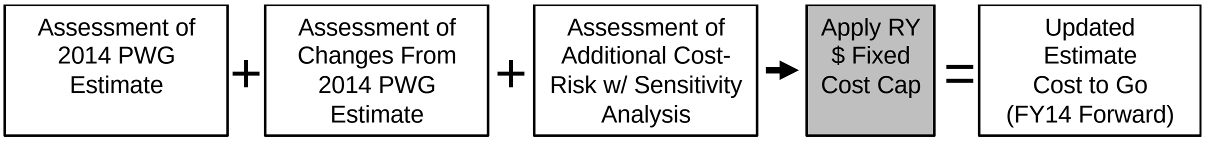

Figure 11. Step 4 of four-step approach, apply RY $ fixed cost cap.

The previous section described the development of the total cost-to-go at the 85% confidence level for Option 1 and Option 4, based on the 2014 PWG estimate timeline with adjustments for the delays that have been realized to date. Year-after-year cost profiles were constructed for the following cost capped scenarios:

1. Option 1 cost profile with a 500M RY$ / year cost cap during MFFF construction (Figure 12)

2. Option 1 cost profile with a 375M RY$ / year cost cap during MFFF construction (Figure 13). 375M RY$ represents the minimum cost cap to complete the MFFF construction, given assumptions on cost confidence level, and escalation factors.

3. Option 4 cost profile (Figure 15). Option 4 construction and capital costs do not exceed 200M RY$ / year and therefore the 375M and 500M RY$ /year cost caps are not applied.

Several key assumptions were made in the construction of the cost profiles. An 85th percentile confidence estimate was used on cost-to-go. It should be noted that small changes in the cost confidence level can have large impacts on the total lifecycle cost-to-go for programs that have very long lifecycles and are subject to cost caps. These programs experience an amplification of the effects of cost escalation in RY$. For example a 15% change from 70% to 85% confidence level results in a 4.2B RY$ increase to the MOX Fuel Program under the 500M RY$ / year cost cap assumed in the 2014 PWG estimate.

The shape of the cost profile for MIFT and MFFF operations is scaled from the 2014 PWG estimate and was not replanned to match an ideal profile. The WSB lay-up period was extended for the MOX Fuel Option to maintain consistency with delays to the MFFF operations start. Program management and integration costs were also extended and a 10% penalty was applied to account for additional labor for on-going replanning.

In all cases, the MIFT costs were *not* constrained to a cost cap, and the feedstock production duration was assumed to be the same as used in the 2014 PWG estimate (19 Years). For the MOX Fuel Option, MFFF operations were *not* constrained to a cost cap, and the MOX Fuel production duration was assumed to be same as used in the 2014 PWG estimate (15 Years). For the Downblend Option, the downblend production duration was also assumed to be the same as used in the 2014 PWG estimate (29 years). A 4% escalation on construction/capital and a 2% escalation on program labor and operations were applied.

The effects of funding caps on the MOX program are significant. Examining the cost profiles for Option 1 shows the $500M RY / year cost cap during MFFF construction increases the total cost-to-go to 47.5B RY$, and extends the task completion date to FY2059. (Figure 12) A reduction in the MFFF construction cost cap from $500M/year to $375M/year increases the total cost-to-go to 110.4B RY$ and extending the completion date to FY2115. (Figure 13)

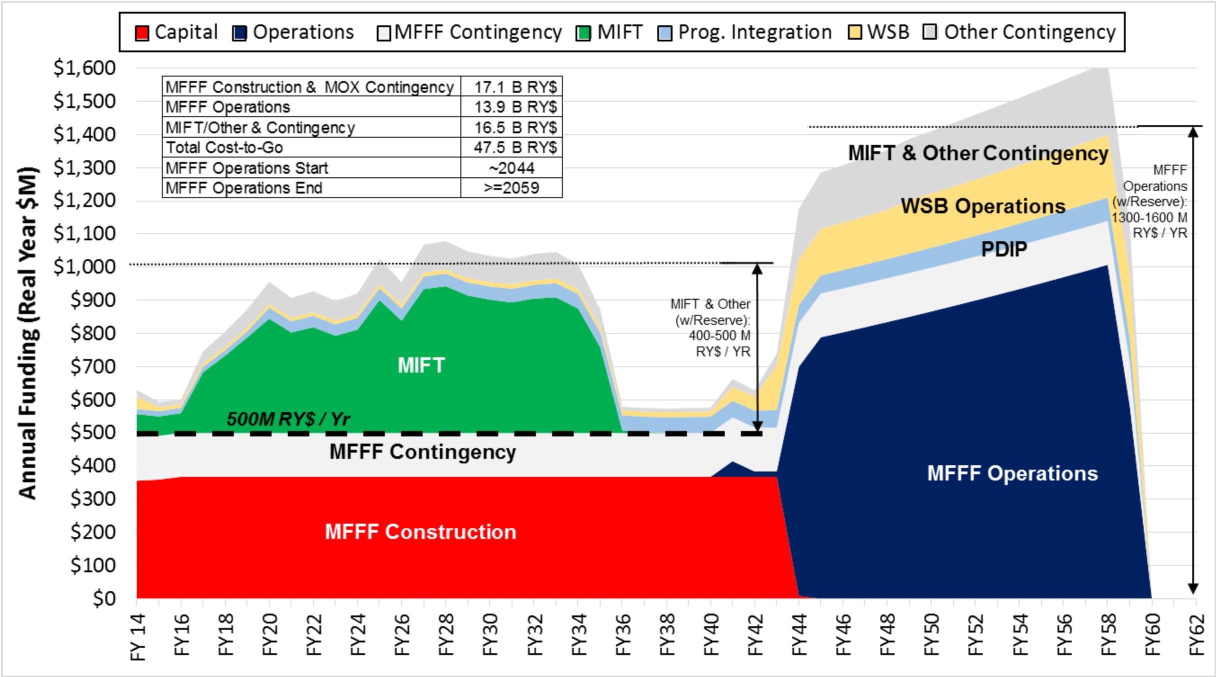

Figure 12. Cost profile, option 1: MOX fuel, $500M RY/YR cap on MFFF construction.

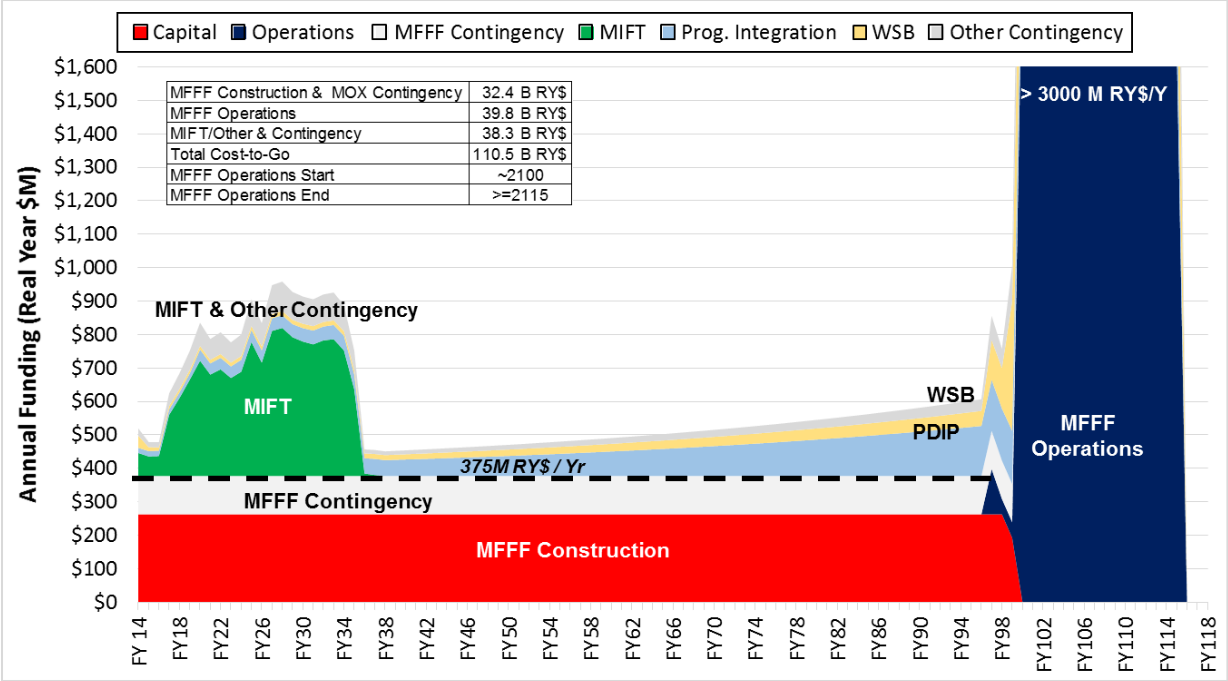

Figure 13. Cost profile, option 1: MOX fuel, $375M RY/YR cap on MFFF construction.

Figure 14 illustrates that MFFF construction cannot be completed under a 350M RY$ / year cost cap using the 85th percentile cost with 4% and 2% escalation on construction/capital and labor, respectively. In the figure, the Y-axis represents the accumulation of value in M FY14$ associated with annual expenditures of 500, 425, 375, 350 and 300 M RY$ / year. As can be seen, approximately 9400M FY14$ is required to complete MFFF construction at 85% confidence. As real-year dollars are added each year, inflation begins to reduce the $FY14 value of each following year. Below about 375M RY$ / year, inflation overwhelms the value of money in the out-years, making it impossible to achieve the needed value in FY14$.

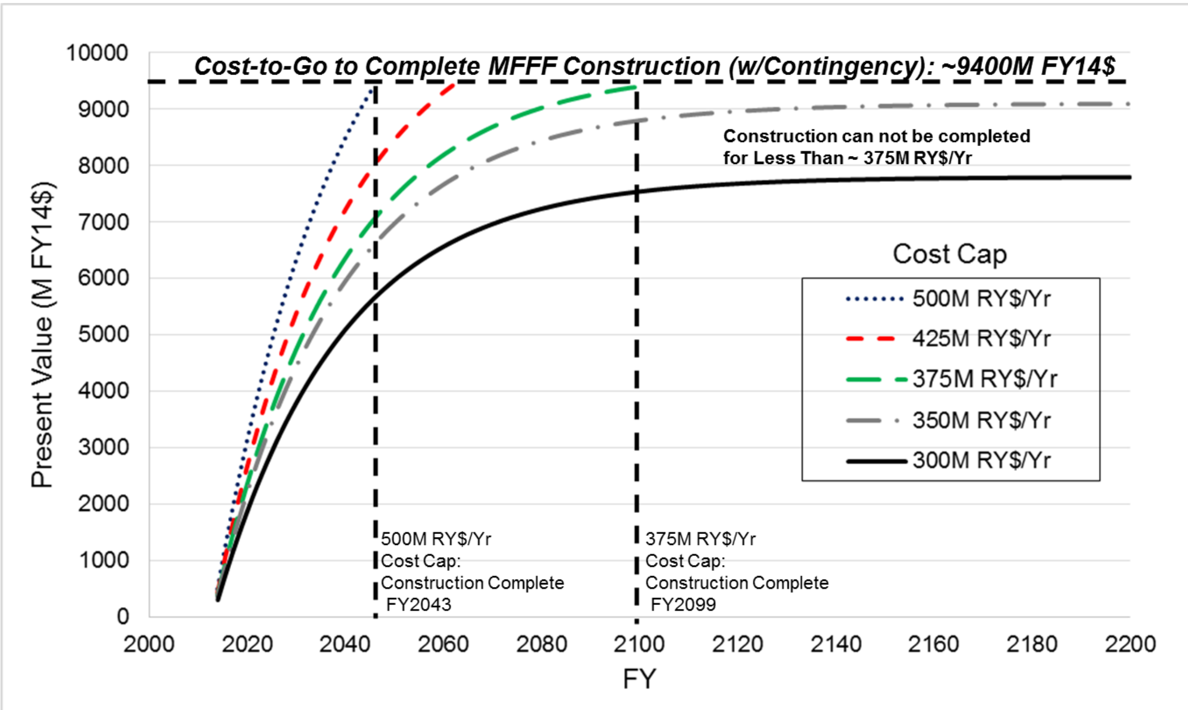

Figure 14. Option 1: MFFF construction cost-to-go FY14$ compared to a series of constant RY$/year cash flows.

The Option 4 cost profile is not subject to cost caps on construction/capital, with the program being executed without similar penalties in completion date or increases in cost-to-go. (Figure 15)

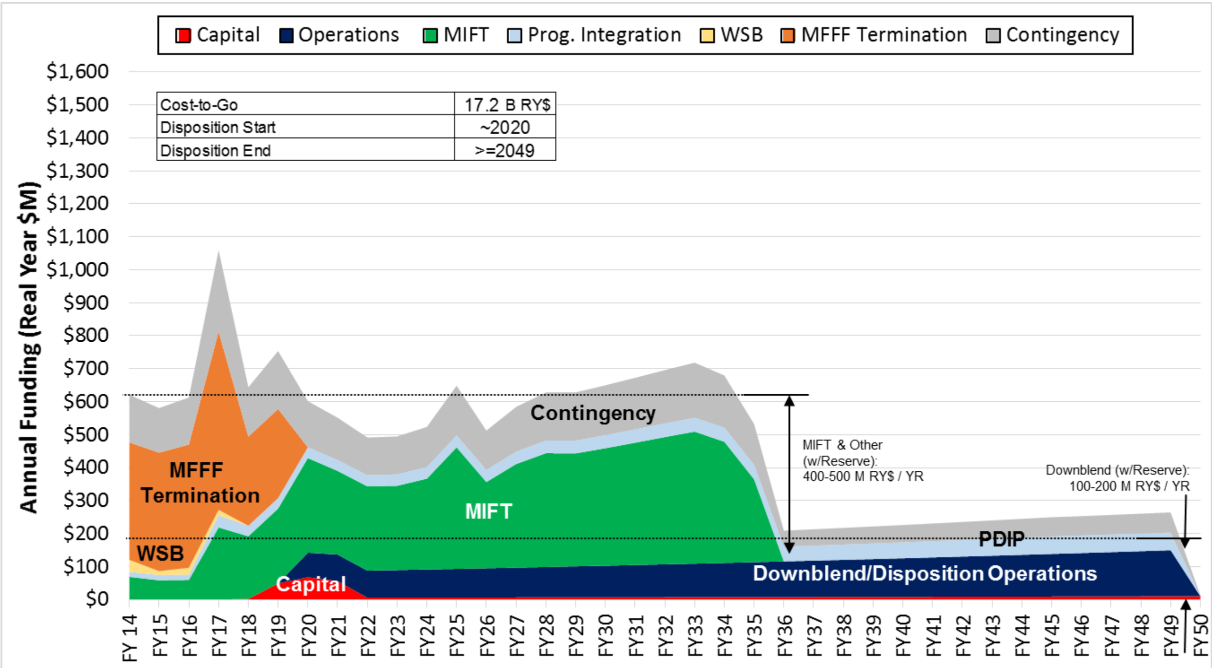

Figure 15. Cost profile, option 4: downblend.

8. Updated Cost Estimate

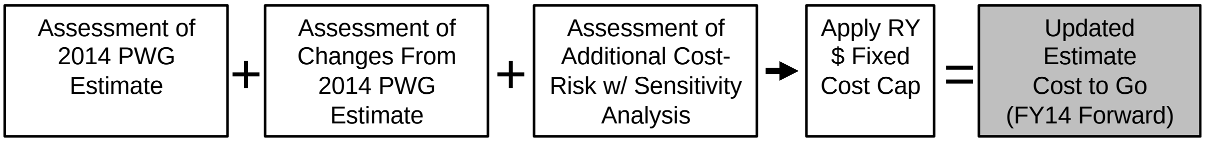

Figure 16. Four step approach produces updated estimate of cost-to-go.

Table 4 summarizes the results of the cost assessment at 85%-tile confidence cost contingency. For the MOX Fuel Option, the 2014 PWG report estimate cost-to-go is 25.1B RY$ (18.6B FY14$). Adding known changes to the program since the time of the estimate, which include the costs of program delays, results in 30.7 $B (21.3B FY14$) cost-to-go. Additional cost contingency determined through the risk-sensitivity analysis and application of the $500M RY$/year cost cap used in the 2014 PWG estimate increases the total lifecycle cost-to-go to 47.5B RY$ (27.2B FY14$). In a similar fashion, for the Downblend Option, the total lifecycle cost-to-go with identified changes to the 2014 PWG estimate and risk sensitivity analysis is 17.2B RY$ (13.1B FY14$).

Table 1 includes costs for the capital and construction projects associated with options 1 and 4, and other key program elements needed to complete the plutonium disposition mission, such as MIFT. MIFT cost-to-go over the lifecycle of the program is 16.5B RY$.

Application of the cost cap results in increased time to compete MFFF construction and an increase in cost-to-go in real year dollars. This is due to additional costs for maintaining the Waste Solidification Building (WSB) and program management and integration functions during the additional years required to complete MFFF construction, and escalation over the lifecycle of the program due to inflation.

Table 4. Summary Cost-To-Go Estimate for Options 1 and 4, 85%-tile Confidence

	Plutonium Working Group (PWG) 2014 Report Estimate	Assessment of Changes Since PWG 2014 Report Estimate	Assessment of Cost-Risk Drivers Through Sensitivity Analysis (85th Percentile Confidence)	
	Cost-to-Go FY14 Forward	+ Changes	+ Cost Risk = Updated Estimate	
			500M RY$/Yr Cap on Construction/Capital	**~375M RY$/Yr Cap** on Construction/Capital
Option 1: MOX Fuel	25.1B RY$ 18.6B FY14$	30.7 B RY$ 21.3B FY14$	47.5B RY$ 27.2B FY14$	110.4B RY$ 29.8B FY14$
Option 4: Downblend	10.3B RY$ 8.2B FY14$	13.2 B RY$ 10.1 B FY14$	17.2B RY$ 13.1B FY14$	

It was determined that the minimum cost cap on capital and construction to complete the MFFF construction was approximately 375M RY$/year. In FY14, the MFFF construction was funded at ~350M RY$/year. The application of a 375M RY$/year cost cap increases the total lifecycle cost-to-go to 110.4B RY$ (29.8B FY14$). For the Downblend Option the total lifecycle cost-to-go, with identified changes to the 2014 PWG estimate and risk sensitivity analysis is 17.2B RY$ (13.1B FY14$).

Note that for the MOX Fuel Option, costs for MFFF shutdown to a safe state at end of operations are included in this assessment. However, this study did not assess MFFF decommissioning and demolition (D&D) and return to green field.

9. Qualitative Assessment Factors

In addition to the monetized risks and cost estimates described in the previous sections, NNSA also asked Aerospace to consider qualitative assessment factors, such as accreditation/certification of new facilities and technologies to transition or dispose of weapons grade Pu, and disposal execution processes and documentation; compliance with existing / potential future environmental regulations and modifications to international agreements; oversight and governance by agencies external to DOE which may affect certification, facilities construction, and regulations to support monitoring; and regulatory and public acceptance issues regarding implementation of such selected alternatives, including interactions with affected States.

9.1 Factors for Option 1, MOX Fuel Fabrication

9.1.1 Lack of Utilities for MOX Fuel

Currently, there is an apparent lack of commitment on the part of the commercial utilities to accept and use MOX fuel; Duke Energy participated in some early testing of MOX fuel assemblies at its Catawba nuclear plant but opted out of the final of three scheduled tests, although there seems to be some debate as to the specific reasons behind this decision[9]. Although the lack of a formal commitment by any utilities to participate in this program could be simply attributed to the timeline for which MOX fuel is expected to be available, there is some concern that fewer than expected utilities, or even no utility, will commit to using MOX fuel in the future; fewer than expected utilities would result in a longer operations time to dispose of all 34 MT, which could result in drawing out the MOX Fuel program costs if production rates need to be adjusted to account for the fewer participants. Although DOE has agreed to pay for the modifications to retrofit reactors, lack of commitment on the part of the utilities could also be attributed to the schedule impacts related to licensing requirements and the associated facility/infrastructure modifications required to adapt the reactor plant to use the plutonium-based MOX fuel. Downtime required to make these modifications could adversely affect a plant's operations and delivery capability for standing contracts, adding risk to the proposition. The fact that the government has not committed to completing the project might also be a factor in the hesitation of potential fuel customers. Even if the government pays for plant modifications, there will be an ongoing, additional cost to the operators to maintain security measures in the presence of plutonium fuel.

If no utilities commit to accepting (using) the MOX fuel, then a significant amount of resource may be required to convert the unspent MOX fuel into a form for disposition that is in accordance with the PDMA.

9.1.2 Utility/Plant Licensing

Once one or more utilities commit to accepting use of MOX fuel, the NRC will impose re-licensing requirements for those participating power plants. Just as there are uncertainties with respect to NRC licensing of the MOX facilities, so too are there risks with respect to re-licensing of the commercial nuclear plants to accept and process MOX fuel. The shortage of recent NRC experience in licensing plants to use plutonium fuel versus uranium may pose a challenge.

[9] "Duke Energy Won't Do More MOX Tests", Augusta Chronicle, November 17, 2009. Accessed Feb 2015 at http://chronicle.augusta.com/stories/2009/11/17/met_556022.shtml

9.1.3 Cybersecurity

Though certainly not unique to DOE or NRC, cybersecurity continues to be a global concern and an evolving threat without regard for international boundaries. The viability of cyber-attacks and cyber-attack simulations against national and international infrastructure has been common knowledge for years. Events such as Titan Rain, Operation Aurora, Stuxnet, and Saudi Aramco are just a few examples, and illustrates the potential for harm to nuclear facilities via cyber methods. However, the risk described here is not necessarily the potential for security breaches due to cyber-attacks (though that risk certainly exists) but rather the potential for delays due to evolving cybersecurity regulations and the need to meet those requirements prior to certification. The heavy reliance by the MFFF on software and automation make this risk particularly problematic.

9.1.4 NRC Regulations

The NNSA, a separately organized agency within the DOE, manages the Plutonium Disposition program and is tasked with converting surplus weapons-grade plutonium to MOX fuel in specialized facilities and reactors as part of the current program of record. MOX Services is responsible for providing multiple layers of oversight to the construction of the MOX facilities. These facilities are required to comply with DOE policies and NRC regulations. The NRC and DOE organizations have noted differences related to process and requirements, particularly with safety but also related to licensing. Those differences may impose additional cost and schedule implications if compromise and/or negotiations ensue to mitigate any differences. Additionally, DOE policies and NRC regulations are subject to change and this consequently creates the potential to impact project costs and schedules, especially given the MOX facilities construction timeline spans over decades.

NRC regulations and licensing experience are primarily geared for construction and operations of commercial nuclear reactors using uranium versus plutonium-based fuels. The PWG report identifies these risks, stating, “Several risks to start up exist which make estimating the cost and duration of this project phase difficult: availability of necessary skill and experience within the NRC to oversee startup of this type of facility; the time that can occur between when the Operational Readiness Review occurs onsite (demonstrating that the operations personnel have necessary procedures developed and mature conduct of operations in place to ensure safe operations) and when the final approval to operate is granted by the NRC; and NNSA unfamiliarity with the conduct of an NRC ORR and any features of it that are different from those run by DOE personnel”[10]. Consequently, there is some risk that the regulations may drive construction activities during the licensing processes, potentially adding schedule and cost implications. The GAO report establishes NRC regulations as one of the causes contributing to MOX’s cost growth[11].

9.1.5 IAEA Monitoring

The International Atomic Energy Agency (IAEA) Department of Safeguards actively supports efforts related to the development of guidance for proliferation resistance for future nuclear fuel cycle facilities. Current guidance for proliferation resistance for future nuclear fuel cycle facilities is a safeguards-by-design (SBD) approach, wherein international safeguards are fully integrated into the design process of a nuclear facility, from initial planning through design, construction, and operation, and decommissioning. All Nuclear Weapon States (NWS), including the United States, provide for safeguards on a voluntary basis at selected facilities. With respect to MFFF, several meetings have been held with the branches of

[10] Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon-Grade Plutonium Disposition Options, U.S. Department of Energy, April 2014.

[11] GAO-14-231, “Plutonium Disposition Program: DOE Needs to Analyze the Root Cause of Cost increase and Develop Better Cost Estimates”, February 2014

the IAEA to review the MFFF design with respect to incorporating a PMDA verification regime in the available space, so that the verification equipment could be accommodated at a later date, once the facility is completed. There does not appear to be significant challenges in meeting the IAEA monitoring requirements at this time. However, given the uncertainty in the time to complete MFFF construction and that portions of the detailed design will not be completed until subcontractors and vendors are contracted to complete the design (shop drawings) and construction, there is the potential for further work being needed to support the IAEA monitoring regime.

9.1.6 Acquisition Approach Issues

There are uncertainties in potential cost growth due to implications related to the chosen acquisition approach and on-going funding issues.

NNSA's Office of Acquisition and Project Management is responsible for managing construction of the MOX facilities within approved cost and schedule estimates. The office conducts reviews of the construction projects to evaluate technical, cost, scope and other aspects of projects. The NNSA entered into cost-reimbursable contracts (with a strategic alliance/team) for construction of the MOX, with a fee structure intended to limit contractor's profits[12]. The cost-reimbursable contract is not unreasonable given the uncertainties related to this project. Complex requirements, particularly those unique to the government, usually result in greater risk assumption by the government. This is especially true for complex research and development contracts, when performance uncertainties or the likelihood of changes makes it difficult to estimate performance costs in advance[13]. However, the MOX project evidence seems to indicate that a design-build methodology is being implemented to design and construct the project, which is somewhat at odds with the reason why the cost-reimbursable contract is a reasonable approach for this particular project. The reason being that the Design-Build approach is typically not suited for:

- Unique, one-of-a-kind projects (with special requirements)
- Projects with high complexity engineering
- Facilities with clients that need frequent attention (regulations fall in this area)
- Projects requiring flexibility implementing innovative construction methodologies

The list above aligns with the qualities inherent in the MOX Fuel project. As a result, there is some concern with respect to cost implications associated with an ill-fitted implementation approach (that cannot be mitigated at this stage of the project) that will continue to play a factor through the remainder of the construction project. Because construction is initiated prior to completion of design, there is added cost and schedule risk if something in the engineering (interfaces, integration, etc.) was not considered early enough to preclude rework in construction or if there are substantial deviations from the original direction/design. Furthermore, the design-build approach typically compresses the overall construction project schedule, but the variation in available funding and annual funding cap limitations on the MOX project have actually worked to expand the overall schedule timeline, impacting costs.

[12] U.S. Department of Energy Office of Inspector General Office of Audits and Inspections, "Audit Report: Cost & schedule of the Mixed Oxide Fuel Fabrication at the Savannah River Site", May 2014

[13] Federal Acquisitions Regulations (FAR), Subpart 16.3, Cost-Reimbursement Contracts and 16.1, Factors in selecting contract types.

The 2014 DOE IG report pointed out that project estimates indicated that approximately 40% of the budget had been spent on the MOX Facility project and that the project was about 60 percent complete (as of October 2013)[14]. However, design work is still underway in a number of critical areas including software, instrumentation and control systems, as well as fire suppression and various mechanical systems[15]. The fact that design work is still incomplete or on-going suggests potential risk, particularly with integration of systems. The contractor indicated that the majority of related equipment has already been purchased and is currently in storage, which will help with limiting costs related to escalation. However, there is a flip side to this concept in that there is potential cost risk with expired warranties if this equipment is found to be malfunctioning during functional/operational testing and replacements are required. There is also potential for added costs related to obsolescence of equipment, particularly with software and controls, given the current estimated date of construction completion.

9.1.7 Areva Financial Status

Areva SA, one of the joint owners of MOX Services[16], is a French multi-national group specializing in nuclear and renewable energy. It is primarily owned by a French government agency and the French government itself (54% by the French Atomic Energy Commission and 29% by the French government)[17].

On March 4, 2015, Areva announced a 2014 loss of €4.8 billion ($5.29 billion), making a cumulative loss of over €8 billion over the past four years. On March 6, ratings agency Standard & Poor's downgraded the credit rating of Areva from BB+ to BB-; this move follows a downgrade (into "junk bond" status) in November. Areva has incurred multi-billion euro cost overruns on two fixed-price reactors under construction, including a €5.4 billion overrun on a €3.2 billion contract.[18]

According to a study commissioned by Areva's unions, the firm requires €2.0-€2.5 billion in additional capital to maintain ongoing operations. Due to its junk bond status, issuing additional debt appears to be problematic. Therefore, the firm is currently studying its available options to raise capital, including a merger with EDF (French utility company, also largely owned by the government), sale of uranium mines to Chinese investors, and sale of its nuclear transport (TNI) and nuclear decommissioning units (STMI)[19].

The impact of Areva's financial difficulties on the MOX Fuel project will depend on whether Areva is able to secure additional funding for ongoing operations, either through public or private sources, but the net effect of either a significant restructuring or a bankruptcy may be disruptive to MFFF construction.

9.1.8 WSB Readiness and Lifecycle

The WSB was constructed to substantial completion and placed in "lay-up" status. Substantial completion denotes the facility has met regulatory requirements for occupancy but it was noted that some items were incomplete.

---

[14] U.S. Department of Energy Office of Inspector General Office of Audits and Inspections, "Audit Report: Cost & schedule of the Mixed Oxide Fuel Fabrication at the Savannah River Site", May 2014
[15] U.S. Department of Energy Office of Inspector General Office of Audits and Inspections, "Audit Report: Cost & schedule of the Mixed Oxide Fuel Fabrication at the Savannah River Site", May 2014
[16] According to CB&I's most recent 10-K report, the MOX project is a joint venture with CB&I owning 52% and Areva owning 48%. Chicago Bridge & Iron Company N.V., Form 10-K, 31 Dec. 2014. SEC website. Accessed 16 Mar. 2015.
[17] "Capital Structure", Areva. Accessed 14 Mar. 2015
[18] "S&P downgrades Areva debt further into junk status", Reuters, 6 Mar. 2015. Accessed 14 Mar. 2015.
[19] Ibid.

Savannah River Nuclear Solutions (SRNS) has provided the WSB Federal Project Manager with recommendations for the level of staffing, and required materials to ensure that the core systems remain operational to provide facility habitability and minimize equipment degradation during the lay-up period. In addition SRNS has identified those systems that will be operated periodically or will not be operated during the lay-up period. In addition to the recommendations provided, other priorities to preserve the value and readiness of facilities intended for future use are:

1. Protect the building from sudden loss (fire, etc.)
2. Weatherize and maintain the property and systems to stop moisture penetration (example: pressurization of tanks and pressure vessels, pipes)
3. Control the humidity levels inside once the building has been secured (example: monitoring and trending)
4. Maintain operating permits, especially those that are presently or could be "grandfathered" and difficult to obtain in the future (regulatory requirements)
5. Yearly maintenance should be performed and should include periodic inspections to verify condition of building/systems
6. Maintaining good records (configuration management)
7. Maintain sufficient funding for preservation activities (including maintenance)

Facilities that are properly prepared for a lay-up state (IAW NACE 38394 guidelines) retain a higher PRV (Plant Replacement Value) and demonstrate a greater capability for restart. From discussions with the WSB Federal Project Director, and based on the walk-down review of the facilities, it appears that attempts have been made to properly secure the facility for future restart. However, future restart of a facility in a lay-up state is also dependent upon the length of time and estimated PRV. There are recapitalization benchmarks that help determine the feasibility of improving the facility versus building new. These benchmarks vary across industries and facility types and are typically based in part upon the facility condition assessment, also known as the Facility Condition Index (FCI). If the modifications/upgrade costs for restarting the facility are significant, then there is a risk that the project may become not feasible. Additionally, given the potentially long time lapse, unless requirements have been "grandfathered", there are risks that additional regulatory requirements (codes, Defense Board and new DOE safety requirements.) may prove to be unachievable for the built WSB as well.

Therefore, completing the WSB and bringing it into operational readiness becomes technically and programmatically more costly and risky with the continued delays to completing the MFFF construction.

9.1.9 Utility/Plant Modifications and Specific Fuel Qualification

Modifications will be required at each of the utility plants to accommodate the plutonium-based MOX fuel. Since the reactor design/configuration varies from site to site, specific fuel qualifications will vary with each plant. Given the uncertainties associated with the fuel qualifications and physical plant modifications required, this remains a risk.

9.1.10 Environmental Activist Groups

Nuclear activist groups are highly active in South Carolina (e.g., Nuclear Watch South). Legal filings by environmental/anti-nuclear activists and consequential delays may increase as MOX progresses closer to licensing and operation.

9.2 Factors for Option 4, Downblend and Disposal

9.2.1 Availability of a Repository for Permanent Disposal of Downblended Material

The availability of a geologically stable underground repository (GSUR) for permanent disposal of the transuranic downblended material remains an issue. The February 2014 incidents (salt haul truck fire and radiological release into the environment) at the repository reference model used in this study, the Waste Isolation Pilot Plant (WIPP), resulted in the suspension of operations at the site for receipt of transuranic (TRU) waste. The accident investigation was concluded in 2015, and DOE is implementing a recovery plan. Option 4 is singly dependent on a repository like WIPP for the permanent disposal of downblended plutonium oxide material. WIPP is currently the only domestic repository capable of permanently storing the downblended material, once it has restarted operations. In the absence of WIPP, another facility would need to be constructed and certified for use, which would add significant time and cost to the Downblend Option.

9.2.2 Modification of PMDA

As with all non-MOX options, the downblend and disposal approach would require negotiations with the Russians and written agreement regarding use of this option under the disposition agreement, pursuant to existing PMDA provisions. Such an agreement is permitted under Article III (1) of the PMDA and therefore it is anticipated that reaching agreement would not be a lengthy process compared with a complete renegotiation. There are certain risks with negotiating for a non-reactor based approach. In the original agreement, both countries agreed to a mainly MOX-fuel approach: Russia would dispose of its 34 MT by irradiating MOX in LWRs, while the U.S. would use the same approach for the majority of its plutonium, but would dispose of 6.5 MT via immobilization (since cancelled due to budget constraints). Subsequently, Russia changed its approach to irradiate MOX fuel in fast reactors rather than LWRs, but fundamentally the Russian approach is still a reactor-based one. Russia may be reluctant to accept a disposition approach that is entirely reliant on geologic emplacement for the entire 34 MT.

9.2.3 Security Basis Change Due to Quantity of Material to be Dispositioned

The report of the Plutonium Disposition Working Group stated that an amendment to the GSUR reference case Land Withdrawal Act would be necessary for Option 4 based on calculations for total space required for emplacement of 34 MT of downblended plutonium[20]. If an amendment is required, Congressional approval would be required, along with potential involvement by EPA.

A number of methods for increasing the amount of material that can be disposed of within the current constraints of the GSUR reference case Land Withdrawal Act are being investigated by the Department of Energy.

The current baseline plan is to package 380 fissile-gram equivalent (FGE) of downblended plutonium into criticality control overpack (CCO) packages to be shipped to a GSUR for disposal. One method under consideration may reduce the number of shipments and shorten the timeline to dispose of all 34 MT of plutonium. An alternative approach to increase the loading per can from 380 FGE in CCOs up to 1000 FGE using 9975 containers is being considered. Because of uncertainties in whether there is sufficient volume available at the GSUR reference case, the higher loading afforded by this alternative is attractive from a space perspective; however, the higher loading would likely change the shipments from a

[20] Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon-Grade Plutonium Disposition Options, U.S. Department of Energy, Apr. 2014.

Category III (less than 500 g per IAEA guidelines[21]) to II rating, resulting in associated costs for storage and transport to meet higher security requirements.

9.2.4 IAEA Monitoring

Although complexity of monitoring is anticipated to be less than at the MOX facility due to the reduced number of facilities involved and transportation routes, it is unclear what IAEA verification regime will be needed to account for the plutonium as it transitions via multiple facilities from weapons grade plutonium to disposition at the GSUR reference case in regards to any new Russian agreements.

9.2.5 State and Local Issues

The availability of WIPP for disposal of surplus plutonium will require significant engagement with federal, state, and local representatives. The Waste Isolation Pilot Plant Land Withdrawal Act of 1992 contained specific limitations on the quantity of transuranic waste that could be disposed of in WIPP and limitations on the overall capacity of the facility. Disposal of surplus plutonium in WIPP would require amendment of the WIPP Land Withdrawal Act as well as federal and state regulatory actions. Resistance to facility expansion and additional storage capability is possible, and the resultant cost and schedule impacts are unknown at this time.

9.2.6 Environmental Activist Groups

Local tribal groups and nuclear activist groups are active in New Mexico (e.g., Nuclear Watch NM). If the alternative Option 4 approach is implemented and the GSUR reference case is designated for disposition, there is potential for legal filings by these activists and potential consequential delays. The same risk holds true for any potential revisions/amendments to the WIPP Land Withdrawal Act that might be required.

[21] IAEA Information Circular (INFCIRC) 225 Revision 5, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities, Jan 2011.

10. Summary

Summary findings of the Aerospace team are as follows:

- Under the 500M RY$ / year cost cap on the Mixed Oxide Fuel Fabrication Facility (MFFF) capital and construction assumed in the 2014 PWG estimate, the total cost-to-go for the MOX Fuel Option is 47.5B RY$ (85% confidence cost contingency). The MOX Fuel Irradiation, Feedstock, and Transportation Program (MIFT) and other costs are 400-500M RY$ / year, including cost contingency starting in FY2017. MFFF operations costs are 1100-1300 M RY$ / year, starting in 2044. The MOX Fuel Program completion is ~ FY2059.
- The MFFF construction cannot be completed at current (FY14) funding level (350M RY$ / year cost cap on construction/capital) and the assumed escalation rates (4% construction and capital, 2% labor). The minimum cost cap on capital and construction to complete the MFFF construction is approximately 375M RY$/year, and results in completion of construction in FY2100, and a total cost-to-go of 110.4B RY$ (85% confidence cost contingency) for the MOX Fuel Program. Annual operations costs are > 3.0B RY$ / year. The MOX Fuel Program completion is in ~ FY2115.
- The Downblend Option project cost-to-go is 17.2B RY$ (85% confidence cost contingency). Downblend construction and operations costs are 100-200 M RY$ / year, under the timeline assumed in the 2014 PWG estimate. MIFT and other costs are 400-500 M RY$ / year, with cost contingency, during feedstock production. Program completion is ~ FY2049.
- In comparing MOX Fuel and Downblend Options, there is a large difference in total lifecycle cost-to-go at any cost-risk confidence level. There is no cost-risk confidence level in the assessment where the MOX Fuel Option lifecycle cost-to-go is less than the Downblend Option.
- 2014 PWG cost estimates were done in a manner consistent with best practices and industry standards for cost estimating.
- Program-level cost contingency in the 2014 Plutonium Working Group (PWG) estimate is underestimated. Contingencies are based on lower level technical risks, and do not consider program element dependencies and interactions. There is uncertainty in the remaining work scope.
- Program delays to the MOX Fuel Program, realized thus far, result in ~ 4.3 $B RY increase from 2014 PWG estimate.
- Program delays to MIFT, realized thus far, result in ~ 1.5 $B RY increase from 2014 PWG estimate.
- For the MOX Fuel Option, the majority of risk is related to the uncertainties in MFFF construction, start of operations, and feedstock and MOX Fuel production rates.
- The Downblend Option is lower in risk than the MOX Fuel Option. The largest risk is the uncertainty in the feedstock production rate.
- An opportunity exists to reduce cost and program complexity for Option 1 or 4 by consolidating the steady state feedstock production into a single product line.

Appendix A: Bibliography

1. Plutonium Disposition Program: DOE Needs to Analyze the Root Causes of Cost Increases and Develop Better Cost Estimates, February 2014, GAO-14-231, Government Accountability Office

2. Waste Isolation Pilot Plant Recovery Plan, Rev 0, Sept 30, 2014, Department of Energy

3. IAEA Information Circular (INFCIRC) 225 Revision 5, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities, Jan 2011.

4. U.S. Department of Energy Office of Inspector General Office of Audits and Inspections, "Audit Report: Cost & schedule of the Mixed Oxide Fuel Fabrication at the Savannah River Site", dated May 2014

5. Federal Acquisitions Regulations (FAR), Subpart 16.3, Cost-Reimbursement Contracts and 16.1, Factors in selecting contract types

6. Duke Energy Won't Do More MOX Tests, Augusta Chronicle, November 17, 2009. Accessed Feb 2015 at http://chronicle.augusta.com/stories/2009/11/17/met_556022.shtml

7. Management and Disposition of Excess Weapons Plutonium Committee on International Security and Arms Control, National Academy of Sciences, ISBN: 0-309-58656-9, 288 pages, (1994)

8. Cost and Schedule of the Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, May 2014, DOE/IG-0911, Department of Energy Office of Inspector General, Office of Audits and Inspections Audit Report

9. NNSA Review of the Steady State Feedstock Program Operations Estimate, Presentation, OUO, dated August 20, 2013 (Updated February 10, 2015), Los Alamos National Laboratory, Charles Richardson, David Hampton

10. Steady State Feedstock Program Fissile Material Disposition: MOX Irradiation, Feedstock, and Transportation, Summary Document (August 1, 2013 Deliverable), Presentation, dated September, 2013, Los Alamos National Laboratory, Mark Dinehart, Jeff Schoeder

11. ARIES Plutonium Oxide Production Program Overview, Presentation, UCNI, dated February 10, 2015, Los Alamos National Laboratory, Julia Whitworth

12. Various Alternatives for Los Alamos to Support the Surplus Plutonium Disposition Program with Pit Disassembly and Conversion, Presentation, UCNI, dated February 10, 2015, Los Alamos National Laboratory, Drew E. Kornreich

13. MOX Fuel Fabrication Facility Total Project Cost Independent Cost Estimate Reconciliation Variance Analysis, Revision 0, March 2013, Contract No. W912EF-12-D-0003, Task Order CG24, U.S. Army Corps of Engineers

14. MOX Fuel Fabrication Facility Total Project Cost Independent Cost Estimate, Revision 0, May 2013, Contract No. W912EF-12-D-0003, Task Order CG11 , U.S. Army Corps of Engineers

15. MOX Fuel Fabrication Facility Total Project Cost Funding Analysis, Revision 0, November 2013, Contract No. W912EF-12-D-0003, Task Order CG44 , U.S. Army Corps of Engineers

16. MOX Fuel Fabrication Facility Independent Cost Estimate Funding Profile Analysis, Revision 0, June 2013, Contract No. W912EF-12-D-0003, Task Order CG30 , U.S. Army Corps of Engineers

17. MOX Project Rebaseline and Plutonium Metal Feed Option, BCP 12-121 Rev 1, OUO 28 Sep 12, Contract DE-AC02-99CH10888, Shaw|Areva MOX Services

18. Alternate 3 "Lite" Supply and Demand (PRD Table Basis), Spreadsheet (Detailed Proposed Feed Table 10-10-12.xlsx), October 10, 2012, National Nuclear Security Administration

19. MOX Fuel Fabrication Facility (MFFF) Option Flow Diagram (Flow Diagram for Options.pdf), Predecisional, provided December 23, 2014, National Nuclear Security Administration

20. Advanced Disposition Reactor (ADR) Option Flow Diagram (Flow Diagram for Options.pdf), Predecisional, provided December 23, 2014, National Nuclear Security Administration

21. Immobilization Option Flow Diagram (Flow Diagram for Options.pdf), Predecisional, provided December 23, 2014, National Nuclear Security Administration

22. Waste Isolation Pilot Plant (WIPP) Option Flow Diagram (Flow Diagram for Options.pdf), Predecisional, provided December 23, 2014, National Nuclear Security Administration

23. Deep Borehole (DBH) Option Flow Diagram (Flow Diagram for Options.pdf), Predecisional, December 23, 2014, National Nuclear Security Administration

24. MOX Fuel, Irradiation, Feedstock, and Transportation (MIFT) Lifecycle Costs for Plutonium Disposition- ADR Option (MIFT Cost ADR option.pdf), Pre-Decisional Draft, April 2013, National Nuclear Security Administration

25. MOX Fuel, Irradiation, Feedstock, and Transportation (MIFT) Lifecycle Costs for Plutonium Disposition- Downblend Option (MIFT Cost ADR option.pdf), Pre-Decisional Draft, April 2013, National Nuclear Security Administration

26. MOX Fuel, Irradiation, Feedstock, and Transportation (MIFT) Lifecycle Costs for Plutonium Disposition- Immobilization Option (MIFT Cost Immob option.pdf), Pre-Decisional Draft, April 2013, National Nuclear Security Administration

27. MOX Fuel, Irradiation, Feedstock, and Transportation (MIFT) Lifecycle Costs for Plutonium Disposition- MOX Option (MIFT Cost MOX option.pdf), Pre-Decisional Draft, April 2013, National Nuclear Security Administration

28. Preliminary Plutonium Disposition Options Analysis - Life Cycle Estimate (Point Estimate), Spreadsheet (SWM Rev 11-25-2013 PM Preliminary Main Options Analysis LCC Spread sheet Premaza 1956.xlsx), November 25, 2013, National Nuclear Security Administration

29. Office of Fissile Materials Disposition (OFMD) MOX Fuel, Irradiation, Feedstock, and Transportation (MIFT) LANL Steady State Feedstock Program (SSFP) Independent Review Report, September 17, 2013, OUO, National Nuclear Security Administration

30. Cost Recovery Model for PF-4, Presentation LA-CP-14-20170, February 10, 2015, OUO, Los Alamos National Laboratory

31. An Initial Examination of Modifications to the ARIES Program Based on Product Requirements, Revision 0, February 3, 2014, Draft for Comment, UCNI, Los Alamos National Laboratory

32. MFFF Architectural Drawing DCS01 BMF DS PLG A 01260, Revision 1 (DCS01 BMF DS PLG A 01260-SH01.pdf), Jan 2006, Shaw|Areva MOX Services LLC

33. MFFF Architectural Drawing DCS01 BMF DS PLG A 01261, Revision 1 (DCS01 BMF DS PLG A 01261-SH01.pdf), Jan 2006, Shaw|Areva MOX Services LLC

34. MFFF Architectural Drawing DCS01 BMF DS PLG A 01262, Revision 1 (DCS01 BMF DS PLG A 01262-SH01.pdf), Jan 2006, Shaw|Areva MOX Services LLC

35. MFFF Architectural Drawing DCS01 BMF DS PLG A 01263, Revision 1 (DCS01 BMF DS PLG A 01263-SH01.pdf), Jan 2006, Shaw|Areva MOX Services LLC

36. MFFF Architectural Drawing DCS01 BMF DS PLG A 01264, Revision 1 (DCS01 BMF DS PLG A 01264-SH01.pdf), Jan 2006, Shaw|Areva MOX Services LLC

37. MFFF Architectural Drawing DCS01 BMF DS PLG A 01265, Revision 1 (DCS01 BMF DS PLG A 01265-SH01.pdf), Jan 2006, Shaw|Areva MOX Services LLC

38. MFFF Architectural Drawing DCS01 BMF DS PLG A 01266, Revision 1 (DCS01 BMF DS PLG A 01266-SH01.pdf), Jan 2006, Shaw|Areva MOX Services LLC

39. MFFF Architectural Drawing DCS01 BMF DS PLG A 01267, Revision 1 (DCS01 BMF DS PLG A 01267-SH01.pdf), Jan 2006, Shaw|Areva MOX Services LLC

40. MFFF Architectural Drawing DCS01 BMF DS PLG A 01268, Revision 1 (DCS01 BMF DS PLG A 01268-SH01.pdf), Jan 2006, Shaw|Areva MOX Services LLC

41. MOX FY12 Rebaseline Total Schedule to Go, Primavera Export (FY12 REBASELINE TO GO.pdf), February 9, 2015, Shaw|Areva MOX Services LLC

42. MFFF Technical Overview, Presentation (MFFF technical overview differences.pptx), January 29, 2015, Shaw|Areva MOX Services LLC

43. Project Cost and Sensitivity Analysis, Presentation (How Good Is our Estimate Rev 2.pptx), January 27, 2015, Shaw|Areva MOX Services LLC

44. MOX Fuel Irradiation, Feedstock and Transportation Lifecycle Overview, Presentation (1 MIFT Lifecycle Overview 01142015.pptx), January 13, 2015, National Nuclear Security Administration Office of Material Management and Minimization

45. MFFF Life Cycle Cost Estimate Operating Costs – Options Study, Presentation (2 MOX Ops LCCE – Options Study3.pptx), January 13, 2015, National Nuclear Security Administration Office of Material Management and Minimization

46. Costs of U.S. Mixed Oxide Fuel Fabrication Facility, Presentation (3 US MOX Cost briefing 1-13-2015 from Richard Person rv2.pptx), January 12, 2015, National Nuclear Security Administration Office of Acquisition and Project Management

47. The Advanced Disposition Reactor Study: A Comprehensive Analysis of Plutonium Disposition Options Using Advanced Fast Reactors, Presentation (4 ADR_appBsummary_aerospacereview.pptx), January 14, 2015, Department of Energy Office of Nuclear Energy

48. Deep Borehole Disposal Concept and Deep Borehole Field Test, Presentation (5 Deep Borehole Disposal briefing 011415_.ppt), January 15, 2015, Department of Energy Office of Nuclear Energy

49. Data Normalization, Presentation (6 normalization.pptx), January 14, 2015, National Nuclear Security Administration Office of Acquisition and Project Management

50. AFS-2 Program Status, Presentation (Aerospace AFS-2 Briefing - 1-26-15 Final.pptx), January 27, 2015, OUO, Savannah River Nuclear Solutions

51. H-Canyon/HBL Facility Cost Overview, Presentation (FY15 H Area NNSA Cost Review rv1.pptx), January 26, 2015, Savannah River Nuclear Solutions

52. MOX Irradiation, Feedstock and Transportation (MIFT) Lifecyle Costs Estimates (LCCE) Analysis – H-Canyon Preliminary Update with Known Changes - Costs in Thousands, Spreadsheet (H-Canyon Life Cycle Cost Analysis - Preliminary Update 1-26-15.xlsx), January 26, 2015, OUO-Draft, Savannah River Nuclear Solutions

53. K-Area Complex, Presentation (Aeorspace K Area Briefing 1-22-15.pptx), January 27, 2015, OUO, Savannah River Nuclear Solutions

54. K Area Facility Cost Overview, Presentation (FY15 K Area NNSA Cost Review with graph.pptx), January 27, 2015, Savannah River Nuclear Solutions

55. Assembly Area Layout, Drawing (UCNI K_Assbly_Layout.pdf), WSRC-SA-2002-00005 Rev 10 Figure 2-13 page 2.11-13, provided January 28, 2015, UCNI, Savannah River Nuclear Solutions

56. Advanced Disposition Reactor (ADR) Input, Presentation (ADR Aerospace.pptx), January 27, 2015, Savannah River Nuclear Solutions

57. ADR Layout, Drawing (UCNI_K ADR Layout.pdf), provided January 28, 2015, UCNI, Savannah River Nuclear Solutions

58. Centerra – Savannah River Site Expense Percentages FY 2015, Presentation (FY15 Centerra-SRS Budget Aerospace.pptx), January 29, 2015, Centerra

59. Centerra – Savannah River Site FY 2015 Projected Direct Facility Breakdown, Spreadsheet (Centerra SRS FY15 and FY14 by Facility.xlsx), January 29, 2015, Centerra

60. (U) WIPP Upgrades Presentation, Presentation (WIPP Upgrades Presentation 1-28-15.ppt), January 28, 2015, UCNI, Savannah River Nuclear Solutions

61. (U) Waste Isolation Pilot Plant Physical Security Upgrade To Receive CAT II D Uranium Oxide White Paper, Executive Summary, Sept 24, 2013, UCNI, The Department of Energy – Savannah River (DOE-SR)

62. MFFF Overview, Presentation (Aerospace - MFFF overview.pptx), January 28, 2015, Shaw|Areva MOX Services LLC

63. MFFF 2012 Rebaseline BCP, Presentation (Aerospace BCP and status R1.pptx), January 28, 2015, Shaw|Areva MOX Services LLC

64. Life Cycle Cost Estimate Basis, Presentation (LCCE Basis 2015 R4.pptx), January 29, 2015, Shaw|Areva MOX Services LLC

65. MOX Fuel Fabrication Facility (MFFF) Operating Costs Lifecycle Overview – Options Study, Presentation (MOX Ops LCCE - Options Study3.pptx), January 13, 2015, National Nuclear Security Administration Office of Material Management and Minimization

66. Summary of Gloveboxes, Presentation (process equipment status Dec.pptx), January 29, 2015, OUO, Shaw|Areva MOX Services LLC

67. Liquid Waste System Plan Revision 19, May 21, 2014, SRR-LWP-2009-00001 REVISION: 19, Savannah River Remediation LLC

68. NA-APM Adjusted Estimate, MFFF Option, Spreadsheet (MFFF Option From VP.xlsx), January 26, 2015, National Nuclear Security Administration Office of Acquisition and Project Management

69. NA-APM Adjusted Estimate, MFFF Option, Spreadsheet (MFFF Option From VP.xlsx), January 26, 2015, National Nuclear Security Administration Office of Acquisition and Project Management

70. Alternative Option - Single Module Pool Type ADR, Spreadsheet (NE Excerpt From VP.xlsx), January 26, 2015, National Nuclear Security Administration Office of Acquisition and Project Management

71. Business Case DOE's Proposed Baseline Approach for Disposing of Surplus Plutonium, April 2007, Department of Energy

72. Business Case Analysis of the Current U.S. Mixed Oxide (MOX) Fuel Strategy for Dispositioning 34 Metric Tons of Surplus Weapon-Grade Plutonium, VI.i. Business case analysis of current U.S. MOX strategy, September 21, 2007, Department of Energy

73. MOX Project Early Option 2: ATTACHMENTS, ATTACHMENT I. RISK ANALYSIS REPORTS, January 26, 2009, RFP No. 08-006, Shaw|Areva MOX Services LLC

74. MOX Project Early Option 2: ATTACHMENTS, ATTACHMENT A. WORK BREAKDOWN STRUCTURE, January 26, 2009, RFP No. 08-006, Shaw|Areva MOX Services LLC

75. FMD Program Schedule, Extract (FMD Program Schedule_from 7-31-13 PPEP.pdf), provided January 14, 2015, National Nuclear Security Administration

76. Lifecyle Costs Estimates (LCCE) for FY 2014 Liability Audit Supporting the MOX Fuel Approach Strategy (as of September 2014), Spreadsheet (FY 2014 Plutonium Liability Audit 10-17-14.xlsx), September 2014, DRAFT AND PRE-DECISIONAL, National Nuclear Security Administration Office of Acquisition and Project Management

77. WSB Total Life Cycle Cost Estimate (LCCE) 18 Aug 2014, Extract (WSB LCCE COST Water Oct.2025 Chem Oct.2026 Rad Oct.2027 Aug 18 2014 Rev.B.pdf), August 18, 2014

78. Cost and Schedule of the Mixed Oxide Fuel Fabrication Facility at the Savannah River Site Audit Report, May 2014, DOE/IG-0911, U.S. Department of Energy Office of Inspector General, Office of Audits and Inspections

79. Cost Estimating Guide, May 9, 2011, DOE G 413.3-21, Department of Energy Office of Management

80. REAL PROPERTY ASSET MANAGEMENT, Change 1 February 8, 2008, DOE O 430.1B, Department of Energy Office of Management

81. MIXED OXIDE FUEL FABRICATION FACILITY- NRC INSPECTION REPORT NUMBER 70-3098/2014-002, August 5, 2014, United States Nuclear Regulatory Commission

82. MIXED OXIDE FUEL FABRICATION FACILITY- NRC INSPECTION REPORT NUMBER 70-3098/ 2013-001, May 9, 2013, United States Nuclear Regulatory Commission

83. MIXED OXIDE FUEL FABRICATION FACILITY- NRC INSPECTION REPORT NUMBER 70-3098/ 2014-003, October 16, 2014, United States Nuclear Regulatory Commission

84. MOX Update, Presentation (ML12019A220 - MOX status Dec 2011.pdf), Dec 2011, Shaw|Areva MOX Services LLC

85. Mixed Oxide Fuel Fabrication Facility (MFFF) Operating Cost Analysis, April 2013, Federal Official Use Only - Contains Proprietary data, National Nuclear Security Administration Office of Defense Programs, Office of Program Integration Analysis and Evaluation

86. Basis of Estimate REA# 11-013 PUDC Equipment, August 31, 2011, Shaw|Areva MOX Services LLC

87. Bulk Cable Replacements REA# 11-018, September 2011, Shaw|Areva MOX Services LLC

88. PF-4 Mission Overview Fissile Material Disposition Program Surplus Plutonium Disposition Options Study, Presentation (W2 - ARIES Aerospace - Mission - Feb 10 2015 Final.pdf), February 10, 2015, Los Alamos National Laboratory

89. Preliminary Program Execution Plan for the National Nuclear Security Administration Fissile Materials Disposition Program, July 31, 2013, OUO, SE&PID-13-0003Revision D, National Nuclear Security Administration Office of Fissile Materials Disposition

90. Report of the Plutonium Disposition Working Group: Analysis of Surplus Weapon-Grade Plutonium Disposition Options, April 2014, Department of Energy

91. Steady State Planning Summary Document, LA-CP-13-00980, August 1, 2013, UCNI, OUO, Los Alamos National Laboratory

92. Independent Cost Review (ICR) and Independent Cost Estimate (ICE) Standard Operating Procedures (SOP) Revision 1, September 2013, Department of Energy Office of Acquisition and Program Management

93. GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs, March 2009, GAO-09-3SP, Government Accountability Office

94. Waste Solidification Building Project Transition to Operations Plan, October 14, 2014, G-PP-F-00013 Revision 0, Savannah River Nuclear Solutions

95. Observations on Project and Program Cost Estimating in NNSA and the Office of Environmental Management, Testimony Before the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate, May 8, 2013, GAO-13-510T, Government Accountability Office

96. Operating and Support Cost-Estimating Guide, March 2014, Office of the Secretary of Defense Cost Assessment and Program Evaluation

97. Savannah River Nuclear Solutions (SRNS) Recommendation for Waste Solidification Building (WSB) Modified Lay-up State, Letter dated January 27, 2014, SRNS-T8000-2014-00018 RSM Track# 10667, Savannah River Nuclear Solutions

98. WSB Total Life Cycle Cost Estimate (LCCE) Summary, Spreadsheet (WSB LCCE COST Water Oct.2025 Chem Oct. 2026 Rad Oct.2027 Aug 18 2014 Rev. B summary.pdf), August 18, 2014, National Nuclear Security Administration

99. WSB Total Life Cycle Cost Estimate (LCCE), Spreadsheet (WSB LCCE COST Water Oct. 2025 Chem Oct.2026 Rad Oct.2027 Aug 18 2014 Rev.B.pdf), August 18, 2014, National Nuclear Security Administration

100. WSB Project Summary, Spreadsheet (WSB Project Summary (Jan 2015) FINAL.xlsx), January 2015, National Nuclear Security Administration

Appendix B: Risk Tables

Option 1, MOX Fuel Risk Table

Rank	ID	Title	WBS Impact	Likelihood	Consequence (RY$M)				Mean Monte Carlo Outputs
					Min	Mode	Max	Years of Impact*	Total Impact ($M)
1	Ops-01	Fuel Production Rate Lower Than Expected	MFFF Operations	75%	1661.2	3451.9	7452.4	2046-2054	3111.5
2	MIFT-01	Feedstock Production Rate Lower Than Expected	MIFT	75%	755.9	1537.5	3181.0	2033-2040	1362.8
3	Const-03	MFFF Construction Cost Uncertainty / Growth	MFFF Construction	75%	-250.2	791.6	3521.2	2018-2031	998.6
4	Ops-03	MFFF Temporary Suspension of Operations	MFFF Operations	90%	211.3	422.5	1690.0	2033-2046	697.3
5	Const-02	MFFF Full Construction Re-Start Delay	MFFF Construction	50%	404.6	1262.2	2187.9	2017-2022	641.6
6	MIFT-03	Feedstock Temporary Suspension of Operations	MIFT	90%	86.3	172.5	690.0	2017-2035	283.2
7	Other-04	SRS Overhead Cost Increases	Other	75%	156.6	234.9	391.5	2033-2047	194.1
8	Other-02	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Other	90%	75.0	150.0	300.0	2028-2030	157.0
9	Other-03	LANL Overhead Cost Increases	Other	25%	336.0	420.0	672.0	2017-2035	118.1
10	Ops-02	MFFF Hot Operations Delay after CD-4 Complete	MFFF Operations	50%	59.8	180.1	365.6	2032	100.0
11	Const-01	MFFF Integrated Functional Testing Delay Before CD-4	MFFF Construction	25%	36.3	219.4	903.6	2031-2033	96.7
12	Storage-01	Needs for Additional Storage	Storage	50%	34.9	74.8	164.5	2017-2046	46.1
13	MIFT-02	LANL Feedstock Production Re-Start Delay	MIFT	25%	61.2	123.6	187.3	2016-2019	30.4
14	Other-01	Funding for Depleted Uranium	Other	10%	9.9	19.8	29.7	2018-2032	2.1
15	MIFT-04	Feedstock Production Consolidated at LANL (Remove HB-Line)	MIFT	75%	-774.9	-510.4	-319.0	2017-2026	-396.1

*** Note: Years of Impact is the time interval during which the risk may be realized, using the 2014 PWG estimate timeline, with known program delays included.**

Option 4, Downblend Risk Table

Rank	ID	Title	WBS Impact	Likelihood	Consequence (RY$M) Min	Mode	Max	Years of Impact*	Mean Monte Carlo Outputs Total Impact ($M)
1	MIFT-01	Feedstock Production Rate Lower Than Expected	MIFT	75%	739.2	1503.7	3111.0	2033-2040	1341.5
2	Const-01	SRS Downblend Facility Start Delay	Construction	25%	427.4	1333.6	2311.6	2016-2021	338.5
3	MIFT-03	Feedstock Temporary Suspension of Operations	MIFT	90%	75.3	150.5	602.0	2017-2035	247.0
4	Ops-01	Downblend Production Rate is Lower Than Expected	Operations	25%	203.5	628.4	1312.1	2048-2057	188.1
5	Ops-02	Downblend Facility Temporary Suspension of Operations	Operations	90%	53.5	107.0	428.0	2021-2049	175.9
6	Const-02	Downblend Construction Cost Estimate Uncertainty/Growth	Construction	75%	100.5	201.0	402.0	2018-2024	174.7
7	Other-03	LANL Overhead Cost Increase	Other	25%	336.0	420.0	672.0	2017-2035	119.2
8	MFFF-01	MFFF Project Termination Cost Uncertainty	MOX Deinventory	25%	-100.0	300.0	800.0	2017-2019	81.1
9	GSUR-02	Downblend Repository Temporary Suspension of Operations	GSUR	90%	12.7	25.3	101.2	2033-2047	41.6
10	Other-04	SRS Overhead Cost Increase	Other	75%	25.2	37.8	63.0	2033-2047	31.4
11	MIFT-02	Feedstock Production Re-Start Delay at LANL	MIFT	25%	61.2	123.6	187.3	2016-2019	30.1
12	GSUR-01	Exceed Downblend Repository TRU Allowable Storage Volume	GSUR	10%	49.2	196.8	393.6	2033-2047	22.0
13	Storage-01	Need for Additional Storage Volume	Storage	25%	19.9	39.8	94.5	2017-2049	12.7
14	Other-02	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Other	75%	5.0	10.0	20.0	2019-2021	8.6
15	MIFT-05	Feedstock Milling and Blending Not Needed/Quality Control Reductions	MIFT	90%	-80.6	-44.8	-22.4	2017-2035	-44.1
16	MIFT-04	Feedstock Production Consolidated at LANL (Remove HB-Line)	MIFT	90%	-771.9	-510.4	-319.0	2017-2026	-479.3

*** Note: Years of Impact is the time interval during which the risk may be realized, using the 2014 PWG estimate timeline, with known program delays included.**

Appendix C: Acronyms

ADR	Advanced Disposition Reactors
ARIES	Advanced Recovery and Integrated Extraction System
$B	Billion
CCO	Criticality Control Overpack
D&D	decommissioning, demolition
DBH	Deep Borehole
DOE	Department of Energy
DOE-SR	DOE- Savannah River
DOT	Department of Transportation
DWPF	Defense Waste Processing Facility
EM-HQ.	NNSA Office of Environmental Management
EPA	Environmental Protection Agency
FCI	Facility Condition Index
FFRDC	Federally Funded Research and Development Center
FGE	Fissile Gram Equivalent
FY	Fiscal Year
GAO	Government Accountability Office
GSUR	Geologically Stable Underground Repository
HEU	Highly Enriched Uranium
HLW	High- Level Waste
HM	Heavy Metal
HVAC	Heating, Ventilating, and Air Conditioning
IAEA	International Atomic Energy Agency
IG	Inspector General
kg	Kilogram
LANL	Los Alamos National Laboratory
LCCE	Lifecycle Cost Estimate
LWA	Land Withdrawal Act
LWRs	Light Water Reactors
$M	Million
MIFT	MOX Fuel Irradiation, Feedstock, and Transportation Program
MFFF	Mixed Oxide Fuel Fabrication Facility
MOX	Mixed Oxide
MT	Metric Tons
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
ORR	Operational Readiness Review
PDIP	Plutonium Disposition Infrastructure Program
PF-4	Plutonium Facility-4
PMDA	United States- Russia Plutonium Management and Disposition Agreement
PREP	Project Risk Evaluation Process
PRV	Plant Replacement Value
Pu	plutonium
PWG	Plutonium Disposition Working Group
RY	Real Year
SBD	safeguards-by-design

SNL	Sandia National Laboratory
SRNS	Savannah River Nuclear Solutions
SRS	Savannah River Site
SSFP	Steady State Feedstock Project
TRU	Transuranic
WBS	Work Breakdown Structure
WIPP	Waste Isolation Pilot Plant
WSB	Waste Solidification Building