

High Bridge Associates, Inc.

September 21, 2015

High Bridge Independent Reviews of Plutonium Disposition Options

- **September 21, 2015 Review of the Final Report of the Plutonium Disposition Red Team**
- **August 21, 2015 Phase 2 Report and Detailed Review of the Aerospace Assessment of the PWG Plutonium Disposition Study Options**
- **June 29, 2015 Phase 1 Report and Summary Review of the Aerospace Assessment of PWG Plutonium Disposition Study Options**

prepared for the

MOX Services Board of Governors



“Connecting Vision and Plans with Performance and Execution”

This document compiles three High Bridge reports and assessments of Plutonium Disposition Options. Presented first is the September 21, 2015 Review of the Final Report of the Plutonium Disposition Red Team. Presented second is the August 21, 2015 Phase 2 Report and Detailed Review of the Aerospace Assessment of the PWG Plutonium Disposition Study Options. The June 29, 2015 Phase 1 Report and Summary Review of the Aerospace Assessment of PWG Plutonium Disposition Study Options is included as Appendix A in the Phase 2 Report

High Bridge Associates, Inc.

September 21, 2015

**Independent Review
of the Final Report of the
Plutonium Disposition Red Team**

prepared for the

MOX Services Board of Governors



“Connecting Vision and Plans with Performance and Execution”

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EXECUTIVE SUMMARY

High Bridge Associates, Inc. (High Bridge) performed an Independent Review of the “August 13, 2015 Final Report of the Plutonium Disposition Red Team.” High Bridge key findings and conclusions include:

1. The Red Team correctly concluded that:
 - The MOX Program annual funding does not need to be \$1B per year, a value inferred from the Aerospace report.
 - Adequate funding for MOX Program needs to be authorized.
 - The Aerospace use of RY\$ and constrained funding scenarios exaggerated costs for MOX.
 - The approximate \$1B value of MOX fuel sales should be included in the economic analysis.
 - The NNSA and MFFF Project contractor organization is dysfunctional and needs to be corrected.
 - The MOX Program needs to develop an updated scope, cost, and schedule baseline.
2. While the Red Team and High Bridge agreed on their evaluations of several key elements of the MOX and the Dilute and Dispose Plutonium Options, High Bridge found many aspects of the Red Team review approach and conclusions to be incomplete or ungrounded:
 - In their own words, the Red Team characterized their review as cursory that only considered other assessment report values and did not develop any of its own costs.
 - It appeared to High Bridge that the Red Team was under a very aggressive deadline, did not have adequate time to analyze the data in other reports, and was rushed to produce a deliverable.
 - The Red Team only reviewed the High Bridge June 29, 2015 Phase 1 Executive Summary 5-page report. It did not review the High Bridge August 21, 2015 Phase 2 Detailed 200-page report.
 - High Bridge believes that the Red Team would have come to different conclusions had it been able to review the High Bridge 200-page Phase 2 detailed report.
3. The Red Team did not recognize that the Aerospace analysis lacked independence:
 - High Bridge discovered in its August 6 meeting with Aerospace and NNSA that the NNSA defined limiting parameters for the Aerospace review approach regarding escalation rates, escalated real year dollars (RY\$), WIPP availability, constrained funding, and evaluation of technical basis.
 - This produced outcomes that increased MOX cost and schedule durations and decreased Dilute and Dispose cost and schedule durations.
4. The Red Team incorrectly concluded that the Dilute and Dispose approach is a viable option for Plutonium Disposition under the PMDA:
 - The Dilute and Dispose Option does not comply with Article III of the PMDA.
 - The Spent Fuel Standard is not invoked by the PMDA or recognized by Russia.
5. The Red Team incorrectly concluded that renegotiating the PMDA to accept the Dilute and Dispose Option will be a simple matter and identified no cost or schedule impacts:
 - The Russian Federation has insisted on changing the isotopic makeup of plutonium for disposition.
 - The Russian Federation is more concerned with the U.S. military than with terrorists or rogue states.
 - The PMDA would have to be renegotiated first before Dilute and Dispose could be started.
 - The previous amendment to the PMDA required 5 years to negotiate.
6. The Red Team incorrectly concluded that the Dilute and Dispose approach and placement at WIPP is achievable without any capital cost, schedule, or risk impacts:
 - WIPP design and licensing changes for Dilute and Dispose must be part of the program costs.
 - Material cannot be accepted by WIPP until design and licensing changes have been accomplished.
 - Recovery from the 2014 incidents at WIPP will take longer and cost more than currently described.

- The critical decision process requirements of DOE 413.3 apply to the Dilute and Disposal Option.
 - The Red Team did not consider the life extension costs for the WIPP.
 - The Red Team did not consider the risk of increasing WIPP repository capacity by over 50%.
7. The Red Team did not address the cost impact of the Dilute and Dispose Option on WIPP operations:
- Canceling the MOX Program requires disposal of at least 51MT of surplus plutonium in WIPP.
 - Purchasing/loading 170,000 criticality control over-packs (CCO) each inside a 55-gallon drum.
 - Transporting over 4,000 shipments (42 CCOs/shipment) from SRS to WIPP across six states.
 - Emplacing over 35,000 M³ in the WIPP repository.
8. The Sterilization Option recommended by the Red Team is not viable for Plutonium Disposition:
- Safeguards and security impacts at WIPP would be astronomical.
 - The Russian Federation would categorically reject this approach.
 - The attractiveness level would remain at Level B-II.
 - An NRC-approved container does not exist for this waste form.
 - It is not permitted to store Special Nuclear Material intermingled with TRU waste packages.
9. The Red Team accepted the Risk and Monte Carlo contingency determination analysis of Aerospace:
- The Red Team did not perform any structured risk and contingency analysis.
 - The Red Team did not provide adequate credit for the operating experience of French plants. The Red Team did not recognize/understand the modest 35% throughput capacity factor for MOX MFFF that provides significant operational flexibility to deal with feedstock and production issues.
 - The Red Team did not have the opportunity to review the High Bridge August 21 Phase 2 detailed report which included a structured risk and contingency Monte Carlo analysis.
10. The Red Team did not recognize the MOX Fuel economic contribution to the GNP through the production of clean non-carbon emitting nuclear power electricity:
- The 34 MTs of surplus weapons plutonium will result in enough nuclear fuel to generate electricity worth \$35B.
 - The value to the GNP of the electricity sales (\$35B) from the MOX fuel is greater than the MOX total life-cycle cost (\$19.4B) in FY14 dollars.
 - MOX represents a net increase in the GNP of the U.S. and creates >10,000 U.S. jobs.
 - The Dilute and Dispose Option produces no GNP contribution and represents a net loss to the taxpayers.
 - Using the 34 MT of plutonium converted to nuclear fuel will eliminate enormous quantities of NO_x, SO₂ and greenhouse gas emissions.

1 REPORT OVERVIEW

Background - High Bridge Associates, Inc. (High Bridge) is a planning and project management company providing consulting and project staffing support services to the commercial nuclear power generation, Department of Energy (DOE), petro-chemical, and industrial business sectors. High Bridge experts are intimate with and understand the technical design and regulatory licensing requirements that drive the parameters for program planning and project execution for complex nuclear and process facilities. It has performed hundreds of third party reviews of cost estimates/schedules/risk contingency assessments developed by others. High Bridge organized a Review Team (five dedicated experts and three part time Peer Review experts) of industry professionals with an average of 40 years of relevant commercial nuclear power and DOE program experience spanning power generation, plutonium disposition, and complex first-of-a-kind (FOAK) facilities.

The MOX Services LLC Board of Governors (MOX Services) requested that High Bridge perform two independent reviews, the first of which had two phases.

On June 10, 2015, the MOX Services LLC Board of Governors (MOX Services) requested High Bridge to perform an Independent Review of the Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Plutonium Disposition Study Options Independent Assessment. The purpose of the first High Bridge review task was to provide an objective analysis of the approach/process used by Aerospace, and of the results contained in its Assessment of the April 2014 Plutonium Working Group (PWG) Report of Disposition Options for the MOX Option and Dilute and Dispose Option Life Cycle Cost Estimates (LCCE). High Bridge delivered its Phase 1 Executive Summary report on June 29, 2015 and delivered its Phase 2 Detailed Report on August 21, 2015. It should be noted that Option 4 Downblend is synonymous with Dilute and Dispose Option.

MOX Services requested that High Bridge perform a second task to provide an independent Review of the August 13, 2015 DOE Red Team Final Report of Plutonium Disposition Options. This September 21, 2015 document is the independent review of the Red Team report. The following High Bridge Overview provides expanded information with some exhibit graphics that follows the format of the Executive Summary. Key findings and conclusions include:

1. **The Red Team correctly concluded that:**

- The MOX Program annual funding does not need to be \$1B per year, a value inferred from the Aerospace report.
- Adequate funding for MOX Program needs to be authorized.
- The Aerospace use of RY\$ and constrained funding scenarios exaggerated costs for MOX.
- The approximate \$1B value of MOX fuel sales should be included in the economic analysis.
- The NNSA and MFFF Project contractor organization is dysfunctional and needs to be corrected.
- The MOX Program needs to develop an updated scope, cost, and schedule baseline.

As summarized above, various High Bridge and Red Team analyses and conclusions aligned closely regarding some fundamental areas of disagreement with the Aerospace report.

High Bridge concludes that the lack of DOE formal acceptance of the 2012 Re-Baseline proposal from the MOX Services contractor and the significantly reduced annual funding picture since 2013 have been the primary contributors to causing the dysfunctional Mixed Oxide Fuel Fabrication Facility (MFFF) organization and management conditions that exist on the MFFF project.

The MFFF project has had an exemplary record of performance across safety, quality, and regulatory compliance parameters. High Bridge concludes that developing an Integrated Project Team (IPT) approach with a “sink or swim together” culture for the DOE and contractor is essential to achieve similar results in day to day management activities. Limited project resources need to be rallied around mutual progress goals where teamwork and open communications can flourish to mitigate problems before they occur. High Bridge agrees and supports the Red Team recommendations regarding its various identified Executive Considerations. High Bridge concludes that development of a realistic MFFF revised baseline coupled with adopting an Integrated Project Team approach will go a long way to resolving deficiencies and supporting success.

2. While the Red Team and High Bridge agreed on their evaluations of several key elements of the MOX and the Dilute and Dispose Plutonium Options, High Bridge found many aspects of the Red Team review approach and conclusions to be incomplete or ungrounded:

- In their own words, the Red Team characterized their review as cursory that only considered other assessment report values and did not develop any of its own costs.
- It appeared to High Bridge that the Red Team was under a very aggressive deadline, did not have adequate time to analyze the data in other reports, and was rushed to produce a deliverable.
- The Red Team only reviewed the High Bridge June 29, 2015 Phase 1 Executive Summary 5-page report. It did not review the High Bridge August 21, 2015 Phase 2 Detailed 200-page report.
- High Bridge believes that the Red Team would have come to different conclusions had it been able to review the High Bridge 200-page Phase 2 detailed report.

Throughout the Red Team report it is stated that their analysis was high-level, general, cursory, and developed with no backup analyses (i.e., it used and extrapolated data from other reports). It stated in the “How to Use this Report” section that the Red Team report should not serve as a basis to judge absolute costs. The result is that most of the actual costs and risks of the Dilute and Dispose Option were missed or assumed to be the responsibility of Environmental Management (EM). For example:

- The Red Team did not address that the DOE/NNSA has to dispose of more than 51 MT of surplus plutonium with the elimination of MOX.
- The transportation costs for the Dilute and Dispose Option is more than 50 times larger than for the MOX program and was not addressed.
- The cost of the containers for packaging the plutonium in the Dilute and Disposal Option is \$374M was not addressed.
- The increased cost of emplacing the waste at WIPP is about \$1.7B for the 51 MT and was not addressed.

The Red Team praised the Aerospace report for their “systems engineering” approach. High Bridge finds this confusing when the Aerospace report includes the following disclaimer: “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.” High Bridge concludes that the Red Team praise for the Aerospace systems

engineering approach was unfounded in that it is not possible to have a systems engineering approach if one does not assess the scientific and technical aspects of the subject matter.

High Bridge found it very puzzling that the Red Team accepted so many Aerospace analyses and conclusions, given Aerospace is an Air Force support contractor with absolutely no nuclear construction experience or expertise.

3. The Red Team did not recognize that the Aerospace analysis lacked independence:

- High Bridge discovered in its August 6 meeting with Aerospace and NNSA that the NNSA defined limiting parameters for the Aerospace review approach regarding escalation rates, escalated real year dollars (RY\$), WIPP availability, constrained funding, and evaluation of technical basis.
- This produced outcomes that increased MOX cost and schedule durations and decreased Dilute and Dispose cost and schedule durations.

This August 6th meeting was arranged by the office of Senator Lindsay Graham to provide the opportunity for the MOX contractor and High Bridge to ask Aerospace questions regarding their April 13, 2015 Assessment Report of Plutonium Options. It was held for one hour at the Russell Senate Office Building in a Senate Hearing Room that included attendance by three High Bridge personnel, seven MOX Services personnel, three Aerospace personnel, three NNSA personnel, and approximately thirty (30) Senate and House staff members. High Bridge followed a line of questioning designed for a one-hour meeting to obtain some details and clarification regarding the Aerospace assumptions, analysis approach, and outcome conclusions. In High Bridge's opinion, Aerospace responses to High Bridge questions regarding five key issues covering escalation rates, escalated RY\$, WIPP availability, constrained funding, and evaluation of technical basis affirmed that:

- The NNSA had provided Aerospace with specific direction regarding fundamental parameters governing the conduct of the Aerospace review;
- The Aerospace report was not independent and it reflected NNSA specific direction; and
- The Aerospace report analysis was influenced by the NNSA to exaggerate the MOX Option estimated schedule duration and costs and to reduce the Dilute and Dispose Option estimated costs.

4. The Red Team incorrectly concluded that the Dilute and Dispose approach is a viable option for Plutonium Disposition under the PMDA:

- The Dilute and Dispose Option does not comply with Article III of the PMDA.
- The Spent Fuel Standard is not invoked by the PMDA or recognized by Russia.

The Red Team correctly concluded that both options are technically achievable. The Red Team overemphasized the complexity of the MOX fuel fabrication facility and incorrectly equated risks and uncertainty with complexity. Additionally, the issue of regulatory compliance and legality of the Dilute and Dispose Option was ignored. The Red Team provided a superficial review of the regulatory issues confronting the Dilute and Dispose Option by assuming that WIPP will accept this waste at no cost to the Plutonium Disposition program. Even though they recognized that WIPP is not able to accept the surplus plutonium under the current legal constraints, they assumed that that regulatory hurdle would be crossed by others.

5. The Red Team incorrectly concluded that renegotiating the PMDA to accept the Dilute and Dispose Option will be a simple matter and identified no cost or schedule impacts:

- The Russian Federation has insisted on changing the isotopic makeup of plutonium for disposition.
- The Russian Federation is more concerned with the U.S. military than with terrorists or rogue states.
- The PMDA would have to be renegotiated first before Dilute and Dispose could be started.
- The previous amendment to the PMDA required 5 years to negotiate.

The MOX Program is a direct result of the PMDA between the Russian Federation and the U.S. government. It is surprising that the Red Team, the Plutonium Working Group (PWG) and Aerospace review all discounted the importance and the difficulty of amending the PMDA. Further, they all asserted that the DOE could begin working on the Dilute and Dispose option almost immediately with little or no delay caused by discussing this issue with the Russian Federation. All three of these groups seem to view the PMDA as a minor issue that can be cleared up easily once DOE management decides to abandon the MOX program in favor of the Dilute and Dispose option.

It should be noted that the PMDA is the result of nearly twenty years of continual discussions between the USA and the Russian Federation. It began with a Presidential Directive in 1993 committing the United States to “seek to eliminate, where possible, accumulations of stockpiles of highly enriched uranium or plutonium.” In January 1994, the United States and Russia established working groups and tasked their experts to develop options for plutonium disposition. Presidents Clinton and Yeltsin committed both countries in 1998 to seek to enter into a bilateral plutonium disposition agreement. This was accomplished in 2000, when the United States and Russia signed the bilateral PMDA that commits each country to dispose of 34 MT of surplus weapon-grade plutonium roughly in parallel.

The Red Team, PWG, and Aerospace reports incorrectly assumed that they could cite irrelevant precedence for other problems and assume that the PMDA did not represent a legal barrier to their proposed action. This is unrealistic and enables those who make this assumption the freedom to ignore costs and schedule delays that are certain to occur if they are pursued. The High Bridge report assumed that the PMDA could be negotiated in parallel with the recovery of WIPP from the February 2014 incidents and that both could be completed in five years starting in 2014. Currently, no one is pursuing these negotiations and so there is no real alternative to MOX that maintains the Russian Federation/USA partnership for reducing weapons of mass destruction.

The MOX program, space exploration, and SALT II represent three areas of cooperation between the US and Russia amidst many other deteriorating geo-political fronts. It appears to High Bridge that maintaining the MOX program commitment needs to be a key element for any hopes of a partnership framework with Russia.

6. The Red Team incorrectly concluded that the Dilute and Dispose approach and placement at WIPP is achievable without any capital cost, schedule, or risk impacts:

- WIPP design and licensing changes for Dilute and Dispose must be part of the program costs.
- Material cannot be accepted by WIPP until design and licensing changes have been accomplished.
- Recovery from the 2014 incidents at WIPP will take longer and cost more than currently described.
- The critical decision process requirements of DOE 413.3 apply to the Dilute and Disposal Option.
- The Red Team did not consider the life extension costs for the WIPP.
- The Red Team did not consider the risk of increasing WIPP repository capacity by over 50%.

The Red Team's approach to assessing the impact of the Dilute and Dispose Option on WIPP is confusing. They clearly realize that WIPP is intended to address the cleanup of the legacy wastes by the EM organization within DOE. Their report includes a section entitled "WIPP as a National Asset" in which they accurately describe the value proposition of the WIPP and identify the physical limits to the waste volume allowed into the repository. Further, they also recognized that, with current disposal container technology, the Dilute and Dispose Option will exceed the legal limit for WIPP waste volume.

In spite of the recognition that WIPP is essential for the EM mission and that the 34 MT of surplus weapons plutonium will not fit within the current legal limit, the Red Team assigned no cost impact to the Dilute and Dispose Option or to the Sterilization Option. They assumed that the Dilute and Disposal Option could begin without addressing the redesign or licensing issues and that some other budget would be available for the expansion and the risk associated with jeopardizing the entire EM program.

The Red Team understood that there is more surplus weapons plutonium to be dispositioned than the 34 MT subject to the PMDA. They referenced the Surplus Plutonium Supplemental Environmental Impact Statement (SEIS) that discusses the disposal of 13.1 tons of plutonium and they spoke with the people currently working on an additional 4.2 MT of surplus plutonium at Savannah River Site (SRS) that had been deleted from the PMDA's final language. It is clear that the Red Team was aware that DOE/NNSA has over 51 MTs of plutonium to dispose of and yet they never addressed it.

High Bridge performed an in-depth analysis of WIPP parameters starting with the 1992 Land Withdrawal Act (LWA) and including the latest EM forecasts of Transuranic (TRU) wastes forecasted to be emplaced at WIPP. **Exhibit 1.1** was developed to summarize High Bridge's evaluation of the impact of the 51 MT of plutonium if dispositioned with the Dilute and Dispose approach and if emplaced at WIPP. As reflected on row 7 of **Exhibit 1.1**, the emplacement of 51MT of plutonium would increase required WIPP capacity from the 1992 LWA stated value of approximately 175,600 cubic meters to approximately 240,000 cubic meters, or an increase of 36%. It would increase the activity of the waste being emplaced at WIPP from 539,000 to 2,875,000 1000-year curies representing an increase of 433%. Given that the US and Russia agree in the future to disposition additional excess weapons plutonium, as much as another 49 MT of plutonium would need to be emplaced at WIPP. As reflected in row 10 of **Exhibit 1.1**, this would result in a required 56% increase in the current licensed capacity volume and about an 843% increase in the 1000-year curies inventory.

These changes in the WIPP mission and the increased emplaced volumes cannot be accomplished by executive fiat. The program needed to accomplish these changes requires a carefully managed capital project to expand the licensing basis of WIPP. In addition, no excess plutonium waste can be shipped to WIPP until this process is completed. The Red Team repeatedly asserted that there is precedence for shipping this waste to WIPP based on the Rocky Flats experience but ignores the fact that the cleanup of Rocky Flats is exactly what WIPP was designed and licensed to support. What they are proposing with the Dilute and Dispose option and with the Sterilization option are not part of the WIPP design mission. While it is true that miscellaneous impure weapons grade plutonium has been placed into WIPP as part of the EM mission, it does not follow that disposing of surplus weapons pure pit plutonium in WIPP is therefore acceptable. It is most likely not acceptable without stakeholder approval. Attempting to send this material to WIPP without gaining stakeholder approval is ill-advised. It is not prudent to abandon the mature MFFF project (that is substantially complete) to adopt the immature Dilute and Dispose Program in the face of a tumultuous and potentially hostile National Environmental Policy Act (NEPA) process.

Exhibit 1.1 – WIPP Capacity and Projected Loads

WIPP Facility Capacity and Projected Loads TRU Waste and Plutonium Approximate Impacts						
	Capacity and Projected Load Element	Cubic Meters	Cubic Meters/ 55 Gal. Drum	Number of 55 Gal. Drums	Plutonium Metric Tons	Curies *
1	Current Technical Basis of WIPP	175,600	0.208	844,231	0	539,000
2	2014 DOE EM TRU Waste Projection	156,000	0.208	750,000	0	0
3	2015 NNSA Excess Plutonium Projection (51 MT)	<u>35,400</u>	0.208	<u>170,192</u>	<u>51</u>	<u>2,300,000</u>
4	Sub Total Projection	191,400	-	920,192	51	2,300,000
5	25% Freeboard for Future Identified Waste Projection	47,850	0.208	230,048		575,000
6	New WIPP Capacity	239,250		1,150,240		2,875,000
7	Approximate % Increase in Capacity/Load	36%		36%		433%
8	Allowance for additional surplus weapons plutonium (49 MT)	34,012	0.208	163,518	49	2,209,804
9	Capacity Basis for NEPA, New Mexico, & CD-1 to CD-4 Amendments	273,262	-	1,313,758	100	5,084,804
10	Approximate % Increase in Capacity/Load	56%	-	56%		843%
* - These are 1000 year curies, i.e., curies remaining in 1000 years.						

WIPP was designed as a pilot project to demonstrate the science and practical operational issues associated with placing radioactive wastes in a salt dome. It was developed with a design life of 25-years and used repurposed equipment where ever possible to reduce costs. It was constructed by 1990 meaning that the 25 year design life has already been exceeded. In order to extend its operations another 30 years, a great deal of equipment would need to be replaced. The Red Team, like the other groups before them, assumed that WIPP is a well-operating repository with robust operation history. In fact, the facility is at the end of its design life and has suffered its first major incident. Given the age of the facility and design life, other failures are certain to become more common. This suggests that the optimistic view of the WIPP operation continuing well into the middle of the 21st century is unwarranted.

The Red Team, Aerospace, and PWG have assumed that there are no costs associated with the Dilute and Dispose Option for modifying WIPP. High Bridge rejects this assumption. If the Dilute and Dispose

Option is selected, then WIPP will need to be expanded and redefined. It would be incumbent upon the Dilute and Dispose Option program to include the costs and management of the effort required to make WIPP available. **Exhibit 1.2** provides a breakdown of the approximate costs for the design elements evaluated by High Bridge for expanding the capacity of WIPP. The approximate **\$1.9B** estimated total cost as shown in **Exhibit 1.2** was ignored by the Red Team and Aerospace in their evaluations.

Exhibit 1.2 – Dilute and Dispose Option Impact on PMDA, WIPP, and SC Fines

Dilute and Dispose Option Impact on PMDA, WIPP, and SC Fines Approximate Cost Estimate			
	PMDA, and WIPP Activities/Steps	Cost Estimate	Basis
	<u>PMDA Amendment Activities</u>		
1	PMDA Negotiations REV -2; MOX to Downblend/WIPP	\$83,750,000	Average 40 FTE for duration and a Team of 10 National Lab SMEs
	<u>WIPP Activities</u>		
2	WIPP 2014 Incidents Resolution	\$360,000,000	Current published estimate is the Low Est. Worst case estimate offered a public meeting by DOE of 5 years is the high (not included in the Total Option 4 Impact below)
3	Record of Decision (ROD)	\$2,406,250	Staff and DOE manager's time to organize and obtain necessary approvals for ROD - 5 FTEs
4	CD-0 Mission Definition	\$11,811,250	DOE management team procuring the services of a Contractor to develop the technical basis
5	CD-1 Conceptual Design	\$28,875,000	DOE management team overseeing the services of a Contractor that prepares the CDR
6	CD-2 Design	\$61,875,000	DOE management team overseeing the services of a Contractor that prepares the design packages
7	NEPA Process	\$326,562,500	DOE management team overseeing the services of a Contractor that prepares the design packages
8	NMED Oversight and Approval	\$18,906,250	5 NMED officials and a 10 person consultant firm 1/2 time
9	Modify WIPP Land Withdrawal Act	\$6,875,000	DOE Officials and staff briefings with staffers and legislators
10	CD-3 Construction	\$284,375,000	DOE management team overseeing the services of Contractors that prepare the procurement packages and actual construction services
11	CD-4 Testing and Commissioning	\$37,109,375	DOE management team overseeing the services of Contractors that conduct the startup testing and the readiness reviews to begin operations with surplus weapons Pu.
12	WIPP Total	\$778,795,625	
13	SC Penalties for missing 2018 start date for shipping Pu offsite	\$1,100,000,000	\$100M/yr starting in 2019
	Total Option 4 Impact	\$1,962,545,625	

7. The Red Team did not address the cost impact of the Dilute and Dispose Option on WIPP operations:

- Canceling the MOX Program requires disposal of at least 51MT of surplus plutonium in WIPP.
- Purchasing/loading 170,000 criticality control over-packs (CCO) each inside a 55-gallon drum.
- Transporting over 4,000 shipments (42 CCOs/shipment) from SRS to WIPP across six states.
- Emplacing over 35,000 M³ in the WIPP repository.

The Red Team report agreed with the Aerospace report that projected an increase in the cost of operations at WIPP of \$360M. There was no granularity provided for the value. The increase in the cost of disposal operations at WIPP for the surplus weapons plutonium would be proportional to the number of extra shipments that result from Dilute and Dispose Option operations. Using 300 Fissile Gram Equivalents (FGE) per CCO, it would take more than 170,000 drums to process all of the plutonium. At 42 CCOs per shipment (i.e., three TRUPACT-II over-packs per shipment), this converts to approximately 4,000 shipments. If SRS could ship 17 shipments per week, it would take about 4.6 years to emplace the entire 51 MT of plutonium at WIPP.

8. The Sterilization Option recommended by the Red Team is not viable for Plutonium Disposition:

- Safeguards and security impacts at WIPP would be astronomical.
- The Russian Federation would categorically reject this approach.
- The attractiveness level would remain at Level B-II.
- An NRC-approved container does not exist for this waste form.
- It is not permitted to store Special Nuclear Material intermingled with TRU waste packages.

The Red Team proposed a new approach called Sterilization for which the argument for removing safeguards is more problematic. The Sterilization Option consists of merely rendering the pit unusable for a weapon and then placing it in the repository. The Red Team did not provide any detail for this option but several aspects were clear. It would not involve changing the chemical characteristics of the plutonium, so it would remain at an attractiveness level of B, Category II. Assuming that the pit would not be divided into smaller pieces and placed in separate waste containers, the amount of material per drum would be far in excess of the current NRC-approved limit of 380 FGE per drum. There is no licensed container for this material, so the addition of a waste container licensing effort would need to be added to the costs. Such a licensing effort would be far from straightforward and would entail a great deal of effort, cost, and time.

The safeguards required for this Sterilization waste form far exceed the security program currently in place at WIPP. It appears that the Sterilization Option merely reconfigures the pit into a non-weapon shape. That would not reduce the attractiveness level like the Dilute and Dispose option that converts the metallic form into an oxide form. The dilute process reduces the attractiveness level to C category IV. The key to removing safeguards from the material at Rocky Flats was to reduce the attractiveness to level C category IV and then declare that the Stardust renders the material too difficult to divert and place it into WIPP. However, the Sterilization process is a more problematic argument because the material remains weapons grade, the quantity is attractive for diversion, and there are only simple separation steps necessary to have material ready for forming into weapons parts.

9. The Red Team accepted the Risk and Monte Carlo contingency determination analysis of Aerospace:

- The Red Team did not perform any structured risk and contingency analysis.
- The Red Team did not provide adequate credit for the operating experience of French plants. The Red Team did not recognize/understand the modest 35% throughput capacity factor for MOX MFFF that provides significant operational flexibility to deal with feedstock and production issues.
- The Red Team did not have the opportunity to review the High Bridge August 21 Phase 2 detailed report which included a structured risk and contingency Monte Carlo analysis.

High Bridge reviewed the Aerospace risks identified in their Appendix 2 Risk Tables covering probability of occurrence (POO) and minimum/maximum financial impact (FI) parameters for MOX Option and Dilute and Dispose Option. High Bridge computed the contingencies from the Aerospace Monte Carlo analyses in FY14\$ using their POO and FI parameters to produce a common basis of comparison with the independent High Bridge risk and contingency Monte Carlo analysis. Several of the Low (Min) and High (Max) FI values from the risk items in the Aerospace report were used in the High Bridge Monte Carlo analyses, along with about one-third of the POO defined by Aerospace. For those risk items where either the Aerospace FI or POO values were not used by High Bridge, values were assigned based on the experience and judgment of the High Bridge team members.

In FY14\$, the High Bridge 85% confidence contingency value for the MOX Option was **\$3.2B** and Dilute and Dispose Option was **\$5.0B**. These values compare to the Aerospace values of **\$7.8B** and **\$3.8B**. The Red Team asserted that High Bridge did not consistently evaluate risk parameters for the MOX Option and the Dilute and Dispose Option. High Bridge disagrees. The structured and detailed risk analysis described above supports the High Bridge case. The Red Team also concluded that the MOX MFFF facility was very complicated and that the Dilute and Dispose Option dilution technology was a relatively simple and mature technology. High Bridge concludes that the Red Team did not have adequate time to review the program parameters and dig into the requirements for the Dilute and Dispose Option, and likely relied too heavily on the opinions of stakeholders at LANL, SRS, and NNSA that were proponents of the Dilute and Dispose Option. High Bridge also concludes that the Red Team did not have time to properly consider the MOX operating plant experience in France, the very conservative MOX operating throughput capacity factor parameters, or the advanced completion status of the MFFF.

Additionally, the Red Team did not perform any review and adjustments to the Aerospace estimated cost outcomes and accepted them as presented. High Bridge not only performed a structured Monte Carlo risk assessment for determining contingency, but applied evaluated adjustments to the base cost categories for each Option. **Exhibit 1.3** provides a summary comparison of MOX vs. Dilute and Dispose costs as evaluated by High Bridge. This reflects that the estimated costs for these options are comparable.

Exhibit 1.3 - Revised Cost Comparison Exhibit from High Bridge Phase 2 Report

Comparison of MOX and Dilute and Dispose Options Life Cycle Costs (B-FY14\$)				
Element	MOX		Dilute and Dispose	
	High Bridge	Aerospace	High Bridge	Aerospace
Base Costs	\$ 15.1	\$ 16.7	\$ 13.0	\$ 7.4
Contingency/Risk	\$ 3.2	\$ 7.8	\$ 5.0	\$ 3.8
Changes	\$ 1.1	\$ 2.7	\$ 1.9	\$ 1.9
Total	\$ 19.4	\$ 27.2	\$ 19.9	\$ 13.1

10. The Red Team did not recognize the MOX Fuel economic contribution to the GNP through the production of clean non-carbon emitting nuclear power electricity:

- The 34 MTs of surplus weapons plutonium will result in enough nuclear fuel to generate electricity worth \$35B.
- The value to the GNP of the electricity sales (\$35B) from the MOX fuel is greater than the MOX total life-cycle cost (\$19.4B) in FY14 dollars.
- MOX represents a net increase in the GNP of the U.S. and creates >10,000 U.S. jobs.
- The Dilute and Dispose Option produces no GNP contribution and represents a net loss to the taxpayers.
- Using the 34 MT of plutonium converted to nuclear fuel will eliminate enormous quantities of NO_x, SO₂ and greenhouse gas emissions.

The Red Team rectified the Aerospace Report omission that identified no net income credit for the MOX Option. They estimated that \$1B would result from MOX fuel sales. However, they rather narrowly focused on the fuel sales and ignored the economic benefit to the GNP or Clean Energy Production. As outlined above, an ancillary benefit of the MOX program is the production of clean, greenhouse gas free, electrical energy using the MOX fuel in nuclear power reactors. **Exhibit 1.4** provides an expanded set of metrics regarding MOX value contributions and a comparison of the MOX Option versus the Dilute and Dispose Options.

Note that the comparison in the Exhibit compares the 34 MT case. However, the Dilute and Dispose Option forces the consideration of 51 MT because it eliminates the option to dispose the surplus plutonium at MOX. If the entire quantity of surplus plutonium had been considered for each case, the value proposition would be even more in favor of MOX. MOX revenue and societal benefits would increase with additional sales at no increase in sunk costs. The Dilute and Dispose costs and adverse impacts would continue to accrue.

Exhibit 1.4 – Comparison of Plutonium Disposition Program Alternatives

Comparison of Plutonium Disposition Program Alternatives Approximate Revenue, Cost Impact, and Value Contribution Metrics MOX Fuel Sales, Clean Energy, and GNP Parameters MOX Option vs. Dilute and Dispose Option				
#	MOX Option		Dilute and Dispose Option	
	Program Element		Program Element	
1	Metric Tonnes of Plutonium Pu 239	34	34	Metric Tonnes of Plutonium Pu 239
2	Pounds of Plutonium Pu 239	74,956	74,956	Pounds of Plutonium Pu 239
3	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved	Yes	No	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved
4	<u>Approximate Product Output</u> Nuclear Fuel PWR Assembly Approx. 8.5" x 8.5" x 13.5' Long Each Containing Approx. 264 Zircalloy Clad Fuel Rods	2,000	113,000	<u>Approximate Waste Form Output</u> Plutonium Diluted/Mixed with Stardust Inert Material in 6" Diameter x 2' Long Container Packed Inside a 55 Gallon Drum
5	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales	\$1,000,000,000	\$0	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales
6	Approximate Number of Shipments in Casks with 2 Fuel Assemblies/Cask, 4 Casks/Truck, and 3 Trucks/Shipment	80	2,700	Approximate Number of Shipments in TRUPACT-II Containers with 14 Drums/Container and 3 Containers/Truck
7	Approximate WIPP Storage Capacity Volume Consumed	~0	23,600 Cu. Meters	Approximate WIPP Storage Capacity Volume Consumed
8	Approximate Megawatt Hours of Clean Electricity Produced	285 Million	0	Approximate Megawatt Hours of Clean Electricity Produced
9	Approximate Value of Clean Electricity Produced	\$35 Billion	\$0	Approximate Value of Clean Electricity Produced
10	Approximate State/Local Tax Revenues Generated	>\$5 Billion	\$0	Approximate State/Local Tax Revenues Generated
11	Approximate Life Cycle Cost of MOX Program	\$19.4 Billion	\$19.9 Billion	Approximate Life Cycle Cost of Downblend Program
12	Approximate US Jobs Created for 20 Years	>10,000	0	Approximate US Jobs Created for 20 Years
13	Avoided Carbon Emissions	335 Million Tons	0	Avoided Carbon Emissions
14	Avoided NOx Gas Emissions	420,000 Tons	0	Avoided NOx Gas Emissions
15	Avoided SO2 Gas Emissions	675,000 Tons	0	Avoided SO2 Gas Emissions
NOTE: The values identified in this Exhibit are approximate based on the analysis performed during the High Bridge Phase 2 Report Review.				

2 AREAS WHERE RED TEAM AND HIGH BRIDGE AGREE

The Aerospace Study of Plutonium Disposition Options was issued April 13, 2015 (~50 pages). The Final Report of the Plutonium Disposition Red Team was issued August 13, 2015 (~40 pages). The High Bridge Phase 2 Detail Report providing and Independent Review of the Aerospace April 13, 2015 Study of Plutonium Disposition Options was issued August 21, 2015 (~200 pages). Various High Bridge and Red Team analyses and conclusions addressing some fundamental areas of disagreement with the Aerospace Report aligned closely or were in complete agreement. The below discussion summarizes these areas of Red Team and High Bridge agreement.

Evaluated MOX program annual funding needed is less than the average of \$1B per year identified by the Secretary of Energy

The Red Team concluded that the MOX Option is viable at a \$700M to \$800M per year average funding level¹. High Bridge concluded that the MOX approach is viable at a \$650M per year funding level during construction and commissioning, and at a \$400M to \$500M average funding level during operations. The Red Team and High Bridge both concluded that Aerospace over-estimated the MOX construction duration at approximately 25 years under the constrained funding level of \$500M per year, with a resulting over-estimated LCC outcome. The Red Team concluded that a 12 to 15 year duration (50% of Aerospace) was required for MOX construction while High Bridge concluded that a 6 to 8 year duration (25% of Aerospace) was required for MOX construction. The MOX Services 2012 Re-Baseline schedule reflected a 5 to 6 year duration to complete construction at a funding level of approximately \$625M per year.

Aerospace escalated RY\$ exaggerated costs for MOX with constrained funding scenarios

The Aerospace analysis focused on RY\$ (escalated) dollars to support cash flow planning and budgeting across out years. The Red Team and High Bridge agree that this Aerospace approach did not provide a common denominator current year (un-escalated) dollars analysis as a decision making basis for evaluating the estimated costs for the MOX Option and the Dilute and Dispose Option. The Aerospace Report approach and emphasis on escalated RY\$ values presented annual funding constraints that drove schedule durations longer and escalation costs higher. This was inappropriate for an economic evaluation. It created an “apples and oranges” situation that made a meaningful economic cost analysis impossible. High Bridge concluded this RY\$ methodology utilized by Aerospace to be technically flawed and not in compliance with nuclear industry standards or with various DOE and GAO policy directives for conducting economic evaluations.

Value of MOX fuel sales needs to be considered

The Aerospace report concluded that revenue from MOX fuel sales was not likely due to the lack of any firm orders being established with potential utility customers. Aerospace included no evaluated credit in their evaluation of the MOX LCC estimate. The Red Team and High Bridge disagreed with this Aerospace evaluation of MOX fuel sales. Each identified a net MOX fuel sales of \$1B that considered in their evaluations.

¹ The Red Team costs were reported in FY15\$. The Red Team did not provide any discussion of escalation factors.

Executive considerations regarding government/MOX contractor organization

The Red Team report outlined various Executive Considerations that needed to be addressed for the successful execution of the MOX program. While these parameters were not part of the High Bridge independent review scope to consider, the High Bridge team totally agrees with the Red Team conclusions and recommendations. These considerations outlined by the Red Team included the need to:

- Re-establish project workforce confidence and morale with full planned funding;
- Resolve the adversarial relationship between the NNSA Project Office and the MOX Services contractor;
- Resolve the dispute between the NNSA Project Office and the MOX Services contractor regarding the true status of completion of the MFFF Project;
- Facilitate a more balanced approach to NNSA staff oversight and adopt an advocacy-based project culture that avoids antagonistic engagement and counter-productive activities;
- Develop a positive and success-oriented culture of trust, open communications, and transparency between the NNSA Project Office and the MOX Services contractor;
- Consider contractual enhancements that may enable a reduction of burdensome oversight and indirect costs associated with the existing counter-productive relationship between the NNSA and contractor.
- Develop a detailed bottoms up revised performance baseline that reflects a realistic estimate-to-complete (ETC) for cost and schedule for the MFFF Project.

The lack of DOE formal acceptance of the 2012 Re-Baseline proposal from the MOX Services contractor and the significantly reduced annual funding picture since 2013 have been the primary contributors to the dysfunctional MFFF organization and management conditions that exist on the MFFF project. The Red Team recommendations outlined above are essential elements for a successful path forward plan.

The MFFF project has had an exemplary record of performance across safety, quality, and regulatory compliance parameters. High Bridge concludes that developing an Integrated Project Team (IPT) approach with a “sink or swim together” approach for the DOE and contractor is essential to achieve similar results in day to day management activities. Limited project resources need to be rallied around mutual progress goals where teamwork and open communications can flourish to mitigate problems before they occur.

High Bridge has extensively researched the root causes for success and failure for large projects like MFFF. It has examined lessons learned associated with over 100 major projects, developed a Top Ten list of keys to success, and presented these lessons learned at many global forums. At the top of this list is project execution with a truly Integrated Project Team of owner and contractor stakeholders. High Bridge agrees and supports the Red Team recommendations regarding its various identified Executive Considerations. High Bridge concludes that development of a realistic MFFF revised baseline coupled with adopting an Integrated Project Team approach will go a long way to resolving deficiencies and supporting success.

3 CURSORY NATURE OF RED TEAM REPORT

General Nature of Red Team Report

Throughout the Red Team report it is stated that their analysis was high-level, general, cursory, and developed with no backup analyses (used data from other reports). The Red Team wrote in the “How to Use this Report” section that the Red Team report should not serve as a basis to judge absolute costs.

The Red Team consisted of 19 highly qualified individuals with a broad background in DOE nuclear programs. They were given a charter to begin this review on June 25th and had a kickoff meeting on June 26th. They conducted tours of facilities in New Mexico and South Carolina for approximately four weeks gathering data and they issued their final report on August 10th slightly more than two weeks later or slightly more than six weeks after they began. It is difficult to distill a large amount of data in a short period of time, especially when all of the data is summary level and ratios of previous work.

The result is that most of the actual costs and risks of the Dilute and Dispose Option have been missed or assumed to be the responsibility of EM. For instance, the fact that DOE/NNSA has to dispose of more than 51 MT of surplus plutonium was never addressed. The transportation costs for the Dilute and Dispose Option is more than 50 times larger than for the MOX program. The cost of the containers for the packaging the plutonium in the Dilute and Disposal Option is \$374M. The increased cost of emplacing the waste at WIPP is about \$1.7B for the 51 MT, and these costs have not been addressed. In addition, there are operational cost increases for the Dilute and Dispose Option in the base costs for converting the plutonium into oxides and packaging the plutonium oxides in the CCOs. High Bridge estimates these cost increases to be approximately \$0.5B, for a total programmatic increase of about \$2.2B. The High Bridge Phase 2 report included a Monte Carlo based contingency analysis of approximately \$5.0B. The selection of the Dilute and Dispose Option forces the consumption of approximately 40% of that contingency without consideration of any other risk that may occur. This reinforces the need for a complete bottom up cost analysis of the Dilute and Dispose Option before any decision is made regarding its selection as a substitute for the MOX Option.

More egregious errors include the assumption that either the Dilute and Dispose Option or the Sterilization Option meet the requirements of the PMDA or the Spent Fuel Standard when they do not. Simply comparing the number of steps to recover weapons grade plutonium is an inadequate measure. Citing EM precedence for accepting their waste forms for disposal at WIPP misses the point that none of that is relevant to compliance with the PMDA.

The Red Team praised the Aerospace report for their “systems engineering” approach when the Aerospace report includes the following disclaimer: “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.” It is not possible to have a “systems engineering approach” if one does not assess the scientific and technical aspects of the subject matter. Without having an ability to assess the technical viability of the alternatives, the results are difficult for the decision makers to make intelligent and realistic choices.

Compliance with the Charter

The Red Team report included a copy of their charter. This document outlined ambitious goals for the Red Team to assess the following:

- Evaluating and reconciling previous cost estimates of plutonium disposition options;
- Analyzing ways to modify the MOX Option, specifically the MOX Fuel Fabrication Facility project, to reduce costs if feasible; and
- Examining how different risk assumptions can impact the total lifecycle cost estimates.

In addition, the assessment should analyze the following:

- Schedule to begin disposition and complete the 34 metric ton mission;
- Technical viability;
- Ability to meet international commitments; and
- Regulatory and other issues.

High Bridge reviewed the Red Team report against these goals and concludes they did not achieve all of the objectives.

Evaluating and reconciling previous cost estimates of plutonium disposition options - The Red Team identified that Aerospace used escalated costs that tended to exaggerate the costs of the MFFF project. Yet, they did no specific evaluations or attempt to reconcile the cost estimates. For instance, a discussion with the MOX Services personnel identified that they had about a \$1.5B to go costs and under their current funding constraints were able to accomplish about \$100M per year of construction scope. The Red Team therefore assumed that the construction schedule was 15 years in duration. This simplistic analysis is characterized as “relatively optimistic” whereas a rather uncritical acceptance of the Aerospace cost for the Dilute and Dispose Options is characterized as “relatively conservative.” This relatively conservative analysis assumed that the project could begin without PMDA approval, it assumed that EM would pay for the expansion of WIPP necessary to accommodate this waste, it assumed that the missing 17 MT of surplus plutonium does not exist, and it ignored the costs of CCOs, the cost of transportation and the increase in cost of WIPP operations.

In short, the Red Team accepted the restricted analysis of Aerospace that was admittedly focused on certain areas of the costs while being directed by DOE to ignore other costs and risks. This does not represent an evaluation and reconciliation of previous cost estimates.

Analyzing ways to modify the MOX fuel approach, specifically the MOX Fuel Fabrication Facility project, to reduce costs if feasible - The Red Team concluded that there are no silver bullets to help reduce costs for the MFFF. However, they identified a key problem in their Executive Consideration chapter as being the hostile working relationship between the DOE staff and the contractor’s staff. Many of the assertions in the Red Team report were biased and likely provided by DOE project staff. An example is the assertion that the contractor had 200 project controls personnel when in fact there are about 70. This assertion was accepted and placed in the report without confirmation. The Red Team did not recognize the Silver Bullet even when they accurately described it. The problem with the MFFF project is the strained and antagonistic relationship of the DOE and MOX contractor project team driven

primarily be reduced funding and the lack of a baseline. If DOE would address this issue, the risk and cost of the remaining work would be minimized.

Examining how different risk assumptions can impact the total lifecycle cost estimates - The Red Team did not understand the Risk Assessment and even confuse technical risks with project risks. The Red Team accepted the Aerospace assertion that since the MOX process is more complex, it must be more risky than the Dilute and Dispose Option. The MFFF project has already experienced all of the cost increases caused by its complexity. Now, all that remains is to install the pieces that have been assembled at the site. These are fairly small cost risk items. Meanwhile, the Red Team focused on the mixing of the plutonium oxide with the material used to reduce its attractiveness and ignored the risks of acceptance of the approach by the Russian Federation, and the cost, schedule and risks associated with getting approval to place this material in WIPP in view of the fact that it will exceed the legal limits for waste and destroy the EM mission. This focus on the dilute portion of the Dilute and Dispose Option while ignoring the risks associated with the disposal part of the program is a serious flaw of the Red Team's review.

Schedule to begin disposition and complete the 34 metric ton mission - The Red Team has essentially rubber stamped the schedule errors of the preceding review teams. The schedule of the MOX program was developed assuming the continuation of the crippling funding restrictions even though the Red Team recommended that the funding be increased if the decision is to go forward with the MOX strategy. The Dilute and Dispose Option is assumed to be able to start without the need to address the PMDA or the design and licensing issues that its selection will force on both WIPP and the EM program. The durations and logic of the schedules were never discussed in detail.

Technical viability - The Red Team correctly concluded that both options are technically achievable although they were intimidated by the complexity of the MOX fuel fabrication facility. However, the issue of regulatory compliance and legality of the Dilute and Dispose Option were ignored. The Red Team failed to identify legality and license ability as two of the largest technical viability issues.

Ability to meet international commitments - This is an area where the Red Team did not fully research or understand the PMDA and the Russian Federation position. High Bridge and their peer reviewers assert that neither the Dilute and Dispose nor the Sterilization options meet the current PMDA requirements or the intent of the agreement. The Russian Federation would view both of these options as "storage" not disposal. The Red Team uncritically accepted the premise that the Dilute and Dispose Option meets the Spent Fuel Standard (SFS), as if that standard had any relevance to the PMDA. The SFS is a U.S. standard applied to assess the Safeguards and Security requirements for certain categories of waste forms. It has no meaning to the Russian Federation or applicability to our international commitment to the PMDA.

Regulatory and other issues - The Red Team provided a superficial review of the regulatory issues confronting the Dilute and Dispose Option by focusing solely on the dilute part of the Dilute and Dispose Option. The Red Team assumed that WIPP will accept this waste at no cost to the Plutonium Disposition program. Even though they recognized that WIPP is not able to accept the surplus plutonium under the current legal constraints, they assumed that that regulatory hurdle would be crossed by others relatively easily. Other issues associated with the EM mission and the status and condition of WIPP were not addressed.

In closing, the above discussion supports the High Bridge conclusion that the Red Team did not achieve all of the objectives outlined in its charter.

4 THE RED TEAM DID NOT RECOGNIZE THAT THE AEROSPACE ANALYSIS LACKED INDEPENDENCE

An August 6th meeting was arranged by the office of Senator Lindsay Graham to provide the opportunity for the MOX contractor and High Bridge to ask Aerospace questions regarding their April 13, 2015 Assessment Report of Plutonium Options. It was held for one hour at the Russell Senate Office Building in a Senate Hearing Room that included attendance by three High Bridge personnel, seven MOX Services personnel, three Aerospace personnel, three NNSA personnel, and approximately thirty Senate and House staff members. High Bridge followed a line of questioning designed for a one-hour meeting to obtain some details and clarification regarding the Aerospace assumptions, analysis approach, and outcome conclusions. In High Bridge's opinion, Aerospace responses to High Bridge questions regarding key issues affirmed that:

1. The NNSA had provided Aerospace with specific direction regarding fundamental parameters governing the conduct of the Aerospace review;
2. The Aerospace report was not independent and it reflected NNSA specific direction; and
3. The Aerospace report analysis was influenced by the NNSA to exaggerate the MOX Option estimated schedule duration and costs and to reduce Dilute and Dispose Option estimated costs.

The Red Team visited SRS during the week of July 20 and conducted interviews/fact finding with MOX Services and NNSA Project personnel. The Red Team and High Bridge personnel had a one-hour telephone call on July 22 to discuss questions that the Red Team had regarding the High Bridge June 29 Phase 1 initial 5-page Executive Summary and Overview assessment of the Aerospace report. The Red Team only considered the High bridge 5-page June 29 Phase 1 initial report in its August 13 Red Team Report. The Red Team did not have the opportunity to read or consider the August 4 High Bridge expanded 18-page Executive Summary and Overview or the High Bridge August 21 Phase 2 Detailed 200-page Assessment Report as part of its August 13 Final Red Team Report.

High Bridge feels that the Red Team needs to be provided the insights gained during the High Bridge meeting with Aerospace on August 6. High Bridge believes that these insights would have influenced the Red Team analysis and outcomes presented in their August 10 Red Team Report.

The five areas where NNSA provided direction to Aerospace that influenced the Aerospace Report conclusions, increased MOX Option LCC outcomes, and minimized Dilute and Dispose Option LCC outcomes are summarized as follows:

1. High Bridge asked Aerospace why they used a 4% escalation rate for construction vs. lower (less than 2%) industry guidance standards provided by sources such as the DOE GAO, Engineering News-Record, US Army Corps of Engineers, or the Construction Industry Institute. ***Aerospace responded that it was directed to use the 4% annual escalation rate for construction by their NNSA customer.*** The NNSA defended this approach as conservative given the uncertainties regarding construction material and labor. High Bridge commented that this escalation approach merely resulted in exaggerated and high life cycle cost (LCC) MOX costs.

2. High Bridge asked Aerospace why it used an escalated real year dollars (RY\$) approach throughout the report that provided confusing and non-common denominator \$ values, while not providing current year constant \$ analysis as required by DOE and GSA guidelines. **Aerospace responded that it performed its initial analysis in constant present day \$, but that it was directed to develop its report in RY\$ by their NNSA customer.** The NNSA defended this approach by saying it needed the LCC expressed in RY\$ to perform budget and funding planning comparisons of options being studied for out years. High Bridge commented that it understood these needs, but that the purpose of the Aerospace Study was to provide an economic comparison of technical alternatives and that it also needed to present its outcomes in current year constant dollars. High Bridge commented that it considered the Aerospace NNSA approach flawed and skewed because it did not present its outcomes in current year constant dollars.
3. High Bridge asked Aerospace why it developed its LCC for two constrained funding scenarios (\$500M/year and \$375M/year) for MOX without developing a LCC for full or optimum funding (\$625M/year) consistent with the MOX contractor 2012 Re-Baseline proposal. **Aerospace responded that it was directed to use the two constrained funding scenarios and not develop a full funding LCC scenario by their NNSA customer.** The NNSA defended this approach by saying it was looking for ways to reduce cash flow/funding, and that the constrained funding scenarios were developed as a result. Additionally, NNSA considered the MOX Services 2012 Re-Baseline proposal as received, not approved, and not authorized. High Bridge commented that the constrained funding scenarios created a very inefficient and ineffective execution approach, which resulted in the LCC for the MOX Option being extremely higher in cost and longer in schedule. High Bridge closed by commenting that it evaluated a full funding scenario for MOX in constant FY14\$ as the basis for its assessment of both Options.
4. High Bridge pointed out to Aerospace that on page 8 of the Aerospace report it states that 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 down blend 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. High Bridge asked Aerospace why they did not examine the science, physics, and chemistry of the options in determining risks and impacts. **Aerospace responded that their NNSA customer to focus on performing an economic analysis of the Options.** High Bridge responded that it did not see how Aerospace could properly assess cost and schedule drivers without assessing and understanding the basis technical requirements for complex programs represented by both Options.
5. High Bridge asked Aerospace why there was minimal discussion and no economic impact analysis of the availability, capacity, and projected inventory for WIPP to support Dilute and Dispose Option delivery of down blended shipments. **Aerospace responded that their NNSA customer directed them to assume that WIPP would be available, not a problem, and required no cost/schedule considerations.** High Bridge asked Aerospace if they had analyzed how many Dilute and Dispose Option criticality control over-pack (CCO) containers would be needed to accommodate 34 metric tons of plutonium with a 380 grams/CCO design. Aerospace responded that they had not done this calculation. High Bridge indicated it had analyzed this and that over 113,000 CCO's and 55 gallon drums would be required. This created a significant cost impact that Aerospace did not address, and indicated that WIPP did not have the capacity to accept all

of the 34 metric tons. NNSA responded that they saw no real risk here, since they could simply reduce the number of Dilute and Dispose Option CCOs/drums by increasing the design from 380 grams to 1,000 grams of plutonium per CCO. High Bridge responded that it felt that this approach was treating the issue very superficially and did not understand the NRC and EPA requirements involved.

5 PLUTONIUM MANAGEMENT AND DISPOSITION AGREEMENT (PMDA)

The MOX Program is a direct result of the Plutonium Management and Disposition Agreement between the Russian Federation and the U.S. government. It is surprising therefore that the Red Team, the PWG, and Aerospace all discounted the importance and the difficulty of amending the PMDA. Further, they all incorrectly asserted that the DOE could begin working on the Dilute and Dispose Option almost immediately before discussing this issue with the Russian Federation. All three of these groups seem to view the PMDA as a minor issue that can be cleared up easily once DOE management decides to abandon the MOX Program in favor of the Dilute and Dispose Option.

The PMDA is the result of nearly twenty years of continual discussions between the U.S. and the Russian Federation. It began with a Presidential Directive in September 1993 committing the United States to “seek to eliminate, where possible, accumulations of stockpiles of highly enriched uranium or plutonium.” In January 1994, the United States and Russia established working groups and tasked their experts to develop options for plutonium disposition. In a September 1998 summit, Presidents Clinton and Yeltsin committed both countries to seek to enter into a bilateral plutonium disposition agreement. This was accomplished in September 2000 when the United States and Russia signed the bilateral PMDA that commits each country to dispose of 34 MT of surplus weapon-grade plutonium roughly in parallel.

Disposition methods allowed under the 2000 PMDA are enumerated in Article III of the agreement as:

- a) irradiation of disposition plutonium as fuel in nuclear reactors;
- b) immobilization of disposition plutonium into immobilized forms; or
- c) any other methods that may be agreed by the Parties in writing.

The DOE originally proposed to use irradiation for the pure plutonium and immobilization for the small fraction deemed to be too difficult to make into fuel. Immobilization was eventually dropped because of cost which resulted in additional systems being added to the MFFF to address the feedstock purity issues.

The Red Team acknowledged that such an agreement would be needed with this sentence in their Executive Summary, “The review team... believes that the Dilute and Dispose Option meets the requirements for permanent disposition, but recognizes that this assertion will ultimately be subject to agreement with the Russians, and that the decision will be as much political as technical.” Thus, one of the few major agreements in place with the Russian Federation is minimized and trivialized by reducing it to a political decision.

In fact, the Russian Federation has always maintained that the goal of disposition is irreversibility. For that to occur, they have long argued that the isotopic makeup of the plutonium needs to be altered. Immobilization, as defined in the PMDA “means disposition plutonium that has been imbedded in a glass or ceramic matrix and encapsulated with high-level radioactive waste in a can-in-canister system

suitable for geologic disposal, or any other immobilization system agreed in writing by the Parties.” Once again, the Dilute and Dispose Option does not meet this agreement unless it is negotiated and agreed to by both Parties in writing before it is undertaken. Even so, the Russian Federation position on immobilization is that “immobilization does not guarantee full irreversibility since mixing plutonium with radioactive waste does not change its isotopic composition and does not exclude the possibility of extracting weapons-grade plutonium from the mixture.”²

While the Russians accepted the U.S. immobilizing 9 MT of oxides and impure metal that had never been in a nuclear weapon (approximately 1/4 of the 34 MT surplus U.S. inventory) they were adamant that the remaining 25 MT of U.S. weapons-grade plutonium from nuclear weapons pits needed to be isotopically degraded by irradiating it in nuclear reactors. This distinction between MOX and immobilization subsequently became moot when DOE eliminated immobilization as a disposition option in 2002 when it was determined that proceeding with both MOX and immobilization was too expensive. Notwithstanding, Russia has long argued that immobilization followed by subsequent placement in a geologic repository (such as Yucca Mountain or WIPP) was a form of long-term storage because the weapons-grade plutonium could subsequently be retrieved for weapons use by a nuclear weapons state in the event of a breakout scenario.

During the negotiations leading up to the signing of the PMDA, the U.S. insisted Russia utilize light water reactors for plutonium disposition because the U.S. was relying on existing and widely available light water reactors in the U.S. for its plutonium disposition program. Fast reactors were not the preferred approach for plutonium disposition for two reasons: (1) while weapon-grade plutonium fuel irradiated in fast reactors is reduced to reactor-grade, its overall plutonium 240 to plutonium 239 ratio is much closer to weapon-grade than reactor grade plutonium irradiated in light water reactors, and (2) fast reactors also contain blanket assemblies, which if irradiated and reprocessed correctly, would result in the separation of additional weapon-grade plutonium.

Russia argued against the use of light water reactors because this approach failed to extract the maximum energy value from the plutonium but reluctantly agreed if the U.S. and its international partners contributed the entire \$2B cost of Russia’s disposition program. When it became clear that the required funding could not be raised, Russia proposed to fund the majority of the cost of its disposition program if they could use fast reactors that are more consistent with Russia’s national energy strategy.

The fast reactor approach offered several major advantages: (1) Russia would pay for the majority of the capital and operational costs associated with implementation; (2) Russia was politically committed to timely implementation of its energy strategy; (3) fast reactors could be configured to burn plutonium more efficiently than other reactors; and (4) the fast reactors would be subject to an extensive monitoring and inspection regime consistent with the 2000 Agreement.

The U.S. agreed with Russia’s use of fast reactors providing that: (1) Russia committed to never reprocess spent fuel containing disposition (34 MT) plutonium; and (2) any reprocessing of other spent fuel (non-34 MT) will never result in the separation of additional weapons-grade plutonium. Russia has agreed to these stringent nonproliferation conditions as well as other stipulations including:

² “Disposition of Excess Weapon Grade Plutonium: New Developments” by A. Diakov and V. Rybachenkov, Center for Arms Control, Energy and Environmental Studies, 2014.

- The plutonium breeding blanket from the BN-600 fast reactor would be removed before that reactor can be used for disposition;
- The BN-800 fast reactor would be operated with a breeding ratio of less than one so the reactor will burn more plutonium than it produces;
- The uranium fuel irradiated in the BN-600 (vs. MOX fuel) could be reprocessed as long as it does not result in the accumulation of new separated weapon-grade plutonium;
- Russia has agreed to forego reprocessing the blanket assemblies from the BN-800 fast reactor; and
- Up to 30% of the assemblies irradiated in the BN-800 could be reprocessed for testing advanced fuel cycle technology as long as it does not result in the separation of any plutonium.

In order to account for these changes and bring the PMDA up to date, the United States and Russia began a series of detailed negotiations in 2007 which resulted in the two sides signing a Protocol in April 2010 amending the 2000 Plutonium Management and Disposition Agreement. According to the amended PMDA, the United States would provide up to \$400 million to support plutonium disposition in Russia, subject to future appropriations, and Russia would fund the balance of its disposition program, estimated to be more than \$3 billion. NNSA and its Russian counterpart, Rosatom, would also jointly seek international contributions for Russia's program. This agreement went into effect in 2011 after the Russian Duma approved the agreement.

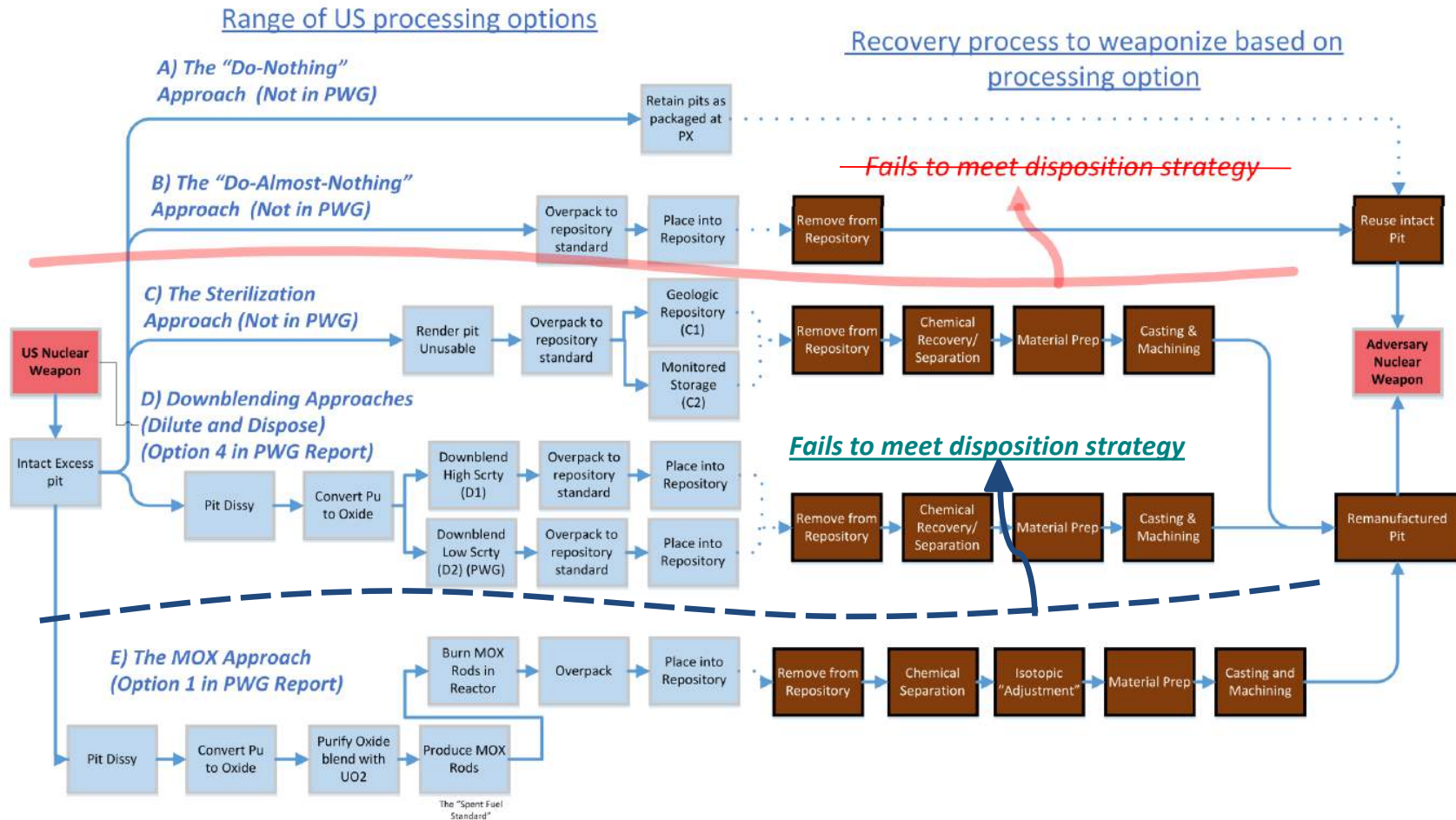
The Red Team, Aerospace, and PWG suggested that these agreements be abrogated in favor of negotiating the non-negotiable position that the Dilute and Dispose Option is equivalent to the Spent Fuel Standard (SFS). First, the dilute and dispose option is not equivalent to the spent fuel standard and second the spent fuel standard is not in the PDMA.

To understand why the Dilute and Disposal Option is not equivalent to the SFS, consider Figure 4 from the Red Team Report reproduced here as **Exhibit 5.1**. It was supposed to demonstrate the acceptability of the Dilute and Dispose Option as well as the sterilization strategy. The key to making this argument was the similarity of the brown boxes on the right side of the figure. It was implied that since the names on the boxes are similar, that there is an equivalence in the degree of safeguards. This is extremely misleading because the name of the process step in no way represents the difficulty of the required effort.

For instance, the first box in all three options is labelled "Remove from Repository." In the case of the first to options, this consists of entering the repository drift with a forklift or suitable hand tools, removing the Criticality Control Overpack and carrying it out of the repository by hand or fork lift. In the case of MOX, the problem confronting someone wishing to recover the used MOX fuel assembly is significantly different. First, the dose rates are many thousands of rads per hour. A lethal dose of radiation is received in minutes and equipment employed needs to be radiation hardened and shielded to protect the workers. The used MOX fuel assembly is stored in a double welded heavy walled pressure vessel weighing several tons. The fuel assembly itself weighs about one thousand pounds and maybe thermally hot as well. Clearly, there is several orders of magnitude difference in the first box on this exhibit.

The next box is labeled Chemical Recovery/Separation in the case of the two non-reactor options and Chemical Recovery in the case of MOX. In the case of the non-reactor options, the containers need only be opened and the contents poured out into a suitable chemical reagent container. The Dilute and Disposal option is packed in a material that makes the recovery difficult and time consuming but once

Exhibit 5.1 – Figure 4 extracted from Red Team Report (and edited by High Bridge – dashed lower line)



completed, the weapons builder is rewarded with weapons grade plutonium. Two CCO containers on average are all that is needed to have enough for a nuclear device so the amount of material processed for each weapon is fairly modest. The dose rates and hazard associated with these steps are compatible with a simple chemical fume hood and readily available chemicals.

In order for one to recover material from a used MOX fuel assembly, they would be confronted by a completely different level of difficulty. First, the material is in 12 to 14 feet long tubes assembled into bundles weighing about half a ton each. The dose rates near the fuel assembly are greater than 1000 r/hr so that simple material handling is extremely difficult and dangerous unless conducted in a specialized facility. The person seeking to recover the plutonium needs to break open the tubes and dump literally thousands of extremely radioactive ceramic pellets into a vat of nitric acid to begin the chemical process. Some of the fission products are gases at room temperature leading to inhalation doses far greater than the general area doses. Instead of removing slightly radioactive plutonium from an inert matrix as part of a non-reactor approach, the MOX fuel assembly requires heavy lifting equipment, specialized chemical processing equipment, and a shielded work area with remote tools to affect the material handling steps. The result of this effort is that the weapons maker gets about 8 kilograms of reactor grade plutonium which is not particularly valuable for a weapon.

An additional complication is that it is not possible to tell whether the spent fuel assembly is a used MOX assembly or a used uranium assembly by looking at it or by any other external measurement. Since the repository would package the assemblies to achieve a certain heat loading in the overpack, it is quite possible that the would-be weapons builder would need to process many assemblies to find the necessary plutonium. A Dilute and Disposal drum would be marked on the outside, would weigh less than other drums, and would have a CCO inside making the identification of the plutonium-bearing overpacks much simpler by comparison.

The next step in the process for the MOX option is to perform Isotopic Adjustment. This process would be required to reduce the amount of Plutonium 240 relative to the amount of Plutonium 239. This can only be done with an enrichment process line designed for plutonium. Since no one has ever done this on a significant scale, the would-be weapons builder needs to design an enrichment system, dissolve the plutonium in hydrofluoric acid to obtain a gaseous form of plutonium to either centrifuge or diffuse the gas through a membrane in a cascade of devices until the desired purity is achieved. This process is so difficult that it renders the diversion of used MOX fuel untenable. Then the product has to be treated with another complex step to remove the fluorine and convert it to a metallic form suitable for casting and machining. This represents several more process steps.

It is impossible to argue that the three options experience the same degree of difficulty in recovering Pu²³⁹. The first two options provide minimal barriers to returning the material to the arsenal; MOX makes this all but impossible. Even granting that security and physical barriers contribute to the safeguarding of this material, the fact is that if the US government wanted to recover this material to fast track weapons production, that there is very little that would prevent it. In conclusion, MOX would render the material nearly useless for even government weapon making.

DOE successfully argued that the repository barrier represented a significant enough boundary to remove safeguards from Rocky Flats materials bound for WIPP. However, this approach does not satisfy the PMDA. Clearly, the standard for an international agreement between weapons states must

be to make the material unattractive for the weapons state to recover. Material disposed by the Dilute and Dispose Option would present an insignificant barrier to the U.S. government to weaponize the plutonium. Sterilization would present even less of a barrier. MOX spent fuel would represent a significant barrier to reusing the material for a weapon and that is the real standard that must be applied to surplus plutonium disposition. It is for that reason that High Bridge has redrawn the line indicating the “Fails to Meet Repository Strategy” above the MOX Option. None of the non-reactor alternatives proposed by the PWG are acceptable for Plutonium Disposition.

The problem with the Red Team, Aerospace, and PWG reports is that they assumed that they could cite irrelevant precedence for other problems and asserted that the PMDA did not represent a legal barrier to their proposed action. This is unrealistic and enables those who make this assumption the ability to ignore costs and schedule delays that are certain to occur if the Dilute and Dispose Option is pursued. The High Bridge report assumed that the PMDA could be negotiated in parallel with the recovery of WIPP from the February 2014 incidents and that both could be completed in five years starting in 2014. However, no one is seriously pursuing these negotiations and so there is no real alternative to MOX that maintains the Russian Federation/U.S. partnership in reducing weapons of mass destruction

6 WASTE ISOLATION PILOT PLANT (WIPP)

The Red Team’s approach to the impact of the Dilute and Dispose Option on WIPP is confusing. They clearly realized that WIPP is intended to address the cleanup of the legacy wastes by the EM organization within DOE. Their report includes a section entitled “WIPP as a National Asset” in which they accurately describe the value proposition of the WIPP and identify the physical limits to the waste volume allowed into the repository. Further, they also recognized that, with current disposal container technology, the Dilute and Dispose Option will exceed the legal limit for WIPP waste volume. They included the following description. “Without substantial changes to container packing efficiency and/or volume accounting techniques at WIPP, the disposal of just 13 MT of the 34 MT U.S. obligation via the Dilute and Dispose approach discussed later in this document would reportedly consume as much as 68% of the remaining unsubscribed capacity.”

This unclear way of describing that the 34 MT of plutonium cannot be placed into WIPP probably came from repeating the findings of the Final Surplus Plutonium Supplemental Environmental Impact Statement of how to dispose of 13.1 MT of surplus plutonium not included in the PMDA. They did not calculate how much extra volume would be needed beyond the legal limit just to disposition this material at WIPP. Instead, the Red Team offered the bromide of the need to increase “efficiency” which was little more than an unsubstantiated distraction from the fact that this course of action is not legal.³

In spite of the recognition that WIPP is essential for the EM mission and that the 34 MT of surplus weapons plutonium will not fit within the current legal limit, the Red Team assigned no cost impact to the Dilute and Dispose Option or to their even more unrealistic Sterilized Option. They assumed

³ There is no NRC-licensed container approved for more than 380 Pu-239 Fissile Gram Equivalent to achieve this “efficiency.” So, even though there are smaller containers that can hold more FGE of plutonium in use, they are not legal for use at WIPP.

that the Dilute and Disposal Option could begin without addressing the redesign or licensing issues and that some other budget would be available for the expansion of WIPP and the risk associated with jeopardizing the entire EM program.

Finally, the Red Team clearly understood that there is more surplus weapons plutonium to be dispositioned than the 34 MT subject to the PMDA. They referenced the Surplus Plutonium Supplemental Environmental Impact Statement that discusses the disposal of 13.1 tons of plutonium and they spoke with the people currently working on an additional 4.2 MT of surplus plutonium at SRS that had been deleted from the PMDA's final language. It is clear that the Red Team was aware that DOE/NNSA has over 51 MTs of plutonium to dispose of and yet they never address it. Moreover, the SRS specialists told them that the average loading per CCO is 300 FGE not the more aggressive 350 FGE used by High Bridge in our August 21, 2015 report. **Exhibit 6.1** below shows the impact of these two facts.

With the data available to the Red Team they should have easily been able to develop the data in **Exhibit 6.1**. It would have showed that the Dilute and Dispose Option exceeds the available unsubscribed volume in WIPP by a factor of nearly two. This would have resulted in the failure of not only the Plutonium Disposition program to meet its obligation but also the probably failure of the EM cleanup program to meet its obligation. It should be noted that the 17.3 MT of surplus plutonium would fit in WIPP if the MOX program was successfully completed. Therefore, it is the adoption of the Dilute and Dispose Option that causes the capacity and mission problems at WIPP. It is difficult to understand how the Red Team did not realize that they would not be allowed to begin this process without solving the capacity and mission problems.

Exhibit 6.1 Dilute and Dispose Impact on WIPP

Dilute and Dispose Option Impact on WIPP			
34 MT of Plutonium	High Bridge Report ¹	Red Team Report ²	Units
Number of Drums	97,143	113,333	
Volume in WIPP	20,225	23,596	m ³
Available Volume in WIPP	19,564	19,564	m ³
Volume Deficit	661	4,032	m ³
51 MT of Plutonium	High Bridge Report ¹	Red Team Report ²	Units
Number of Drums	145,714	170,000	
Volume in WIPP	30,337	35,394	m ³
Available Volume in WIPP	19,564	19,564	m ³
Volume Deficit	10,773	15,830	m ³
Notes: (1) High Bridge used 350 FGE per drum from the Surplus Plutonium Supplemental EIS.			
(2) The Red Team was told by SRS SMEs that 300 FGE was the average loading per drum.			

The first step in defining the revised functional specification for WIPP would be to clarify the mission of WIPP. It would not be prudent to set the new limit at exactly the current understanding of the volume. Instead, the new target for the capacity should include not only the currently identified

wastes but also an allowance for additional EM generated waste and for potential additional surplus weapons plutonium that may be required. High Bridge generated such a table in report on the Aerospace report. A revised version is shown as **Exhibit 6.2**, reflecting the 300 FGE average loading per drum.

Exhibit 6.2 – WIPP Capacity and Projected Loads

WIPP Facility Capacity and Projected Loads TRU Waste and Plutonium Approximate Impacts						
Capacity and Projected Load Element		Cubic Meters	Cubic Meters/ 55 Gal. Drum	Number of 55 Gal. Drums	Plutonium Metric Tons	Curies *
1	Current Technical Basis of WIPP	175,600	0.208	844,231	0	539,000
2	2014 DOE EM TRU Waste Projection	156,000	0.208	750,000	0	0
3	2015 NNSA Excess Plutonium Projection (51 MT)	<u>35,400</u>	0.208	<u>170,192</u>	<u>51</u>	<u>2,300,000</u>
4	Sub Total Projection	191,400	-	920,192	51	2,300,000
5	25% Freeboard for Future Identified Waste Projection	47,850	0.208	230,048		575,000
6	New WIPP Capacity	239,250		1,150,240		2,875,000
7	Approximate % Increase in Capacity/Load	36%		36%		433%
8	Allowance for additional surplus weapons plutonium (49 MT)	34,012	0.208	163,518	49	2,209,804
9	Capacity Basis for NEPA, New Mexico, & CD-1 to CD-4 Amendments	273,262	-	1,313,758	100	5,084,804
10	Approximate % Increase in Capacity/Load	56%	-	56%		843%
* - These are 1000 year curies, i.e., curies remaining in 1000 years.						

Row 1 of **Exhibit 6.2** lists the current WIPP design basis. The volume data come from the WIPP Land Withdrawal Act limit and the curie value is from the FEIS and is the 1,000-year curie value used for pathway analyses. Row 2 shows the current projections of the TRU inventory reports. Row 3 is the impact of adding the entire surplus weapons plutonium inventory into WIPP using currently licensed containers. Row 4 is a subtotal of what is currently identified EM wastes and the Dilute and

Dispose Option fully implemented. Row 5 is an additional allotment for EM Mission expansion. Row 6 is a new proposed size of WIPP. Row 7 is the percentage increase over the current licensing basis. In addition, it may be prudent to increase the allowance further to accommodate an additional reduction in nuclear weapons arsenals. Row 8 shows an additional 49 MT of plutonium that may someday be declared to be surplus and removed from the arsenal to get a round number of 100 MT. (It represents about a 50% reduction in our current arsenal of nuclear weapons.) Row 9 shows one possible new baseline for the revised WIPP baseline and design basis. Row 10 shows the maximum credible expansion is 56% in volume and about an 800% increase in radioactive source term. These represent significant changes in the licensing basis. This would mean that the 6.4 million cubic feet in the LWA would need to be increased to 9.7 million cubic feet and a new NEPA dose assessment analysis would be required.

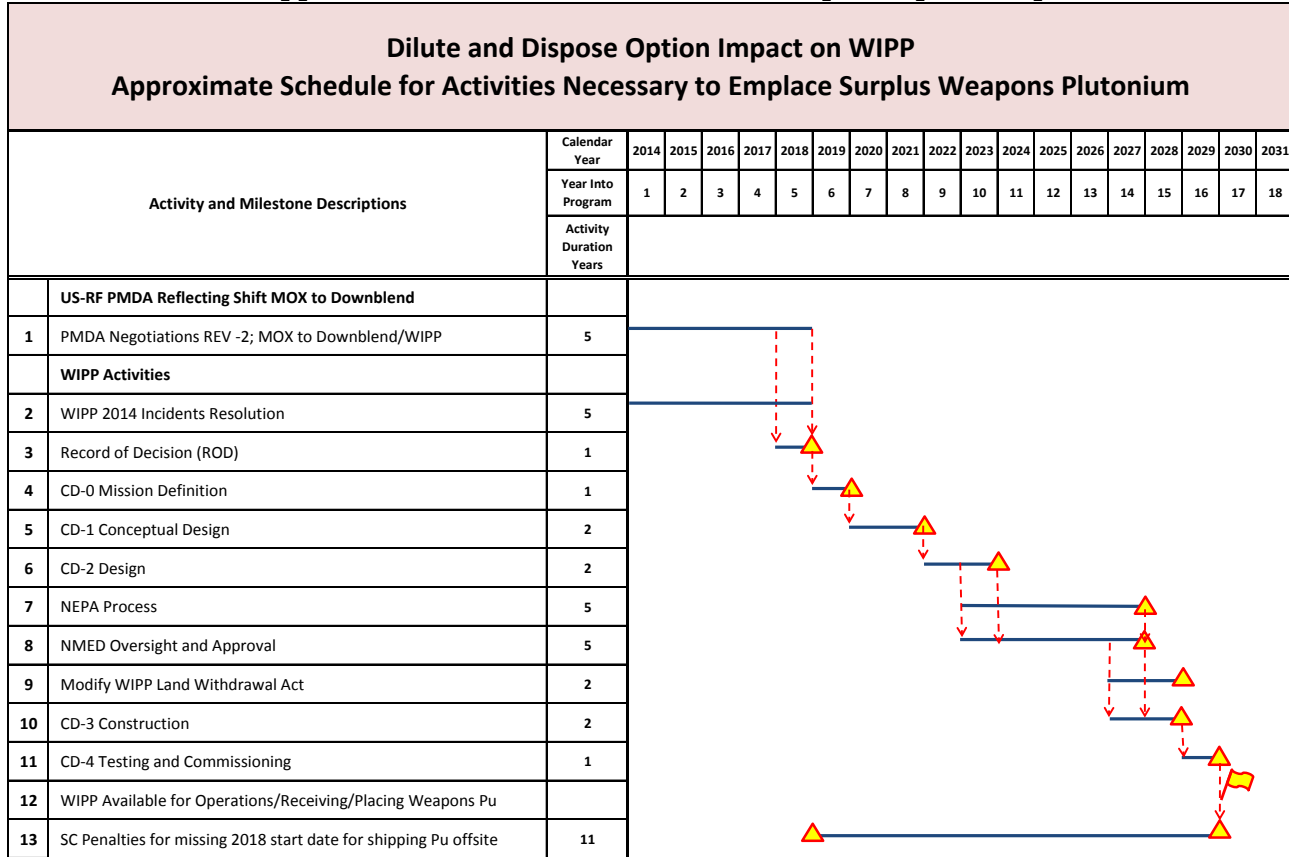
These changes in the WIPP mission and the increased emplaced volumes cannot be accomplished by executive fiat. The program needed to accomplish these changes requires a carefully managed capital project to expand the licensing basis of WIPP. In addition, no excess plutonium waste can be shipped to WIPP until this process is completed. The Red Team repeatedly asserted that there is precedence for shipping this waste to WIPP based on the Rocky Flats experience but ignores the fact that the cleanup of Rocky Flats is exactly what WIPP was designed and licensed to support. What they are proposing with the Dilute and Dispose option and with the Sterilization option are not part of the WIPP design mission. While it is true that miscellaneous impure weapons grade plutonium has been placed into WIPP as part of the EM mission, it does not follow that disposing of surplus weapons pure pit plutonium in WIPP is therefore acceptable. It is most likely not acceptable without stakeholder approval. Attempting to send this material to WIPP without gaining stakeholder approval is ill-advised. It is not prudent to abandon the mature MFFF project (that is substantially complete) to adopt the immature Dilute and Dispose Program in the face of a tumultuous and potentially hostile NEPA process.

Exhibit 6.3 is a notional schedule that shows the optimistic impact of the Dilute and Dispose Option. It assumes that no work can begin until the Russian Federation and the U.S. negotiators have agreed and have modified the language in the PMDA. This is assumed to take place in parallel with the recovery of WIPP after the February 2014 incidents that have shut down waste handling operations at the facility. Near the end of the negotiations, assuming that an agreement can be reached as quickly as the previous amendment, the Secretary of Energy or designee can initiate a Record of Decision describing what the new parameters of the licensing basis will be. This will be followed rather expeditiously with the required critical decision process to put together the design, licensing and cost data documentation necessary to support the Supplemental EIS preparation.

This will be followed by the NEPA process consisting of a two year preparation phase, a two year review and public comment phase, and a year of resolving comments and gaining final approval. This is an aggressive schedule considering the contentious nature of what is being proposed. Once it becomes clear that the Supplemental FEIS will be approved, political forces need to be mobilized in Washington DC to amend the existing WIPP Land Withdrawal Act. Optimistically, this has been assumed to be a two-year effort. The schedule assumes that the construction activities in the KAMS and at WIPP can be accomplished in two years in parallel with obtaining the political solution to amending the Land Withdrawal Act. This is an aggressive schedule assumption since it would be taken at risk since Congress may not approve the use of WIPP for this new purpose. Then, a year of

production startup testing and commissioning would take place before fully compliant operations could begin. That places the start of Dilute and Dispose operations in the 2029 timeframe nearly a decade later than assumed by Aerospace and the Red Team. It also delays the end of the Dilute and Disposal Option until 2059, nearly 30 years after WIPP operations were to have closed down.

Exhibit 6.3 – Approximate Schedule for Dilute and Dispose Option Impact on WIPP



WIPP was designed as a pilot project to demonstrate the science and the practical operational issues associated with placing radioactive wastes in a salt dome. It was developed with a design life of 25-years and using repurposed equipment where ever possible to reduce costs. It was constructed by 1990 meaning that the 25 years has expired. This suggests that, in order to extend its operations another 30 years, a great deal of equipment would need to be replaced. It is unlikely that WIPP operations would be unaffected by these issues. The Red Team, like the other groups before them, assumed that WIPP is a well-operating repository with robust operation history and a secure future. In fact, the facility is at the end of its design life, suffering from reliability issues, and has suffered its first major incident. Given the age of the facility and design life, other failures are certain to become more common which suggests that the optimistic view of WIPP operation well in the middle of the 21st century is unwarranted.

The Red Team, Aerospace, and PWG have assumed that there are no costs associated with the Dilute and Dispose Option for modifying WIPP. High Bridge rejects this assumption. If the Dilute and Dispose Option is selected, then WIPP needs to be expanded and redefined. So, it would be incumbent upon the Dilute and Dispose Option program to include the costs and management of the

effort required to make WIPP available. **Exhibit 6.4** is a listing of the approximate costs for the design elements in the schedule above.

Exhibit 6.4 – Dilute and Dispose Option Impact on PMDA, WIPP, and SC Fines

Dilute and Dispose Option Impact on PMDA, WIPP, and SC Fines Approximate Cost Estimate			
	PMDA, and WIPP Activities/Steps	Cost Estimate	Basis
	<u>PMDA Amendment Activities</u>		
1	PMDA Negotiations REV -2; MOX to Downblend/WIPP	\$83,750,000	Average 40 FTE for duration and a Team of 10 National Lab SMEs
	<u>WIPP Activities</u>		
2	WIPP 2014 Incidents Resolution	\$360,000,000	Current published estimate is the Low Est. Worst case estimate offered a public meeting by DOE of 5 years is the high (not included in the Total Option 4 Impact below)
3	Record of Decision (ROD)	\$2,406,250	Staff and DOE manager's time to organize and obtain necessary approvals for ROD - 5 FTEs
4	CD-0 Mission Definition	\$11,811,250	DOE management team procuring the services of a Contractor to develop the technical basis
5	CD-1 Conceptual Design	\$28,875,000	DOE management team overseeing the services of a Contractor that prepares the CDR
6	CD-2 Design	\$61,875,000	DOE management team overseeing the services of a Contractor that prepares the design packages
7	NEPA Process	\$326,562,500	DOE management team overseeing the services of a Contractor that prepares the design packages
8	NMED Oversight and Approval	\$18,906,250	5 NMED officials and a 10 person consultant firm 1/2 time
9	Modify WIPP Land Withdrawal Act	\$6,875,000	DOE Officials and staff briefings with staffers and legislators
10	CD-3 Construction	\$284,375,000	DOE management team overseeing the services of Contractors that prepare the procurement packages and actual construction services
11	CD-4 Testing and Commissioning	\$37,109,375	DOE management team overseeing the services of Contractors that conduct the startup testing and the readiness reviews to begin operations with surplus weapons Pu.
12	WIPP Total	\$778,795,625	
13	SC Penalties for missing 2018 start date for shipping Pu offsite	\$1,100,000,000	\$100M/yr starting in 2019
	Total Option 4 Impact	\$1,962,545,625	

Item 1 on **Exhibit 6.4** is the estimated DOE cost to support the State Department in their negotiations of the PMDA. It is an optimistic minimum cost. Item 2 is the estimated cost to recover WIPP after the February 2014 incidents. These are ongoing and have been include for comparison only. Currently, the cost of these activities is estimated to be \$100M per year with a duration of between two to five years. The latest estimate of the most likely date shows three years, but the value in the

table assumes about 3.6 years. This value is included for comparison purposes only. It is not included in the totals since it is being paid for by EM to recover from the incidents.

The other items on **Exhibit 6.4** are considered to be aggressive and assume minimal controversy associated with the process. The risks associated with these values have not been assessed but they will have high probabilities and large impacts. Row 12 summarizes the approximate cost of the program to relicense WIPP.

Row 13 lists the penalties for missing the 2018 deadline for removing plutonium from South Carolina. The total cost of the impact of the Dilute and Dispose Option is approximately \$2B that the Red Team did not include in their estimate. They noted that the MOX Irradiation, Fabrication, and Transportation (MIFT) budget for Dilute and Dispose was a subset of the MOX project, but when the missing cost of WIPP modifications and South Carolina penalties are added in, it becomes clear that the cost of the ex-MIFT scope is higher for the Dilute and Dispose Option than for MOX. This is especially true when one considers the need for 170,000 CCOs at a projected cost of \$374M and over 4,000 shipments from SRS to WIPP at an estimated cost of \$1.5B. Both are far greater than for the equivalent scope in the MOX Project. These costs are about 75% larger than the estimate for the 34 MT case using the less conservative waste loading of 350 FGE per drum. The Aerospace report lacks the necessary granularity to identify if they have accurately captured the Transportation and waste package consumable costs. The Red Team failed to note that these costs would be substantially higher than for the MOX Option and essentially endorsed the Aerospace underestimate of these costs.

The Red Team has some basis to assume that the Dilute and Dispose Option does not impact the Safeguards and Security requirements for WIPP. The form of the material considered for placement in WIPP under this option has been accepted before. However, most of that material began its journey to WIPP as Attractiveness Level D. So, the burden of responsibility for removing safeguards from that material was substantially less. In addition, the plutonium disposed under the PMDA is supposed to have International Atomic Energy Agency (IAEA) oversight and observation to provide assurance that the U.S. was not removing the drums from the repository to reuse the material. IAEA does not currently have oversight of WIPP operations. There would be some impact on WIPP operations, Safeguards and costs resulting from adding this material to WIPP. The resources and methods necessary for IAEA to be able to assure themselves that the material is not being removed from the repository would need to be developed and operational issues are certain to result. .

The Red Team proposed a new approach called Sterilization for which the argument for removing safeguards is more problematic. The Sterilization Option consists of merely rendering the pit unusable for a weapon and then placing it in the repository. The Red Team did not provide any detail for this option but several aspects were clear. It would not involve changing the chemical characteristics of the plutonium, so it would remain at attractiveness level B, Category II. Assuming that the pit would not be divided into smaller pieces and placed in separate waste containers, the amount of material per drum would be far in excess of the current NRC-approved limit of 380 FGE per drum. There was no discussion how this material would be secured inside the container to assure subcriticality. There is no licensed container for this material, so the addition of a waste container licensing effort would need to be added to the costs. Such a licensing effort would be far from straightforward and would entail a great deal of effort, cost, and time.

It is also unlikely that the Safeguards could be removed from such a package. Therefore, by extension, WIPP would need to become a Safeguards and Security level facility. **Exhibit 6.5** below is the plutonium attractiveness table extracted from DOE Order 474.2. It appears that the Sterilization Option merely reconfigures the pit into a non-weapon shape. That would not reduce the attractiveness level like the Dilute and Dispose Option that converts the metallic form into an oxide form. That process reduces the attractiveness level to C category IV. The key to the removing safeguards from the material at Rocky Flats was to change the attractiveness level to C category IV and then declare that the Stardust rendered the material too difficult to divert and place it into WIPP. However, the Sterilization process is a more problematic argument because the material remains weapons grade, the quantity is attractive for diversion, and there are only simple separation steps necessary to have material ready for forming into weapons parts.

Exhibit 6.5 – Graded Safeguards Table for Plutonium from DOE Order 474.2

Graded Safeguards Table for Plutonium Extracted from DOE Order 474.2						
	Attractiveness Level	Pu Category (kg)				Relevant Examples of Pu Disposition
		I	II	III	IV	
WEAPONS Assembled weapons and test devices	A	All	N/A	N/A	N/A	
PURE PRODUCTS Pits, major components, button ingots, recastable metal, directly convertible materials	B	≥2	≥0.4<2	≥0.2<0.4	<0.2	Pits in storage Sterilization
HIGH-GRADE MATERIALS Carbides, oxides, nitrides, solutions (≥25 g/L) etc.; fuel elements and assemblies; alloys and mixtures; UF ₄ or UF ₆ (≥50% enrichment)	C	≥6	≥2<6	≥0.4<2	<0.4	Dilute and Dispose
LOW-GRADE MATERIALS Solutions (1 to 25 g/L), process residues requiring extensive reprocessing; Pu-238 (except waste); UF ₄ or UF ₆ (≥20% <50% enriched)	D	N/A	≥16	≥3<16	<3	Rocky Flats Materials
ALL OTHER MATERIALS Highly irradiated forms, solutions (<1g/L), compounds; uranium containing <20% U-235 or <10% U-233 (any form, any quantity)	E	N/A	N/A	N/A	Reportable Quantities	WIPP Design Basis

DOE Order 474.2 describes the process for Terminating Safeguards. The relevant sections are presented below:

- (3) When termination of safeguards for attractiveness level D or higher special nuclear material (SNM) is requested, approval is received from the departmental element after

consultation with the Office of Health, Safety and Security (HSS). For National Nuclear Security Administration (NNSA) facilities, approval is received from the Associate Administrator for Defense Nuclear Security after consultation with HSS.

(4) Require that when disposal of a Category II or greater quantity of SNM is being considered, DOE line management for both the shipping and receiving facilities must concur in a security analysis for theft or diversion of the material performed jointly by the shipping and receiving site/facility operators.

High Bridge concludes that these officials would not approve the termination of Safeguards for Sterilization components. Therefore, High Bridge does not believe that Sterilization is a credible option for plutonium disposition. The Sterilization Option would force additional security barriers to be constructed, additional guard force with enhanced capabilities to be employed, and operational restrictions on WIPP operations to be instituted. These were hinted at in the Red Team report but were not specifically addressed. It is not clear if non-safeguards waste packages could continue to be placed into WIPP with the Sterilized waste packages due to the prohibition of mixing the waste forms.

7 COST, COMPLEXITY, AND RISK EVALUATION

The Red Team primary focus, as stated in the Executive Summary, “was a comparison of the MOX approach to a Dilute and Disposal option” in three areas:

1. Annual Funding levels (during construction and operations),
2. Risks to successful completion
3. Opportunities for improvement

The Red Team report concluded the costs for the MOX Program were less than a billion dollars per year over the life of the program and that the Aerospace report had overstated the costs and schedule to complete the MFFF program (Both of these were in agreement with the High Bridge report). Costs for the MOX Option were concluded to be in the \$700M-\$800M per year and for The Dilute and Dispose Option were \$400M per year.⁴ Risks associated with the Dilute and Dispose Option were deemed to be “far lower” than the MOX Option because the process is “far simpler”. The Red Team did not provide an in-depth cost, schedule, or risk analysis and strangely the costs were reported in FY15\$. This was strange as none of the reported costs or risks contained within the documents in review by the Red Team contained any analysis in FY15\$ and no discussion of escalation factors were disclosed. Opportunities for improvement included “Sterilization”, which was a new approach introduced as a “means of reducing Program LCC” for the Dilute and Disposal option, without any cost details. No meaningful opportunities for improvement of the MOX program was provided.

The report further states that each option can be executed “over roughly the same timeframe”. A conclusion that lacks any granularity or technical basis other than “simple math” based on assumed annual funding levels. The schedule of 15 years for construction was based on this “simple math” calculation. Additionally, this timeframe stems from the Aerospace report constrained funding scenarios that were imposed as part of the original direction provided for analysis. These durations

⁴ The Red Team costs were reported in FY15\$. The Red Team did not provide any discussion of escalation factors.

became more suspect when the Aerospace funding scenarios analyzed were reduced by 25% (\$500M to \$375M) and the schedule durations increased 300%. The Red Team noted neither was realistic. However, 15 years is not accurate with optimum funding levels

High Bridge understands that the time constraints placed on the Red Team for the development of the Red Team report did not allow for the review of the High Bridge detailed Phase 2 report. As such, the lack of the ability to review the High Bridge final output, coupled with the assumptions made and criteria changed to accommodate the dilute and dispose option, contributed to the conclusions drawn by the Red Team. One fundamental difference between the Red Team, Aerospace, and PWG reports and the High Bridge Phase 2 report is the preference shown for the Dilute and Dispose Option within each of the first three reports.

The High Bridge Phase 2 report concluded that the Dilute and Dispose Option as being described can only be a viable alternative if the activities discussed in **Sections 5 and 6** above are successfully carried out. Based on this conclusion High Bridge performed a cost estimate and risk assessment for the Dilute and Dispose Option. The results of the cost estimate and risk assessment are discussed in considerable detail in the High Bridge Phase 2 report.

Costs

Table 4 (shown below as **Exhibit 7.1**) from the Red Team report was a duplicate of the summary exhibit within the preliminary High Bridge Phase 1 Executive Summary. The Red Team indicated the ETC values shown in the table were not reconcilable with the Aerospace reported values. High Bridge agrees that the values shown in FY14\$ made it difficult to reconcile the cost estimates from the three sources (PWG, Aerospace and High Bridge). Although, admittedly, **Exhibit 7.1** is difficult to follow. For that reason, and as a result of additional analysis, High Bridge reformatted the exhibit in our Phase 2 report and it is shown here as **Exhibit 7.2**.

Exhibit 7.1 – Cost Comparison from High Bridge Phase 1 Executive Summary

High Bridge Cost Comparison		
Cost Element	Option 1 - MOX (\$B FY14)	Option 4 - Downblend (\$B FY14)
Unescalated Base Cost (with Contingency)	24.3	13.0
Aerospace Evaluation of Risks/Contingency	7.4	2.3
High Bridge Evaluation of Risks/Contingency	3.7	9.3
Aerospace and High Bridge Differences	-3.7	7.0
Evaluated Cost Reflecting Differences	20.6	20.0

Exhibit 7.2– Revised Cost Comparison Exhibit from High Bridge Phase 2 Report

Comparison of MOX and Dilute and Dispose Options Life Cycle Costs (B-FY14\$)				
	MOX		Dilute and Dispose	
Element	High Bridge	Aerospace	High Bridge	Aerospace
Base Costs	\$ 15.1	\$ 16.7	\$ 13.0	\$ 7.4
Contingency/Risk	\$ 3.2	\$ 7.8	\$ 5.0	\$ 3.8
Changes	\$ 1.1	\$ 2.7	\$ 1.9	\$ 1.9
Total	\$ 19.4	\$ 27.2	\$ 19.9	\$ 13.1

In any case, the difficulties associated with analyzing the cost and risk data were primarily due to the RY\$ used by PWG and Aerospace with little granularity. Since the High Bridge Phase 2 report was issued after the Red Team report, the Red Team could not review analysis and additional explanation that support our conclusions. Therefore, it is not surprising the reconciliation problem was encountered.

During a brief discussion between the Red Team and the High Bridge team before either had issued their final Aerospace review reports, the Red Team expressed surprise that the High Bridge evaluated contingency and base cost resulted in nearly equal the MOX Option and the Dilute and Dispose Option LCC costs. High Bridge responded that these Phase 1 Base Cost evaluations were preliminary and based on the collective nuclear experience/judgments of the Team that evaluated MOX, Downblend, MIFT, PMDA and WIPP costs or revenue credits not addressed or understood by Aerospace. High Bridge informed the Red Team that it would be analyzing and developing supporting details/calculations during its Phase 2 detailed analyses. The Phase 2 report would provide a crosswalk comparison and justification of the major adds and deletes between the Aerospace and High Bridge analyses of Base Costs. However, the Red Team could not delay their report to the Secretary to permit time for the consideration of this analysis.

High Bridge disagrees with the Red Team and Aerospace conclusions that the cost and schedule impacts of negotiating a PMDA amendment with the Russian Federation and dealing with the NEPA process to address the WIPP capacity issues could be ignored. High Bridge finds this outcome reflects the cursory Red Team review approach driven by a short review time frame, and a lack of Red Team knowledge/understanding of fundamental regulatory, scientific, and geo-political requirements driven by the PMDA.

High Bridge evaluated what would be required to satisfy PMDA geo-political expectations and WIPP licensing and statutory requirements, and developed a scope basis for these approaches. High Bridge developed a schedule and constant FY14\$ estimate for the following cost adds/deletes and revenue credit that it evaluated in detail for key MOX Option and Dilute and Dispose Option elements summarized below and itemized on **Exhibits 7.3 and 7.4**:

- MOX Option - SC penalties, MOX fuel sales revenue, and SRS security operations. These resulted in a High Bridge evaluated decrease of approximately \$1.4B.
- Dilute and Dispose Option - SC penalties, PMDA cost impacts, WIPP NEPA/licensing/design impacts, WIPP operations, and MIFT packaging/transportation. These resulted in a High Bridge evaluated increase of approximately \$4.8B.

Details of the Options 1 and 4 cost analyses can be found in Section 3 (15 pages) of the High Bridge August 21 Phase 2 Report. **Exhibits 7.3 and 7.4** below were extracted from the High Bridge Phase 2 Report and provide an explanation of differences between Aerospace and High Bridge Base Cost estimates. High Bridge believes that these Phase 2 report data will provide the Red Team with convincing back up that explains the High Bridge basis and approach for evaluating Base Costs for Options 1 and 4.

Exhibit 7.3 – MOX Option - High Bridge Evaluation of Aerospace Report Costs

High Bridge Evaluated MOX Option Costs (M-FY14\$) - ETC Unconstrained							
	MFFF Construction	Operations	MIFT and Other	Changes Since PWG 2014	Penalties ²	Revenue ³	Total
Base ¹	\$ 4,342.0	\$ 6,255.4	\$ 5,924.2	\$ 1,136.0			\$ 17,657.6
Penalties ²					\$ 400.0		\$ 400.0
Revenue ³						\$ (1,000.0)	\$ (1,000.0)
Operations/Security ⁴	\$ -	\$ (800.0)	\$ -	\$ -	\$ -	\$ -	\$ (800.0)
Subtotal	\$ 4,342.0	\$ 5,455.4	\$ 5,924.2	\$ 1,136.0	\$ 400.0	\$ (1,000.0)	\$ 16,257.6
Contingency	\$ 900.0	\$ 1,070.0	\$ 1,220.0	\$ -	\$ -	\$ -	\$ 3,190.0
Total	\$ 5,242.0	\$ 6,525.4	\$ 7,144.2	\$ 1,136.0	\$ 400.0	\$ (1,000.0)	\$ 19,447.6
Notes							
1	Base Cost of \$18.6B from PWG has \$1.9B contingency in FY14\$; High Bridge did not distribute.						
2	Penalty payment to South Carolina for non-shipment of weapons grade Pu239 from SRS.						
3	Sales of MOX fuel to electric utilities - based on the sale of approximately 2,000 PWR fuel assemblies.						
4	Overestimate of SRS shared infrastructure, for example, MOX Services operational cost estimate of \$50M/year vs HBA estimate of \$15M/year (saving of \$800M on project).						

Exhibit 7.4 – Dilute and Dispose Option - High Bridge Evaluation of Aerospace Report Costs

High Bridge Evaluated the Dilute and Dispose Option Costs (M-FY14\$ - ETC)							
	MFFF Termination	WIPP Capital	Operations	"MIFT" and Other	Changes Since PWG 2014	Penalties ²	Total
Base ¹	\$ 1,492	\$ 214	\$ 2,094	\$ 4,444	\$ 1,873		\$ 10,117
Penalties ²						\$ 1,100	\$ 1,100
PMDA & WIPP ³		\$ 863					\$ 863
Operations - WIPP ⁴			\$ 1,640				\$ 1,640
MIFT-Trans/Pkg's ⁵			\$ -	\$ 1,150			\$ 1,150
Subtotal	\$ 1,492	\$ 1,077	\$ 3,734	\$ 5,594	\$ 1,873	\$ 1,100	\$ 14,870
Contingency	\$ 430	\$ -	\$ 512	\$ 4,101	\$ -	\$ -	\$ 5,043
Sub Total	\$ 1,922	\$ 1,077	\$ 4,246	\$ 9,695	\$ 1,873	\$ 1,100	\$ 19,913
Notes							
1	Base Cost of \$8.2B from PWG has \$0.8B contingency in FY14\$; High Bridge did not distribute.						
2	Penalty payment to South Carolina for non-shipment of weapons grade Pu239 from SRS.						
3	High Bridge estimate for PMDA amendments and WIPP revised federal legislation, NEPA, NMED, and CD-0 to CD-4 activities.						
4	High Bridge re-estimate for the resources required for 30 years of WIPP operations (PWG = \$360M vs HBA = \$2,000M).						
5	High Bridge estimate for additional transportation costs (80 for MOX vs 2300 for Downblend Shipments) and material costs (Shipping Containers) for MIFT.						

The starting point for the to-go cost estimate data, shown above, in both of the High Bridge tables coincide with those given to Aerospace by the PWG. It is important to note once again that the High Bridge to-go cost estimates include the following attributes:

- An unconstrained funding scenario for the MOX Option. The unconstrained funding scenario has a construction, startup and commissioning schedule of 7 years and an operation period of 15 years)
- Additional costs necessary for the Dilute and Dispose Option viability and PMDA revisions. The High Bridge estimated schedule to provide this option is 16 years for solving regulatory and PMDA issues and 30 years of operation.

High Bridge as well as the Red Team indicated the difficulties with cost data reconciliation. Two interesting and key facts were discovered during the High Bridge discussions with the Aerospace management team. The first was the reasoning behind the Aerospace report and analysis development in real year inflated and escalated dollars. Both the High Bridge report and the Red Team report concluded this led to over estimation of LCC costs, schedule durations, and a distortion of MOX Program completion. Secondly, the Aerospace report and analysis lacked the programmatic costs and risks associated with the utilization of WIPP for the dilution and dispose option. In each of these two instances the Aerospace team indicated clear direction was provided by the sponsoring officials. Aerospace had been directed to develop the report using this unusual real year dollar comparative analysis methodology and to not consider any needed changes to WIPP. They were to assume that WIPP is fully functional requiring minimal upgrades, and the risks were negligible.

The previous sections on WIPP include the increased quantities based on the termination of the MFFF. Increasing the disposal quantities will impact total costs of Dilute and Dispose option. The cost uncertainties associated with increasing the disposal quantities to 51MT will also impact the base costs evaluated in the Aerospace report. Since the Aerospace report lacked granularity, High Bridge has not shown any changes to the base cost or the impact in the WIPP operations and MIFT costs. Cost uncertainties are contained in the risk costs and profiles provided and detailed in the High Bridge Phase 2 Report.

High Bridge maintains that the life cycle costs (LCC) and the schedule duration of both the MOX Program and the Dilute and Dispose Program (as analyzed in the Phase 2 report) although lengthy and costly are similar. LCC for each program is in the range of \$18B to \$22B and the cash flow for each of the options will require annual funding levels of \$600M to \$700M.

The Red Team asserted that High Bridge did not consistently evaluate risk parameters for MOX Option and the Dilute and Dispose Option. High Bridge disagrees and feels its structured and detailed risk analysis, as described below, supports its case. The Red Team also concluded that the MOX MFFF facility was very complicated and that the Dilute and Dispose Option dilution technology was a relatively simple and mature technology. High Bridge concludes that the Red Team did not have adequate time to review the program parameters and dig into the requirements for Dilute and Dispose Option, and likely relied too heavily on the opinions of stakeholders at Los Alamos National Lab (LANL), SRS, and NNSA that were proponents of the Dilute and Dispose Option. High Bridge also concludes that the Red Team did not have time to properly consider the MOX operating plant experience in France, the very conservative MOX operating throughput capacity factor parameters, or the advanced completion status of the MFFF facility.

The Red Team needs to be provided key insights covered in the High Bridge Phase 2 August 21 Detail Report. These insights would have influenced the Red Team analysis and outcomes presented in their August 10 Red Team Report. The following provides an overview of the complexities and risks that drove the conclusions and insights contained in the High Bridge Phase 2 Report.

Complexity and Risks

The influence of risk and complexity within the two options are primarily based on program maturity and the technically diverse nature of each option. The two options are clearly at opposite poles in these two key areas. In contrast to the discussions in the Red Team report, the cost ranges for each option recognizes the important differences in the base costs and the risks leading to the contingency values for both options.

MOX Fuel Option - MOX is technological mature, the principle components (MFFF and MIFT) have no serious technical risks, and MFFF complexity attributable to stringent NRC and NNSA regulatory issues (attributable to considerable cost growth) have been solved.

MFFF has been designed with more than sufficient throughput margin to accommodate operational problems that might arise from the failure of any Items Relied on for Safety (IROFS) or automation problems.

Dilute and Dispose Option – Dilute and Dispose Option for disposal of Transuranic (TRU) waste is technological mature but the process does not meet the PMDA (see Section 4) and will exceed the capacity of WIPP. Because the Dilute and Dispose Option as proposed by the Red Team does not meet the PMDA, High Bridge developed an ETC and schedule of what would be involved to make the option meet the PMDA. The risks and contingency from High Bridge’s estimated Dilute and Dispose Option were evaluated. With a few exceptions, noted below, High Bridge used the same discrete risk events as those used in the Aerospace report.

Risks associated with the Dilute and Dispose Option range from being technical in nature to those associated with time delays in acquiring licensing, overcoming regulatory issues, obtaining PMDA revision, transportation complexity (large number of shipments vs MOX) and ensuring there is adequate storage available (that does not jeopardize the EM mission) at WIPP. (See Sections 4 and 5). High Bridge maintains that its risk profiles and associated contingencies as shown in exhibits of this section included adequate bounding for the impacts created by increasing disposal quantities to 51MT. This reinforces the need for a complete bottom up cost analysis of the Dilute and Dispose Option before any decision is made regarding its selection as a substitute for the MOX Option.

Detailed Risk Identification, Quantification, and Monte Carlo Contingency Analysis – During the July 22 conference call between the Red Team and High Bridge, the Red Team expressed its difficulty in understanding how High Bridge assessed the MOX Option risks/contingency as lower than the Dilute and Dispose Option risks/contingency. High Bridge responded that these Phase 1 risk evaluations were preliminary and based on the collective nuclear experience/judgments of the Team. High Bridge informed the Red Team that it would be conducting a formal risk and contingency Monte Carlo analysis during its Phase 2 detailed analysis and would provide a crosswalk comparison and justification of differences between the Aerospace and High Bridge risk and contingency analyses.

High Bridge reviewed the Aerospace risks identified in their Appendix 2 Risk Tables covering probability of occurrence (POO) and minimum/maximum financial impact (FI) parameters for MOX Option and Dilute and Dispose Option. As the Aerospace financial \$ data was presented in escalated RY\$, High Bridge de-escalated these RY\$ to constant current year dollars. High Bridge computed the contingencies from the Aerospace Monte Carlo analyses in FY14\$ using their POO and FI parameters to produce a common basis of comparison with the independent High Bridge risk and contingency Monte Carlo analysis. Several of the Low (Min) and High (Max) FI values from the risk items in the Aerospace report were used in the High Bridge Monte Carlo analyses, along with about one-third of the POO defined by Aerospace. For those risk items where either the Aerospace FI or POO values were not used by High Bridge, values were assigned based on the experience and judgment of the High Bridge team members.

In FY14\$, the High Bridge 85% confidence contingency value for MOX Option was \$3.2B and Dilute and Dispose Option was \$5.0B. These values compare to the Aerospace values of \$7.8B and \$3.8B. Details of the MOX Option and Dilute and Dispose Option risk analyses can be found in **Section 5** (10 pages) and **Appendix F** (30 pages) of the High Bridge August 21 Phase 2 report. **Exhibits 7.5** and **7.6** below were extracted from the High Bridge Phase 2 Report and provide an explanation of differences between Aerospace and High Bridge. High Bridge believes that these Phase 2 report data will provide the Red Team with convincing back up that justifies the High Bridge risk/contingency analysis for the MOX and Dilute and Dispose Options.

Exhibit 7.5 – Risk Register for MOX Option

High Bridge Risk Register for MOX Option (FY14 \$'s)				
Risk Item Number	Description of Discrete Risk	Probability of Occurrence	Low	High
1	Fuel Production Rate Lower Than Expected	75%	\$ 477,900,000	\$ 1,194,750,000
2	Feedstock Production Rate Lower Than Expected	0%	\$ -	\$ -
3	MFFF Project Construction Cost Uncertainty / Growth	75%	\$ 75,080,000	\$ 187,700,000
4	MFFF Temporary Suspension of Operations	0%	\$ -	\$ -
5	MFFF Full Construction Re-Start Delay	50%	\$ 312,833,333	\$ 625,666,667
6	Feedstock Temporary Suspension of Operations	25%	\$ 106,200,000	\$ 318,600,000
7	SRS Overhead Cost Increases	50%	\$ 73,170,000	\$ 487,800,000
8	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	50%	\$ 75,000,000	\$ 300,000,000
9	LANL Overhead Cost Increases	50%	\$ 33,096,000	\$ 220,640,000
10	MFFF Hot Operations Delay after CD-4 Complete	50%	\$ 26,550,000	\$ 159,300,000
11	MFFF Integrated Functional Testing Delay Before CD-4	25%	\$ 52,138,889	\$ 156,416,667
12	Needs for Additional Storage	50%	\$ 74,800,000	\$ 164,500,000
13	LANL Feedstock Production Re-Start Delay	25%	\$ 106,200,000	\$ 318,600,000
14	Funding for Depleted Uranium	0%	\$ -	\$ -
15	Feedstock Production Consolidated at LANL (Remove HB-Line)	10%	\$ (774,900,000)	\$ (319,000,000)
16	MOX Program estimate accuracy/uncertainty as a function of design maturity for overall program	75%	\$ 74,800,000	\$ 187,000,000
Risk Item Number 2 was eliminated by High Bridge because it was considered a subset of Risk Item Number 1; i.e. the fuel production rate will be lower if a significant reduction in feedstock occurs. Risk Item Number 4 was eliminated by High Bridge because at an expected low operating capacity factor (<30%) makes it unlikely that a temporary suspension of MFFF Project operations is significant enough to affect the overall operation schedule. Risk Item Number 14 was eliminated by High Bridge because further investigations identified that the depleted Uranium is to be furnished to the MOX Program at no cost. There will be minimal annual costs for conversion during operations. These have not been added to base cost. Risk Item Number 16 was added by High Bridge because there is still an uncertainty in the MOX Program cost over and above what is currently being forecast.				
Aerospace Risk Register for MOX Option (FY14 \$'s)				
Risk Item Number	Description of Discrete Risk	Probability of Occurrence	Low	High
1	Fuel Production Rate Lower Than Expected	75%	\$ 799,434,896	\$ 3,586,388,527
2	Feedstock Production Rate Lower Than Expected	75%	\$ 475,124,327	\$ 1,999,431,781
3	MFFF Construction Cost Uncertainty / Growth	75%	\$ (161,368,308)	\$ 2,271,023,532
4	MFFF Temporary Suspension of Operations	90%	\$ 125,423,175	\$ 1,003,147,972
5	MFFF Full Construction Re-Start Delay	50%	\$ 314,255,556	\$ 1,699,356,727
6	Feedstock Temporary Suspension of Operations	90%	\$ 67,105,812	\$ 538,868,226
7	SRS Overhead Cost Increases	75%	\$ 92,082,154	\$ 230,205,385
8	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	90%	\$ 54,640,578	\$ 218,562,311
9	LANL Overhead Cost Increases	25%	\$ 261,269,443	\$ 522,538,886
10	MFFF Hot Operations Delay after CD-4 Complete	50%	\$ 41,048,559	\$ 250,959,086
11	MFFF Integrated Functional Testing Delay Before CD-4	25%	\$ 17,238,356	\$ 429,106,836
12	Needs for Additional Storage	50%	\$ 24,551,778	\$ 115,723,997
13	LANL Feedstock Production Re-Start Delay	25%	\$ 55,996,010	\$ 171,373,411
14	Funding for Depleted Uranium	10%	\$ 7,834,684	\$ 23,504,052
15	Feedstock Production Consolidated at LANL (Remove HB-Line)	75%	\$ (655,913,367)	\$ (270,017,246)

Exhibit 7.6 – Risk Register for Dilute and Dispose Option**High Bridge Risk Register for Dilute and Dispose Option (FY14 \$'s)**

Item	Description of Discrete Risk	Probability of Occurrence	Low	High
1	Feedstock Production Rate Lower Than Expected	75%	\$ 447,800,000	\$ 1,343,400,000
2	SRS Downblend Facility Start Delay	75%	\$ 168,333,333	\$ 673,333,333
3	Feedstock Temporary Suspension of Operations	90%	\$ 223,900,000	\$ 671,700,000
4	Downblend Production Rate is Lower Than Expected	25%	\$ 139,666,667	\$ 698,333,333
5	Downblend Facility Temporary Suspension of Operations	90%	\$ 60,522,222	\$ 149,642,857
6	Downblend Construction Cost Estimate Uncertainty/Growth	90%	\$ 62,500,000	\$ 250,000,000
7	LANL Overhead Cost Increase	50%	\$ 183,000,000	\$ 457,500,000
8	MFFF Project Termination Cost Uncertainty	50%	\$ (74,600,000)	\$ 746,000,000
9	Downblend Repository Temporary Suspension of Operations	90%	\$ 154,285,714	\$ 462,857,143
10	SRS Overhead Cost Increase	50%	\$ 27,000,000	\$ 135,000,000
11	Feedstock Production Re-Start Delay at LANL	25%	\$ 111,950,000	\$ 335,850,000
12	Exceed Downblend Repository TRU Allowable Storage Volume			
13	Need for Additional Storage Space			
14	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	75%	\$ 4,353,370	\$ 17,413,480
15	Feedstock Milling and Blending Not Needed/Quality Control Reductions	25%	\$ (62,673,563)	\$ (17,417,963)
16	Feedstock Production Consolidated at LANL (Remove HB-Line)	20%	\$ (653,374,020)	\$ (270,017,246)
17	NEPA Revision to WIPP EIS process takes longer than expected	50%	\$ 261,250,000	\$ 391,875,000
18	NMED Disputes Land Use Issues	50%	\$ 15,125,000	\$ 22,687,500
19	Cost uncertainty for WIPP modifications for life extension	50%	\$ 220,000,000	\$ 500,000,000

Risk Item Number 12 was eliminated because the High Bridge analysis showed that WIPP capacity will be exceeded if Option 4 is selected. This becomes a part of the High Bridge ETC for Option 4.

Risk Item Number 13 was eliminated by High Bridge because this becomes a part of the High Bridge estimate for licensing, constructing, and operating the WIPP to accommodate the additional weapons grade Pu 239.

Risk Item Numbers 17, 18, and 19 were added by High Bridge as risks arising from High Bridge's estimate for licensing, constructing, and operating the WIPP to accommodate the additional weapons grade Pu 239.

Aerospace Risk Register for Dilute and Dispose Option (FY14 \$'s)

Item	Description of Discrete Risk	Probability of Occurrence	Low	High
1	Feedstock Production Rate Lower Than Expected	75%	\$ 464,627,467	\$ 1,955,432,968
2	SRS Downblend Facility Start Delay	25%	\$ 345,243,049	\$ 1,867,252,767
3	Feedstock Temporary Suspension of Operations	90%	\$ 58,552,348	\$ 468,107,752
4	Downblend Production Rate is Lower Than Expected	25%	\$ 93,230,907	\$ 601,121,735
5	Downblend Facility Temporary Suspension of Operations	90%	\$ 35,082,812	\$ 280,662,497
6	Downblend Construction Cost Estimate Uncertainty/Growth	75%	\$ 73,660,491	\$ 294,641,965
7	LANL Overhead Cost Increase	25%	\$ 261,269,443	\$ 522,538,886
8	MFFF Project Termination Cost Uncertainty	25%	\$ (90,584,921)	\$ 724,679,365
9	Downblend Repository Temporary Suspension of Operations	90%	\$ 7,467,710	\$ 59,506,475
10	SRS Overhead Cost Increase	75%	\$ 14,817,818	\$ 37,044,545
11	Feedstock Production Re-Start Delay at LANL	25%	\$ 13,631,475	\$ 64,732,383
12	Exceed Downblend Repository TRU Allowable Storage Volume	25%	\$ 55,996,010	\$ 171,373,411
13	Need for Additional Storage Space	10%	\$ 28,930,025	\$ 231,440,204
14	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	75%	\$ 4,353,370	\$ 17,413,480
15	Feedstock Milling and Blending Not Needed/Quality Control Reductions	90%	\$ (62,673,563)	\$ (17,417,963)
16	Feedstock Production Consolidated at LANL (Remove HB-Line)	90%	\$ (653,374,020)	\$ (270,017,246)

In summary the MOX option risks are better known and defined as the program is considerably more mature and fulfills the requirements of the existing PMDA. The Dilute and Dispose Option would require a thorough vetting and disclosure process as well as renegotiation of the PMDA. High Bridge concurs with the Red Team report that each of the options will require a dedicated project management team and consistent funding to complete either mission. More importantly as presented in Section 4 of this report, the Dilute and Dispose Option does not satisfy the requirements and expectations of the PMDA and is not a negotiable alternative for the U.S. or Russia to consider.

8 VALUE OF MOX FUEL TO GNP AND CLEAN ENERGY

Value of MOX Fuel to GNP

The Red Team rectified the Aerospace Report omission that identified no net income credit for the MOX Option. The estimated that \$1B would result from MOX fuel sales. However, they rather narrowly focused on the fuel sales and ignored the economic benefit to the GNP or Clean Energy Production. An ancillary benefit of the MOX program is the production of clean, green-house gas free, electrical energy.

A nuclear reactor currently “burns” its nuclear fuel at a rate of 45,000 MW-Days/Metric Ton. The 34 MTs of surplus weapons plutonium will result in approximately 875 MT of fuel. This fuel would generate 15,300 MW-Days of electricity. At an average retail price of electricity of \$110 per MW-Hr, that amount of electricity is worth \$35B. This would be done without consuming uranium from the normal fuel cycle, so it would be accomplished with no new mining, milling, converting, or enriching processes. In addition, it consumes depleted uranium that would otherwise be deposited in a radioactive waste dump, would cost the DOE several hundred million dollars in disposal fees, and would pose an environmental risk for years to come. The value to the gross national product of the electricity sales (\$35B) from the MOX fuel is greater than the MOX Option capital cost and the total life-cycle cost (\$19.4) in FY14 dollars. Therefore this investment by the DOE yields considerably greater value than its cost. Unlike the Dilute and Dispose Option that produces no trickle-down revenue or GNP contribution and represents a net loss to the taxpayers, MOX Option represents a net improvement in the GNP wealth of the U.S. and creates >10,000 U.S. jobs driven by the availability and consumption of clean electricity. Using the 34 MT of Plutonium converted to approximately 30 nuclear power reactor MOX Fuel core loads will eliminate approximately 335 million tons of carbon emissions, 420,000 tons of NO_x emissions, and 675,000 tons of SO₂ emissions.

Exhibit 8.1 provides a summary comparison of revenue, cost impact items, and value considerations for key elements of the MOX Option and Dilute and Dispose Option.

Overall jobs creation for MOX Option Fuel is estimated at >5,000 job during construction and >2,000 jobs during operation. As identified on **Exhibit 8.1** above, it is estimated that >10,000 jobs will result from the consumption of clean electricity over 20 years.

GNP and Clean Energy

An ancillary benefit of the MOX program is the production of clean, greenhouse gas free, electrical energy. A nuclear reactor currently “burns” its nuclear fuel at a rate of 45,000 MW-Days/Metric Ton.

The 34 MTs of surplus weapons plutonium will result in approximately 875 MT of fuel. This fuel would generate 15,300 MW-Days of electricity. At an average retail price of electricity of \$110 per MW-Hr, that amount of electricity is worth \$35B. This would be done without consuming uranium from the normal fuel cycle, so it would be accomplished with no new mining, milling, converting, or enriching processes. In addition, it consumes depleted uranium that would otherwise be deposited in a radioactive waste dump, would cost the DOE several hundred million dollars in disposal fees, and would pose an environmental risk for years to come. The value to the gross national product of the electricity sales (\$35B) from the MOX fuel is greater than the MOX Option capital cost and the total life-cycle cost (\$19.4) in FY14 dollars. Therefore this investment by the DOE yields considerably greater value than its cost. Unlike the Dilute and Dispose Option that produces no trickle-down revenue or GNP contribution and represents a net loss to the taxpayers, MOX Option represents a net improvement in the GNP wealth of the U.S. and creates >10,000 U.S. jobs driven by the availability and consumption of clean electricity. Using the 34 MT of Plutonium converted to approximately 30 nuclear power reactor MOX Fuel core loads will eliminate approximately 335 million tons of carbon emissions, 420,000 tons of NO_x emissions, and 675,000 tons of SO₂ emissions.

Exhibit 8.1 – Comparison of Plutonium Disposition Program Alternatives

Comparison of Plutonium Disposition Program Alternatives Approximate Revenue, Cost Impact, and Value Contribution Metrics MOX Fuel Sales, Clean Energy, and GNP Parameters MOX Option vs. Dilute and Dispose Option				
#	MOX Option		Dilute and Dispose Option	
	Program Element		Program Element	
1	Metric Tonnes of Plutonium Pu 239	34	34	Metric Tonnes of Plutonium Pu 239
2	Pounds of Plutonium Pu 239	74,956	74,956	Pounds of Plutonium Pu 239
3	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved	Yes	No	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved
4	Approximate Product Output Nuclear Fuel PWR Assembly Approx. 8.5" x 8.5" x 13.5' Long Each Containing Approx. 264 Zircalloy Clad Fuel Rods	2,000	113,000	Approximate Waste Form Output Plutonium Diluted/Mixed with Stardust Inert Material in 6" Diameter x 2' Long Container Packed Inside a 55 Gallon Drum
5	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales	\$1,000,000,000	\$0	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales
6	Approximate Number of Shipments in Casks with 2 Fuel Assemblies/Cask, 4 Casks/Truck, and 3 Trucks/Shipment	80	2,700	Approximate Number of Shipments in TRUPACT-II Containers with 14 Drums/Container and 3 Containers/Truck
7	Approximate WIPP Storage Capacity Volume Consumed	~0	23,600 Cu. Meters	Approximate WIPP Storage Capacity Volume Consumed
8	Approximate Megawatt Hours of Clean Electricity Produced	285 Million	0	Approximate Megawatt Hours of Clean Electricity Produced
9	Approximate Value of Clean Electricity Produced	\$35 Billion	\$0	Approximate Value of Clean Electricity Produced
10	Approximate State/Local Tax Revenues Generated	>\$5 Billion	\$0	Approximate State/Local Tax Revenues Generated
11	Approximate Life Cycle Cost of MOX Program	\$19.4 Billion	\$19.9 Billion	Approximate Life Cycle Cost of Downblend Program
12	Approximate US Jobs Created for 20 Years	>10,000	0	Approximate US Jobs Created for 20 Years
13	Avoided Carbon Emissions	335 Million Tons	0	Avoided Carbon Emissions
14	Avoided NOx Gas Emissions	420,000 Tons	0	Avoided NOx Gas Emissions
15	Avoided SO2 Gas Emissions	675,000 Tons	0	Avoided SO2 Gas Emissions
NOTE: The values identified in this Exhibit are approximate based on the analysis performed during the High Bridge Phase 2 Report Review.				

It is noteworthy that this contribution to the U.S. is realized without the production of greenhouse gases. The enrichment of uranium is an energy intensive process and much of the electricity consumed in this process comes from coal fired power plants.⁵ The remainder of the front end of the fuel cycle uses a modest amount of electricity and is of the same order as the MFFF. However, the substitution of Plutonium 239 for Uranium 235 in the fuel is a huge energy reduction and therefore a net improvement in the U.S.'s goal to reduce greenhouse gas emissions.

⁵ This is an academic point at present because most of the uranium fuel used in U.S. today comes from the downblending of weapons grade uranium into low enriched uranium for fuel supplies. This is only a temporary perturbation of the market place and this point will be valid in the future when the MOX plant comes on line.

The use of nuclear power in the generation of electricity contributes significantly to greenhouse gas reductions. Using the 34 MT of Plutonium converted to approximately 30 nuclear power reactor core loads will eliminate approximately 335 million tons of carbon emissions, and prevents 420,000 tons of NO_x and 675,000 tons of SO₂ emissions.

APPENDIX A

Point By Point Comparison: Red Team Assertions and High Bridge Responses

High Bridge Summary of Plutonium Disposition

Red Team Report

September 2015

	High Bridge Associates Observation
1	The Red Team, Aerospace, and DOE Management are incorrectly assuming that the MOX Program can be changed without any major political and cost ramifications. The MOX Program is the culmination of nearly 20 years of negotiation and careful preparation to execute an international arms control agreement between the U.S.A. and Russian Federation. The goals of this program are set in the Plutonium Management and Disposition Agreement (PMDA), which states: Disposition shall be by one or more of the following methods: a) irradiation of disposition plutonium as fuel in nuclear reactors; b) immobilization of disposition plutonium into immobilized forms; or c) any other methods that may be agreed by the Parties in writing. Clearly the proposed Dilute and Dispose option does satisfy any of the goals of the PMDA. The assumption that it does has led the Red Team to discuss may issues in their review that tries to justify the Dilute and Disposal as a viable means of disposing of weapons plutonium under the PMDA. For Dilute and Dispose Option to go forward, DOE must request that the State Department begin negotiations with the Russian Federation to include this disposal technique as a new approach. This must happen BEFORE any actions take place to execute this Option or DOE runs the risk of destroying the PMDA and any vestige of the momentum for removing weapons plutonium from the world. The National Academy of Sciences report from 1994 is not the guiding document. The PMDA agreement signed in 2000 and later amended in 2011 is the controlling document. The Dilute and Dispose option does not accomplish the Russian Federation goal of changing the isotopic makeup of the plutonium and it is not immobilization (which referred to vitrification with other high level wastes.) So, the option does not comply and puts the United States in the position of violating an arms agreement signed by the current Administration.
2	By their own admission the Red Team review was cursory and does not take into account the totality of the activities that must take place for the Dilute and Dispose Option to be executed. It mentions the need for fundamental changes to the licensing basis and the legal foundation for the WIPP repository yet assumes that it is not connected to the selection of the Dilute and Dispose Option. This is a serious flaw in their review.
3	The Red Team review assumes that the Dilute and Dispose Option program can begin without obtaining approval for disposing of this waste in WIPP. WIPP was intended as a test program to validate the use of salt domes as geological formations for disposing of nuclear material. It was supposed to store the legacy wastes from the cleanup of the Weapons Complex. Attempting to store additional material that represents very large increases in volume and curie
4	The Red Team puts forth the argument that EM work more efficiently in order to accommodate their proposal to bury NNSA's weapons grade plutonium at WIPP. Given that the Red Team review was cursory and that EM has been storing waste at WIPP for nearly 20 years begs the question -- How could WIPP possibly be more efficient? There are no real recommendations as to how to achieve this but a range of unworkable suggestions were mentioned.
5	The Red Team has proposed the Sterilization Option be considered seriously by DOE. This idea is hardly better than storing the pits at Pantex or some other secured site.
6	The Red Team does not mention that NNSA has 51 tons of surplus plutonium to dispose of and all of the problems with 34 MTs will be exasperated. With MOX as currently planned and agreed to in the PMDA, there is no need for any

7	The Red Team does correctly identify a fundamental problem in the MOX Program related to the MFFF. The relationship between the DOE/NNSA and MOX Services is dysfunctional and needs significant changes in order for the MOX Program to be successfully completed without continued cost and schedule increases.
8	The Red Team review of cost is muddled and did not meet the charge they described and noted in the introduction. They did not provide any detailed cost evaluation or reconciliation of the previous cost estimates and attempted to discredit the MOX Services 2012 BCP that the Red Team did not review. Any discussions regarding schedule were cursory and based on simple math calculations of cash flow dollars per year.

**High Bridge Response to Plutonium Disposition
Red Team Report
September 2015**

	Red Team Assertion	High Bridge Associates Response
1	The MOX disposition pathway is a realization of the spent fuel standard (SFS) as envisaged in the 1994 National Academy of Sciences (NAS) review that recognized the value of physical, chemical, and radiological barriers to future use of the material in nuclear weapons whether by state or non-state actors. Pg. ix	The inference of this statement is the belief that the Spent Fuel Standard is the goal of the MOX program. The goal of the program contained in the PMDA is to change the isotopic composition of the weapons plutonium to render it unattractive to a weapon designer. This goal is why MOX was chosen over all others. The National Academy of Sciences is not a signatory of the Plutonium Management and Disposition Agreement.
2	Nonproliferation policy has been increasingly focused on potential threats from non-state actors, which increases the sense of urgency for timely disposition and potentially offers greater flexibility in the final form of the material to prevent future use... Pg. ix	This is an irrelevant point. The U.S.A. nonproliferation policy is based on the PMDA. This is an agreement with the Russian Federation, a weapons state, who has lately been acting very aggressively on the international stage. It is myopic to believe that Russia is not a significant threat or that ignoring an agreement with them is a good idea.
3	A disposition alternative not available in the nineties has been successfully demonstrated in support of the closure of Rocky Flats and other projects—downblending or dilution of PuO ₂ with adulterating material and disposal in the Waste Isolation Pilot Plant (WIPP). pg. ix	This statement misses the point that the MOX Disposition Program implements an agreement with the Russian Federation (RF). The RF has always insisted on fundamentally altering the isotopic make-up of the weapons grade plutonium. The Dilute and Dispose Option does not achieve this and in spite of the success at RFP, this option does not meet the fundamental goal of the U.S. and RF. It requires a revision to the PMDA or unilateral abandonment of the PMDA.
4	The Scoping Comment Summary from the Draft Surplus Plutonium Disposition Supplemental Environmental Impact Statement (SEIS) noted: "DOE believes that the alternatives, including the WIPP Alternative, analyzed in this Surplus Plutonium Disposition SEIS provide protection from theft, diversion, or future reuse in nuclear weapons akin to that afforded by the Spent Fuel Standard." The review team concurs with this assessment and believes that the Dilute and Dispose approach meets the requirements for permanent disposition, but recognizes that this assertion will ultimately be subject to agreement with the Russians, and that the decision will be as much political as technical. Pg. ix	What the DOE chooses to do with the material not covered by the PMDA is at DOE's option. The Surplus Plutonium Disposition Final SEIS addresses 13.1 MT of Plutonium that is not covered by the PMDA. Regardless of the assertion in the quotation, the plutonium disposed of in this manner does not meet the SFS and even if it did meet the SFS, the PMDA does not cite the SFS as a goal and the Russians do not agree that the SFS is adequate for the disposition of surplus weapons Pu.
5	The cost of the MOX approach has increased dramatically compared to early estimates. Pg. ix	MOX is now an amalgamation of several programs and includes the costs and savings associated with a Total Operating Costs (TOC) of these once separate programs.
6	The Red Team's analysis focused on annual funding levels (during both construction and operations), risks to successful completion, and opportunities for improvements over time that could accelerate the program and save money. Pg. ix	The Red Team did not provide an in-depth cost, schedule, or risk analysis and strangely the costs were reported in fiscal year 2015 (FY15 dollars). This was strange as none of the reported costs or risks contained within the documents in review by the Red Team contained any analysis in FY 15 dollars and no discussion of escalation factors were disclosed. Opportunities for improvement included "Sterilization", which was a new approach introduced as a "means of reducing Program LCC" for the Dilute and Disposal option, without any cost or technical details.
7	...the Red Team describes a relatively optimistic view of the MOX approach [adjusted somewhat to account for a dispute in the present status of the MOX Fuel Fabrication Facility (MFFF) project], and compares it to a relatively conservative version of the Dilute and Dispose alternative. Pg. x	In their cursory investigation of disposal options the Red Team incorrectly assesses that the cost of the MFFF project, which is in construction, will increase by a factor of three and will take twice as long as the contractor claims. At the same time they incorrectly ignore or discount most of the costs of the Dilute and Disposal option.
8	... (all in FY15 dollars). Several references of FY15\$ in the report. Pg. x	The Red Team chose to report costs in fiscal year 2015 (FY15 dollars). None of the reported costs or risks contained within the documents in review by the Red Team contained any analysis in FY 15 dollars. The Red Team provided no discussion of how or why escalation was applied to FY14\$ for their report.

High Bridge Independent Review of Red Team Report

9	The Red Team concluded that if the MOX pathway is to be successful, then annual funding for the whole program (MFFF plus other activities that produce feed material and support fuel licensing and reactor availability) would have to increase from the current ~\$400M per year to ~\$700M-\$800M per year over the next 2-3 years, and then remain at \$700M-\$800M per year until all 34 MT are dispositioned (all in FY15 dollars). Pg. x	This confirms that the Red Team believe the cost of the MOX program will be less than a billion dollars a year as implied by ~~inferred in~~ the Aerospace report, but these values are significantly higher than expected by the MOX Services rebaseline, revealing a bias in favor of the Dilute and Dispose Option.
10	At [the ~\$700M-\$800M per year] funding level, operations would only commence after as much as 15 more years of construction and ~3 years of commissioning. Pg. x	At the funding level projected by the contractor's rebaselining proposal in 2012, the cost of MFFF to construct is less than \$650 m/yr. and will take 7 - 8 years including commissioning. The Red Team's numbers are derived from a simple calculation described later in the report and a lack of familiarity with nuclear commissioning. Later in their report, the Red Team uses a conflicting value of 10 years to complete MOX construction including commissioning.
11	The Dilute and Dispose Option could be executed at approximately the current \$400M annual program funding level over roughly the same timeframe as the MOX approach. Faster progress could be made if, during the 2-3 year period while MFFF construction and associated unneeded program elements are discontinued and demobilized, an appropriate, modest increase in funding over current levels could be used to support the initiation of oxide production and small-scale dilution operations, as well as the relatively small capital efforts needed to expand into full-scale production. Pg. x	This ignores the reality that no work could begin on the Dilute and Dispose Option until the Russian Federation agrees to the change in direction. Shutting down the MOX program would cost millions and would immediately abrogate the PMDA. Also, this statement assumes that DOE can place this material into WIPP without modification and that EM will "hide" the real costs in their budget. These assumptions are unsubstantiated and unrealistic. The cost of modifying WIPP to accept this material must take place before waste is shipped there and the cost for the design changes and the licensing efforts will be borne by the Dilute and Dispose Option. These will increase the annual costs to an average similar to the MOX program of ~\$600M/Yr.
12	The Red Team also noted that the Dilute and Dispose option would have headroom within an annual program operating cost of about \$400M (FY15 dollars) available for process optimization, which could increase annual throughput and decrease life cycle costs (LCCs) by reducing the overall program duration. Pg. x	See above item.
13	Several optimization variations to the Dilute and Dispose approach are discussed in the body of this document. Pg. x	These "optimization variations" represent changes to the design and licensing criteria of WIPP or introduce a costly variant that will adversely impact WIPP operations and stakeholder support.
14	Aerospace correctly concluded that even the best case scenario for the remaining MOX approach would be more expensive and riskier than the worst case scenario for the Dilute and Dispose approach, assuming that the latter approach is sufficient for compliance with the PMDA and is efficiently enabled in cooperation with the State of New Mexico. Pg. xi	Neither Aerospace nor the Red Team included the risks and costs impacts to WIPP if the Dilute and Dispose Option is selected. Aerospace was directed not to consider it, but the Red Team seems to have chosen to ignore it. Even though the Red Team correctly pointed out that this option would have major impacts on WIPP, but assumed that they could be addressed without schedule or cost impacts. They also assumed that they would be allowed to start shipping this waste to WIPP without first negotiating an amendment to the PMDA or addressing all of the issues related to WIPP first. Both of these assumptions are incorrect.
15	For this reason it is imperative that WIPP be used as efficiently as possible, and the Red Team encourages DOE to work with the State of New Mexico to implement efficiency improvements regardless of the Pu disposition path forward. The Red Team offers for consideration two techniques for disposal efficiency related to Pu disposition which may obviate any perceived need to amend the WIPP Land Withdrawal Act of 1992 (LWA) specifically to support this program. However, given the tremendous value of a TRU waste repository to both DOE and the State of New Mexico, it may eventually become desirable to explore expansion of WIPP's capacity beyond the current LWA limit regardless of Pu Disposition Program needs. Pg. x	The State of New Mexico does not regulate WIPP with regard to nuclear wastes. They are the agency for the RCRA wastes license and can use that to shut down the facility. However, WIPP was designed for a 25-year life which it has exceeded. It is currently shut down as a result of two incidents in 2014 and has no restart date. The "efficiency improvements" the Red Team has suggested are revisions to the criteria of the WIPP that would have a deleterious impact on operations. These suggestions appear to arise the cursory nature of the Red Team review rather than a well-thought approach.

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16	The MOX approach would satisfy the SFS in the PMDA, but would not achieve agreed timeframes for the disposition of excess plutonium. Pg. xi	Once again, the SFS is not the goal of the PMDA. The goal is to change the isotopic makeup of the plutonium to render it unusable for a weapon. The second part of this is disingenuous. The Dilute and Dispose Option is even slower than the MOX approach because of the impact on WIPP that the Red Team ignored.
17	Aerospace over-estimated the MFFF construction duration under funding-constrained circumstances, and hence the LCC of the MOX approach in those scenarios. Pg. xi	This statement is correct. However, the Red Team appears to have been unaware that Aerospace was directed to make most of the assumptions that led to this incorrect assessment.
18	Aerospace correctly concluded that even the best case scenario for the remaining MOX approach would be more expensive and riskier than the worst case scenario for the Dilute and Dispose approach, assuming that the latter approach is sufficient for compliance with the PMDA and is efficiently enabled in cooperation with the State of New Mexico. Pg. xi	The Red Team assumed that the Dilute process of the Dilute and Dispose Option encompassed the entire program. They have ignored negotiating with the Russian Federation and redesigning and relicensing WIPP to support this extended program. Also, they assume that the State of New Mexico will welcome this new waste form -- an assumption that has no basis at this time.
19	There are no obvious silver bullets to reduce the LCC of the MOX approach. Pg. xi	This is an odd conclusion in view of the fact that the Red Team successfully identified the core of the problem: the dysfunctional relationship between the NNSA Program office and the MFFF contractor. Solving this problem is the "silver bullet."
20	As soon as the new MOX facilities go hot, DOE is committed to long-term surveillance and maintenance costs and has adopted a complex new decontamination and decommissioning liability, regardless of whether the Pu Disposition Program is ever completed using the MOX approach. Pg. xi	It is not clear what this statement could possibly mean. The MFFF will only "go hot" if it is making fuel. The other "facilities" are needed for all options. So, this statement seems to suggest that there is a chance that the MFFF would get contaminated but would not be able to sell the fuel. This is a highly unlikely scenario.
	The Dilute and Dispose approach is viable at about \$400M per year (FY15 dollars), over a similar duration as the MOX approach. Pg. xi	This ignores the cost of WIPP, transportation and WIPP operations.
21	Unlike the MOX approach, the Dilute and Dispose approach offers opportunities for introduction of efficiencies which could reduce life cycle duration and cost, many of which could be implemented after the program is underway. Pg. xi	If MFFF is in operation, there is no reason why it could not be used as an acceptable disposal method for all of the surplus plutonium which would significantly reduce the loading at WIPP, thus saving the cost of expanding WIPP. Most of the "efficiencies" proposed by the Red Team are subterfuges to permit less secure disposal or to revise criteria that underpin the entire WIPP operation.
22	DOE should consider a "sterilization" approach to excess Pu disposition in parallel with startup of a Dilute and Dispose strategy as a means of reducing Program LCC. Pg. xi	<u>This is perhaps the worst conclusion of the Red Team review.</u> The Sterilization approach does not offer attributes that satisfy any aspect of a Pu disposal program option.
23	Contrary to conclusions in the High Bridge report, risks associated with the Dilute and Dispose Option are far lower than the MOX approach, since both the technology and the disposition process associated with Dilute and Dispose are far simpler. Pg. xi	The Red Team admits later that they did not review the High Bridge report, only the summary of the report. They can only pretend that this (MOX is riskier than Dilute and Dispose) is a valid point if they ignore the costs and schedule impacts of WIPP caused by the Dilute and Dispose Option.
24	The Dilute and Dispose approach would utilize existing facilities, and consequently creates essentially no incremental post-program liability. Pg. xi	This statement is unsupported. The sheer magnitude of the additional activities and increased size to accommodate the throughput will increase cleanup, decommissioning and security for the SRS. Costs are indeterminate at this time but should be included in Dispose and Dilute option.
25	Perceived fundamental barriers to the Dilute and Dispose approach, namely WIPP capacity limits and PMDA compliance, are not viewed as insurmountable by the Red Team, but should be retired as early in the planning phase for this option as possible. The combination of evolving international circumstances and the fact that the U.S. has already accommodated a Russian national interest in a previous PMDA modification causes the Red Team to believe that the federal government has a reasonable position with which to enter PMDA negotiations. Pg. xi	This superficial treatment of these important issues the cursory nature of the Red Team review. The Red Team assumes that they can negotiate their way out of these international agreements and legal constraints quickly and without cost. This assumption is simply wrong.
26	Regardless of the DOE chosen path forward, it is vitally important to make a decision as soon as possible and secure consistent funding to prevent further degradation of the Pu Disposition Program. Pg. xi	This recommendation regarding decisiveness and adequate funding is correct unless it is intended to rush into a new half-developed program with no critical review and which has no hope of success, i.e., Dilute and Dispose.

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27	Specifically, the Secretary requested that the Red Team: 1. Evaluate and reconcile previous cost estimates;... ...The Secretary specified use of the same comparison criteria that were used by the Plutonium Disposition Working Group (PWG) in their previous assessment of options: • Schedule to begin and complete disposition... Pg. 1	Evaluations and reconciliation of previous cost estimate were cursory, general in nature, and not explained in any detail. The schedule was not assessed with any rigor and was the one attribute the Red Team left off the "Attribute Comparison Summary" Table on page 35.
28	This Red Team report does not provide a bottoms-up estimate of any Pu disposition option. It should therefore not serve as a basis to judge absolute costs. Pg. 2	This is clearly correct. Yet, since this entire matter is allegedly a budgetary issue, the lack of any credibility on cost invalidates the conclusions of the report.
29	Clearly, any path forward selected by DOE will require the development of a new bottoms-up baseline cost and schedule estimate at both an integrated program level and for any major capital components, as well as contractual action to align a new acquisition strategy and incentive structure with the chosen path forward. Both DOE and the contractors have acknowledged this. Pg. 2	This is a good idea and should be done before any decision is made. The PWG, Aerospace, and the Red Team have narrowly focused on the feed preparation and the mixing process without due consideration of the external programmatic issues. The Red Team did not have time; the others were directed by NNSA/DOE into assumptions that biased the results. The MOX contractor tried unsuccessfully to get an incentivized contract but was told by DOE that it violated the FAR.
30	The current lack of sustained funding for the MFFF project illustrated in Table 1, which shows planned (based on the MOX Services 2012 BCP) versus actual funding, has created an environment of intense uncertainty, ultimately manifesting itself through project inefficiencies and strained relationships between DOE and the contractor. This uncertainty has in-turn led to a lack of workforce confidence in program stability, resulting in low levels of staff retention (exacerbated by loss of the most qualified workers), and low morale in the remaining workforce. A high turnover rate was noted by the Red Team, and the project is reportedly viewed regionally as a training ground for nearby nuclear and other major construction projects with better outlooks. Pg. 4	This passage summarizes the problem but neglects to mention the Sequester Budget battle that triggered the need for budget cutting without thought of the impact. DOE has lost focus and broken faith with the contractor, and it must be corrected for there to be a success.
31	Should the MOX option be chosen for continuation, it is vital to create and sustain an adequate and stable funding profile. Indeed, consistent support will be vital for any path forward. Pg. 4	This summary sentence is true but does not go far enough. Other vital steps include developing an integrated program approach with all aspects of the program under the same leadership and performing a bottom up rebaseline of the MOX Project with everyone involved in the process. Everyone involved needs to believe in the Program and the budgeted costs.
32	The Red Team saw an opportunity to realize meaningful cost savings through improved governance of the Pu Disposition Program. While the Federal Program Manager's Senior Technical Advisor is clearly engaged and knowledgeable, overall Federal Ownership of the Pu Disposition Program should reside with a senior career executive who has the overall responsibility and authority for the Pu Disposition Program, including integration across the various sites and across the various Programs and organization at DOE-Headquarters. This executive should have the authority to convene, coordinate (using a systems integration approach), and hold accountable all parties associated with the Pu Disposition Program (regardless of organization), including the major capital projects, and should establish joint ownership and governance expectations for both Federal and Contractor leadership. Indeed, multiple contractors involved in the current MOX approach expressed a desire for immediate reformulation of a centrally coordinated, integrating steering committee involving all executing parties. If a decision is made to pursue the Dilute and Dispose Option, this need for multi-site, multi-program coordination at the DOEHQ level will remain acute. Pg. 5	THIS is the Silver Bullet that the Red Team claims that they could not find. There is nothing wrong with the project or the technology, the problem appears to be a decision made by the management at DOE to destroy this investment of billions of dollars and 20-years of effort. This silver bullet is the way to reliably solve the surplus plutonium problem... for all 51 MT.

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33	At the local level, the Red Team observed an antagonistic relationship between the local NNSA Federal Project Director's office and the MOX Services organization. As previously discussed, some of this would be a natural outcome of difficult, downward spiraling circumstances, but the Red Team noted that some of it may be arising from a genuine dispute regarding the degree of completion of the MFFF project (a perception likely to be exacerbated by the difficult work environment). It is difficult to judge how much work is actually accomplished when funding is only slightly more than the annual hotel load (level-of effort fixed costs), since construction logic and productivity are so negatively affected by drastic funding reductions. Pg. 5	True. This must be part of the solution. New people with the proper attitude and commitment to the success of the project must be brought in to replace the combatants.
34	The Red Team asserts that a true ETC cannot be developed and authenticated until it can be based on a sound schedule that in turn is based on firm funding level commitments at a reasonable and sustained level through project completion. Pg. 6	Agree. As such, the Dispose and Dilute option costs are less determinate. It has benefitted from a preliminary scoping effort only and there is no believable schedule or baseline cost estimate that encompasses the totality of the project. It is significantly less mature than the MOX program and yet the Red Team did not address this deficiency of the Dilute and Dispose Option.
35	Simultaneously, the contractor staff will need to demonstrate a stronger culture of performance under which commitments big and small are routinely delivered on time, transparently, and in accordance with expectations. Pg. 6	This is an unfair charge. Large projects are collaborative exercises that require a unified management team, clear lines of authority and a collective commitment to the success of the project. DOE has not addressed the 2012 BCP other than to commission a string of review bodies to criticize it. The Contractor has been working under increasing pressure to perform without optimum funding or support. Technically, they are working outside of the scope because the changes reflected in the 2012 BCP are not approved although they are now included in the project. Moreover, the budget is less than the budget before the scope changes and yet the contractor continues to try to complete the project. The problems with the MOX project go both ways and to only identify the contractor's issues indicates a bias that is inappropriate for an independent review body.
36	Without substantial changes to container packing efficiency and/or volume accounting techniques at WIPP, the disposal of just 13 MT of the 34 MT U.S. obligation via the Dilute and Dispose approach discussed later in this document would reportedly consume as much as 68% of the remaining unsubscribed capacity. It is imperative that WIPP be used as efficiently as possible. The Department should ensure that waste placed in WIPP be as densely packed as practical to minimize volumetric use as well as shipping. Pg. 7	This is a specious argument. The maximum FGE content of waste packages stored in WIPP are determined by the concentration limit approved by the NRC. Currently, the maximum FGE is in a Criticality Control Overpack at 380 FGE per 55-gallon drum. As a practical limit, the Red Team found that SRS averages about 300 FGE per container. There is no way to be more "efficient" than this legal limit. Packing more waste into each overpack simply runs the risk of a massive QA shutdown of the entire program for violating the licensed amount of waste per container. Getting a new container design that can accommodate more waste requires a NRC licensing process before any waste can be processed. Counting only the waste volume and not the external container volume brings operational problems associated with verification. Merely citing "efficiency" improvements with no hint of what they might be is not a real solution.
37	Recognizing that not all waste is in forms that are amenable to dense packing, DOE should also work with the State of New Mexico to account for the true waste volume placed at WIPP as accurately as possible (i.e., using actual waste volume, as opposed to container volume). Pg. 7	This is a proposal to violate the WIPP Land Withdrawal Act by simply recalculating the volume of waste rather than the volume of the container. However, this is an operational issue since the contents of the drum are hidden and cannot be verified in the field without opening the containers. This would impose an enormous burden on the already overtaxed WIPP staff.

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38	However, given the tremendous value of a TRU waste repository, it may eventually become desirable to explore expansion of WIPP's capacity beyond the current LWA limit regardless of how much volume is utilized by the Pu Disposition Program. Pg. 7	Here the Red Team ignores the cost and the schedule impact of this "tremendous value." Since the Pu Disposition Program would be responsible for the overloading WIPP, it should bear the cost for expanding it. The Red Team has danced around the problem citing "efficiencies" that cannot apply and negotiations with New Mexico who has no jurisdiction (over the waste volume).
39	While it is appropriate to seek out incremental programmatic funding to support specific facility improvements that might be needed to support a particular mission, it does not make sense to piecemeal the funding of base operations at a nuclear facility. A more viable model is to recognize the stewardship role played by EM on behalf of the broader DOE missions and adequately fund the base operating cost of H-Canyon in the EM budget. Pg. 7	It is disingenuous to propose hiding the costs of H-Canyon upgrades in the EM budget, that has no role in facility "stewardship" other than to arrange for the deactivation and demolition of extraneous infrastructure. (Something EM has been trying to do to H-Canyon for years.) DOE-EM's Mission Statement is: "The mission of the Office of Environmental Management (EM) is to complete the safe cleanup of the environmental legacy brought about from five decades of nuclear weapons development and government-sponsored nuclear energy research."
40	The Red Team reviewed each of the estimates performed since the 2012 contractor BCP to evaluate estimate approach, assumptions, risks and conclusions..... There was not uniform access to detailed basis of estimate information for all components of the Pu Disposition Program. Pg. 9	The Secretary requested an evaluation and reconciliation of previous cost estimates. None was provided. Instead, the Red Team provided a cursory review.
41	Additionally, the Red Team noted that many of the cost-estimating best practices recommended by the U.S. Government Accountability Office were not consistently followed in essentially all of these estimates. Pg. 9	Red Team acknowledged they did not review the 2012 contractor BCP and the only other full scope estimate performed was the USCOE bottom up estimate which was utilized by the PWG in their review. The other estimates were actually assessments of other estimates so it is not surprising that they did not follow cost estimating best practices... they were not cost estimates.
42	The Aerospace report used the cost estimates produced by the PWG for Option One (MOX) and Option Four (Downblend) and applied the results of an assessment of programmatic risks and resultant cost impacts to establish a total program LCC estimate with an 85% confidence level for each of the two options, without crediting any MOX progress since the 2012 BCP. Pg. 9	The Aerospace assessment also was narrowly focused by the limiting parameters set by their sponsoring organization that included: Providing the analysis in real year escalated dollars using escalation rates far in excess of accepted standard rates that significantly skewed the results; and the disregard for any WIPP costs. The Red Team did not identify these deficiencies even though they had unlimited access to the Aerospace team to answer questions.
43	The High Bridge report challenged the assumptions of the Aerospace report. Using the PWG costs as a starting point, they applied their own risk assumptions to determine a different set of LCC estimates. Pg. 9	The Red Team only reviewed the preliminary 5-page High Bridge report and did not have the benefit of the detailed costs and risks continued within detailed Phase 2 report. High Bridge believes this to be an issue that may change the Red Team views.
44	The PWG LCC estimates for these remaining two options are shown in Table 2. (These are depicted as \$25.12B of the MOX option, and \$8.78B for the Dilute and Dispose option) Pg. 10	These are in real year dollars, which is not shown, and the costs for the Dilute and Dispose are not accurate. The PWG report indicated the Downblend option (same as The Red Team Dilute and Dispose option) as \$10.3B RY\$

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45	The Aerospace assessment was conducted in early 2015 and included a review of the previous PWG options evaluation report, tours at SRS and LANL, and discussions with relevant DOE, NNSA, MOX Services, and Savannah River Nuclear Solutions personnel. Aerospace organized and executed their evaluation in accordance with sound systems engineering principles, analyzed the previous cost and schedule estimates for both options, and performed independent risk assessments for each option with a focus on broad programmatic issues. Pg. 11	This is a misrepresentation of the Aerospace report. Aerospace's report admitted as much when they said: "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. " If the Red Team missed the fact that Aerospace did not start with the Plutonium Disposition requirements and evaluate the processes used to obtain outputs, it is difficult to understand how they concluded that Aerospace used "sound systems engineering principles." This could have misled the Red Team into believing that there was more rigor to the analysis than there was.
46	Of specific benefit was the "S" curve LCC comparison provided in Figure 10 of the Aerospace report. This figure provided an efficient comparative summary of the base and risk-adjusted LCCs of the two options without imposing additional capital funding constraints. The clear and compelling conclusion illustrated in this figure is that the Dilute and Dispose option will result in lower LCCs than the MOX facility option under all credible scenarios—a conclusion with which the Red Team agrees. Pg. 12	The Red Team conclusions are inaccurate. Figure 10 uses the real year basis of the Aerospace report, which the Red Team criticized several times in the report because it skewed the true cost basis. The second reason the Red Team's conclusion is inaccurate is because the data presented in Figure 10 does not include the base costs associated with WIPP modifications and licensing as described throughout this point by point rebuttal. Finally, the band of the costs shown in the Figure 10 in the "S" curves are too narrow for an immature and conceptual program such as the Dilute and Dispose Option.
47	...the Red Team concludes that the MOX approach to Pu disposition could be completed within a reasonable timeframe for less than \$1B per year. Pg. 13	Since the reason given by the Secretary for abandoning the MOX Program was that it would cost more than a \$1B a year, the Red Team has determined that assertion is unfounded. However, they did not reach that conclusion.
48	However, the most fundamental Aerospace conclusion, illustrated in their "S curve" figure, remains intact: The worst case scenario for the Dilute and Dispose Option is significantly less expensive and comes with lower technical and operational risk than the best case scenario for the MOX approach. Pg. 13	This reveals a superficial review of the data and no formal risk assessment. The Red Team report states that WIPP would need significant relicensing to accommodate the Dilute and Dispose Option wastes, but assumes that these efforts would be both cost-free and rapid. The report ignores two additional key facts: 1) the State Department would need to begin a new round of negotiations with the Russian Federation and 2) Dilute and Dispose involves a far larger logistics commitment for consumables and transportation. None of these facts are captured in the Red Team Review.
49	In their report, published June 29, 2015, High Bridge concluded that Aerospace's identification and analysis of risk issues and contingency impacts identified for the MOX and Dilute and Dispose Options was flawed. Specifically, they stated the MOX risk elements and resulting impacts appear to be overstated and inconsistent, while Dilute and Disposal risk elements are "clearly understated." Pg. 14	The Red Team did not read the High Bridge Final Report that would have explained most of the problems they had with the Preliminary Report.

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50	The Red Team was also concerned with the application of a project risk profile to the Dilute and Dispose Option commensurate with the application of DOE Order 413.3B for a major new nuclear facility acquisition. the Dilute and Dispose Option primarily involves the use of existing facilities, some of which have been used in conversion or dilution before, including the disposition of plutonium at WIPP. The Red Team believes it is inappropriate to equate the Dilute and Dispose Option to a complicated greenfield project that is at CD-0, and then reflect that kind of a risk profile in a calculation of LCCs. However, the High Bridge report did correctly identify that the shutdown costs of MFFF need to be part of the Dilute and Dispose Option's cost profile. Pg. 15	The National Resources Council reviewed DOE's historically poor performance for undertaking new projects and in their 1999 report to Congress they recommended that the Department adopt programs that ultimately resulted in DOE Order 413.3 for capital acquisition projects. The Red Team's assertion that this painful lesson can be ignored for this instance is irresponsible. This is a major undertaking requiring the modification of major DOE assets and the procurement of high tech nuclear systems and components. It also requires a massive relicensing effort for a nuclear waste repository. It is unconscionable to believe that this can be done using operating funds not designated for this purpose. The MOX program cannot legally use funds to build something not needed for the MOX program.
51	High Bridge strongly emphasized the challenge of going from CD-0 to CD-4 on the Dilute and Dispose Option in just three years, even though the capital scope amounts to the relatively simple installation of two gloveboxes in an existing facility. While the Red Team agrees that three years would be an aggressive schedule, High Bridge's criticism failed to acknowledge an existing, capable glovebox which could be operational in a matter of months. Once International Atomic Energy Agency (IAEA) inspection is integrated into this single box operation, DOE could begin taking credit for progress toward disposition of the agreed 34 MT. In the meantime, DOE could use the existing glovebox to reduce the risk of fines and penalties from the State of South Carolina for failing to make any progress at all toward Pu disposition. Pg. 15	Currently, the IAEA is not permitted to oversee operations in the KAMS, so moving the classified work aside to permit this is problematic. Also, the existing glovebox is completely occupied with its current mission, which the Red Team casually dismisses as unimportant in favor of the Dilute and Dispose Option. This is at best a cursory summary of this complex issue.
52	Given the importance of getting WIPP re-opened to the greater DOE nuclear enterprise and the previously discussed history of PMDA modifications negotiated to date, the Red Team believes that it is reasonable to assume that resumption of operations at WIPP and its designation as the repository for all 34 MT, as well as a successful negotiated adjustment to the PMDA, could be achieved within a reasonable time frame. Pg. 15	Currently, the COO is projecting first calendar quarter of 2017 for WIPP to restart. Even if they achieve this date, they are certain to start up at considerably less than the 17 shipments per week that they are designed for. The three years during which WIPP received no waste will have resulted in a critical backup at all of the generator sites, and many of them are under civil penalties imposed by the Courts for failure. It is unlikely that this waste stream will be accepted in a "reasonable time frame." Moreover, it is likely that this waste stream is not even part of the mission of WIPP and is therefore excluded from being accepted without a new design and relicensing effort.
53	With 19,000 cubic meters of unsubscribed capacity, SRS could ship at this rate for a long time if necessary, once WIPP is reopened and until either existing volume-based capacity limits are increased, or one of the variants to Dilute and Dispose obviates the need for early expansion of the volume limitation. Pg. 15	It is disingenuous to propose shipping this waste to WIPP using the EM surplus capacity as if EM might not need it. First, it is not clear that it is even legal to ship this waste to WIPP. (Spent fuel associated with weapons production is not permitted. It is not clear why the Red Team assumes that ANY TRU waste the Secretary wants to get rid of can be sent to WIPP.) Especially since doing this eliminates the MOX option and forces all future DOE Secretaries to deal with the problems that this causes.
54	Another issue is the fact that the High Bridge report incorrectly took MIFT-related risks out of the MOX Program estimate. Even though there might be slight variances in those costs depending on the option chosen, many MIFT costs apply to both Pu disposition options and such risks should be treated consistently. If anything, the MIFT risks are lower in the Dilute and Dispose case due to relaxed specifications on the quality of plutonium oxide, and elimination of the fuel qualification program. Pg. 15	High Bridge evaluated the MIFT (MOX Irradiation, Feedstock, and Transportation) costs and found them to be similar or significantly higher for Dilute and Dispose than for MOX. This evaluation appears in the final High Bridge Phase 2 report that the Red Team did not review. The MI costs for the MOX option are replaced by the WIPP costs for the Dilute and Dispose Option; the F costs are about the same for both options albeit the Dilute and Dispose Option takes longer to achieve; and the T costs are vastly higher for the Dilute and Dispose Option consisting of 2300 -2700 shipments compared to 80.

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55	In any event, the High Bridge analysis fails to recognize that the majority of scope related to the Dilute and Dispose alternative is a subset of the MOX approach to Pu disposition. Under any credible scenario, therefore, Dilute and Dispose cannot be as costly or as complex as the MOX approach. Pg. 15	The Red Team's opinion shows a narrow focus on the Dilution portion of the new Pu Disposition Program. They have ignored the massive impact on WIPP and the EM program. MOX has already experienced many of the problems of complexity. They are now at the stage of finalizing construction and startup testing. The Dilute and Dispose Option's total program is not even described in detail and is in fact based on several flaws in logic. One, that NNSA will be able to push EM aside and take over all the remaining space in WIPP, is the most seriously flawed Red Team logic.
56	The Waste Solidification Building (WSB): A separate capital project to design/build a facility to treat and dispose of liquid wastes from the cancelled Pit Disassembly and Conversion Facility (PDCF) and MOX facilities. WSB construction is essentially complete, and the facility is in standby awaiting operation. Since the PDCF has been cancelled at SRS, this facility has excess capacity, and absent pursuit of the MOX approach, may never be used. Pg. 17	This is an example of the fiscal waste and irresponsibility of the Dilute and Dispose Option. The MOX program represents a great deal of investment to achieve strategic needs of the country and nearly 20-years of effort by three different Administrations. Canceling it now to pursue a new direction that is almost certain to fail would be ill-advised.
57	First, the conservative approach to meeting NRC requirements has resulted in an extremely robust facility (manifest, in part, in high capital construction costs exceeding European benchmarks), and very tight controls. MOX Services reported 8,000 active items relied on for safety (IROFS) and 7,000 passive IROFS within the MFFF, all with attendant quality assurance (QA) and/or monitoring and reporting requirements. To the extent that these (especially the active ones) are analogous to Technical Safety Requirements within a DOE nuclear facility, each of these IROFS (especially the active ones) potentially represents a threat to continuous operation. Pg. 19	In the first place, it was the NNSA requirements that forced the robust design of the MFFF; not the NRC. The NRC requires seismic and missile resistant designs, but the NNSA required the ability to resist a focused military-style assault with shaped charges and vertical envelopment. The Items Relied on For Safety (IROFS) list is a simple procurement tool to avoid inadvertent reductions to quality in the future. Moreover, the Quality of French fuel is in no way inferior to US fuel, so the inference of this argument is baseless.
57	The second risk is excessive automation. The Red Team notes that excessive automation, inability to perform corrective maintenance on failed systems within gloveboxes, and inadequate buffer storage between process steps were causes of disappointing throughput rates at the Sellafield MOX Plant (SMP) in the United Kingdom (designed for a fuel output of 120 MT/yr., but only achieved 5 MT/yr.). It appears that the MFFF design has addressed lessons learned from the SMP and incorporated maintenance capability and buffer storage to mitigate these risks. However, automated systems integration challenges in the facility add schedule risk to commissioning and startup, and could pose an ongoing risk to future operations and maintenance. Pg. 19	The glovebox operations are no more automated than the ones in France that were copied for this application. The automation consists of means of avoiding worker contact with Plutonium products. The throughput analyses assume a 35% operability and so large scale buffer space is not required. The inclusion of the failed Sellafield MOX facility is an attempt to sully the design basis of MFFF that has nothing to do with the Sellafield design. Then to admit that MFFF does not have the same problems reveals a profound bias in the Red Team against MOX.
58	The irradiation of MOX fuel prepared with weapon-grade plutonium in LWRs constitutes the U.S. commitment under the PMDA, although the project is behind the agreed-upon schedule. Thus, even though the technical approach is consistent with provisions of the PMDA, the agreement may nevertheless need to be renegotiated to accommodate new schedules and throughput rates, particularly if the deviation grows. Pg. 20	The Red Team notes that only the MOX approach meets the PMDA but totally underestimates its value. Missing the 2018 start date in the PMDA was unavoidable since this Administration decided not to live up to its obligations under the Agreement. Still, 2018 is a soft target goal of the PMDA and if the program were making good progress towards completion it would not be as significant as abandoning the program and redirecting into the Dilute and Dispose Option. Moreover, the likely delay in meeting the commitment with the Dilute and Dispose Option will most certainly be longer.
59	If DOE chooses to continue with the MOX approach, it is important that the MOX Program leadership establish sufficient priority and funding to address long-lead elements associated with the actual use of the MOX fuel in licensed nuclear reactors. Pg. 20	High Bridge totally agree with this.

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60	In a review of the MOX services hotel load scope and staffing levels for FY 2014, the ratio of non-manual to manual labor was found to be slightly higher than 1:1. This non-manual staffing level seemed excessive given the levels during previous fiscal years prior to the partial suspension of the project. When reviewed with the MOX Services team, the contractor stated that the non-manual level of effort portion of the hotel load has not been optimized, and in fact, resources were maintained at a higher level to retain talent in anticipation of ramping the project back to a full funding level. Pg. 21	MOX Services is committed to the successful completion of the MFFF project. Therefore, they have retained valuable staff during the current budget shortfall to minimize remobilization costs. Reducing the overhead staffing to match the construction effort would require narrowing the skills to focus on the work being performed, therefore losing the resources the project needs to succeed. This seems to be a logical approach at the present and it seems unfair to criticize MOX Services for this approach.
61	The Red Team was surprised, for example, that MOX Services currently carries a project controls staff in excess of 200 people. Pg. 21	The actual number is around 71. This is an example of incorrect statements arising from the cursory nature of the Red Team review. It would have been a simple matter to verify, but the Red Team did not follow through.
62	The maximum possible value associated with MOX fuel is the value of the displaced uranium fuel, or 36 assemblies every reload. Current prices for uranium and enrichment, the key components in nuclear fuel cost, are near historic low levels. The cost of a uranium fuel assembly in today's dollars is approximately \$1M, or \$36M per reload. Over the life of the Pu Disposition Program, that would result in approximately \$1.8B of potential revenue. From a utility perspective, the risks to MOX fuel use are large and will potentially require a substantial price discount, perhaps to the point of being "free" in the beginning, to incentivize the utility to make modifications to their reactor and go through NRC license amendments, to use fuel that is less optimum than their current fuel. To the extent that such incentives become necessary, they subtract from the total potential revenue of \$1.8B. However, the net value should be subtracted from the LCCs of the MOX approach when comparing point estimates of LCCs to other alternatives (which, as previously discussed, can be misleading). The Red Team believes it is unrealistic to assume a net value of more than \$1B for the 34 MT of surplus plutonium. Pg. 21	Nuclear utilities do not buy uranium at the current spot price. They have long-term contracts for the fuel set many years ago. Since fuel costs are such a small part of nuclear electrical generation costs, utilities prefer the certainty of supply over potential cost savings in the spot market. In spite of the Red Team's belief, the best estimate for the value of the fuel from all 34 MTs of Pu is approximately \$3B. The net contribution to the U.S. Treasury would be about \$1B.
63	The Red Team noted that some utilities operate in regulated power markets where public utility commissions decide on what qualifies to go into the electricity rate base. In those utilities, fuel costs are usually passed directly to customers and it may be unlikely that a regulated utility would bear the risk of MOX fuel, even if it is free. This puts at risk the assumption of seven available reactors to support the movement of material through the MFFF facility fast enough to support the facility's designed throughput rate. However, the Red Team believes it may be possible to accomplish the irradiation mission with fewer than seven reactors, as some reactors are capable of 100% MOX loadings (e.g., Combustion Engineering Reactor designs, AP-1000), and/or by irradiating some MOX assemblies for one cycle only, increasing the number of new MOX assemblies loaded above 36 per cycle. Pg. 22	This is an example of the chaos in the Red Team Report. The beginning of the paragraph begins to assert that since some reactor operators may be prevented from gaining any economic benefit from MOX, there is no need for MOX. However, the Red Team concludes the paragraph saying essentially, that it will probably work. The fuel surcharge in a regulated market is mostly for fossil fueled plants and does not impact nuclear plants. Their fuel cost are such a minor part of the costs of operations, that it seldom comes up. MOX fuel cost savings would essentially pay for the refueling outage, which while attractive, would not have a major impact on the overall cost of operations. So, the regulators would not bother with it but the plant operators would be extremely interested.

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64	Furthermore, utilities will demand that MOX fuel meet strict QA requirements and delivery guarantees, the same as fresh fuel. It is the Red Team's understanding that no vendor has ever failed to supply fuel and thus caused a delay in reactor startup. To address the risk of potential delay in the supply of in-spec MOX fuel, NNSA has created a large backup supply of low enriched uranium fuel, consisting of 170 MT of uranium at 4.95% enrichment. This provides substantial risk mitigation to fuel supply interruption, and thus facilitates the eventual development of a sufficient customer base. In summary, the Red Team believes the risk that an insufficient number of reactors will be available for the MOX fuel has been overstated. It was always unrealistic to expect utilities to effectively "sign up" so far in advance, and with sufficient incentives, the Red Team is convinced that there would be an adequate number of buyers and reactors available. Until the MFFF is delivering licensed fuel to an operating reactor, DOE would be proceeding with the MOX approach at risk since that will be a necessary condition to secure final agreements for a full suite of reactors. Pg. 22	The beginning of the paragraph seems to imply that no utility would commit to the fuel because it is difficult to gain assurance that the fuel would be delivered. It should be noted that the French plants that are operating now using the same technology have NEVER missed a shipment. There is no reason to assert that the MFFF would operate any less reliably. The second half of the paragraph changes direction and admits that the lack of subscribers for the MOX fuel has more to do with DOE's failure to support the project than it does with any other cause. As soon as the MFFF begins making fuel, the subscribers will appear because of a clear economic advantage for them.
65	As discussed in Section 2.1.2, the decision to perform a qualitative safety assessment during design development is considered to have provided a short-term cost and schedule benefit during early design efforts, but appears to have generated a capital and expense burden through over designation of the safety features (the IROFS). Quantitative risk assessment may have led to at least 1,500 fewer such designations. The MOX Services project team has already identified a small potential savings of \$11M capital at this late date in construction, and \$0.7M in annual operating expenses, related to a reasonable reduction in the number of IROFS. The risk reduction value described in Section 2.1.2 related to the avoidance of operational upsets may be far higher. Pg. 23	The Red Team appears to be obsessed with the "complexity" of the MFFF and points to a need to consolidate the IROFS database. This is curious. The IROFS list is a simple listing of all of the components that need to be purchased using special specifications and extra Quality to assure conformance with the design requirements. It is not clear why anyone in the nuclear industry thinks that consolidating the listing will improve performance.
66	The laboratory defined in the scope of the MFFF serves to provide physical and chemical analyses of samples from both the AP and MOX Process areas of the facility, with specifications established by production and compliance requirements. It was reported that laboratory unit operations may be sized with some redundancy to support operations during peak load times, and/or as a safeguard against equipment failures. Although significant progress has been made in the procurement of equipment, installation and procedure development is at a low level of completion. In addition, there is some risk that equipment will become outdated as the MFFF is completed, requiring additional investment. Opportunities for better integration were discussed to take advantage of other laboratories (notably, existing SRS analytical laboratories) by subcontracting a range of scope for these operations. This carries the opportunity of modest construction and operational cost savings (in the range of millions to tens of millions of dollars), with associated variable degrees of risk reduction. The viability of these options may be more likely when combined with a reduction in IROFS. Pg. 23	Another contradictory point raised during the Red Team cursory review. The Red Team just concluded that tight chemistry control is essential for proper fuel performance. Yet, here they seem to be arguing for a decrease in thoroughness and even substituting an expensive expedient of shipping plutonium products around the country to other national and/or private laboratories to "save" money and reduce IROFS. Even in the case of using available SRS laboratories, it ignores the need to make these laboratories plutonium compatible and to upgrade the performance standards to meet fuel production needs. Then, there is the cost and complexity of shipping plutonium from one secured area to another and back again. So while it appears to be making a significant point, the implications of this paragraph are not helpful.

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67	For purposes of considering alternatives that have not already been screened out as impractical, the Red Team articulated a guiding principle to use as a framework for examining alternative approaches: “Develop an alternative disposition pathway that can be executed at an affordable cost, with an acceptable schedule and risk profile, using an approach that has a reasonable probability of achieving Russian concurrence on a revised PMDA.” Pg. 24	It is not clear who made the unattributed quote but this is the crux of the failure of the Red Team report. They either did not know of the Russian Federation insistence on the isotopic conversion of the weapons grade material to reactor grade, or they chose to ignore it. There is absolutely no chance that the Russian Federation will accept the Dilute and Dispose Option without completely gutting the non-proliferation aspects of the PMDA that the US side negotiated into the agreement.
68	In this option all diluted plutonium oxide materials would be sent to WIPP for disposition. As previously discussed, WIPP has already received and disposed of such materials in the past. Thus, the receipt of similarly diluted materials is not expected to pose technical problems; but there are regulatory issues that would need to be addressed to allow the disposition of all 34 MT of plutonium... Pg. 28	This is a very significant and unsubstantiated assumption that the Red Team, the PWG and Aerospace have all made. Given the current PMDA policy it is simply wrong. So far, WIPP has only accepted wastes from the cleanup of the weapons complex by EM. While admittedly, some of the waste forms, from Rocky Flats especially, were weapons grade materials, they were not finished weapons components removed from the active arsenal. They were incidental products left over from the chaotic shutdown of the weapons facilities. As two Op Eds by former NM governor Bill Richards have asserted, the disposal of this material at WIPP is highly charged politically and is problematic in the extreme. Once again, the Red Team has understated the size of the problem by stating that this is a 34 MT problem when, in fact, it is a 51 MT problem.
69	Figure 4 - Remaining Practical Approaches to Pu Disposition Pg. 25	This figure attempts to show the potentially successful options for plutonium disposition. The most instructive part of the figure is the right-hand side that identifies the Recovery Process to Weaponize Based on Processing Option for all of the alternatives. It then shows boxes describing the process steps. However, there is no equivalence between the boxes with similar names. For instances, the first box for all three options shows "Remove from the Repository". For the two options that the Red Team supports, this would involve a straight forward process of entering the repository, using the drum handling equipment and removing the drums from the repository. If desired, the CCO could be removed from the drum and hand carried out of the repository. For MOX, this would involve the moving of a multi-ton container from a repository in a dose rate of several thousand rads/hour. Opening the fuel canister requires elaborate cutting tools and heavy equipment. To do this safely requires shielded working area (hot cell) and specialized remote cutting tools and equipment. The second box is labelled "Chemical Recovery/Separation" in the case of the Red Team preferred options and "Chemical Separation in the case of MOX. That is because the non-reactor options are not particularly radioactive and can simply be recovered in their nearly original form by simple physical and chemical processes. Used MOX fuel, on the other hand, requires a chemical separation facility located in a hot cell or canyon that simply does not exist. There is no way that existing systems could be clandestinely converted without raising the alarm.

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		MOX has a third box entitled Isotopic "Adjustment." This means enrichment of the reactor grade plutonium residues to weapons grade quality. This has never been done and there are no examples of technology that could do this. To suggest that this is a simple "Adjustment" is disingenuous. Separate Work Units to separate U-235 from U-238 is the largest single cost of the uranium fuel cycle. To separate Pu-239 from Pu-240 would be an even more impractical solution. It is for this reason that an honestly drawn line for Failing to Meet Disposition Strategy would be above the MOX option eliminating all others
70	The plutonium oxide would be diluted with an adulterant mixture that serves to reduce the attractiveness level of the plutonium oxide by yielding a mixture that: 1) has a reduced plutonium concentration; and 2) requires extensive processing to achieve a purified material. As such, the diluted plutonium oxide material would meet a Safeguards and Security Attractiveness Level D, and safeguards could be terminated on the material so that it could be disposed at the WIPP. Pg. 26	WIPP is designed for Attractiveness Level E; not D. The Pit is Attractiveness Level B. The Pit converted to Pu Oxide powder is Attractiveness Level C regardless of concentration. The difficulty of recovering the oxide from the Adulterant might make it an Attractiveness Level D depending on the whim of the authorities in the Complex required to sign off on the reclassification. This is almost an irrelevant point since the PMDA requires either irradiation in a reactor or immobilization in vitrified HLW.
71	To assess this option, the Red Team toured the SRS K-Area facility, the LANL PF-4 facility, and WIPP, and held multiple discussions with facility and Program personnel. Based on these inputs, and the fact that this approach for dispositioning excess plutonium oxide materials has already been used at several DOE sites in the past (the Rocky Flats Environmental Technology Site, the Hanford Site, and SRS), the Red Team judges that: • The dilution of plutonium oxide with an inert adulterant is a low complexity technology; • There are no real technical challenges to the successful implementation of this option, given the systems already in place to produce oxide for MFFF; and • The primary risks with this approach would be regulatory and stakeholder issues. Pg. 26	The third bullet is as close to addressing the major flaw with the non-reactor options that the Red Team supports. It is simply not legal or credible to proceed with the Dilute and Dispose Option until and unless the regulatory and stakeholder (read legal challenges) issues are overcome.
72	The anticipated throughput of this glovebox is 400-500 kg of plutonium per year. To increase the throughput up to about 1,500 kilograms of plutonium per year, this option includes the installation of two additional gloveboxes into KAMS at an unofficial estimated cost of up to \$240 million. That installation not only includes the two gloveboxes but also non-destructive assay equipment and changes to the KAMS documented safety analysis to allow for increased throughput, as well as support systems such as ventilation systems, fire suppression systems, staging rooms, electrical upgrades, and installation of several instrument and monitoring systems. The Red Team believes that the \$240M estimate is conservative when compared to the much less expensive installation cost of the very similar, existing glovebox. Pg.27	The Red Team nor any of the other reviewers has indicated any rigor in this number. This is a stretch to state this is conservative for the scope identified without a rigorous analysis of scope, schedule and implementation. These "minor" plant modifications are well known throughout the nuclear industry to be highly suspect without full vetting. Indicative of immature group think without benefit of knowledge of operation parameters of the existing facility coupled with difficulty factors associated with these type of operating plant modifications. It is also fair to point out that the low end of the estimate of performance would suggest that three gloveboxes could only be relied upon conservatively to process 1,200 kg per year. In order to guarantee 1,500 kg per year per the PMDA, it would be necessary to purchase THREE new gloveboxes and to find room for them in the tight confines of KAMS.

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73	To increase the throughput up to about 1,500 kilograms of plutonium per year, this option includes the installation of two additional gloveboxes into KAMS at an unofficial estimated cost of up to \$240 million. That installation not only includes the two gloveboxes but also non-destructive assay equipment and changes to the KAMS documented safety analysis to allow for increased throughput, as well as support systems such as ventilation systems, fire suppression systems, staging rooms, electrical upgrades, and installation of several instrument and monitoring systems. The Red Team believes that the \$240M estimate is conservative when compared to the much less expensive installation cost of the very similar, existing glovebox. Pg. 28	As noted above, the cost could easily be \$360M assuming that the extra gloveboxes can even be made to fit in KAMS. Regardless of the cost, the Red Team apparently assumes that a retrofit project that costs \$240M to \$360M does represent a Capital Acquisition and therefore does not need to follow the Critical Decision Process. This is unlikely scenario. It is unlikely that DOE will allocate that amount of money for a capital acquisition without following a rigorous process. Operational budgets do not contain amounts of undesignated funds large enough for this purpose and diverting the MOX Program budgets would be illegal.
74	The diluted plutonium oxide material would be packaged in product cans, removed from the glovebox in bag-out sleeves, and packaged into a slip-lid can. That can-bag-can configuration would be loaded into a Criticality Control Overpack (CCO) that will be used to ship material to WIPP in a TRUPACT II. The average plutonium loading of the CCO is anticipated to be about 300 grams. Pg. 28	300 grams per CCO results in 113,333 CCOs at a cost of \$261M requiring 2700 shipments at approximately \$675 M and disposal costs at WIPP in excess of \$4 B. Assuming it even gets approval, of course. The Dilute and Dispose Option requires a thorough cost estimate if it is to be pursued.
75	In this option all diluted plutonium oxide materials would be sent to WIPP for disposition. As previously discussed, WIPP has already received and disposed of such materials in the past. Thus, the receipt of similarly diluted materials is not expected to pose technical problems; but there are regulatory issues that would need to be addressed to allow the disposition of all 34 MT of plutonium (see Section 3.1.1.4). To accommodate the number of CCO packages anticipated for this option, at least one additional panel would need to be mined at a cost of about \$8-10 million/panel, but it is not clear that this would be an NNSA cost. Pg. 28	Here is the crux of the Red Team argument. At 300 FGE per drum, it will require 4000 m³ more space than the law authorizing waste emplacement in WIPP permits. The Red Team apparently believes that some other budget will pay for this and that this program will not be impacted by the delays certain to arise in obtaining the required approvals to go forward. This also assumes that EM does not need the existing unsubscribed space for their mission.
76	Perhaps the greatest technical risk during full-scale operations will be the standard challenge of managing tightly controlled material movement logistics within a high security nuclear facility. Ultimately, the rate of oxide production at LANL is expected to control the maximum rate of diluted plutonium drums sent to WIPP each year. Pg. 28	This is a significant cost as well since there are so many shipments. A point ignored by the Red Team because they apparently believe that someone else will pick up the costs for shipping to WIPP.
77	Regardless, there is a stark contrast in the required technology for the MOX approach versus the Dilute and Dispose approach. Each involves the usual supporting technology required for safe and secure plutonium operations such as a complex facility ventilation system, airlocks, nuclear material control and accountability, etc., but the technology comparison is between the highly automated process equipment in a newly constructed, highly controlled MFFF on the cutting edge of integrated manufacturing technology, versus the simple mixing and measuring technology of the Dilute and Dispose approach. Pg. 29	This ignores the cost of security, the cost of transportation, and the impact on WIPP. The assertions in this argument reinforce the mistaken belief that the costs and risks of what the Dilute and Dispose Option does to WIPP are not part of the Dilute and Dispose Option. The assumption is also made that there are no significant consequences from violating the PMDA on the cost, schedule and risks of this program. The Red Team focused on the narrow comparison of mixing oxide powders together and throwing them away vs making a fuel assemble that makes power; a specious argument.

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78	While the NAS report adopted a SFS as discussed at the beginning of this report, and the irradiation component of the PMDA requires spent MOX fuel to no longer be weapon-grade (i.e., the Pu-240 to Pu-239 ratio should be greater than 10%), it was also clear in the NAS report that similar chemical, physical, and radiological barriers to proliferation should be acceptable as well. Consistent with this, the Russians agreed in the original PMDA to allow the U.S. to use immobilization for a portion of the inventory, which involves no isotopic dilution but achieves all three of the barriers discussed by NAS. As pointed out in the PWG report, the Dilute and Dispose Option would implement two of these three barriers (chemical and physical). Pg. 29	This reflects the U.S. viewpoint that the most important aspect of the Pu Disposition program is to prevent non-weapons State organizations from gaining access to the surplus weapons Plutonium. This has never been the Russian Federation's concern. They are concerned with the U.S. cheating and putting the plutonium back into the arsenal. Therefore, it is merely the Red Team's opinion that, since the Dilute and Dispose Option is good enough for our concerns, it would be acceptable to the Russian Federation. In fact, the Russian Federation only accepted immobilization for a minor subset of the plutonium. The major disposition has to be isotopic destruction of the plutonium. The Dilute and Dispose Option is more likely to be the cause of a further erosion in the arms reduction cooperation between these two cold war enemies.
79	Much has been, and will continue to be, said about the risk of unacceptability of this option from the standpoint of meeting the letter and intent of the PMDA. However, as discussed in Executive Considerations, the Red Team believes that based on the history of modifications negotiated to date under the framework of the PMDA it is reasonable to conclude that a new modification could be successfully negotiated on the basis of a Dilute and Dispose approach, provided a strong U.S. commitment is maintained with regard to timely disposition. Pg. 29	This statement is naïve and again seems to arise from the cursory nature of the Red Team review.
80	The Red Team conclusion is supported by the following considerations: ... • The U.S. has previously accommodated Russian national interests in an amendment to the PMDA. Pg. 29	So, the Red Team believes that current Russian political regime will not try to gain unfair advantage over the U.S. during any negotiations to change the PMDA.
81	The Red Team conclusion is supported by the following considerations: ... • International circumstances have changed, such that it now appears appropriate to credit engineering and institutional measures, such as physical security, disposal site characteristics, and safeguards, as essentially equivalent to the barriers provided by SFS. Indeed, the Surplus Pu Disposition SEIS Scoping Comment Summary stated that Dilute and Dispose is “akin” to the SFS, which implies that the U.S. has already made a “sufficiently equivalent” determination. Pg. 29	Yes, international circumstances have changed... for the worse. Russia has invaded two countries, and is currently flying nuclear bombers off our borders while sailing nuclear warships off our coast. There is no reason to assume that the Russian Federation will now accept something that is “sufficiently equivalent” when it could benefit them to deny the U.S.'s request.
82	The Red Team conclusion is supported by the following considerations: ... • Regardless of any path forward, PMDA negotiations must be renewed with the Russians. In the case of the MOX approach, it is already too late to achieve the agreed timeline for disposition of the 34 MT. Based on interviews conducted by the Red Team, the Russians may consider the agreement abrogated on this basis alone, but will nevertheless proceed with Pu disposition as part of their overall nuclear energy strategy (although they may hold weapons grade material aside and use recycled reactor grade MOX). Regardless, the proliferation risk of Russian held material has changed substantially since the PMDA was first negotiated, as previously discussed. This leaves room for negotiation, assuming that overall relations allow cooperative exchange. Pg. 29	If we are making substantial progress toward meeting the goal, there is little need for a renegotiation. If on the other hand, we are changing the fundamentals of the agreement as in the case of Dilute and Dispose, there is little reason to expect this to go smoothly or quickly.

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83	The Red Team conclusion is supported by the following considerations: ... • The U.S. has already successfully disposed of non-MOXable weapons grade Pu at WIPP via a Dilute and Dispose approach, although none of this material can count toward the 34 MT commitment since it was not independently verified by the IAEA. DOE has determined that the blending technique utilized for this material achieves the reduction of attractiveness required to eliminate safeguards as discussed in DOE Order 474.2. Thus, the U.S. will have a reasonable position to enter into negotiations of the PMDA. Pg. 29	This material was not part of the PMDA and so DOE was free to do whatever it considered prudent. This is an irrelevant point.
84	During the first three years of this assumed WIPP recovery period, DOE would need to spend a significant fraction of the expected available annual funding (as much as 75%, assuming annual budgets remain at current levels) on MFFF cessation anyway, and could spend the rest on development of a detailed baseline program plan and funding-capped pursuit of the relatively small capital investments at LANL and SRS needed to support an optimized version of the Dilute and Dispose Option. As the relatively small capital projects are completed, DOE could ramp up oxide production capacity and produce a feedstock backlog to ensure that LANL does not become an unacceptable production limiter. The primary impact due to delayed start, therefore, would be escalation of present-day dollars, but the Red Team asserts that an accurate baseline plan for Dilution and Disposal would involve a relatively long ramp up period anyway, which would prevent WIPP restart from appearing as the critical path. Pg. 30	This seems to imply that the budget for the MOX Program could be seamlessly realigned to support the non-MOX Program. This seems unlikely. Rather, a new budget would need to be developed using all of the Critical Decision processes that the Red Team chose to ignore.
85	Second, the WIPP LWA restricts the total TRU waste volume to 176,000 cubic meters, and to date, 91,000 cubic meters have already been emplaced. Of the remaining 85,000 cubic meters, only about 19,000 cubic meters are considered "unsubscribed", and as previously discussed, the Red Team believes this number may be over estimated (depending of course, on value judgements related to disposal priority). The base Dilute and Dispose Option would require a considerably larger volume allowance, perhaps as much as 34,000 cubic meters. Unless some of the subscribed capacity is re-directed toward support of the Pu Disposition Program, an increase in the volume allowance would require action by the U.S. Congress. But the Red Team posits that the eventual expansion of WIPP capacity will be necessary anyway from the emerging recognition of other TRU waste sources that are not included in the current DOE-EM baseline, irrespective of the needs of the Plutonium Disposition Program, although any such expansion would be subject to cooperation and regulation from the State of New Mexico regardless of the source of waste. Pg. 30	This seems to imply that the State of New Mexico is the licensing agency for WIPP. It is not. It cannot increase the regulatory limit or improve the packaging efficiency of EM waste handling contractor. Moreover, DOE is in possession of 51 MTs of plutonium and is likely to generate more not less.

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86	In any event, well over half of the entire duration of a Dilute and Dispose operation could be completed before facility expansion would be needed. This leaves adequate time to address the national imperative for additional capacity at WIPP (subject to concurrence from the State of New Mexico) without it becoming a critical path item on the Dilute and Dispose schedule, and there are opportunities for mitigating the residual risk discussed below in Section 3.1.2. Similar to the WIPP restart risk, the Red Team does not consider WIPP expansion to be a catastrophic risk to the base Dilute and Dispose approach, even ignoring the potential enhancements (discussed below) which may obviate the need for any legislative or regulatory action to expand WIPP specifically to support a Dilute and Dispose approach. The Red Team notes that long-term WIPP operation and available capacity is also a requirement for the MOX Fuel approach since the WSB would generate TRU Waste as a consequence of MFFF Operations. Pg. 30	This assumes that someone else will pay to expand WIPP. It would require a new NEPA process in addition to a new RCRA process. It also sets the program onto a dead-end course. If WIPP cannot be expanded, there is no disposal path for the existing EM mission or for future TRU from the Defense mission. The cost in terms of delay, and security exposure extends off into the indefinite future.
87	A third regulatory risk relates to the Resource Conservation and Recovery Act (RCRA) Permit for hazardous wastes from the New Mexico Environment Department under which WIPP operates. Based on discussions with personnel at WIPP during the July 13, 2015 visit, large-scale support of the Pu Disposition Program would require one or more Class III permit modifications, which are subject to public involvement. Although such revisions to the permit have been made in the past rather routinely, the recent incidents at WIPP may stimulate heightened public interest, and non-governmental organizations may mobilize in an attempt to prevent the large-scale disposal of excess weapon-grade plutonium at WIPP. Ultimately, any such permit modifications would be subject to State of New Mexico approval and regulation. Pg. 31	New Mexico is only responsible for the RCRA permit for WIPP which would also need to be modified, but the capacity issue was the result of a negotiation at the congressional level of the federal government... not New Mexico.
88	The updating of National Environmental Policy Act (NEPA) present a similar opportunity for public input. The current NEPA action governing the plutonium oxide documentation to support this alternative will dilution effort at SRS is an Interim Action which allows for a limited amount of material to be diluted and sent to the WIPP. The Surplus Plutonium Disposition SEIS allows for a larger amount of plutonium oxide to be diluted and shipped to WIPP, but the Record of Decision for that NEPA action has not been issued. To cover the full scope of diluting 34 MT plutonium oxide and shipping it to the WIPP for disposition would require additional NEPA review. Pg. 31	This Supplemental EIS is specifically NOT for the Pu covered by the PMDA. Therefore, another EIS would be required. Once again, it is assumed that this licensing process is a zero-cost formality and that it results in no net change to operations or to physical systems at WIPP. These are wholly unsubstantiated opinions at this point and should be scheduled and priced against the Dilute and Dispose Option.
89	Increasing the plutonium amount per container would have a direct impact on LCCs of the Dilute and Dispose Option because of the reduction in processing time, and the reduction in drums, shipments, and other logistics associated with the campaign. This opportunity would incur increases in cost from enhanced security requirements consistent with the approach in the PWG report variant to the Dilute and Dispose Option Downblending approach, as depicted as path D1 on Figure 4. One possible benefit of this approach is the volume reduction needed for the final disposal in WIPP. It may be possible to increase loading to a level that negates the need LWA changes to accept the waste from 34 MT of surplus plutonium. Pg. 31/32	True, however this comes at the cost of going through a NRC design, licensing and demonstration testing program which the Red Team chose to ignore. The schedule delay for this "savings" is certain to be substantial because the NRC, if not the Red Team, is certain to be concerned with assuring that densely packaged plutonium remained subcritical throughout all time periods of concern.

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90	The Red Team was surprised to learn that the WIPP RCRA permit requires that the volume considered utilized at WIPP is based on the volume of the external container rather than the volume of the TRU waste within. Thus, it is estimated that 30-50% of the 176,000 cubic meters at WIPP may eventually be consumed by empty space within outer containers. In the limited time available for this study, the Red Team identified no basis for this accounting method in worker or environmental protection or regulatory compliance. Likewise, the total volume restriction that appears in both the RCRA permit and the LWA is not rooted in WIPP's performance assessment. As discussed in our Executive Considerations, the treatment of WIPP as a valuable national asset requires addressing these limitations in cooperation with the State of New Mexico. In combination with enhanced Pu loading discussed in Section 3.1.2.1, proper waste volume accounting may obviate the need for any changes to the LWA. Pg. 32	To change the licensing basis for WIPP that has stood in place for its entire active life as a waste repository is an enormous risk that the Red Team seems to underestimate. This change even if successful would not change the status of the waste already emplaced. This is likely to be a difficult and expensive proposition. Once again, it would need to be added to the cost of the Dilute and Dispose Option.
91	Determining the optimum number of glovebox lines to be added to KAMS may result in more than the two currently envisioned in the base Dilute and Dispose approach in order to reduce project duration and LCC. However, the utility of such an investment requires an understanding of limiting conditions, which is likely to be oxide production at LANL, where limited capital investment may have a greater benefit. If the addition of more than two gloveboxes at KAMS makes sense, the Red Team notes that such an addition of scope should be made early in the design phase to take advantage of economies of scale. Installation of new gloveboxes may be difficult once the supporting infrastructure is installed, and especially after the existing gloveboxes become contaminated. Pg. 33	This is an inconsistency in the Red Team report. In their Executive Summary, they down played the problems with the Dilute and Dispose Option, making it sound extremely simple to execute. Here, they identify some of the engineering and potential construction difficulties required. And in spite of their assurances that this is not a CD-0 situation, they are certain to run into the standard DOE problem of starting a project before they have determined what is to be accomplished and what problems need to be overcome.
92	the Dilute and Dispose approach was intended to meet the established requirements for shipping and disposal. Although far more efficient than the MOX approach, these requirements result in limitations that cause considerable expense, lengthen the time for program execution, and require frequent transportation of nuclear material. Option C from Figure 4 illustrates a potentially simpler option. Under this option, two major changes occur relative to the "base" Dilute and Dispose Option. First, instead of transporting pits to LANL for disassembly and the plutonium to either SRS or LANL for processing, the pits would be processed at Pantex to "sterilize" them to the extent necessary to achieve disposition. Second, instead of transportation to a geologic repository, the sterilized pits would remain at Pantex under monitored storage (Variant C1 in Figure 4). Variant C2 would have the sterilized pits transported to WIPP for permanent disposal, thus achieving equivalency to the Dilute and Dispose alternative. Pg. 33	This is almost a perfect example of Admiral Rickover's letter regarding "paper reactors." This idea is almost totally unworkable. First, "sterilizing" a pit does nothing to its Attractiveness Level; it remains Attractiveness Level B. So, leaving it at Pantex is a continuation of the current situation albeit at the cost of rendering the pit no longer a pit. This is a meaningless point of a new weapon is to be constructed. It would almost certainly be recast and finished for the new purpose. Second, if these pits are shipped to WIPP it is only after a massive security upgrade to WIPP that will adversely impact all future EM shipments and may make them unacceptable because of the prohibition of storing normal wastes with SNM wastes.
93	However, there are also significant challenges to this approach: • The sterilization approach, although viewed by the Red Team as essentially equivalent to Dilute and Dispose (under variant C2), may not be viewed by the Russian Federation as sufficiently compliant with the PMDA; • Under Variant C1, Pantex storage capacity may be insufficient to support this approach absent a capital investment; • Under Variant C2, the acceptability of this material form as a waste that can be transported and disposed at WIPP is not clear. At a minimum, it may require exemptions to obtain safeguards termination, and there may be challenges related to compliance with WIPP waste acceptance criteria. Pg. 34	Well, at least the Red Team acknowledges some of the challenges with the Dilute and Dispose Option, although the assumption that these problems could be solved for free remains. It is clear that this option would eliminate any pretense of meeting the PMDA allowing the Russians to do whatever they chose to do with their pits.... including returning them to their arsenal. I cannot speak to the storage at Pantex, but it is clear that this would destroy WIPP. There is no way a package containing sterilized pits could be stored in the same repository as normal TRU waste from the Weapons Complex cleanup. A significant increase in security would be required.

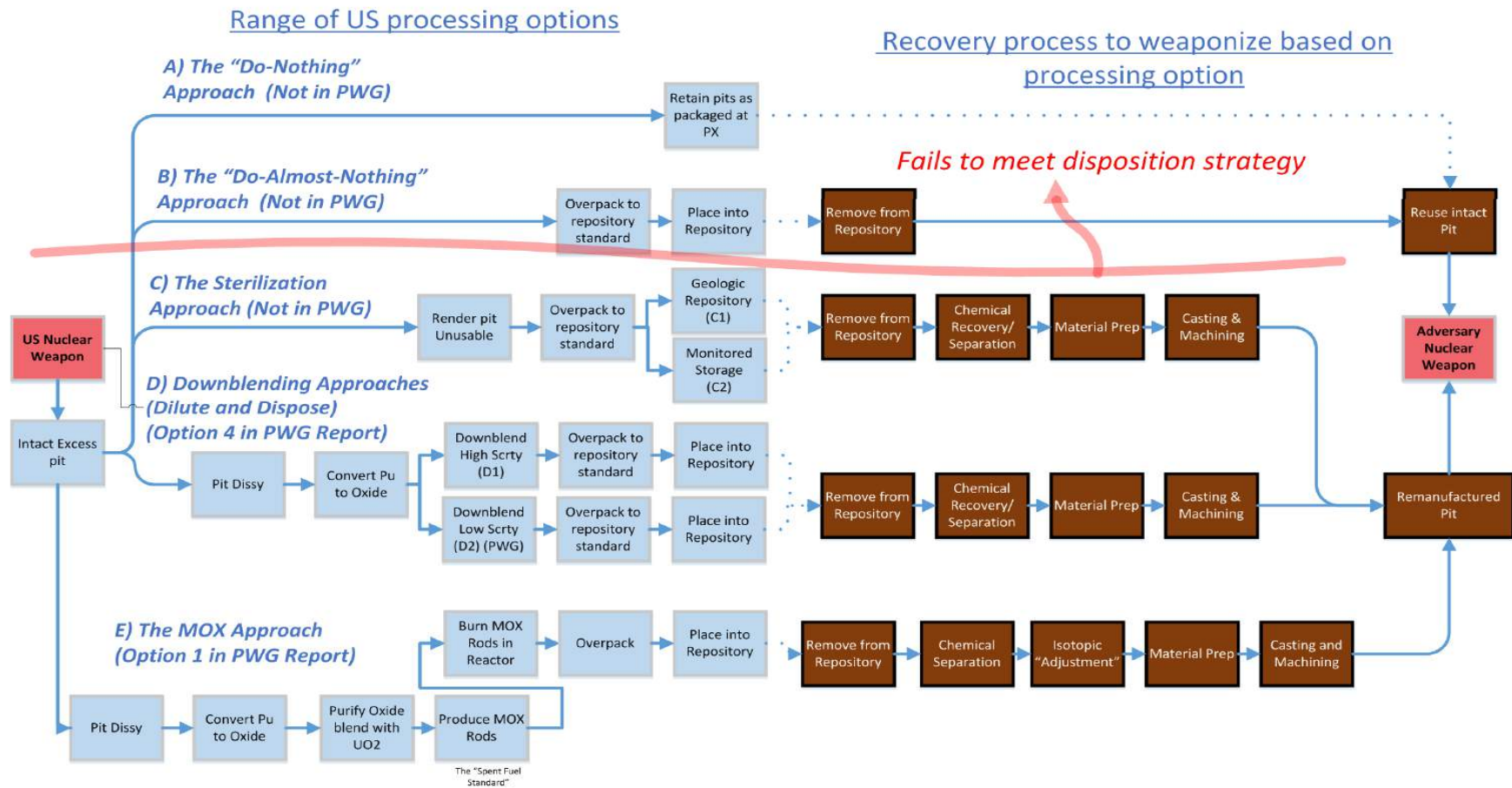
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94	The Red Team has concluded that the nature of the risks associated with the two options puts the MOX approach at greater risk of cost growth throughout its life cycle. Since the technology for Dilute and Dispose is so much simpler, and the overall disposition process so much less complex, the most significant risks associated with this approach could be retired early, as issues associated with WIPP restart and potential expansion and the PMDA are strategized and addressed during a protracted planning phase, while small-scale Pu dilution proceeds using the existing glovebox, NNSA is installing two additional gloveboxes, and the MOX approach is being discontinued. Pg. 34	This continues the obsession with one portion of the Dilute and Dispose Option with the assumption that the costs and risks associated with requalifying WIPP for this waste are borne by some other program. MOX has already experienced its growth and most of its project risk elements are behind it. The Dilute and Dispose Option is essentially undefined because it does not comply with the PMDA, cannot be made to comply with the intent of the PMDA and will significantly destroy the stakeholder support for WIPP. Moreover, it ignores the operational impact on WIPP which must now remain open until 2050 or 2060 well beyond its design life.
95	Table 5 Attribute Comparison Summary	It is interesting to note the superficial nature of the comparison. The MOX Option has more categories with positive attributes than the Dilute and Dispose Option, so the Red Team added multiple arrows to try to indicate that the Dilute and Dispose Option has some intrinsic advantage. In fact, the Technical Viability rating of Dilute and Dispose over MOX is irrational because the MOX process has made hundreds of fuel assemblies and literally hundreds of thousands of pellets for decades. There is no reason to believe that there is any difference. The Cost Effectiveness ranking is meaningless because the Red Team refused to address the cost and risk elements facing the Dilute and Dispose Option, namely the PMDA negotiations and the regulatory and legal issues at WIPP that are certain to rise if that option is pursued. This table was intended to depict the charge given for the Red Team Review comparison, yet it does not depict all the attributes in the charge. The first charge was the "Schedule to begin and complete disposition". This would most likely have provided another red down arrow for the Dilute and Dispose Option. The AS report optimistically predicted a start relatively similar to MOX. However, once the funding constraints are removed MOX completes considerably before the D&D, even without any WIPP program needs.
96	There are no obvious "silver bullets" for LCC reduction, but if DOE decides to proceed with the MOX approach, the replacement of impure feedstocks and the introduction of new technology for Ga removal could enable the elimination of the AP operations and the associated waste management, and substantially reduce the analytical load. This may be an opportunity worthy of additional investigation in light of the potentially significant reduction in operating costs. Pg. 36	The Red Team identified the silver bullet in their Executive Considerations. Eliminate the poisonous relationship between the DOE/NNSA management and the project team. Dedicate adequate funding to support an efficient construction project and support the program by developing an integrated management team approach that guarantees success. It is curious why the Red Team would ignore their own findings.
97	The Red Team agrees with the overall Aerospace conclusion that the worst case Dilute and Dispose Option will never be as expensive as even the best case MOX-based approach, but disagrees with the assertion that the MOX approach becomes essentially unviable with the imposition of a capital cap of \$500M/yr. or less. Pg. 36	This the Red Team has destroyed the DOE's stated reason for abandoning their own project. The costs are not a billion dollars a year and the program is technically viable.
98	While the Red Team recognizes that planning for the Dilute and Dispose approach has just begun, and that MOX suffers from a high degree of familiarity when it comes to characterizing risk, High Bridge nonetheless overstated the capital and operational risks of the Dilute and Dispose Option by equating it to a complicated nuclear construction project at pre-CD-0. The Dilute and Dispose Option utilizes far simpler technology relative to the MOX option and can be performed in modifications to existing facilities that require relatively small capital investments. Pg. 36	The Red Team assumes that EM will pay for the disposal of NNSA in their repository. This is unlikely. While the technical expertise necessary is less for the Dilute and Dispose Option, its regulatory and programmatic risks are huge and unknown. The Critical Decision Process was put into place specifically to avoid the problems posed by the Dilute and Dispose Option.

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99	Furthermore, the Red Team finds that the program risks related to the Dilute and Dispose approach, typically characterized as delayed restart, and/or insufficient space and permission for disposal at WIPP, as well as inconsistency with the PMDA, are not insurmountable given historical precedence (i.e., they are not technical risks associated with the dilution process itself). The Red Team believes that these issues can be solved within a timeframe that need not be on the critical path for the Dilute and Dispose approach. On the contrary, with 19,000 cubic meters of unsubscribed space, there is adequate time to solve the space issue through a combination of means which may not even have to include modification of the LWA, and with perhaps five front end years of MOX demobilization, capital improvements at LANL and SRS, and ramp up of feedstock production, there is sufficient time to engage the Russians and establish IAEA verification. Pg. 36	With the data in the Red Team's possession it should have been clear that the Dilute and Dispose Option would exceed the LWA volume limit by 4,000 cubic meters and would completely eliminate the use of the repository for any continuing EM efforts. They incorrectly assumed that they would be allowed to begin waste disposal activities without approvals from regulatory agencies or a revision to the PMDA. The optimistically assume that all will go well with the Dilute and Dispose Option and that all will go wrong with the MOX Option. This is the sort of thinking that the Critical Decision process was put in place to avoid, yet they are insisting that it is not required.
100	In short, DOE could accomplish a MOX approach to Pu disposition for about \$700M-\$800M/yr. that involves a high level of technical complexity and risk, but would eventually meet the agreed SFS provisions of the PMDA. Or, DOE could sustain current program funding levels and implement the relatively simple Dilute and Dispose approach with reasonable confidence that the political and regulatory risks could be successfully managed. The Red Team believes that the Dilute and Dispose approach has as many opportunities for base improvement as it does true capital and operational risks, but that this option has been tarnished by a perception of catastrophic risks which the Red Team believes can be successfully mitigated in cooperation with the State of New Mexico. Pg. 37	This downplays the risks of the conceptual approach while exaggerating the Risks of a proven process that the government has invested billions of dollars and nearly 20 years of effort to get this far.
101	It should be noted that some of these benefits can be attained using the Dilute and Dispose Option as well, albeit to a lesser degree. Pg. 37	Near-zero compliance is a lesser degree to be sure.

Red Team Report - Figure 4



Red Team Report - Table 5

MOX Option			Dilute and Dispose Option	
Attribute	Rating	Issues	Rating	Issues
Technical viability	↑	• Uses proven technology • Accommodates diverse feedstock • Conservative approach to meet NRC requirements led to very tight controls that could threaten throughput • Operational and facility availability risk associated with automation • Relatively high operations risk • Very complex program to manage with multiple entities, locations, and contractual interfaces • Execution relies on five high-hazard processing facilities after MFFF and WSB are added	↑↑↑	• Uses proven technology • Amenable to diverse feedstock • Straightforward process • No complex equipment involved so maintenance and replacement would be relatively easy • Pu disposition can begin at a low throughput within a matter of months, but will only count toward the 34 MT obligation after IAEA inspection has been integrated. • Multiple opportunities for efficiency improvement • Detailed program baseline needed • Program complexity is moderate with low technology risk • Execution relies on three high-hazard processing facilities
Ability to meet international commitments	↑	• Meets the U.S. SFS commitment under the PMDA • Does not meet PMDA timeline	↓	• Does not meet the letter of the PMDA • PMDA allows for modification to approach if agreed to in writing • PMDA will need to renew negotiations anyway as the timeline will not be met • Surplus Plutonium Disposition SEIS notes Dilute and Dispose is “akin” to the spent fuel standard
Regulatory and other issues	↑	• No significant issues identified with NRC licensing of the MFFF • Potential issue with dual regulation if NNSA adds requirements to the NRC requirements for licensing • Consistent funding to assure continued NRC engagement/progress for long-lead items such as fuel qualification, and avoidance of a downward performance spiral • Could result in a protracted removal of Pu from the State of SC, and a higher potential for associated fines and penalties	↓	• WIPP issues – ◦ restart will occur but may be in the five-year time frame but dilute/dispose program activities could be initiated at a low level of effort ◦ NM Environment Dept RCRA Permit modifications would be needed; permit revisions have been obtained before but public interest may be heightened after the February 2014 incidents • LWA may need to be revised to increase volume of TRU waste allowed in WIPP • NEPA actions are needed to allow for the 34 MT to be dispositioned at WIPP
Cost effectiveness	↓↓↓	• See Section 4.2	↑↑	• See Section 4.2

High Bridge Associates, Inc.

August 21, 2015

**Phase 2 Report
Independent Review of
Aerospace April 13, 2015 LCCE Report TOR-2015-01848
Plutonium Disposition Study Options Independent Assessment**

prepared for the

MOX Services Board of Governors



“Connecting Vision and Plans with Performance and Execution”

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1 EXECUTIVE SUMMARY

High Bridge Associates, Inc. (High Bridge) performed an Independent Review of the Aerospace “Plutonium Disposition Study Options Independent Assessment Phase 1 Report; Option 1 MOX Fuel and Option 4 Downblend (April 13, 2015, No. TOR-2015-01848).” High Bridge key findings and conclusions regarding the Aerospace Assessment Report and methodology include:

1. The Aerospace analysis focused on real year (escalated) dollars to support cash flow planning and budgeting across out years. It did not provide a common denominator current year (unescalated) dollars analysis as a decision making basis for evaluating the estimated costs for Option 1 and Option 4. The analysis methodology used by Aerospace is inconsistent with industry standard practice.
2. Adjusting the Aerospace costs to current year dollars and evaluated errors/omissions, the total project costs for Option 1 and for Option 4 are comparable. The Life Cycle Cost Estimate for Option 1 MOX is approximately \$19B and for Option 4 Downblend is approximately \$20B.
3. Option 1 MOX fully meets PMDA requirements for disposition and does not impact any operations at WIPP or other DOE-EM programs.
4. Option 4 Downblend is not immobilization and does not meet PMDA requirements. Also, Option 4 is not technically downblending in that it does not change the isotopic makeup of the Plutonium as the name suggests. The described process is dilution which clouds the discussion of its merits.
5. Option 4 will exceed the capacity of WIPP and will require a complete redesign/relicensing of WIPP to proceed. The current operational status of WIPP, its backlog of other wastes, its design life of 25 years and the need for Congressional action make selection of Option 4 problematic.
6. High Bridge estimates that the annual costs for MFFF construction are approximately \$650 M from 2016 to 2022. MFFF annual operations costs after 2023 are estimated at approximately \$400M.
7. High Bridge confidence in the Option 1 MOX to-go-costs is greater than that of Option 4 Downblend to-go costs due to the status of Program Maturity. While Downblend technology is relatively mature, there are significant political, programmatic and regulatory uncertainties in the Downblend Program including compliance with the National Environmental Policy Act.
8. The MFFF Project experienced significant cost increases resulting from scope changes caused by the MOX Program consolidating the Pit Disassembly and Conversion Facility and the Immobilization Facility into the MFFF Project. This consolidation reduced the overall MOX Program costs while increasing the MFFF Project costs.
9. The Aerospace Option 1 MOX Fuel 20% annual funding reduction from \$625 to \$500M resulted in a 400% construction schedule duration growth from 6 to 25 years. This constrained funding analysis and outcome were seriously flawed.
10. High Bridge concludes that incorporating the MOX Services 2012 planned re-baselined funding level for the MFFF Project will reduce construction cost by more than \$1 B and will reduce the schedule duration by more than 10 years compared to the Aerospace report.
11. MFFF total production would result in approximately 2,000 MOX PWR fuel assemblies shipped eight at a time in convoys of three trucks for a total of approximately 80 shipments. Option 4 Downblend would result in approximately 97,000 drums shipped 42 at a time in approximately 2,300 truck shipments. This significantly affects transportation costs, safety, and security concerns.
12. The value of MOX fuel in terms of clean energy production vs. waste disposal was not explored by Aerospace. This value is estimated at 285B kilowatt hours of electricity generating an economic value of approximately \$35B compared to the estimated MOX Program cost of \$19B.
13. The decision to change Plutonium Disposition would reverse a policy based on 20 years of study and analysis. Options 1 and 4 are both costly. It should be recognized that the United States / Congress selected the Option 1 MOX Fuel approach in 1997 as the solution for Plutonium Disposition.

2 REPORT OVERVIEW

2.1 Background

On June 10, 2015, the MOX Services LLC Board of Governors (MOX Services) requested High Bridge Associates, Inc. (High Bridge) to perform an Independent Review of the Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Plutonium Disposition Study Options Independent Assessment (**Reference 1**). The purpose of this High Bridge review task is to provide an objective analysis of the approach/process used by Aerospace, and of the results contained in its Assessment of the April 2014 Plutonium Working Group (PWG) Report of Disposition Options for the Option 1 MOX Fuel Project and Option 4 Downblend Life Cycle Cost Estimates (LCCE) (**Reference 2**). The High Bridge Phase 1 Executive Summary and Overview Report was delivered to MOX Services on June 29, 2015. It is included here as **Appendix A**. This August 14, 2015 document is the High Bridge Phase 2 Detailed Report which provides more comprehensive analyses and supporting information for the Phase 1 Report. It confirms and expands the evaluations and conclusions presented in the Phase 1 Report. **Appendix B** provides a Power Point presentation of this August 14 Phase 2 Report.

In summary, this Phase 2 Report is organized to easily extract summary key points or supporting details and analyses. Section 1 provides a 1-page summary of key findings and conclusions. Section 2 provides a 17-page overview with key exhibits. Sections 3 to 7 provide the report analysis details and exhibits. Each section includes an overview subsection that duplicates parts of Section 2 for stand-alone convenience. Section 8 summarizes the nuclear experience for High Bridge and the Review Team Experts.

High Bridge is a planning and project management company providing consulting and project staffing support services to the commercial nuclear power generation, Department of Energy (DOE), petro-chemical, and industrial business sectors. High Bridge experts are intimate with and understand the technical design and regulatory licensing requirements that drive the parameters for program planning and project execution for complex nuclear and process facilities. It has performed hundreds of third party reviews of cost estimates/schedules/risk contingency assessments developed by others. High Bridge organized a Review Team (five dedicated experts and three part time Peer Review experts) of industry experts with an average of 40 years of relevant commercial nuclear power and DOE program experience spanning power generation, plutonium disposition, and complex first-of-a-kind (FOAK) facilities.

2.2 Cost Analysis and Conclusions

Summary and Review Methodology - The Aerospace Report approach and emphasis on escalated real year dollar (RY\$) values presented annual funding constraints that drove schedule durations longer and escalation costs higher. This was inappropriate for an economic evaluation. It created a situation where we were examining “apples and oranges” RY\$ without the common denominator of Present Day dollars needed to perform an economic cost analysis. We found this RY\$ methodology utilized by Aerospace to be technically flawed and not in compliance with nuclear industry standards or with various Federal policy directives for conducting economic evaluations including DOE Order 413.3B (**Reference 3**); DOE Guideline 413.3-21 (**Reference 4**);

Government Accountability Office (GAO) Cost Estimating and Assessment Guide GAO-09-3SP (**Reference 5**); and OMB A-94 Guidelines for Benefit-Cost Analysis of Federal Programs (**Reference 6**).

We were not provided detailed cost estimate, schedule, and risk information to sample and evaluate the details to determine the basis and fidelity of what is reflected in the higher level elements and values being examined. While the U.S. Army Corps of Engineers (USACE) Independent Cost Estimate (ICE) provided some details (**Reference 8**), it did not provide adequate cost estimate and schedule details required to fully understand the basis and outcomes presented in the PWG and Aerospace Reports. High Bridge could not verify that various Aerospace Phase 1 assessed values did not duplicate estimated cost elements already contained in the PWG 2014 report or MOX Services 2012 Re-Baseline Estimate (**Reference 9**). Due to these limitations, High Bridge reviewed the MOX Services 2012 Re-Baseline proposal to understand the starting point and basis for our review of the Aerospace Report, as well as to understand the outcomes presented in the PWG Report of Disposition Alternatives.

- In reviewing the MOX Services 2012 Re-Baseline Detailed Cost Estimate and Schedule for Construction Commissioning and Hot Start Up, High Bridge finds the estimate to complete (ETC)/ estimate at completion (EAC) to be adequate and representing high confidence. It concludes that the scope complexities were well understood after over 20 years of program evolution.
- In reviewing the MOX Services 2008 Operating Cost Estimate proposal, along with National Nuclear Security Administration (NNSA) negotiation values through 2012 (**Reference 10**), High Bridge concludes the LCCE to be conservative and representing high confidence based on 30 years of AREVA experience operating similar facilities at La Hague and MELOX in France.
- High Bridge did not have back up cost estimate details to review for the Option 4 Downblend approach. We assessed estimated values at the higher levels provided and found various DOE reference sources providing insights into construction and operation elements as best as possible.

High Bridge performed de-escalation calculations to convert all Aerospace RY\$ values to FY14\$ values to allow comparison with the PWG report outcomes and to provide the basis for a common denominator evaluation of Options 1 and 4 base, contingency, and escalation cost estimate elements. We performed a formal Monte Carlo analysis of risks in these de-escalated FY14\$. We evaluated scope and impact elements not considered by Aerospace, along with various inconsistencies found in their technical analysis. **Exhibit 2.2.1** provides a summary of the High Bridge evaluation of Options 1 and 4 estimated life cycle costs in FY14\$ compared against the Aerospace evaluation of Options 1 and 4 estimated costs in FY14\$:

Exhibit 2.2.1 – Comparison of Options 1 and 4 Life Cycle Costs

Comparison of Options 1 and 4 Life Cycle Costs (B-FY14\$)				
	Option 1 - MOX		Option 4 - Downblend	
Element	High Bridge	Aerospace	High Bridge	Aerospace
Base Costs	\$ 15.1	\$ 16.7	\$ 13.0	\$ 7.4
Contingency/Risk	\$ 3.2	\$ 7.8	\$ 5.0	\$ 3.8
Changes	\$ 1.1	\$ 2.7	\$ 1.9	\$ 1.9
Total	\$ 19.4	\$ 27.2	\$ 19.9	\$ 13.1

When presented in current fiscal year dollars FY\$ and corrected for inaccuracies, **Exhibit 2.2.1** reflects that High Bridge evaluated costs for Options 1 and 4 are very close. These evaluated Options 1 and 4 cost estimates have an accuracy range within the maturity level of the data.

Option 1 Cost Analysis Summary - **Exhibit 2.2.2** provides an expansion of High Bridge evaluated cost elements for Option 1 MOX Fuel presented on **Exhibit 2.1.1**.

Exhibit 2.2.2 – Option 1 MOX Fuel - High Bridge Evaluation of Aerospace Report Costs

HIGH BRIDGE EVALUATED OPTION 1 MOX FUEL COSTS (M-FY14\$) - ETC Unconstrained)							
	MFFF Construction	Operations	MIFT and Other	Changes Since PWG 2014	Penalties ²	Revenue ³	Total
Base ¹	\$ 4,342.0	\$ 6,255.4	\$ 5,924.2	\$ 1,136.0			\$ 17,657.6
Penalties ²					\$ 400.0		\$ 400.0
Revenue ³						\$ (1,000.0)	\$ (1,000.0)
Operations/Security ⁴	\$ -	\$ (800.0)	\$ -	\$ -	\$ -	\$ -	\$ (800.0)
Subtotal	\$ 4,342.0	\$ 5,455.4	\$ 5,924.2	\$ 1,136.0	\$ 400.0	\$ (1,000.0)	\$ 16,257.6
Contingency	\$ 900.0	\$ 1,070.0	\$ 1,220.0	\$ -	\$ -	\$ -	\$ 3,190.0
Total	\$ 5,242.0	\$ 6,525.4	\$ 7,144.2	\$ 1,136.0	\$ 400.0	\$ (1,000.0)	\$ 19,447.6
Notes							
1	Base Cost of \$18.6B from PWG has \$1.9B contingency in FY14\$; High Bridge did not distribute.						
2	Penalty payment to South Carolina for non-shipment of weapons grade Pu239 from SRS.						
3	Sales of MOX fuel to electric utilities - based on the sale of approximately 2,000 PWR fuel assemblies.						
4	Overestimate of SRS shared infrastructure, for example, MOX Services operational cost estimate of \$50M/year vs HBA estimate of \$15M/year (saving of \$800M on project).						

As reflected above on **Exhibit 2.2.2**, High Bridge evaluated Option 1 scope elements and made base cost adjustments for estimated South Carolina penalties for not shipping Plutonium out of state as agreed with the DOE (**Reference 11**); estimated MOX fuel sales revenue to the DOE; and Mixed Oxide Fuel Fabrication Facility (MFFF) estimated security guard force costs during operation.

With regard to the above MFFF site security guard force estimate adjustment, High Bridge reviewed the Shaw AREVA Annual Operating proposal provided to NNSA in 2008, and negotiated with NNSA through 2012, as a way to understand the makeup of key driver scope

elements comprising the operating program for MFFF (**Reference 10**). This included labor, capital improvements, maintenance contractors, government furnished items, other costs and security. Several of the cost elements within the ETC costs of MFFF plant operations were scrutinized. High Bridge examined the MFFF Site Security Guard Force estimate as this has many reliable industry benchmarks for comparison.

The MFFF Site Security Guard Force during Operations was estimated at \$50.1M (FY08), or 13.6% of the total estimated annual operating cost of \$368.6M (FY08). High Bridge found this to be unrealistically high by a factor of three to four times. It was determined that the Annual Cost Estimate for the Site Security Guard Force was composed of two elements that covered MFFF Site Security and an overhead pro-ratio of overall Savannah River Site (SRS) Site Security Infrastructure costs.

High Bridge understands accounting transfer charge practices for items such as the overall SRS Site Security Infrastructure costs for helicopters, vehicles, personnel, barricades, check points, etc. However, these SRS site-wide infrastructure costs are being incurred now and will be incurred in the future, with or without the MFFF at SRS. These SRS site-wide infrastructure costs are already budgeted and funded elsewhere and do not represent net incremental costs and funds required for the MFFF Project.

High Bridge reviewed Site Security Guard Force cost estimates for several two-unit operating commercial nuclear power plants. Based on these benchmarks and its experience, it concludes that an annual MFFF Site Security Guard Force cost estimate of \$15M (FY08) represents an accurate net incremental value that will require additional funding. This represents a difference and overstated cost estimate of approximately \$35M/year and \$700M (FY08) over the operating life of MFFF. In FY14\$, this represents approximately \$40M/year and \$800M over the operating life of MFFF.

High Bridge believes this Site Security Guard Force example represents scope elements that likely have been treated similarly in the process used by Aerospace and PWG in developing factored and extrapolated estimated costs without going into the details to examine and understand their basis.

Option 4 Downblend Cost Analysis Summary - **Exhibit 2.2.3** provides an expansion of High Bridge evaluated cost elements for Option 4 Downblend presented on **Exhibit 2.2.1**.

As reflected on **Exhibit 2.2.3**, High Bridge evaluated various Option 4 Downblend scope elements and made base cost adjustments for estimated South Carolina penalties for not shipping Plutonium out of state as agreed with the DOE; estimated costs for negotiating a PDMA amendment between the U.S. and the Russian Federation; additional Waste Isolation Pilot Plant (WIPP) estimated costs for facility regulatory/National Environmental Policy Act (NEPA) and design/construction modifications; additional estimated costs for WIPP operation to receive/place Downblend waste forms; and additional estimated costs for transportation of Downblend waste forms in TRUPACT-II containers.

Exhibit 2.2.3 - Option 4 Downblend - High Bridge Evaluation of Aerospace Report Costs

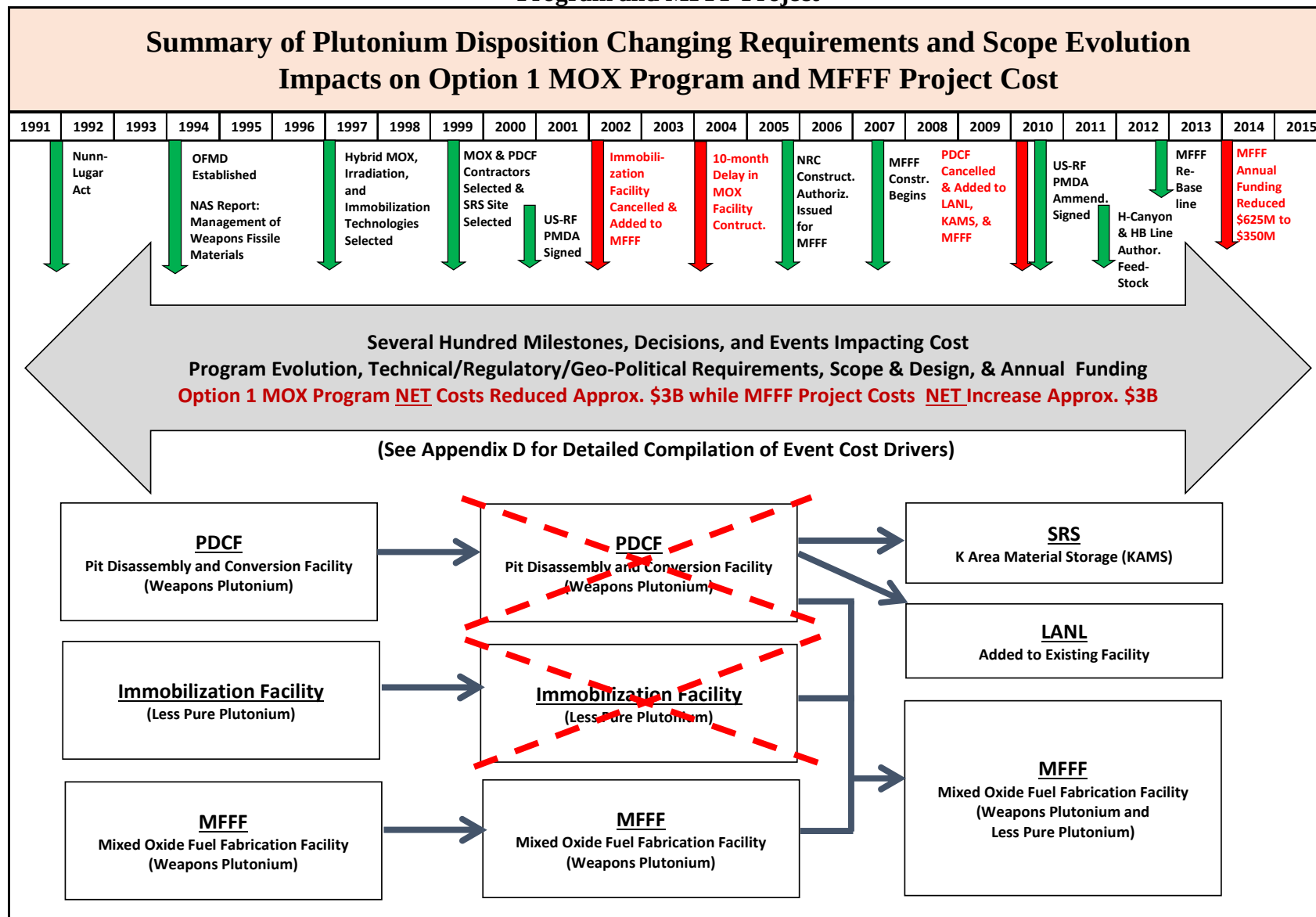
High Bridge Evaluated Option 4 Downblend Costs (M-FY14\$ - ETC)							
	MFFF Termination	WIPP Capital	Operations	"MIFT" and Other	Changes Since PWG 2014	Penalties ²	Total
Base ¹	\$ 1,492	\$ 214	\$ 2,094	\$ 4,444	\$ 1,873		\$ 10,117
Penalties ²						\$ 1,100	\$ 1,100
PMDA & WIPP ³		\$ 863					\$ 863
Operations - WIPP ⁴			\$ 1,640				\$ 1,640
MIFT-Trans/Pkg's ⁵			\$ -	\$ 1,150			\$ 1,150
Subtotal	\$ 1,492	\$ 1,077	\$ 3,734	\$ 5,594	\$ 1,873	\$ 1,100	\$ 14,870
Contingency	\$ 430	\$ -	\$ 512	\$ 4,101	\$ -	\$ -	\$ 5,043
Sub Total	\$ 1,922	\$ 1,077	\$ 4,246	\$ 9,695	\$ 1,873	\$ 1,100	\$ 19,913
Notes							
1	Base Cost of \$8.2B from PWG has \$0.8B contingency in FY14\$; High Bridge did not distribute.						
2	Penalty payment to South Carolina for non-shipment of weapons grade Pu239 from SRS.						
3	High Bridge estimate for PMDA amendments and WIPP revised federal legislation, NEPA, NMED, and CD-0 to CD-4 activities.						
4	High Bridge re-estimate for the resources required for 30 years of WIPP operations (PWG = \$360M vs HBA = \$2,000M).						
5	High Bridge estimate for additional transportation costs (80 for MOX vs 2300 for Downblend Shipments) and material costs (Shipping Containers) for MIFT.						

Both Options are very costly. Given there is a policy to eliminate excess Plutonium and address security and strategic arms reduction as outlined in the Plutonium Management and Disposition Agreement (PMDA), funds need to be made available to follow either Option. High Bridge evaluates Option 1 and the completion of the MOX Program as the lowest cost alternative and best solution of the options presented. It needs to be recognized that the United States / Congress selected the Option 1 MOX Fuel approach in 1997 as the solution for Pu Disposition.

Program Evolution and Cost Impacts - The Option 1 MOX Fuel Program has spanned 25 years of program definition and evolution. This High Bridge Phase 2 report has focused on evaluating the Aerospace April 2015 Assessment of Plutonium Disposition Alternatives. However, it is important to provide a context of Option 1 Program scope and cost evolution as a framework for evaluating where the Plutonium Disposition Program was, where it is, and where it is going regarding evaluated costs.

As with all large and complex FOAK Projects like Option 1 MOX Fuel, many events and parameters shaped cost and schedule outcomes. These included regulatory and technical requirements, program scope evolution, design and procurement status, and funding levels. The Option 1 MFFF has already experienced its major life cycle risk impacts and a near tripling of costs. The Aerospace report projected yet another tripling of the ETC for Option 1. This is inconsistent with the current stage of MFFF completion.

Exhibit 2.2.4 – Summary of Plutonium Disposition Changing Requirements and Scope Evolution Impacts on Option 1 MOX Program and MFFF Project



High Bridge has been tracking Plutonium Disposition Program activities since the mid 1990's. The complexities of cost driving milestones, decisions, and events were very unique. **Exhibit 2.2.4** was developed to provide a Summary of Changing Requirements and Scope Evolution Impacts on Option 1 MOX Plutonium Disposition Costs since 1991.

- A Hybrid Technology approach involving MOX Fuel/Irradiation (for pure Pit Plutonium sources) and High Level Waste Immobilization (for impure non-pit Plutonium sources) was selected for the Plutonium Disposition approach in 1997.
- The approach changed in 2002 with the elimination of the Immobilization of impure non-pit Plutonium sources in high-level waste (HLW) and incorporating this scope into the MFFF design.
- In February 2004, DOE announced a 10-month delay in MOX Facility construction.
- It changed again with the Pit Disassembly and Conversion Facility (PDCF) being slowed down in 2006 and cancelled in 2010, resulting in many process steps being incorporated into the MFFF. This program consolidation was undertaken to reduce costs.

At the time, High Bridge concludes that the evaluated reduced costs were sound. However, various challenges were also created by introducing these impure non-pit plutonium sources into the MFFF design approach that required the addition of an aqueous polishing system. These challenges have been successfully dealt with, and High Bridge finds the ETC/EAC to be conservative, adequate, and representing high confidence. It concludes that the 20 years of scope design evolution complexities of the Program are well understood. It is also important to note that the resulting/current Option 1 MOX Fuel approach represents a net overall cost savings of approximately \$3B compared to the original three-facility approach, even though the MFFF project cost increased approximately \$3B over the past ten years to accommodate this consolidation. This Option 1 program saving was not acknowledged in either the Aerospace or the PWG reports.

Escalation, Funding, and Schedule - High Bridge found the Aerospace analysis using escalated RY\$ to be very confusing, extremely difficult to follow, and flawed in its overall approach to comparing the Option 1 MOX Fuel and Option 4 Downblend alternatives:

- Aerospace used a RY\$ approach to presenting dollar values for Options 1 and 4 with escalation rolled in to all values, rather than presenting dollar values in a constant year "Present Day" value. This approach did not follow industry practice, created a situation of "Apples and Oranges" across the entire report that prevented a common denominator comparison of Option 1 and 4 Alternatives, and distorted/exaggerated the outcomes.
- Aerospace developed two less-than-optimum reduced funding scenarios for Option 1 MOX Fuel (i.e., \$500M/year and \$375M/year) without any schedule basis detail. This significantly impacted their extrapolated resulting longer schedule durations and their resulting escalation calculations. They did not develop a funding/schedule scenario reflecting the optimum approach to completing construction efficiently in a minimal

duration, similar to that provided in the 2012 MOX Services Re-Baseline proposal to NNSA (i.e., \$625M/year).

- Aerospace utilized inconsistent and flawed assumptions in calculating the impacts of reduced funding which is inconsistent with industry standards and practice. They developed escalated costs but did not escalate funding to match. This resulted in a ratcheting of the schedule durations even longer with fewer dollars available to support production work activities and estimated costs being driven even higher.

High Bridge has performed over 100 Independent Cost Estimate/Schedule/Risk Assessments of large nuclear and FOAK projects. Consistent with various commercial industry guidelines outlined by the Project Management Institute (PMI) and the Association for the Advancement of Cost Engineering (AAECE), High Bridge has always performed economic evaluations of alternatives using a Net Present Value (NPV) approach to establish a constant fiscal year basis for providing a common denominator basis for comparison. Again, the accepted industry practice is to evaluate an investment decision based on constant year dollars.

The above methodology utilized by Aerospace to evaluate estimated costs for technology alternatives is not in compliance with nuclear industry standards or with various Federal policy directives including DOE Order 413.3B; DOE Guideline 413.3-21; GAO Cost Estimating and Assessment Guide GAO-09-3SP; and OMB A-94 Guidelines for Benefit-Cost Analysis of Federal Programs.

Aerospace did not present an Option 1 MOX Fuel case for planned optimum funding consistent with the MOX Services 2012 Re-Baseline proposal of approximately \$625M/year spanning a six year construction and commissioning duration. Figure 12 on page 23 of the Aerospace report reflects an overall evaluated construction and commissioning duration of approximately 25 years with a \$500M/year (RY\$) funding case. High Bridge concludes this Aerospace analysis resulting in a 400% schedule duration increase (i.e., 6 years becoming 25 years) based on a 20% annual funding reduction (i.e., \$625M/year becoming \$500M/year (RY\$)) is flawed. High Bridge concludes that the Aerospace analysis did not reflect an understanding of industry practice, and large nuclear project construction management parameters and requirements to perform work efficiently and effectively.

2.3 Risk, Opportunity, and Contingency

The High Bridge initial review of the Aerospace report led to the observations that the evaluated discrete risks were understated for Option 4 and overstated for Option 1. Based on these observations High Bridge performed an in-depth review of the risks discussed in the report. Aerospace risk (and opportunity) tables for both options can be found on page 44 (Option 1 – MOX Fuel Risk Table) and page 45 (Option 4 Downblend Risk Table).

High Bridge computed the contingencies from the Monte Carlo analyses in FY14\$ to produce a common basis of comparison between cost estimates for Option 1 and Option 4. Except for a few items eliminated or added (discussed in more detail below), High Bridge accepted the risks items listed in the Aerospace report tables on pages 44 and 45 (**Reference 1**).

Several of the Low (Min) and High (Max) Financial Impact (FI) values from the risk items in the Aerospace report were used in the High Bridge Monte Carlo analyses. These financial impacts were de-escalated from the time period of expected impact to FY14\$. Additionally, High Bridge agreed with the Probability of Occurrence (POO) assumed by the Aerospace report in approximately one-third of the risk items. In those risk items that were not used, either the FI or POO, values were assigned based on the experience of the High Bridge team members.

High Bridge performed a Monte Carlo analysis of the discrete risks using a slightly modified version of commercial software, @RISK, from the Palisade Corporation. A double triangle distribution was used to model the probability distribution of the risk ranges, and 10,000 iterations were carried out to define the final total impact distribution.

The 85% confidence contingency value from the independent Monte Carlo analyses performed by High Bridge on Option 1 was **\$3.2B** and Option 4 was **\$5.0B**. These values compare to the Aerospace values of **\$7.8B** and **\$3.8B** as shown above in **Exhibit 2.2.1**. All the values are in FY14\$. Details of the Option 1 analysis can be found in the following sections (**Section 4.2** Option 1 MOX Fuel, **Section 4.3** Option 4 Downblend, and **Appendix F**).

High Bridge performed Monte Carlo analyses of the discrete risks reported by Aerospace for both options using the @RISK software. The Aerospace RY\$'s for the Min and Max values were de-escalated to FY14\$ and the Aerospace POO's were used in the analyses. The resulting 85% confidence contingencies from the analyses were **\$9.80B** (FY14\$) for Option 1 MOX Fuel and **\$4.14B** (FY14\$) for Option 4 Downblend. These compare to the Aerospace Monte Carlo analyses of **\$7.80B** for the Option 1 MOX Fuel and **\$3.80B** for the Option 4 Downblend indicating that the Monte Carlo analyses by both companies yield similar results for the same set of inputs.

2.4 Option 4 Downblend and Impacts on WIPP

Much of the 25-year history of the design and construction of the WIPP was devoted to developing a better understanding of the size of the Transuranic Waste (TRU) waste problem and of the geological subtleties of this deep salt deposit. The final design was summarized in the Waste Isolation Pilot Plant Land Withdrawal Act of 1992 which authorized the placement of waste in the completed facility. Among other requirements, it sets the maximum size of the WIPP repository at 6.2 million cubic feet or approximately 175,600 cubic meters of TRU waste. Nothing in the law or in any of the licensing submittals has mentioned the possibility of disposing of weapons plutonium in WIPP, which suggests at least the possibility that an unanalyzed licensing issue may exist.

The Aerospace report includes the following passage on page 8:

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 the Downblend Options (**Reference 1**).

Not assessing these technical parameters reflects a deficiency in the Aerospace analysis process. Since these options are both inherently complex and the facilities being used by Option 4 are beyond their design life and need to be repurposed for that option, the failure to assess the scientific and technical aspects of the two options is a significant flaw in their methodology.

An intrinsic assumption of the Aerospace analysis of Option 4 Downblend is that there is adequate capacity at WIPP for the additional loading of TRU represented by 34 metric tons (MT) of excess weapons plutonium. Moreover, it is further assumed that no other organization will be using that available capacity. In fact, WIPP was created to support the DOE Environmental Management (EM) mission to clean up the legacy TRU wastes from the Cold War weapons production. This is an important effort that can only be accomplished with unimpeded access to WIPP.

In the Aerospace report risk table for Option 4 (**Reference 1**), risk 12 is entitled “Exceed Downblend Repository TRU Allowable Storage Volume.” It lists a probability of 10% with a predicted impact of \$22M. Risk 13 on the same risk table is entitled, “Need for Additional Storage Volume.” It lists a probability of 25% with a predicted impact of \$12.7M. It is difficult to reconcile these two risks and even more difficult to understand how they may have been quantified without at least examining the physical constraints of WIPP. In the absence of any technical rigor in the analysis, Aerospace has assumed that there is:

1. Space available for the waste to be placed in WIPP not needed for anything else, and
2. Only 34 MT of surplus weapons plutonium.

As demonstrated in **Section 5.3** below, the existing capacity of WIPP will be exceeded by using Option 4 Downblend for the 34 MTs of surplus plutonium. Moreover, DOE/NNSA is not in possession of 34 MTs of surplus weapons plutonium; they are in possession of over 51 MTs of surplus weapons plutonium. So, the Risk Assessment by Aerospace of the Option 4 Downblend alternative is flawed by the approach they used that did not evaluate the technologies. The probability of Option 4 exceeding the volume allowed at WIPP is 100% and the cost would be significantly greater than the \$22M and the \$12.7M risk impacts cited in the Aerospace report.

Exhibit 2.4.1 provides a summary analysis of WIPP capacity and projected loads based on the latest TRU Waste Projection, the latest excess Plutonium projection of 51 MT, and a realistic allowance for future growth of projected loads of TRU-waste and Plutonium. It reflects that the legislated volume capacity of WIPP will be exceeded by approximately 49% and that the 1,000-year Curie inventory will increase by 843%.¹

Based on this capacity and projected waste inventory load analysis, the WIPP facility will require a NEPA Amendment, Revised Legislation, and a full Critical Decision (CD) 0 through 4 process in accordance with DOE Order 413.3. High Bridge also concludes that the resolution of WIPP corrective actions to address the 2014 incidents will require approximately five years to complete. Additionally, High Bridge believes that the PMDA Amendment with the Russian Federation needs

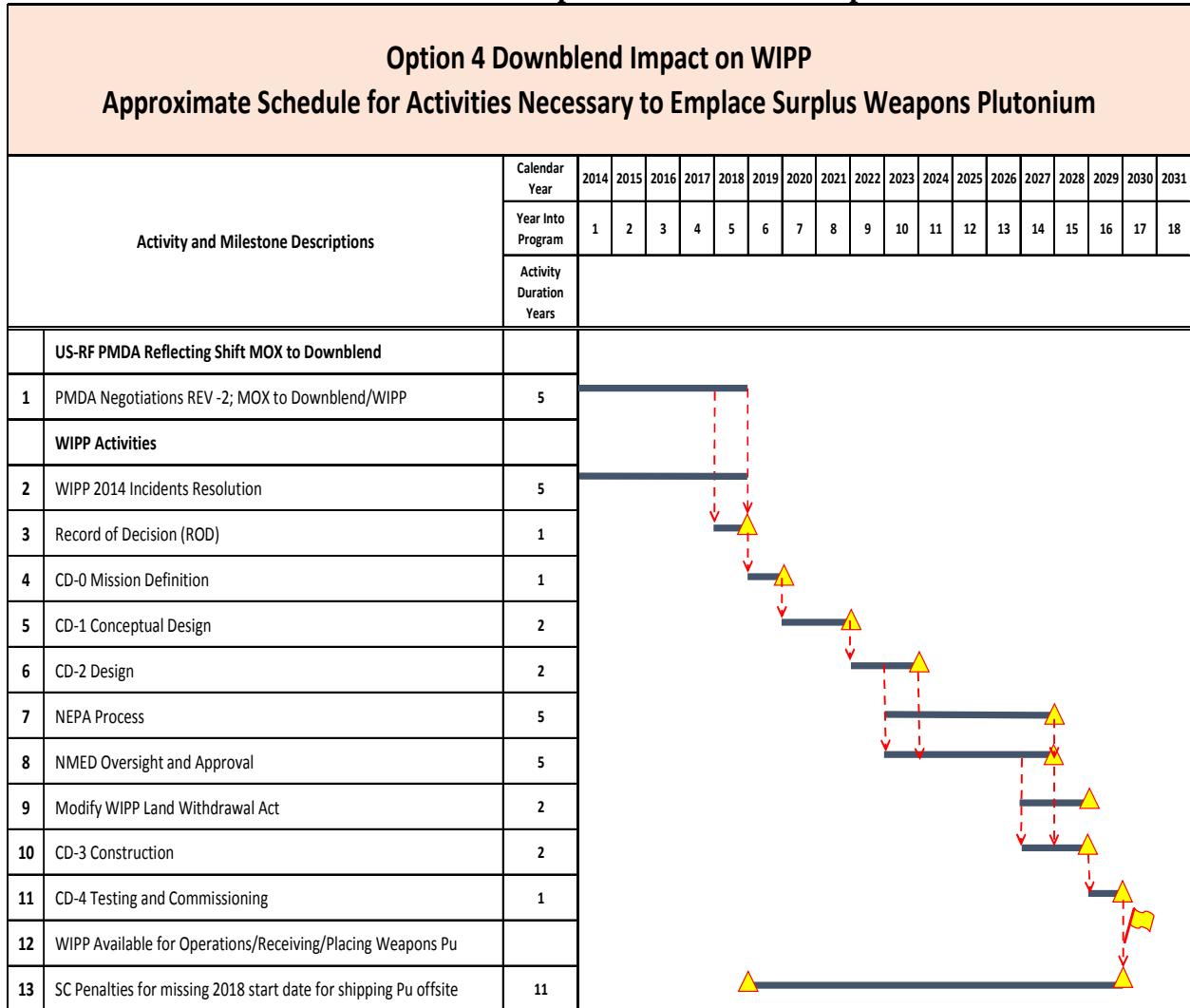
¹ The Waste Isolation Pilot Project Land Withdrawal Act does not have an overall curie limit for TRU. It only has a curie limit for remote handled TRU to ensure that WIPP does not become a de facto High-Level Waste repository. This increase was measured against the value used to calculate the 1000 year source term for the NEPA FEIS.

to be completed prior to beginning this NEPA and CD process. As reflected in **Exhibit 2.4.2**, these steps add approximately eleven years to the WIPP availability date to begin receiving plutonium under the Option 4 Downblend approach.

Exhibit 2.4.1 – WIPP Capacity and Projected Loads

WIPP Facility Capacity and Projected Loads TRU Waste and Plutonium Approximate Impacts						
Capacity and Projected Load Element		Cubic Meters	Cubic Meters/ 55 Gal. Drum	Number of 55 Gal. Drums	Plutonium Metric Tons	Curies *
1	Capacity per 1992 Land Act Law Low Level & Mixed TRU Waste	175,600	0.208	844,231	0	539,000
2	2014 DOE EM TRU Waste Projection	156,000	0.208	750,000	0	0
3	2015 NNSA Excess Plutonium Projection	<u>30,300</u>	0.208	<u>145,673</u>	<u>51</u>	<u>2,300,000</u>
4	Sub Total Projection	186,300	-	895,673	51	2,300,000
5	25% Freeboard for Future Identified Waste Projection	46,575	0.208	223,918		575,000
6	Allowance for additional surplus weapons plutonium	29,112	0.208	139,960	49	2,209,804
7	Capacity Basis for NEPA, New Mexico, & CD-1 to CD-4 Amendments	261,987	-	1,259,552	100	5,084,804
8	Approximate % Increase in Capacity/Load	49%	-	49%		843%
* - These are 1000 year curies, i.e., curies remaining in 1000 years.						

Exhibit 2.4.2 – Schedule for Option 4 Downblend Impact on WIPP



As reflected in **Exhibit 2.4.2**, there will be penalties owed the State of South Carolina for 11 years for missing the start date for shipping plutonium out of state.

Exhibit 2.4.3 provides a cost estimate for the activities and steps reflected on **Exhibit 2.4.2**. High Bridge concludes that approximately \$2.0B in additional costs will be incurred to follow the Option 4 Downblend approach. High Bridge considers this as a 100% certainty to occur and added this to the estimated base costs for Option 4.

Exhibit 2.4.3 – Option 4 Downblend Impact on PMDA, WIPP, and SC Fines

Option 4 Downblend Impact on PMDA, WIPP, and SC Fines Approximate Cost Estimate			
	PMDA, and WIPP Activities/Steps	Cost Estimate	Basis
	<u>PMDA Amendment Activities</u>		
1	PMDA Negotiations REV -2; MOX to Downblend/WIPP	\$83,750,000	Average 40 FTE for duration and a Team of 10 National Lab SMEs
	<u>WIPP Activities</u>		
2	WIPP 2014 Incidents Resolution	\$360,000,000	Current published estimate is the Low Est. Worst case estimate offered a public meeting by DOE of 5 years is the high (not included in the Total Option 4 Impact below)
3	Record of Decision (ROD)	\$2,406,250	Staff and DOE manager's time to organize and obtain necessary approvals for ROD - 5 FTEs
4	CD-0 Mission Definition	\$11,811,250	DOE management team procuring the services of a Contractor to develop the technical basis
5	CD-1 Conceptual Design	\$28,875,000	DOE management team overseeing the services of a Contractor that prepares the CDR
6	CD-2 Design	\$61,875,000	DOE management team overseeing the services of a Contractor that prepares the design packages
7	NEPA Process	\$326,562,500	DOE management team overseeing the services of a Contractor that prepares the design packages
8	NMED Oversight and Approval	\$18,906,250	5 NMED officials and a 10 person consultant firm 1/2 time
9	Modify WIPP Land Withdrawal Act	\$6,875,000	DOE Officials and staff briefings with staffers and legislators
10	CD-3 Construction	\$284,375,000	DOE management team overseeing the services of Contractors that prepare the procurement packages and actual construction services
11	CD-4 Testing and Commissioning	\$37,109,375	DOE management team overseeing the services of Contractors that conduct the startup testing and the readiness reviews to begin operations with surplus weapons Pu.
12	WIPP Total	\$778,795,625	
13	SC Penalties for missing 2018 start date for shipping Pu offsite	\$1,100,000,000	\$100M/yr starting in 2019
	Total Option 4 Impact	\$1,962,545,625	

The Aerospace report identified the increase in the cost of WIPP operations for placing Option 4 Downblend plutonium at WIPP is \$360M and provided no backup. The increase in the cost of disposal operations at WIPP for the surplus weapons plutonium would be proportional to the number of extra shipments that result from Option 4 operations. Using 350 Fissile Gram Equivalents (FGE) per criticality control overpack (CCO), it would take more than 97,000 drums to package all of the plutonium. At 42 CCOs per shipment (i.e., three TRUPACT-II overpacks per shipment), this converts to approximately 2,300 shipments. If SRS could ship 17 shipments per week, it would take about 2.6 years to emplace the entire 34 tons of plutonium at WIPP.

The National TRU Waste Management Plan prepared by the DOE Carlsbad office provided an estimate of operational costs for WIPP (**Reference 14**). It identified the cost for disposal of TRU over the life of the EM TRU program. The values vary yet the projection for the disposal costs, not including transportation costs, are within 95.6% of the cost of preparing the waste packages. The resulting approximate WIPP costs for waste placement and for other mission critical activities is 95.6% of the Option 4 Downblend costs of \$2.094B or approximately \$2.0B. This would represent a net increase of nearly \$1.64B more than the Aerospace report predicted.

2.5 Value of MOX Fuel Sales, Clean Energy

The Aerospace Report identified no net income credit for the Option 1 MOX Fuel alternative, provided little discussion of the status, and exhibited limited understanding of the fuel sales process and approach. The Aerospace report provided no analysis or identified cost benefit for the economic contribution to the gross national product (GNP) or Clean Energy Production. High Bridge finds this lack of analysis to be an important omission.

MOX Fuel Sales - The goal of the MOX project is to transmute the isotopic makeup of the surplus weapons plutonium into a form that makes it less usable by a weapons state for weapons. This is done by incorporating the plutonium into fuel for use in commercial nuclear reactors. The surplus stockpile can produce approximately 2,000 pressurized water reactor (PWR) fuel assemblies. AREVA began MOX fuel marketing activities in the 2009 timeframe and was successfully building a list of interested nuclear operating companies. By 2013, AREVA had several letters of intent or expressions of interest and several more being developed to strengthen their negotiating position for future discussions.

The core of a nuclear reactor is “reloaded” every 18 or 24 months² and about a third of the total core is replaced with fresh fuel assemblies. Overall, the 34 MT of plutonium would produce approximately 30 core reloads for a 1,200 megawatt electric (MWe) reactor. The approximate cost for a replacement uranium fuel reactor core is \$100M. The value of the displaced uranium fuel assemblies would cost approximately \$3B. Assuming a 20% discount to the nuclear utilities and a 40% to 50% cost of materials supplied by AREVA³, the net revenue for the U.S. Treasury for fuel sales would be approximately \$1B over the life of the project.

Contribution to GNP and Clean Energy - An ancillary benefit of the MOX program is the production of clean, green-house gas free, electrical energy. A nuclear reactor currently “burns” its nuclear fuel at a rate of 45,000 MW-Days/MT. The 34 MTs of surplus weapons plutonium will result in approximately 875 MT of fuel. This fuel would generate 15,300 MW-Days of electricity. At an average retail price of electricity of \$110 per MW-Hr, that amount of electricity is worth \$35B. This would be done without consuming uranium from the normal fuel cycle, so it would be accomplished with no new mining, milling, converting, or enriching processes. In addition, it consumes depleted uranium that would otherwise be deposited in a radioactive waste dump, would cost the DOE several hundred million dollars in disposal fees, and would pose an environmental risk for years to come. The value to the gross national product of the electricity sales (\$35B) from

² The variability of the existing core designs makes the following analysis qualitative. It assumes a PWR and provides indicative values to make a point. It is not intended to be a rigorous treatment of fuel costs. AREVA will seek to get the most value for the MOX fuel consistent with finding host nuclear operating companies.

³ The MOX project is purchasing the hardware for the MOX fuel assemblies from AREVA to simplify the QA/QC issues associated with fabricating fuel assemblies.

the MOX fuel is greater than the Option 1 capital cost and the total life-cycle cost (\$19.4) in FY14\$. Therefore this investment by the DOE yields considerably greater value than its cost. Unlike Option 4 that produces no trickle-down revenue or GNP contribution and represents a net loss to the taxpayers, Option 1 represents a net improvement in the GNP wealth of the U.S. and creates >10,000 U.S. jobs driven by the availability and consumption of clean electricity. Using the 34 MT of Plutonium converted to approximately 30 nuclear power reactor MOX Fuel core loads will eliminate approximately 335 million tons of carbon emissions, 420,000 tons of NO_x emissions, and 675,000 tons of SO₂ emissions. **(Reference 29).**

Exhibit 2.5.1 below provides a summary comparison of revenue, cost impact items, and value considerations for key elements of the Option 1 and Option 4 Alternatives.

Exhibit 2.5.1 – Comparison of Plutonium Disposition Program Alternatives

Comparison of Plutonium Disposition Program Alternatives Approximate Revenue, Cost Impact, and Value Contribution Metrics MOX Fuel Sales, Clean Energy, and GNP Parameters Option 1 MOX Fuel vs. Option 4 Downblend				
#	Option 1 - MOX Fuel		Option 4 - Downblend	
	Program Element		Program Element	
1	Metric Tonnes of Plutonium Pu 239	34	34	Metric Tonnes of Plutonium Pu 239
2	Pounds of Plutonium Pu 239	74,956	74,956	Pounds of Plutonium Pu 239
3	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved	Yes	No	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved
4	Approximate Product Output Nuclear Fuel PWR Assembly Approx. 8.5" x 8.5" x 13.5' Long Each Containing Approx. 264 Zircalloy Clad Fuel Rods	2,000	97,000	Approximate Waste Form Output Plutonium Diluted/Mixed with Stardust Inert Material in 6" Diameter x 2' Long Container Packed Inside a 55 Gallon Drum
5	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales	\$1,000,000	\$0	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales
6	Approximate Number of Shipments in Casks with 2 Fuel Assemblies/Cask, 4 Casks/Truck, and 3 Trucks/Shipments	80	2,300	Approximate Number of Shipments in TRUPACT-II Containers with 14 Drums/Container and 3 Containers/Truck
7	Approximate WIPP Storage Capacity Volume Consumed	~0	20,200 Cu. Meters	Approximate WIPP Storage Capacity Volume Consumed
8	Approximate Megawatt Hours of Clean Electricity Produced	285 Million	0	Approximate Megawatt Hours of Clean Electricity Produced
9	Approximate Value of Clean Electricity Produced	\$35 Billion	\$0	Approximate Value of Clean Electricity Produced
10	Approximate State/Local Tax Revenues Generated	>\$5 Billion	\$0	Approximate State/Local Tax Revenues Generated
11	Approximate Life Cycle Cost of MOX Program	\$19.4 Billion	\$19.9 Billion	Approximate Life Cycle Cost of Downblend Program
12	Approximate US Jobs Created for 20 Years	>10,000	0	Approximate US Jobs Created for 20 Years
13	Avoided Carbon Emissions	335 Million Tons	0	Avoided Carbon Emissions
14	Avoided NO _x Gas Emissions	420,000 Tons	0	Avoided NO _x Gas Emissions
15	Avoided SO ₂ Gas Emissions	675,000 Tons	0	Avoided SO ₂ Gas Emissions
NOTE: The values identified in this Exhibit are approximate based on the analysis performed during the High Bridge Phase 2 Report Review.				

Overall jobs creation for Option 1 MOX Fuel is estimated at >5,000 job during construction and >2,000 jobs during operation. As identified on **Exhibit 2.5.1** above, it is estimated that >10,000 jobs will result from the consumption of clean electricity produced by MOX fuel.

2.6 Geo-Political Considerations

Significant geo-political risks are associated with abandoning Option 1 MOX Fuel and transitioning to Option 4 Downblend. Replacing the Non-Proliferation partnership embraced in the PMDA between the United State and the Russian Federation could result in undesired outcomes. These issues, risks, and costs were not addressed by Aerospace, either quantitatively or qualitatively:

- a. In the past, the Russian Federation has rejected any option that did not convert weapons Plutonium to a non-weapons transuranic form, including immobilization. The Option 4 Downblend process is less rigorous than the Immobilization Option that was rejected by the Russian Federation in the past. The plutonium isotopic characteristics are not altered to a non-weapons form by Option 4.
- b. Transitioning to the Option 4 Downblend approach would, at best, require many years of negotiation and/or result in the Russian Federation withdrawing from the Plutonium Management and Disposition Agreement (PMDA). This process would delay the Option 4 start and would significantly increase overall costs.
- c. There is no recognition or discussion of the strategic value of Option 1 and its key role in the 2000 PMDA between the U.S. and the Russian Federation.

Option 4 has been mischaracterized as Downblending. The term downblending implies blending non-fissile plutonium isotopes with the weapons plutonium to fundamentally alter its nuclear characteristics as was done in the High-Enriched Uranium (HEU) U-235 Uranium Downblending Program. This is not possible with plutonium since there is no source of non-fissile plutonium available to mix with the weapons plutonium to achieve a similar goal. The Downblending option is actually a simplified Dilution and Immobilization process that would mix small amounts of the plutonium with an inerting agent referred to as “Stardust.” This provides a means of lowering the Attractiveness Level of the dilute plutonium bearing wastes so that the material could be handled as normal contact handled TRU waste. While this approach has been used to lower the Attractiveness Level of plutonium bearing wastes in the past, High Bridge finds that the actual safeguards may require additional security because the resulting waste form is a mechanical mixture that has not altered the chemical or isotopic form of the Plutonium.

In a recent paper written by V. Rybachenkov (a Senior Research Scientist, Center for Arms Control, Energy & Environment Studies, Moscow), he offered a concise commentary regarding Russian Federation expectations and insights concerning the U.S. adopting Option 4 Downblending. From his perspective, the Russian Federation would want U.S. concessions for option 4 to be acceptable. It is not clear what these concessions could be but in the past the Russian Federation has made statements that they would like to operate their fast reactors in a "breeding" configuration while burning the PMDA 34 MT of weapons plutonium. This would move the Russian Federation and the U.S. away from a strong Non-Proliferation Partnership founded on the PMDA.

Former Secretary of Energy Bill Richardson (under President Clinton at the time of PMDA execution in 2000) recently had an Op-Ed news clip in January 2015 (See **Appendix E**). He emphasizes the critical strategic importance of the PMDA and MOX Project in maintaining a dialogue with the Russian Federation and continuing a Non-Proliferation Partnership.

The PMDA is an important International Agreement. The Aerospace Report discusses the PMDA in Section 9 but only mentions that it will need to be discussed with the Russian Federation. It downplays the difficulty and time required to negotiate a mutually satisfactory PMDA Amendment that maintains a geo-political partnership. The first revision to the PMDA completed in 2010 addressed fairly mundane issues and yet it required five years of effort to finalize. This revision involves extremely contentious issues that are likely to take an extremely long time to reach agreement, or to result in both parties abandoning the PMDA as unworkable. The Aerospace Report did not address the geo-political value and potential cost impacts, and the PWG likewise did not address this.

In summary, Option 1 MOX is an important DOE program and needs to be evaluated in the greater context that formed it. The DOE proceeding unilaterally in a new direction with the Option 4 Downblend approach when the Congress/United States have evaluated and selected Option 1 MOX Fuel approach could have undesired consequences.

3 COST ANALYSIS AND CONCLUSIONS

3.1 Overview

The Aerospace Report approach and emphasis on escalated real year dollars dollar values presented annual funding constraints that drove schedule durations longer and escalation costs higher. This was inappropriate for an economic evaluation. It created a situation where we were examining “apples and oranges” RY\$ without the common denominator of Present Day dollars, commonly referred to as Fiscal Year dollars, needed to perform an economic cost analysis. High Bridge found this RY\$ methodology utilized by Aerospace to be technically flawed and not in compliance with nuclear industry standards or with various Federal policy directives for conducting economic evaluations including DOE Order 413.3B (**Reference 3**); DOE Guideline 413.3-21 (**Reference 4**); GAO Cost Estimating and Assessment Guide, GAO-09-3SP (**Reference 5**), and OMB A-94 Guidelines for Benefit-Cost Analysis of Federal Programs (**Reference 6**). Real year dollars are typically used for cash flow determinations; not in economic decision making evaluations.

Detailed cost estimate, schedule, and risk information to sample and evaluate the details to determine the basis and fidelity of what is reflected in the higher levels elements and values being examined was not provided. While the United States Army Corps of Engineers (USACE) Independent Cost Estimate (ICE) provided some details (**Reference 8**), it did not provide adequate cost estimate and schedule details required to fully understand the basis and outcomes presented in the PWG and Aerospace Reports. High Bridge could not verify that various Aerospace Phase 1 assessed values did not duplicate estimated cost elements already contained in the PWG 2014 report or MOX Services 2012 Re-Baseline Estimate (**Reference 9**). High Bridge reviewed the MOX Services 2012 Re-Baseline proposal to understand the starting point and basis for our review

of the Aerospace Report, as well as to understand the outcomes presented in the PWG Report of Disposition Alternatives.

- In reviewing the MOX Services 2012 Re-Baseline Detailed Cost Estimate and Schedule for Construction Commissioning, and Hot Start Up, High Bridge finds the ETC/EAC to be adequate, and representing high confidence. It concludes that the scope complexities were well understood after over 20 years of program evolution.
- In reviewing the MOX Services 2008 Operating Cost Estimate proposal, along with NNSA negotiation values through 2012 (**Reference 10**), High Bridge concludes the LCCE to be conservative and representing high confidence based on 30 years of AREVA experience operating similar facilities in France (La Hague and MELOX).
- High Bridge did not have back up cost estimate details to review for the Option 4 Downblend approach. We assessed estimated values at the higher levels provided and found various DOE reference sources providing insights into construction and operation elements as best as possible.

High Bridge performed a de-escalation calculation to convert all Aerospace RY\$ values to FY14\$ to allow comparison with the PWG report outcomes and to provide the basis for a common denominator evaluation of Options 1 and 4 base, contingency, and escalation cost estimate elements. We performed a formal Monte Carlo analysis of risks. We evaluated scope and impact elements not considered by Aerospace. **Exhibit 3.1.1** provides a summary of the High Bridge evaluation of Options 1 and 4 estimated costs in FY14\$:

Exhibit 3.1.1 – Comparison of Options 1 and 4 Life Cycle Costs

Comparison of Options 1 and 4 Life Cycle Costs (B-FY14\$)				
Element	Option 1 - MOX		Option 4 - Downblend	
	High Bridge	Aerospace	High Bridge	Aerospace
Base Costs	\$ 15.1	\$ 16.7	\$ 13.0	\$ 7.4
Contingency/Risk	\$ 3.2	\$ 7.8	\$ 5.0	\$ 3.8
Changes	\$ 1.1	\$ 2.7	\$ 1.9	\$ 1.9
Total	\$ 19.4	\$ 27.2	\$ 19.9	\$ 13.1

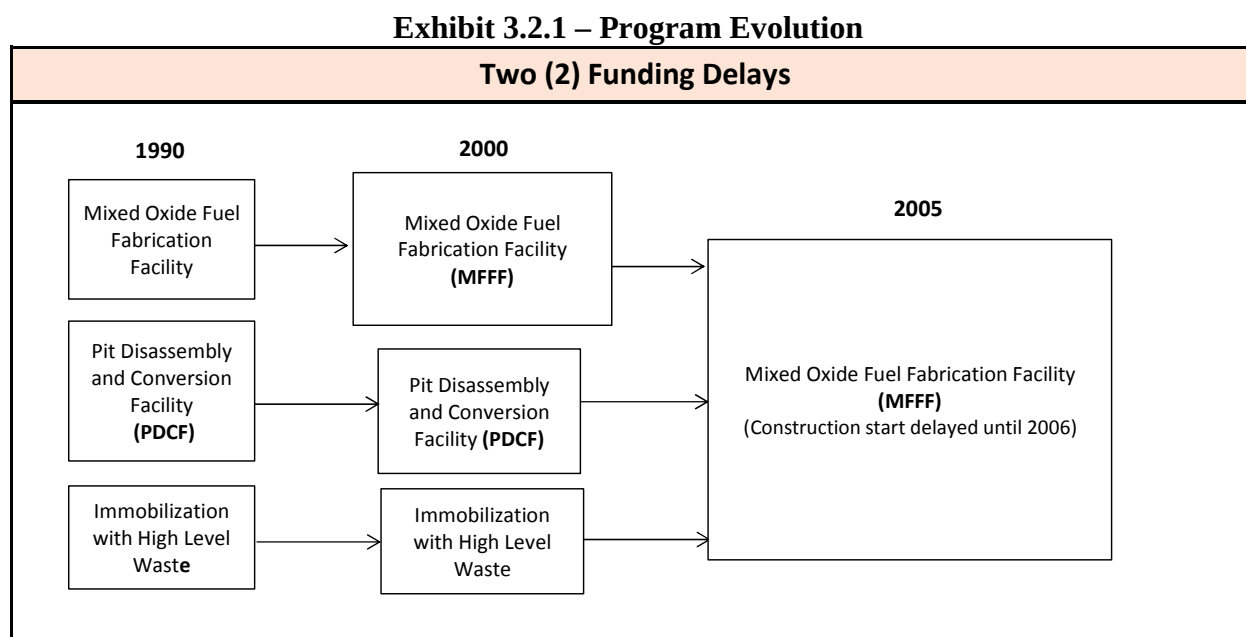
When presented in current FY\$ and corrected for inaccuracies, **Exhibit 3.1.1** reflects that High Bridge evaluated costs for Options 1 and 4 are very close. These evaluated option cost estimates have an accuracy range of within the maturity level of the data. The confidence of Option 1 to go costs is greater than that of Option 4.

3.2 Background and Methodology

Costs associated within the two options reviewed by Aerospace, Option 1 MOX Fuel and Option 4 Downblend included base costs, contingency/risks, funding limits, escalation, and RY\$ costs. These costs were presented at a summary level that was difficult to follow. It depicted key program estimated costs in RY\$. Costs element values for each option had limited granularity, were presented in escalated RY\$, and had significant large programmatic elements. For example, Mixed oxide Irradiation, Feedstock, and Transportation (MIFT) accounted for nearly a third of the total program costs but were not defined. MFFF construction and operations cost were also at a

summary level. The integrated program estimate was noted to be underestimated, yet the granular details were not present that supported this conclusion. Estimated program risk and escalation costs were the focal points of the report.

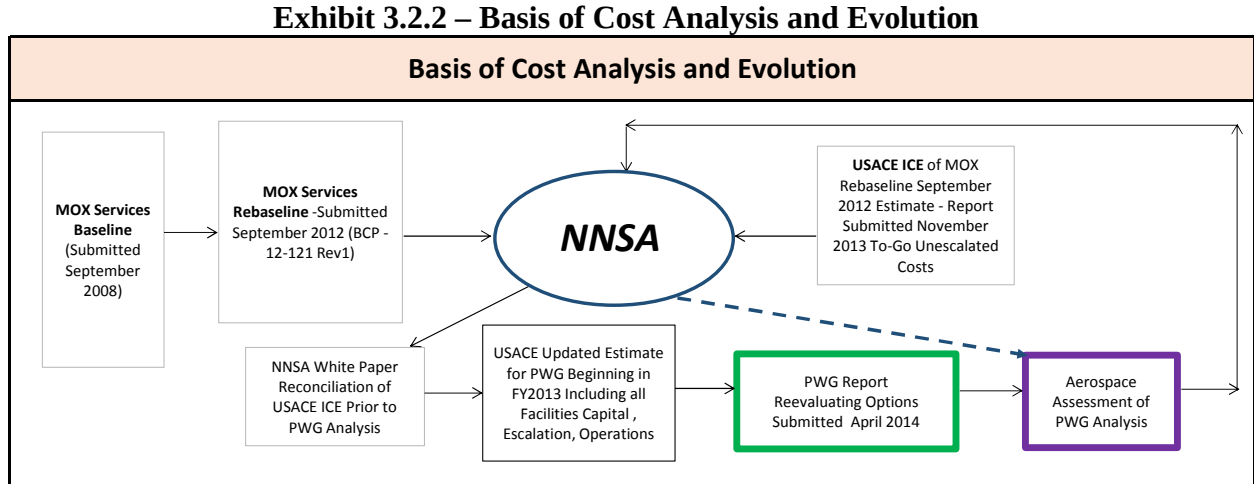
High Bridge had discussions with the appropriate MOX Services personnel and performed in-depth research of the documentation associated with each of the programs within each Option. Since Option 1 is in CD-3 status and is moving to a CD-4 status, High Bridge reviewed the total programmatic scope from inception, as well as the changes, additions, and other program evolutions as Option 1 matured dating back to the early 1990s. The figure below depicts the program evolution.



High Bridge concludes that the 20 years of scope design evolution complexities of the Program are well understood. It is also important to note that the resulting/current Option 1 MOX Fuel approach represents a net overall cost savings of approximately \$3B compared to the original three-facility approach, even though the MFFF project cost increased approximately \$3B over the past ten years to accommodate this consolidation. This Option 1 program saving was not addressed in the Aerospace or PWG reports. These avoided additional programmatic costs are not part of the discussion but should be taken in context as realized benefits of Option 1.

Option 4 is a conceptual program with projects within the program at a development stage referred to as CD-0. Risks for a program with this level of development and detail were understated.-0. Aerospace review of the cost elements provided no additional granularity or bases for cost element estimates. The Downblend concept requires appropriate quantification of risk for contingency determinations based on concept maturity and understanding of the programmatic needs, sound estimating principles and practices, all coupled with detailed documentation of the bases. It was not apparent that Aerospace understood the complexities of a nuclear grade program and project management, or the rigor required in the development of these types of projects.

The High Bridge review was performed in a two-phased approach. Phase 1 concluded with a preliminary report, High Bridge Phase 1 Report (see **Appendix A**). The information provided and subsequent in-depth reviews of the documents associated with the Aerospace report as well as other pertinent information as noted within the High Bridge reference appendices were the basis for the development of the cost evolution findings and conclusions contained within this report section. High Bridge’s initial review of the Aerospace report led to the observations that the evaluated cost in real year dollars led to the flawed conclusion that presented Option 4 in a favorable position over Option 1. The following flow chart, **Exhibit 3.2.2**, represents the basis of the High Bridge cost analysis and reconciliation:



Aerospace utilized the reference data from the PWG, as depicted in the flow chart above (outlined in green), in the cost analysis and manipulated/restrained the cash flow in the out years to derive the various ETC scenarios. These costs were initially part of the effort performed by the USACE for the PWG. The following tables, **Exhibit 3.2.3 and 3.2.4** depict the key cost elements and the escalation, as extracted from the PWG report and utilized by Aerospace for analysis, for Option 1 and for Option 4.

Exhibit 3.2.3 – Summary Cost-To-Go for Option 1 MOX Fuel

Summary Cost-To-Go for Option 1 MOX Fuel					
KEY COST ELEMENT	To-Go Estimate - PWG Analysis (\$M)			To-Go Estimate - Aerospace Report (\$B-RY)	
	ETC FY14 \$'s	USACE Escalation	ETC RY \$'s	To-Go Estimate - From FY14	\$ 22.6
MFFF (Capital)	\$ 5,205	\$ 1,255	\$ 6,460	PWG Analysis Risk	\$ 2.5
Operations	\$ 6,707	\$ 3,551	\$ 10,258	Subtotal	\$ 25.1
MIFT	\$ 4,123	\$ 822	\$ 4,945	Add'l Changes - From AS Table 2 (p.11)	\$ 5.6
				Subtotal	\$ 30.7
Program Integration	\$ 870	\$ 304	\$ 1,174		
WSB	\$ 1,539	\$ 738	\$ 2,277	Add'l Risk - From AS Fig. 8 (p.17)	\$ 8.6
Total w/PWG Risk	\$ 18,445	\$ 6,670	\$ 25,114	Constrained Funding Escalation	\$ 8.2
				Total To-Go Estimate	\$ 47.5

The key cost elements and associated figures on the left of each table are the de-escalated values in FY14\$. The escalation costs are shown separately within the tables. The table was developed to first discern each of the key cost elements then allow for comparison and analysis of each element

independently. The Aerospace report contained only the summary total of \$25.1B RY\$ for Option 1 and \$10.3B RY\$ for Option 4 as shown in the totals respectively. High Bridge extracted the cost elements within each of the options and de-escalated each cost element based on average RY\$ of expenditure and planned year of implementation to FY14\$ for analysis. This is the standard estimating practice referenced in many of the DOE, GAO, ANSI, PMBOK, and ASCE publications. Utilizing escalated cost for comparison adds unaccounted risk into the analysis and is commonly used for cash flow determination only. Escalation is a calculation performed after the base costs are determined. Much discussion and guidance on escalation practices are given in each of the references noted further in this report.

Exhibit 3.2.4 – Summary Cost-To-Go for Option 4 Downblend

Summary Cost-To-Go for Option 4 Downblend					
KEY COST ELEMENT	To-Go Estimate - PWG Analysis (\$M)			To-Go Estimate - Aerospace Report (\$B-RY)	
	ETC FY14 \$'s	USACE Escalation	ETC RY \$'s		
Capital	\$ 214	\$ 73	\$ 287	To-Go Estimate - From FY14	10.3
Operations	\$ 2,094	\$ 912	\$ 3,006	PWG Analysis Risk (N/A)	0
MIFT	\$ 3,457	\$ 710	\$ 4,167	Subtotal	10.3
				Add'l Changes - From AS Table 3 (p.12)	2.9
				Subtotal	13.2
Program Integration	\$ 951	\$ 373	\$ 1,324		
MOX Termination	\$ 1,492	\$ 34	\$ 1,526	Add'l Risk - From AS Fig.9 (p.19)	4.0
WSB	\$ 36	\$ 0	\$ 36	Subtotal	17.2
				Constrained Funding Escalation	0.0
Total w/PWG Risk	\$ 8,245	\$ 2,102	\$ 10,346	Total To-Go Estimate	17.2

Aerospace depicted the Option 1 program with significantly higher risk than Option 4. Option 1 risk costs, as noted in the Aerospace report and shown in the Exhibit 3.2.3 on the right side of the exhibits, totals \$11.1B RY\$ as compared to \$4B RY\$ for Option 4. As shown in the above exhibits, on the right side of the tables, the risk associated with Option 1 and noted in the Aerospace report is considerable, representing a 40% increase to the \$25.1B RY\$ costs. Aerospace concluded, “no cost-risk confidence level in the assessment where the MOX Fuel Program lifecycle cost-to-go is less than the Downblend Option.” This conclusion was largely due to the understated risks associated with Option 4 and the overstated risks associated with Option 1. On the surface this was illogical as Option 1 is well-defined and past the CD-3 milestone while Option 4 is still a conceptual program.

The Option 1 ETC totaled \$47.5B RY\$ with funding constrained to \$500M RY\$ per year including risks and escalation costs, as shown in **Exhibit 3.2.3**. Aerospace further constrained the funding cash flows to \$375M RY\$ pushing the total ETC costs to over \$100B RY\$ and concluded the project could not be completed at this level of funding. Option 4 Downblend had no funding constraints. This \$375M funding level is not considered in the High Bridge analysis.

The Aerospace assessment of the changes since the PWG 2014 Report totaled \$5.57B RY\$ for Option 1 and \$2.87B RY\$ for Option 4. The cost estimates for the changes since the PWG Report and the MIFT costs were not discussed in great detail by Aerospace. When the changes are summed, these RY\$ costs represent over 30% of the total estimated RY\$ costs for Option 1 and over 50% of the cost estimate for Option 4. This lack of detail for such a large portion of the estimated cost is flawed. High Bridge analysis and additional details are provided in **Section 3.8**.

3.3 Option 1 MOX Fuel

High Bridge reviewed the key cost elements within the Aerospace and PWG reports to determine the basis for the estimated costs. This involved extrapolations from the tables within the Aerospace report and additional research coupled with further review and analysis to understand the data. The USACE ICE was the basis for the PWG report. In addition, High Bridge reviewed many documents obtained from CB&I AREVA MOX Services and historical High Bridge documents. **Exhibit 3.3.1** provides an expansion of High Bridge evaluated cost elements for Option 1 MOX Fuel presented on **Exhibit 3.2.3**. The discussions that follow provide insight into the estimate cost elements.

Exhibit 3.3.1 – Option 1 MOX Fuel - High Bridge Evaluation of Aerospace Report Costs

HIGH BRIDGE EVALUATED OPTION 1 MOX FUEL COSTS (M-FY14\$) - ETC Unconstrained)							
	MFFF Construction	Operations	MIFT and Other	Changes Since PWG 2014	Penalties ²	Revenue ³	Total
Base ¹	\$ 4,342.0	\$ 6,255.4	\$ 5,924.2	\$ 1,136.0			\$ 17,657.6
Penalties ²					\$ 400.0		\$ 400.0
Revenue ³						\$ (1,000.0)	\$ (1,000.0)
Operations/Security ⁴	\$ -	\$ (800.0)	\$ -	\$ -	\$ -	\$ -	\$ (800.0)
Subtotal	\$ 4,342.0	\$ 5,455.4	\$ 5,924.2	\$ 1,136.0	\$ 400.0	\$ (1,000.0)	\$ 16,257.6
Contingency	\$ 900.0	\$ 1,070.0	\$ 1,220.0	\$ -	\$ -	\$ -	\$ 3,190.0
Total	\$ 5,242.0	\$ 6,525.4	\$ 7,144.2	\$ 1,136.0	\$ 400.0	\$ (1,000.0)	\$ 19,447.6
Notes							
1	Base Cost of \$18.6B from PWG has \$1.9B contingency in FY14\$; High Bridge did not distribute.						
2	Penalty payment to South Carolina for non-shipment of weapons grade Pu239 from SRS.						
3	Sales of MOX fuel to electric utilities - based on the sale of approximately 2,000 PWR fuel assemblies.						
4	Overestimate of SRS shared infrastructure, for example, MOX Services operational cost estimate of \$50M/year vs HBA estimate of \$15M/year (saving of \$800M on project).						

As reflected above on **Exhibit 3.3.1**, High Bridge evaluated each of the Option 1 scope elements, MFFF Construction, Operations, and MIFT and other to determine the optimum scenarios. Costs adjustments were developed for estimated South Carolina penalties for not shipping Plutonium out of state as agreed with the DOE (**Reference 11**). High Bridge then estimated MOX fuel sales revenue to the U.S. Treasury and estimated MFFF security guard force costs during operation. The base cost analysis utilizes optimum funding scenarios without constrained funding. High Bridge noted and questioned why Aerospace provided no evaluation or mention of the optimum full funding scenarios for Option 1. More discussion of this apparent oversight and flawed logic is within Section 3.7. High Bridge concluded that with full funding the MFFF Project construction costs would be reduced by more than \$1B and the schedule would be shortened by over ten years as compared to the Aerospace report.

Aerospace assessment of the existing PWG estimate for Option 1 provided minimal granularity and limited discussion of the individual key cost elements. As stated in the Aerospace report, “each

of the key cost elements were summarily considered to have been estimated within published GAO cost estimating guidelines, consistent with best practices for grass roots estimating, and sufficiently complete.” As such, only the summary cost was within the report discussions, tables and figures.

The 2012 MFFF Re-baseline cost estimate was reviewed by High Bridge in detail. This included the estimate elements that make up the total capital cost estimate along with the schedule for completion. High Bridge concluded the cost estimate values were sufficiently robust and representative of the project estimate at completion provided the project is adequately funded for optimum completion and not constrained artificially.

Considerable discussion was provided in the Aerospace report regarding funding constraints and the cost consequences associated with each constraint. The introduction of RY\$ only provided a means to place doubt on the ability to complete the MFFF in a timely manner. Much additional discussion of the RY\$ usage, commonly referred to as escalation costs, is contained within this report in the other sections. Project cost estimates identify and contain escalation along with risk related contingencies. These costs are not part of base project estimated costs and provide undetermined risk during analysis.

MFFF Operations cost profiles were used by Aerospace from the PWG report with durations unchanged. Costs were \$1.1B/year RY\$ to \$1.3B/year RY\$ for 16 years, beginning in 2044. Although as depicted in the tables these costs were represented to be \$13.9B RY\$ to \$39.8B RY\$ depending on the MFFF construction cost cap utilized. As with other key cost elements no granularity was provided nor discussed in the Aerospace report other than summary costs and expected yearly average ranges noted in the tables. High Bridge reviewed many of the source documents that were developed for the estimates as well as interviewing the team from CB&I AREVA MOX Services at the MFFF office complex on the SRS site. Additional discussions were held to understand bases and benchmarking that was performed with the operating AREVA facilities (MELOX and La Hague).

The MOX Services 2008 cost estimate for the MFFF Operations is very robust at approximately \$400M/year (FY14\$). The estimate elements within this operations cost are based on lessons learned from benchmarking and SRS infrastructure costs. The costs unduly burdened the MFFF project with SRS overhead expenses. See **Section 3.5**.

MIFT costs were identified in the Aerospace report as key program elements and were defined as \$400M/year RY\$ to \$500M/year RY\$ for a total escalated estimate to complete of \$16.5B RY\$ for each of the two options. As with other cost elements, no further granularity of cost was defined. This cost estimate was the total RY cost estimate for Option 1 and was indicated to be the same for both options. The estimate does not provide much flexibility to cover other Option 4 cost elements as the total Option 4 ETC is 17.2B RY\$. Additional discussions later in this High Bridge Phase 2 Report provide insight into the differences between MIFT for each option.

The Waste Solidification Building (WSB) is substantially complete and in lay-up status. Discussions regarding the cost estimates associated with the facility referenced the LCCE yet were not discussed other than at the summary level. High Bridge agrees with the reports assessment of the WSB Readiness and Lifecycle discussions within the Aerospace report. Costs for completing

the systems and operational processes for WSB have not been quantified and are within the risk and contingency profile.

3.4 Option 4 Downblend

Exhibit 3.4.1 provides an expansion of High Bridge evaluated cost elements for Option 4 Downblend presented on **Exhibit 3.2.4**.

Exhibit 3.4.1 – Option 4 Downblend - High Bridge Evaluation of Aerospace Report Costs

High Bridge Evaluated Option 4 Downblend Costs (M-FY14\$ - ETC)							
	MFFF Termination	WIPP Capital	Operations	"MIFT" and Other	Changes Since PWG 2014	Penalties ²	Total
Base ¹	\$ 1,492	\$ 214	\$ 2,094	\$ 4,444	\$ 1,873		\$ 10,117
Penalties ²						\$ 1,100	\$ 1,100
PMDA & WIPP ³		\$ 863					\$ 863
Operations - WIPP ⁴			\$ 1,640				\$ 1,640
MIFT-Trans/Pkg's ⁵			\$ -	\$ 1,150			\$ 1,150
Subtotal	\$ 1,492	\$ 1,077	\$ 3,734	\$ 5,594	\$ 1,873	\$ 1,100	\$ 14,870
Contingency	\$ 430	\$ -	\$ 512	\$ 4,101	\$ -	\$ -	\$ 5,043
Sub Total	\$ 1,922	\$ 1,077	\$ 4,246	\$ 9,695	\$ 1,873	\$ 1,100	\$ 19,913
Notes							
1	Base Cost of \$8.2B from PWG has \$0.8B contingency in FY14\$; High Bridge did not distribute.						
2	Penalty payment to South Carolina for non-shipment of weapons grade Pu239 from SRS.						
3	High Bridge estimate for PMDA amendments and WIPP revised federal legislation, NEPA, NMED, and CD-0 to CD-4 activities.						
4	High Bridge re-estimate for the resources required for 30 years of WIPP operations (PWG = \$360M vs HBA = \$2,000M).						
5	High Bridge estimate for additional transportation costs (80 for MOX vs 2300 for Downblend Shipments) and material costs (Shipping Containers) for MIFT.						

As reflected above on **Exhibit 3.4.1**, High Bridge evaluated various Option 4 scope elements and made base cost adjustments. These include the following costs:

- South Carolina penalties for not shipping Plutonium out of state as agreed with the DOE
- Estimated costs for negotiating a PDMA amendment between the U.S. and the Russian Federation
- Additional WIPP estimated costs for facility regulatory/NEPA and design/construction modifications
- Additional estimated costs for WIPP operation to receive/place Downblend waste forms
- Additional estimated costs for transportation of Downblend waste forms in TRUPACT-II containers.

The Aerospace assessment of the existing PWG estimate for Option 4 Downblend provided minimal granularity and no discussion of the individual key cost elements. As stated in the Aerospace report, “each of the key cost elements were summarily considered to have been estimated within published GAO cost estimating guidelines, consistent with best practices for grass roots estimating, and sufficiently complete.” As such, only the summary cost was within the report discussions, tables and figures. High Bridge used the de-escalated base costs for each element as shown within **Exhibit 3.4.1**. The additions are explained within the notes section of the exhibit.

Option 4 Downblend is a conceptual program with projects within the program at a development stage. Cost estimates were conceptual and included two variants as the choices. Cost estimates for operations were in a tight band of ranges with discrepancies noted between options. Cost estimates ranged from \$2.2B to \$2.9B, FY14\$ in the PWG report. Aerospace captured the total costs to go at \$17.2B RY\$: Construction and operations costs are \$100M FY\$ to \$200M RY\$; MIFT costs are \$400M RY\$ to \$500M FY\$ (same as Option 1).

Exhibit 3.4.1 above depicts the High Bridge evaluated costs with contingency/risks based on unconstrained funding levels to complete Downblend. This provided a clearer picture for these key decision making cost elements. High Bridge disagrees with the Aerospace report assessment regarding the Option 4, Downblending discussion. The conclusions reached are indicative of flawed logic stemming from an early premise that a complex project with a conceptual basis will have less risk than a mature program. The flawed logic continued with conclusions that the MIFT costs were the same for both Option 1 and Option 4.

The High Bridge confidence in Option 1 MOX ETC costs is greater than that of Option 4 Downblend due to program maturity. While downblend technology is mature, there are programmatic and regulatory uncertainties in the Downblend Program including compliance with the National Environmental Policy Act.

3.5 SRS Infrastructure Cost Considerations

Cost estimate details for Option 1 MOX Fuel scope elements during plant operation were not discussed in the Aerospace Report. The USACE ICE did not provide estimated costs for Option 1 MOX Fuel scope element details during plant operation. Given the approximate 20 year operating period used by Aerospace with a funding limitation of \$500M/year, various scope elements would impact the Aerospace evaluated operating costs.

High Bridge reviewed the Shaw AREVA Annual Operating proposal provided to NNSA in 2008, and negotiated with NNSA through 2012, as a way to understand the makeup of key driver scope elements comprising the operating program for MFFF (**Reference 10**). This included labor, capital improvements, maintenance contractors, government furnished items, other costs and security. Several of the cost elements within the ETC costs of MFFF plant operations were scrutinized. High Bridge examined the MFFF Site Security Guard Force estimate as this has many reliable industry benchmarks for comparison.

The MFFF Site Security Guard Force during Operations was estimated at \$50.1M (FY08), or 13.6% of the total estimated annual operating cost of \$368.6M (FY08). High Bridge found this to be unrealistically high by a factor of three to four times. It was determined that the Annual Cost

Estimate for the Site Security Guard Force was composed of two elements that covered MFFF Site Security and an overhead pro-ratio of overall SRS Site Security Infrastructure costs.

High Bridge understands accounting transfer charge practices for items such as the overall SRS Site Security Infrastructure costs for helicopters, vehicles, personnel, barricades, check points, etc. However, these SRS site-wide infrastructure costs are being incurred now and will be incurred in the future, with or without the MFFF at SRS. These SRS site-wide infrastructure costs are already budgeted and funded elsewhere and do not represent net incremental costs and funds required for the MFFF Project.

High Bridge reviewed Site Security Guard Force cost estimates for several two-unit operating commercial nuclear power plants. Based on these benchmarks and its experience, it concludes that an annual MFFF Site Security Guard Force cost estimate of \$15M (FY08) represents an accurate net incremental value that will require additional funding. This represents a difference and overstated cost estimate of approximately \$35M/year and \$700M (FY08) over the operating life of MFFF. In FY14\$, this represents approximately \$40M/year and \$800M over the operating life of MFFF.

High Bridge believes this Site Security Guard Force example represents scope elements that likely have been treated similarly in the process used by Aerospace and PWG in developing factored and extrapolated estimated costs without going into the details to examine and understand their basis.

3.6 Timeline Discussion

High Bridge has performed over 100 independent cost estimate/schedule/risk reviews for large commercial and DOE nuclear projects in various stages of their life cycle. In all of these reviews, we were provided detailed cost estimate, schedule, and risk information to sample and “drill down” into the details to determine the basis and fidelity of what is reflected in the higher levels elements and values being examined. While the Corps of Engineers (COE) Independent Cost Estimate (ICE) provided some details, it did not provide adequate cost estimate and schedule details required to fully understand the basis and outcomes presented in the PWG and Aerospace Reports.

As discussed in other sections of our report, High Bridge found many areas in the Aerospace Report to be confusing and unclear, particularly with the emphasis of escalated real year \$ dollar values being presented. High Bridge could not verify that various Aerospace assessed values did not duplicate estimated cost elements already contained in the PWG 2014 report or the MOX Services 2012 Re-Baseline Estimate proposal to the NNSA. High Bridge reviewed the MOX Services 2012 Re-Baseline proposal to understand the starting point and basis for our review of the Aerospace Report, as well as to understand the outcomes presented in the Plutonium Working Group (PWG) Report of Plutonium Disposition Alternatives.

- In reviewing the MOX Services 2012 Re-Baseline Detailed Cost Estimate and Schedule for Construction and Commissioning/Hot Start Up, High Bridge finds the ETC/EAC to be conservative, adequate, and representing high confidence. It concludes that the scope complexities of the Program were well understood after over 20 years of program evolution.

- In reviewing the MOX Services 2008 Operating Cost Estimate proposal, along with NNSA negotiation values through 2012 (**Reference 10**), High Bridge concludes the ETC/EAC to be conservative, adequate, and representing high confidence based on 30 years of AREVA experience operating similar facilities at La Hague and MELOX in France along with supporting U.S. Nuclear Regulatory Commission (NRC) requirements.
- High Bridge did not have back up cost estimate details to review for the Option 4 Downblend approach. We assessed estimated values at the higher levels provided and found various DOE reference sources providing insights into construction and operation elements as best as possible..

The Option 1 MOX Fuel Program has spanned 25 years of program definition and evolution. This High Bridge Phase 2 report has focused on evaluating the Aerospace April 2015 Assessment of Plutonium Disposition Alternatives. However, it is important to provide a context of Option 1 Program scope and cost evolution as a framework for evaluating where the Plutonium Disposition Program was, where it is, and where it is going regarding evaluated costs.

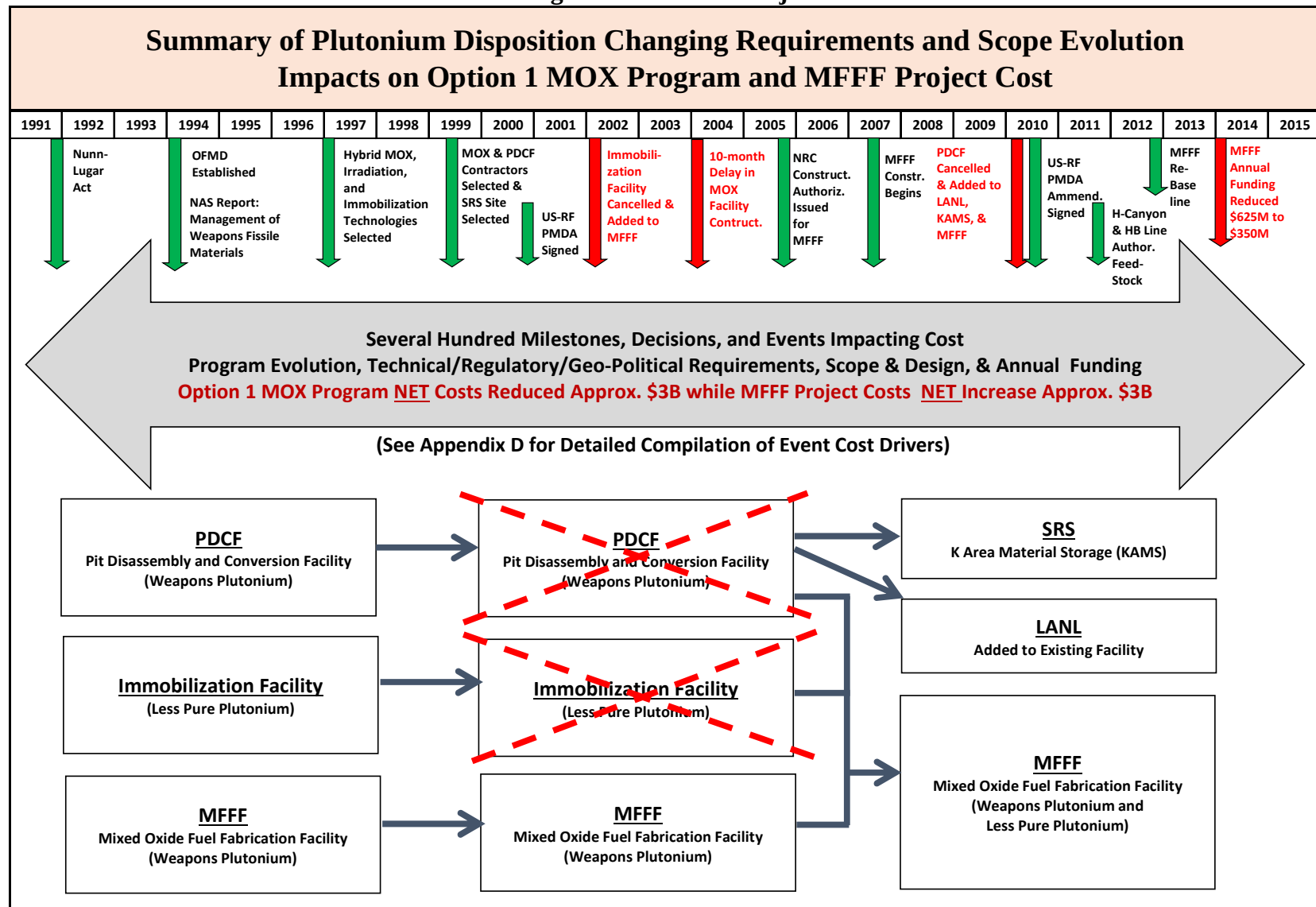
As with all large and complex First of a Kind (FOAK) Projects like Option 1 MOX, many events and parameters shaped cost and schedule outcomes. These included regulatory and technical requirements, program scope evolution, design and procurement status, and funding levels. The Aerospace report projected a tripling of the estimated cost to complete for Option 1 which is inconsistent with the current stage of completion. Option 1 MFFF has already experienced its major life cycle growth.

High Bridge has been tracking Plutonium Disposition Program activities since the mid 1990's. The complexities of cost driving milestones, decisions, and events were very unique. **Exhibit 3.6.1** was developed to provide a Summary of Changing Requirements and Scope Evolution Impacts on Option 1 MOX Plutonium Disposition Costs since 1991.

- A Hybrid Technology approach involving MOX Fuel/Irradiation (for pure Pit Plutonium sources) and High Level Waste Immobilization (for impure non-pit Plutonium sources) was selected for the Plutonium Disposition approach in 1997.
- The approach changed in 2002 with the elimination of the Immobilization of impure non-pit Plutonium sources in HLW and incorporating this scope into the MFFF design.
- In February 2004, DOE announced a 10-month delay in MOX Facility construction.
- It changed again with the Pit Disassembly and Conversion Facility (PDCF) being slowed down in 2006 and cancelled in 2010, resulting in many process steps being incorporated into the MFFF. This program consolidation was undertaken to reduce costs.

At the time, High Bridge concludes that the evaluated reduced costs were sound. However, various challenges were also created by introducing these impure non-pit plutonium sources into the MFFF design approach that required the addition of an aqueous polishing system. These challenges have

Exhibit 3.6.1 – Summary of Plutonium Disposition Changing Requirements and Scope Evolution Impacts on Option 1 MOX Program and MFFF Project



been successfully dealt with, and High Bridge finds the ETC/EAC to be conservative, adequate, and representing high confidence. It concludes that the 20 years of scope design evolution complexities of the Program are well understood. It is also important to note that the resulting/current Option 1 MOX Fuel approach represents a net overall cost savings of approximately \$3B compared to the original three-facility approach, even though the MFFF project cost increased approximately \$3B over the past ten years to accommodate this consolidation. This Option 1 program saving was not addressed in the Aerospace or PWG reports.

High Bridge prepared **Appendix D** to provide a chronological list of over 100 Key Events and Milestones that have shaped the Option 1 MOX Fuel scope, estimate of cost, and schedule. These 100 Key Events and Milestones were consolidated from more than 200 Events and Milestones that have been identified. These 100 Key Events and Milestones were then portrayed in a graphic timeline spreadsheet format that provides a linear picture of what has occurred since 1991. **Exhibit 3.6.1** is a summary of the information provided in **Appendix D**. Some items to note regarding the information presented on **Exhibit 3.6.1**:

- About 15 of the over 100 Milestones and Key Events from **Appendix D** are displayed across the top of the Exhibit. These portray the evolution of the overall program at a very high level.
- The January 2002 Milestone 61 in **Appendix D** identifies the DOE strategy change to pursue a MOX-only plutonium disposition strategy, halting further work on immobilization. The revised approach saves time and money over the previous strategy and is acceptable to the Russian Federation, whereas a U.S. immobilization-only approach strategy was not. A graphic portrayal of the program evolution and this Milestone 61 policy/scope change is summarized depicting three Option 1 Facilities (PDCF, Immobilization, and MOX) that were essentially consolidated into one (MOX).

The program consolidation was undertaken to reduce costs. At the time and on paper, High Bridge concludes that the evaluated reduced costs were sound. However, various challenges were also created by introducing less pure plutonium into the MFFF design approach. These challenges have been successfully dealt with, and High Bridge finds the ETC/EAC to be conservative, adequate, and representing high confidence. It concludes that the 20 years of scope design evolution complexities of the Program are well understood. High Bridge concludes that the resulting/current Option 1 MOX Fuel approach represents a net overall cost savings of approximately \$3B compared to the original three-facility approach, even though the MFFF project cost increased approximately \$3B. This Option 1 program saving was not addressed in the Aerospace or PWG reports.

The DOE has a history of challenges and performance shortfalls in managing large projects. In 1999, the 105th Congressional Committee on Energy and Water Development directed the U.S. Department of Energy (DOE) to undertake a review and assessment of its overall management structure and processes for identifying, managing, designing and constructing facilities (**Reference 17**). It directed that this review be done by an impartial, independent organization with expertise in the evaluation of government management and administrative functions. Consequently, DOE requested that the National Research Council conduct a study to review the policies, procedures,

and practices used by DOE to identify, plan, design, and manage its portfolio of projects. The goal of the study was to develop recommendations to improve DOE's oversight and management of projects. The National Research Council Report "Improving Project Management in the Department of Energy" was issued in November 1999 and is cited as **Reference 18**. This is also identified as Milestone #46 in **Appendix D**. Key National Research Council conclusions included:

- DOE culture is not aligned to support Project Management principles
- Indecision and constant change in project direction and funding levels resulted in large cost impacts
- Lack of structure, policies, and procedures for project scoping, authorization, and execution resulted in work proceeding without adequate planning, organizing, and design maturity

A major outcome from this National Research Council report was the development and implementation of comprehensive DOE Project Management policies and procedures, as outlined in DOE Order 413.3 (**Reference 3**). This included the definition and adoption of a five-step Critical Decision (CD) Milestone and Authorization process on which all DOE projects are executed.

As reflected on **Exhibit 3.6.1** and **Appendix D**, an exhaustive technical, cost, and geo-political evaluation was performed over ten years involving various organizations and hundreds of industry experts to arrive at the Option 1 approach and Record of Decision (ROD). The negotiation and execution of the PMDA between the Russian Federation and the United States in 2000 represents a true international partnership and non-proliferation accord. The Option 1 MOX Fuel Program has progressed from Critical Decision 0 to beyond Critical Decision 3 in accordance with DOE Order 413.3. Across 15 years from 2000 to 2015, the MOX Project has worked its way through identifying, quantifying, and managing risks, as well as dealing with the consolidation of three projects into one project, all resulting in a near tripling of the estimated cost. High Bridge finds it perplexing that this advanced CD-3 project status, along with the strategic non-proliferation geo-political value, was not addressed in the Aerospace or PWG evaluations of the Option 1 MOX Fuel Program LCCE risks, costs and benefits. Additionally, High Bridge finds it incorrect that the Aerospace assessment resulted in a nearly tripling of the to-go Option 1 costs, when they had already tripled from 2000 to 2015. Former Secretary of Energy Bill Richardson (under President Clinton at the time of PMDA execution in 2000) recently had an Op Ed news clip in January 2015 that lines up with this High Bridge view. See Section 7.4 and **Appendix E**.

Industry has many examples of cancelled large projects and successful large projects. It appears when challenges and difficulties of a large complex project need to be faced and managed, an easier and lower cost solution often becomes attractive, even though it may not meet the original goals and requirements. U.S. Navy Admiral Hyman Rickover summed up his thoughts regarding "Paper vs. Practical Reactors" in his 1953 letter to congress, **Appendix C**. In many ways, Option 1 MOX Fuel represents a Practical Solution and Option 4 Downblend represents a Paper Solution for a complex challenge. The available information regarding Option 1 is robust and voluminous and at a CD-3 design maturity status. While there is abundant information regarding Option 4, it is at a immature program development status. As outlined in Section 5, High Bridge concludes that Option 4 was presented with unrealistic assumptions and is not viable without an amended PMDA and WIPP Facility revised legislation, revised design, amended NEPA process, and

enlarged capacity. The schedule realities of these elements results in Option 4 being more costly than Option 1.

High Bridge examined the science, chemistry, physics, geo-political, and regulatory parameters for both Options 1 and 4. These needed to be understood to evaluate risks, the quantifiable estimated costs, and the more difficult and abstract geo-political non-proliferation values.

However, as stated on page 8 of the Aerospace report, 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. High Bridge finds this stated Aerospace approach to be a significant process review flaw.

3.7 Funding, Schedule, and Escalation

High Bridge found the Aerospace analysis using escalated RY\$ to be very confusing, extremely difficult to follow, and flawed in its overall approach to comparing the Option 1 MOX Fuel and Option 4 Downblend alternatives:

- Aerospace used a RY\$ approach to presenting dollar values for Options 1 and 4 with escalation rolled in to all values, rather than presenting dollar values in a constant year “Present Day” value. This approach did not follow industry practice, created a situation of “Apples and Oranges” across the entire report that prevented a common denominator comparison of Option 1 and 4 Alternatives, and distorted/exaggerated the outcomes.
- Aerospace developed two less than optimum reduced funding scenarios for Option 1 MOX Fuel (i.e., \$500M/year and \$375M/year) without any schedule basis detail. This significantly impacted their extrapolated resulting longer schedule durations and their resulting escalation calculations. They did not develop a funding/schedule scenario reflecting the optimum approach to completing construction efficiently in a minimal duration, similar to that provided in the 2012 MOX Services Re-Baseline proposal to NNSA (i.e., \$625M/year).
- Aerospace utilized inconsistent and flawed assumptions in calculating the impacts of reduced funding which is inconsistent with industry standards and practice. They developed escalated costs but did not escalate funding to match. This resulted in a ratcheting of the schedule durations even longer with fewer dollars available to support production work activities and estimated costs being driven even higher.

High Bridge has performed over 100 Independent Cost Estimate/Schedule/Risk Assessments of large nuclear and FOAK projects. Consistent with various commercial industry guidelines outlined by the Project Management Institute (PMI) and the Association for the Advancement of Cost Engineering (AAECE), High Bridge has always performed economic evaluations of alternatives using a Net Present Value (NPV) approach to establish a constant fiscal year basis for providing a

common denominator basis for comparison. Again, the accepted industry practice is to evaluate an investment decision based on constant year dollars.

The above methodology utilized by Aerospace to evaluate estimated costs for technology alternatives is not in compliance with nuclear industry standards or with various Federal policy directives including DOE Order 413.3B; DOE Guideline 413.3-21; GAO Cost Estimating and Assessment Guide GAO-09-3SP; and OMB A-94 Guidelines for Benefit-Cost Analysis of Federal Programs.

Aerospace did not present an Option 1 MOX Fuel case for planned optimum funding consistent with the MOX Services 2012 Re-Baseline proposal of approximately \$625M/year spanning a six year construction and commissioning duration. Figure 12 on page 23 of the Aerospace report reflects an overall evaluated construction and commissioning duration of approximately 25 years with a \$500M/year (RY\$) funding case. High Bridge concludes this Aerospace analysis resulting in a 400% schedule duration increase (i.e., 6 years becoming 25 years) based on a 20% annual funding reduction (i.e., \$625M/year becoming \$500M/year (RY\$)) is flawed. High Bridge concludes that the Aerospace analysis did not reflect an understanding of industry practice, and large nuclear project construction management parameters and requirements to perform work efficiently and effectively.

3.8 Updated Program and MIFT Cost Analysis

The Aerospace report presented changes to the PWG FY14 report for each of the two options. These changes were \$5.6B RY\$ to Option 1 and \$2.9B RY\$ to Option 4. Additionally, the MIFT costs were represented as being the same for both options at \$16.5B RY\$. No supporting basis was provided for these values. Moreover, the MIFT costs were represented in several locations with conflicting values ranging from \$10B RY\$ to over \$35B RY\$. High Bridge utilized the lower end of the Aerospace range.

Updated Program Costs - The cost estimate updates from the PWG 2014 report were provided to Aerospace for analysis. These updates are tabulated in Aerospace Table 1 – Option 1 MOX Fuel and Table 2 – Option 4 Downblend (**Reference 1**). As with most of the Aerospace data, the costs were given in RY\$. Data for both options are shown in **Exhibit 3.2.3** and **Exhibit 3.2.4** to illustrate the cost build-up for the ETC for Option 1 and Option 4. The costs shown in Aerospace Tables 1 and 2 were developed in a three step process for Option 1 and a four step process for Option 4. An examination of data in Tables 1 and 2 show that the program changes represent a significant percent of the total RY\$ ETC, approximately 12% for Option 1 and approximately 17% for Option 4.

A significant amount of the Aerospace total program up-dated costs were associated with escalation. The lack of detail for the data in Tables 1 and 2 made it difficult for High Bridge to perform a meaningful analysis of these costs. Without details High Bridge assumed the **\$1.23B RY\$** changes appearing in Step 1 of each option are related to actual program or project costs. De-escalating this value to FY14 resulted in a value of **\$1.136B FY14\$**.

Updates to Option 1 MOX Fuel - The cost value reported in Step 2 of Table 1 Option 1 MOX Fuel was assumed to be all escalation that did not make a contribution to the FY14 cost estimate. The

cost value reported in Step 3 of Table 1 did not make a contribution to the FY14 cost estimate. Aerospace assumed that the project was not making any progress during this reduced funding period. After discussions with MOX Services personnel, High Bridge determined that the cost values for delays and escalation should not be included in the FY14 cost estimate. In fact the project continues to make progress and will not need a lengthy re-start effort. The corrected value is shown in **Exhibit 3.1.2**, Section 3.1 in the column titled “Changes Since PWG 2014.”

Updates to Option 4 Downblend - The cost values for the glove boxes and program were **\$0.09B and \$0.803** respectively as reported in Step 2 and Step 4 of Table 2. High Bridge assumed that these were related to actual program or project costs. The de-escalated sum of these two values to FY14\$ is **\$0.737B FY\$**. Adding this value to the **\$1.136B** yields the cost estimate of **\$1.873B** shown in **Exhibit 3.1.3** in the column titled “Changes Since PWG 2014.” The cost value reported in Step 3 of Table 2 was assumed to be all escalation that did not make a contribution to the FY14 cost estimate.

MOX Irradiation, Feedstock, and Transportation (MIFT) Cost - Aerospace added the MIFT cost to both Option 1 MOX Fuel and Option 4 Downblend. The MIFT cost represented a significant fraction of the final estimated ETC for both options. High Bridge noted that the Aerospace MIFT estimated ETC costs lacked any supporting documentation. High Bridge de-escalated the MIFT ETC costs to FY14\$. The results were \$4.1B for Option 1 and \$3.5B for Option 4. A comparison of the relative costs for each is discussed below to determine if the apparent ~\$600 million reduction for Option 4 is warranted.

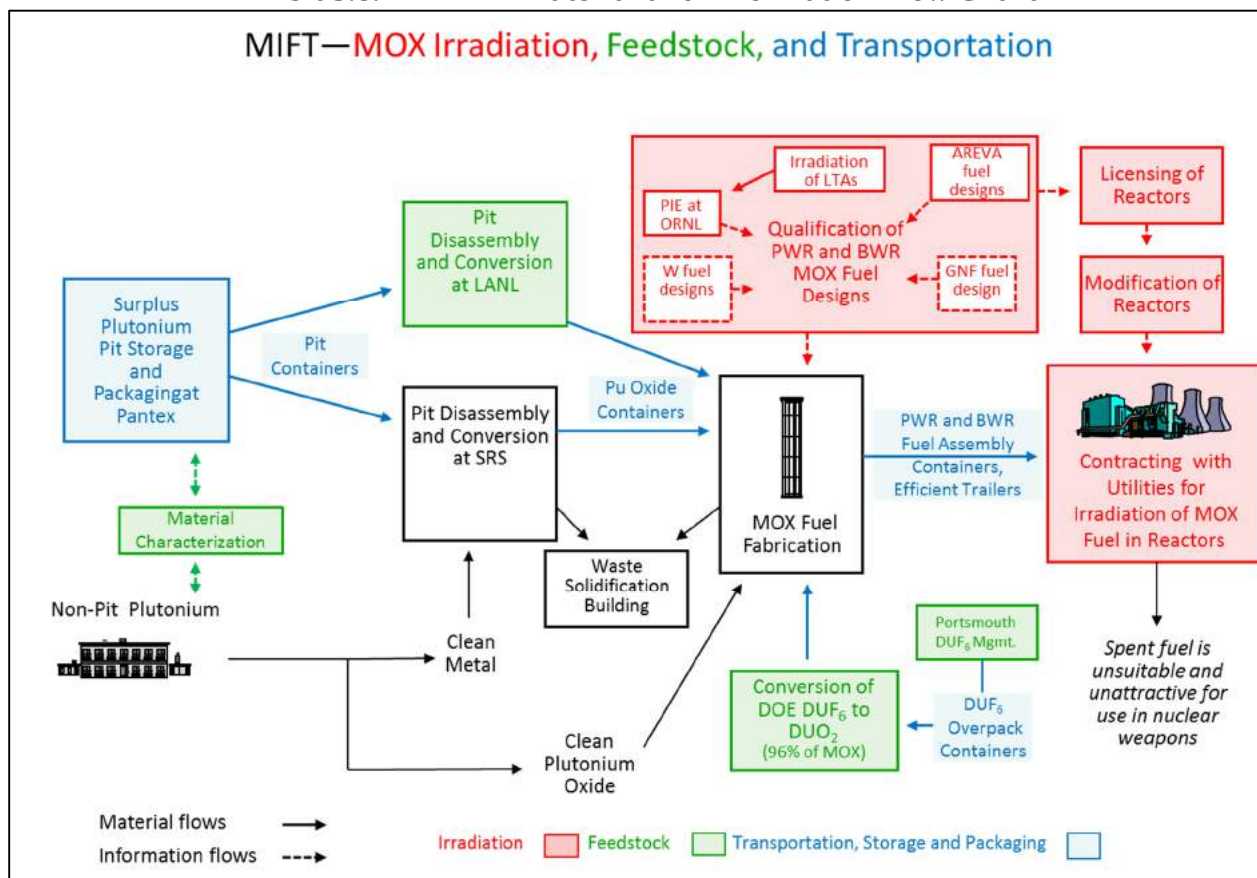
High Bridge investigated the components of MIFT to determine if the added MIFT costs were the same (or nearly the same) for each option. The components and interrelationships among the components are shown in **Exhibit 3.8.1**.

MOX Irradiation (MI) includes:

- Qualification of fuel designs for use in nuclear reactors
- Licensing of the reactors to use MOX including any modifications that may be required
- Contracting with interested utilities to use MOX fuel.

The costs of these activities are difficult to assess without knowing which reactors will be selected to use MOX fuel. Some reactors are already licensed for MOX cores, while others may require significant modifications to be licensed. The budget is for Option 1 is difficult to assess without backup but High Bridge has estimated that the MI cost of the MIFT budget is approximately \$1.0B FY14\$.

Exhibit 3.8.1 – MIFT Material and Information Flow Chart



(Reference 19)

None of these activities are required for Option 4 but the budget would be required to carry out other activities necessary for Option 4. These activities include:

- Providing technical support to the Department of State to renegotiate the PMDA
- Supporting the redesign and relicensing of WIPP for the revised mission to accommodate the additional downblend plutonium waste form
- Paying the fine to South Carolina required by Public Law 50 U.S. Code § 2566
(Reference 34)

The State Department would require DOE support to develop the details of the revised PMDA. High Bridge has estimated that this effort would take approximately five years and would cost \$84M FY14\$. The second item required for Option 4 is the redesign and relicensing of WIPP to accommodate the new mission that includes the disposition of weapons-usable plutonium. Since DOE Environmental Management (EM) would not be interested in managing this for NNSA, the program described to redesign and relicense WIPP would be paid for by the MIFT budget for the MI. High Bridge has estimated that these costs would be \$0.779B FY14\$. In addition, the delay in moving the required amount of plutonium will result in a fine being imposed on DOE/NNSA

of \$1 million a day up to \$100 million per year. High Bridge has estimated that the delay would be approximately 11 years. The resulting fine would be \$1.1B FY14\$, as reflected in **Exhibit 3.1.3**. These three costs for Option 4 Downblend would be approximately \$2.00B FY14\$ without contingency or escalation. The similar MI costs for Option 1 would be the same or likely less than the costs for Option 4.

The “F” in MIFT stands for Feedstock preparation and it includes several aspects for Option 1 MOX. There are two major feedstock pathways for MOX. The first is the conversion of the pits into plutonium oxide for use in manufacturing MOX fuel. This effort is essentially unchanged for Option 4 Downblend with the exception that the throughput would be lower because the capacity would be reduced by the loss of the MFFF oxide production subsystems. It is expected that it would take nearly 50% longer to convert the pits into plutonium oxide which would suggest that the overall cost would be higher based on the hotel load.

The plutonium portion of the MIFT costs for Option 4 Downblend is likely to be more than for Option 1 because the loss of capacity resulting from the cancellation of the MFFF will extend the period required to convert the pits into plutonium oxide. Aerospace suggested a reduction in the Quality Control of the feedstock preparation for Option 4 to offset this but it is likely to be counterproductive. Preparing the Stardust mixture for plutonium oxide requires a predictable product both in terms of physical appearance and chemical form. High Bridge does not agree that reducing Quality Control is a prudent option.

The second part of the Feedstock preparation for Option 1 will be the conversion of depleted uranium hexafluoride into uranium dioxide for the fabrication of MOX fuel pellets. This effort consists of transporting the uranium product from Portsmouth, OH or Paducah, KY to Richland, WA where AREVA has process lines to convert the DUF6 to DUO2. The DUO2 is then transported to SRS for incorporation into the fuel. The DUF6 is provided at no cost to the MOX Program, but the transportation and the conversion process would represent a small cost.

Once again, Option 4 Downblend would not have this cost, but this advantage is offset by the need to have a large amount of Stardust procured, delivered, blended and placed in the CCO. Each CCO contains about 1000 cc of Stardust. The 34 MTs of plutonium would require over 97,000 CCOs which would require approximately 100 cubic meters of Stardust. High Bridge was unable to obtain a reference for the cost of Stardust. The slightly higher cost of the plutonium oxidation and the near equivalence of the uranium costs with the Stardust costs means that the cost for the feedstock preparation is approximately the same.

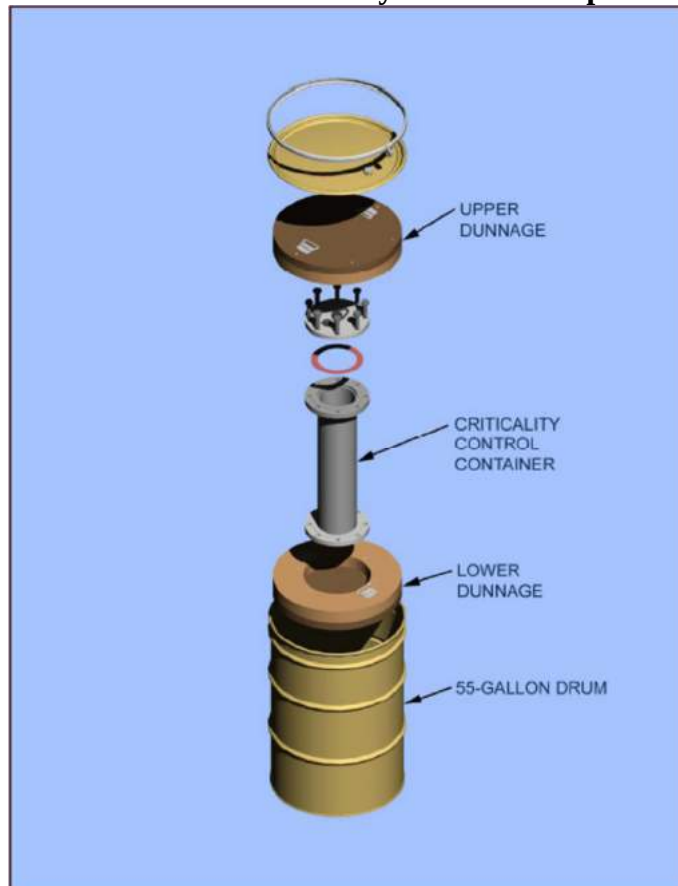
The third part of MIFT is the transportation cost. Both the shipment of MOX fuel and the packaged TRU will involve the same level of safeguards. As described in an Oak Ridge National Laboratories (ORNL) report (**Reference 20**) this packaging and transportation of unirradiated MOX fuel from the MFFF to commercial nuclear reactor(s) involved in the disposition mission will utilize DOE’s safe-secure trailers (SSTs) and packages designed and certified to accommodate fresh (unirradiated) MOX fuel assemblies. The assemblies will be packaged two to a container and four containers per truck. To facilitate security, the shipments will be made in three-truck convoys. Therefore, the shipment of all 2,000 PWR assemblies will be made in approximately 80 shipments. Since the fuel shipping containers are reusable, the program would need no more than

20 of these containers⁴. This reference lists an approximate cost for a new fuel shipping package at \$100,000 (1997\$) or \$160,000 (2014\$) or a total cost of **\$3.2M FY14\$**.

With Option 4, the downblended waste is packaged in a criticality control overpack (CCO), (**Exhibit 3.8.2**). This is a Type B shipping package in accordance with NRC requirements. These CCOs are packaged in a TRUPACT-II overpack in two layers of seven drums for a total of 14 drums per TRUPACT-II. The TRUPACT-II are usually packed three to a truck so each shipment carries 42 CCOs. If loaded to the maximum amount of plutonium each shipment would contain about 15 kg of plutonium. These are shipped using the same care and oversight as is the fuel. The difference is the number of shipments. The 34 tons of plutonium converted to fuel represents approximately 80 shipments while the 34 tons of plutonium converted into downblend shipments to WIPP represents approximately 2,300 shipments - over 28 times as many.

The cost per shipment for both options would be approximately the same, but the greater number of shipments required for the downblend option results in significantly higher transportation costs.

Exhibit 3.8.2 – Criticality Control Overpack



Each CCO costs approximately \$2,200 based on a price sheet used for an RFP for ORNL for TRU handling (**Reference 23**). Since there will be over 97,000 CCOs required, the cost for CCOs is greater than \$210M. This is over 60 times greater than the \$3.2M needed for the 20 MOX fuel

⁴ If BWR containers were required instead of PWR containers, there could be up to 50 BWR containers.

shipping packages. Therefore, the Transportation portion of the MIFT should be significantly greater for Option 4 compared to Option 1.

Based on the above analysis of the transportation difference between Option 1 MOX Fuel and Option 4 Downblend High Bridge estimates that Option 4 Downblend will incur approximately **\$1.15B FY14\$** in additional transportation costs.

4 RISK, OPPORTUNITY, AND CONTINGENCY

4.1 Overview

The High Bridge initial review of the Aerospace report led to the observations that the evaluated discrete risks were understated for Option 4 and overstated for Option 1. Based on these observations High Bridge performed an in-depth review of the risks discussed in the report. Aerospace risk (and opportunity) tables for both options can be found on page 44 (Option 1 MOX Fuel Risk Table) and page 45 (Option 4 Downblend Risk Table).

High Bridge computed the contingencies from the Monte Carlo analyses in FY14\$ to produce a common basis of comparison between cost estimates for Option 1 and Option 4. Except for a few items eliminated or added (discussed in more detail below), High Bridge accepted the risks items listed in the Aerospace report tables on pages 44 and 45 (**Reference 1**).

Several of the Low (Min) and High (Max) Financial Impact (FI) values from the risk items in the Aerospace report were used in the High Bridge Monte Carlo analyses. These financial impacts were de-escalated from the time period of expected impact to FY14\$. Additionally, High Bridge agreed with the Probability of Occurrence (POO) assumed by the Aerospace report in approximately one-third of the risk items. In those risk items that were not used, either the FI or POO, values were assigned based on the experience of the High Bridge team members.

High Bridge performed a Monte Carlo analysis of the discrete risks using a slightly modified version of commercial software, @RISK, from the Palisade Corporation. A double triangle distribution was used to model the probability distribution of the risk ranges, and 10,000 iterations were carried out to define the final total impact distribution.

The 85% confidence contingency value from the independent Monte Carlo analyses performed by High Bridge on Option 1 was **\$3.2B** and Option 4 was **\$5.0B**. These values compare to the Aerospace values of **\$7.8B** and **\$3.8B** as shown above in **Exhibit 3.1.1**. All the values are in FY14\$. Details of the Option 1 analysis can be found in the following sections (**Section 4.2** Option 1 MOX Fuel, **Section 4.3** Option 4 Downblend, and **Appendix F**).

High Bridge performed Monte Carlo analyses of the discrete risks reported by Aerospace for both options using the @RISK software. The Aerospace RY\$'s for the Min and Max values were de-escalated to FY14\$ and the Aerospace POO's were used in the analyses. The resulting 85% confidence contingencies from the analyses were **\$9.80B** (FY14\$) for Option 1 MOX Fuel and **\$4.14B** (FY14\$) for Option 4 Downblend. These compare to the Aerospace Monte Carlo analyses

of **\$7.80B** for the Option 1 MOX Fuel and **\$3.80B** for the Option 4 Downblend indicating that the Monte Carlo analyses by both companies yield similar results for the same set of inputs.

4.2 Option 1 – MOX

The High Bridge Monte Carlo analysis used several of the Low (Min) and High (Max) Financial Impact (FI) values from the risk items in the Aerospace report. These financial impacts were de-escalated from the time period of expected impact to FY14\$. Additionally, High Bridge agreed with the Probability of Occurrence (POO) assumed by the Aerospace report in approximately one-third of the risk items. Where Aerospace risk items were not used, the FI and/or POO values were assigned based on the experience of the High Bridge team members.

The result of either eliminating or adding to the discrete list is displayed in **Exhibit 4.2.1**.

Exhibit 4.2.1 – Risk Register for Option 1 MOX Fuel

Risk Item Number	Description of Discrete Risk	Probability of Occurrence	Financial Impacts
1	Fuel Production Rate Lower Than Expected	High Bridge	High Bridge
2	Feedstock Production Rate Lower Than Expected	Eliminated	
3	MFFF Project Construction Cost Uncertainty / Growth	High Bridge	High Bridge
4	MFFF Temporary Suspension of Operations	Eliminated	
5	MFFF Full Construction Re-Start Delay	High Bridge	High Bridge
6	Feedstock Temporary Suspension of Operations	Aerospace	High Bridge
7	SRS Overhead Cost Increases	Aerospace	High Bridge
8	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Aerospace	Aerospace
9	LANL Overhead Cost Increases	Aerospace	High Bridge
10	MFFF Hot Operations Delay after CD-4 Complete	High Bridge	High Bridge
11	MFFF Integrated Functional Testing Delay Before CD-4	High Bridge	High Bridge
12	Needs for Additional Storage	High Bridge	Aerospace
13	LANL Feedstock Production Re-Start Delay	High Bridge	High Bridge
14	Funding for Depleted Uranium	Eliminated	
15	Feedstock Production Consolidated at LANL (Remove HB-Line)	Aerospace	Aerospace
16	MOX Program estimate accuracy/uncertainty as a function of design maturity for overall program	High Bridge	High Bridge

Exhibit 4.2.2 provides a comparison of the High Bridge and Aerospace input values for the Option 1 MOX Fuel Monte Carlo Analysis. Except where noted above, High Bridge assigned the POO, Low, and High financial impact range based on experience in design, construction, and operations of nuclear facilities. All of the financial values in **Exhibit 4.2.2** are expressed in FY14\$. High Bridge used a simple average of the Low and High values to make a reasonable estimate of the expected value of each risk item.

Exhibit 4.2.2 – High Bridge Monte Carlo Parameters for Option 1 MOX Fuel

High Bridge Risk Register for Option 1 MOX Fuel (FY14 \$'s)				
Risk Item Number	Description of Discrete Risk	Probability of Occurrence	Low	High
1	Fuel Production Rate Lower Than Expected	75%	\$ 477,900,000	\$ 1,194,750,000
2	Feedstock Production Rate Lower Than Expected	0%	\$ -	\$ -
3	MFFF Project Construction Cost Uncertainty / Growth	75%	\$ 75,080,000	\$ 187,700,000
4	MFFF Temporary Suspension of Operations	0%	\$ -	\$ -
5	MFFF Full Construction Re-Start Delay	50%	\$ 312,833,333	\$ 625,666,667
6	Feedstock Temporary Suspension of Operations	25%	\$ 106,200,000	\$ 318,600,000
7	SRS Overhead Cost Increases	50%	\$ 73,170,000	\$ 487,800,000
8	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	50%	\$ 75,000,000	\$ 300,000,000
9	LANL Overhead Cost Increases	50%	\$ 33,096,000	\$ 220,640,000
10	MFFF Hot Operations Delay after CD-4 Complete	50%	\$ 26,550,000	\$ 159,300,000
11	MFFF Integrated Functional Testing Delay Before CD-4	25%	\$ 52,138,889	\$ 156,416,667
12	Needs for Additional Storage	50%	\$ 74,800,000	\$ 164,500,000
13	LANL Feedstock Production Re-Start Delay	25%	\$ 106,200,000	\$ 318,600,000
14	Funding for Depleted Uranium	0%	\$ -	\$ -
15	Feedstock Production Consolidated at LANL (Remove HB-Line)	10%	\$ (774,900,000)	\$ (319,000,000)
16	MOX Program estimate accuracy/uncertainty as a function of design maturity for overall program	75%	\$ 74,800,000	\$ 187,000,000

Risk Item Number 2 was eliminated by High Bridge because it was considered a subset of Risk Item Number 1; i.e. the fuel production rate will be lower if a significant reduction in feedstock occurs.

Risk Item Number 4 was eliminated by High Bridge because at an expected low operating capacity factor (<30%) makes it unlikely that a temporary suspension of MFFF Project operations is significant enough to affect the overall operation schedule.

Risk Item Number 14 was eliminated by High Bridge because further investigations identified that the depleted Uranium is to be furnished to the MOX Program at no cost. There will be minimal annual costs for conversion during operations. These have not been added to base cost.

Risk Item Number 16 was added by High Bridge because there is still an uncertainty in the MOX Program cost over and above what is currently being forecast.

Aerospace Risk Register for Option 1 MOX Fuel (FY14 \$'s)				
Risk Item Number	Description of Discrete Risk	Probability of Occurrence	Low	High
1	Fuel Production Rate Lower Than Expected	75%	\$ 799,434,896	\$ 3,586,388,527
2	Feedstock Production Rate Lower Than Expected	75%	\$ 475,124,327	\$ 1,999,431,781
3	MFFF Construction Cost Uncertainty / Growth	75%	\$ (161,368,308)	\$ 2,271,023,532
4	MFFF Temporary Suspension of Operations	90%	\$ 125,423,175	\$ 1,003,147,972
5	MFFF Full Construction Re-Start Delay	50%	\$ 314,255,556	\$ 1,699,356,727
6	Feedstock Temporary Suspension of Operations	90%	\$ 67,105,812	\$ 538,868,226
7	SRS Overhead Cost Increases	75%	\$ 92,082,154	\$ 230,205,385
8	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	90%	\$ 54,640,578	\$ 218,562,311
9	LANL Overhead Cost Increases	25%	\$ 261,269,443	\$ 522,538,886
10	MFFF Hot Operations Delay after CD-4 Complete	50%	\$ 41,048,559	\$ 250,959,086
11	MFFF Integrated Functional Testing Delay Before CD-4	25%	\$ 17,238,356	\$ 429,106,836
12	Needs for Additional Storage	50%	\$ 24,551,778	\$ 115,723,997
13	LANL Feedstock Production Re-Start Delay	25%	\$ 55,996,010	\$ 171,373,411
14	Funding for Depleted Uranium	10%	\$ 7,834,684	\$ 23,504,052
15	Feedstock Production Consolidated at LANL (Remove HB-Line)	75%	\$ (655,913,367)	\$ (270,017,246)

The following items were either eliminated or added to the Option 1 discrete risks from the Aerospace report as shown in **Exhibit 4.2.2**:

- **Risk Item Number 2** was eliminated by High Bridge because it was considered a subset of Risk Item Number 1; i.e. the fuel production rate will be lower if a significant reduction in feedstock occurs.
- **Risk Item Number 4** was eliminated by High Bridge because at an expected low operating capacity factor (<30%) makes it unlikely that a temporary suspension of MFFF Project operations is significant enough to affect the overall operation schedule.
- **Risk Item Number 14** was eliminated by High Bridge because further investigations identified that the depleted Uranium is to be furnished to the MOX Program at no cost. There will be minimal annual costs for conversion during operations. These have not been added to base cost.
- **Risk Item Number 16** was added by High Bridge because there is still an uncertainty in the MOX Program cost over and above what is currently being forecast.

Details of the Monte Carlo outputs, including the rationale used to evaluate the Low and High financial impacts, are in **Appendix F**. The Monte Carlo analysis resulted in a contingency of \$3.2B in FY14\$ at the 85% confidence level. The cumulative cost risk (contingency) probability is displayed in **Exhibit 4.2.3**.

Exhibit 4.2.3 – Cumulative Cost-Risk Probability Option 1 MOX Fuel (FY14\$)

Confidence Level	Contingency
0%	\$ (801,037,932)
5%	\$ (561,089,733)
10%	\$ (10,862,326)
15%	\$ -
20%	\$ -
25%	\$ 567,791,668
30%	\$ 798,146,165
35%	\$ 869,112,864
40%	\$ 924,324,875
45%	\$ 968,477,927
50%	\$ 1,178,749,360
55%	\$ 1,946,874,480
60%	\$ 2,106,856,325
65%	\$ 2,236,311,855
70%	\$ 2,348,018,847
75%	\$ 2,578,259,191
80%	\$ 2,993,585,024
85%	\$ 3,192,444,337
90%	\$ 3,399,729,102
95%	\$ 3,670,936,231
100%	\$ 4,298,324,746

The top six risk items that contributed to the \$3.2B contingency are displayed in **Exhibit 4.2.4**

Exhibit 4.2.4 – Top 6 Risk Items for Option 1 MOX Fuel

Risk Item Number	Description of Discrete Risk
1	Fuel Production Rate Lower Than Expected
2	Feedstock Production Rate Lower Than Expected
7	SRS Overhead Cost Increases
8	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)
13	LANL Feedstock Production Re-Start Delay
6	Feedstock Temporary Suspension of Operations

The Option 1 MOX Fuel contingency in the Aerospace report is \$11.2B RY\$ at 85% confidence level. High Bridge de-escalated the Aerospace Min and Max values from Option 1 MOX Fuel to make a comparison. The resulting contingency is \$9.8B FY14\$ versus \$3.2B FY14\$ from High Bridge's independent Monte Carlo analysis.

4.3 Option 4 Downblend

The High Bridge Monte Carlo analysis used several of the Low (Min) and High (Max) FI values from the risk items in the Aerospace report. These financial impacts were de-escalated from the time period of expected impact to FY14\$. Additionally, High Bridge agreed with the POO assumed by the Aerospace report in approximately one-third of the risk items. Where Aerospace risk items were not used, the FI and/or POO values were assigned based on the experience of the High Bridge team members.

The result of either eliminating or adding to the discrete list is displayed in **Exhibit 4.3.1**.

Exhibit 4.3.1 – Risk Register for Option 4 Downblend

Risk Item Number	Description of Discrete Risk	Probability of Occurrence	Financial Impacts
1	Feedstock Production Rate Lower Than Expected	Aerospace	High Bridge
2	SRS Downblend Facility Start Delay	High Bridge	High Bridge
3	Feedstock Temporary Suspension of Operations	Aerospace	High Bridge
4	Downblend Production Rate is Lower Than Expected	Aerospace	High Bridge
5	Downblend Facility Temporary Suspension of Operations	Aerospace	High Bridge
6	Downblend Construction Cost Estimate Uncertainty/Growth	High Bridge	High Bridge
7	LANL Overhead Cost Increase	High Bridge	High Bridge
8	MFFF Project Termination Cost Uncertainty	High Bridge	High Bridge
9	Downblend Repository Temporary Suspension of Operations	Aerospace	High Bridge
10	SRS Overhead Cost Increase	High Bridge	High Bridge
11	Feedstock Production Re-Start Delay at LANL	Aerospace	High Bridge
12	Exceed Downblend Repository TRU Allowable Storage Volume	Eliminated	
13	Need for Additional Storage Space	Eliminated	
14	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Aerospace	Aerospace
15	Feedstock Milling and Blending Not Needed/Quality Control Reductions	High Bridge	Aerospace
16	Feedstock Production Consolidated at LANL (Remove HB-Line)	High Bridge	Aerospace
17	NEPA Revision to WIPP EIS process takes longer than expected	High Bridge	High Bridge
18	NMED Disputes Land Use Issues	High Bridge	High Bridge
19	Cost uncertainty for WIPP modifications for life extension	High Bridge	High Bridge

Exhibit 4.3.2 provides a comparison of the High Bridge and Aerospace input values for the Option 4 Downblend Monte Carlo Analysis. Except where noted above, High Bridge assigned the POO, Low, and High financial impact range based on experience in design, construction, and operations of nuclear facilities. All of the financial values in **Exhibit 4.3.2** are expressed in FY14\$. High Bridge used a simple average of the Low and High values to make a reasonable estimate of the expected value of each risk item.

Exhibit 4.3.2 – High Bridge Monte Carlo Parameters for Option 4 Downblend

High Bridge Risk Register for Option 4 Downblend (FY14 \$'s)				
Item	Description of Discrete Risk	Probability of Occurrence	Low	High
1	Feedstock Production Rate Lower Than Expected	75%	\$ 447,800,000	\$ 1,343,400,000
2	SRS Downblend Facility Start Delay	75%	\$ 168,333,333	\$ 673,333,333
3	Feedstock Temporary Suspension of Operations	90%	\$ 223,900,000	\$ 671,700,000
4	Downblend Production Rate is Lower Than Expected	25%	\$ 139,666,667	\$ 698,333,333
5	Downblend Facility Temporary Suspension of Operations	90%	\$ 60,522,222	\$ 149,642,857
6	Downblend Construction Cost Estimate Uncertainty/Growth	90%	\$ 62,500,000	\$ 250,000,000
7	LANL Overhead Cost Increase	50%	\$ 183,000,000	\$ 457,500,000
8	MFFF Project Termination Cost Uncertainty	50%	\$ (74,600,000)	\$ 746,000,000
9	Downblend Repository Temporary Suspension of Operations	90%	\$ 154,285,714	\$ 462,857,143
10	SRS Overhead Cost Increase	50%	\$ 27,000,000	\$ 135,000,000
11	Feedstock Production Re-Start Delay at LANL	25%	\$ 111,950,000	\$ 335,850,000
12	Exceed Downblend Repository TRU Allowable Storage Volume			
13	Need for Additional Storage Space			
14	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	75%	\$ 4,353,370	\$ 17,413,480
15	Feedstock Milling and Blending Not Needed/Quality Control Reductions	25%	\$ (62,673,563)	\$ (17,417,963)
16	Feedstock Production Consolidated at LANL (Remove HB-Line)	20%	\$ (653,374,020)	\$ (270,017,246)
17	NEPA Revision to WIPP EIS process takes longer than expected	50%	\$ 261,250,000	\$ 391,875,000
18	NMED Disputes Land Use Issues	50%	\$ 15,125,000	\$ 22,687,500
19	Cost uncertainty for WIPP modifications for life extension	50%	\$ 220,000,000	\$ 500,000,000
Risk Item Number 12 was eliminated because the High Bridge analysis showed that WIPP capacity will be exceeded if Option 4 is selected. This becomes a part of the High Bridge ETC for Option 4. Risk Item Number 13 was eliminated by High Bridge because this becomes a part of the High Bridge estimate for licensing, constructing, and operating the WIPP to accommodate the additional weapons grade Pu 239. Risk Item Numbers 17, 18, and 19 were added by High Bridge as risks arising from High Bridge's estimate for licensing, constructing, and operating the WIPP to accommodate the additional weapons grade Pu 239.				

Aerospace Risk Register for Option 4 Downblend (FY14 \$'s)				
Item	Description of Discrete Risk	Probability of Occurrence	Low	High
1	Feedstock Production Rate Lower Than Expected	75%	\$ 464,627,467	\$ 1,955,432,968
2	SRS Downblend Facility Start Delay	25%	\$ 345,243,049	\$ 1,867,252,767
3	Feedstock Temporary Suspension of Operations	90%	\$ 58,552,348	\$ 468,107,752
4	Downblend Production Rate is Lower Than Expected	25%	\$ 93,230,907	\$ 601,121,735
5	Downblend Facility Temporary Suspension of Operations	90%	\$ 35,082,812	\$ 280,662,497
6	Downblend Construction Cost Estimate Uncertainty/Growth	75%	\$ 73,660,491	\$ 294,641,965
7	LANL Overhead Cost Increase	25%	\$ 261,269,443	\$ 522,538,886
8	MFFF Project Termination Cost Uncertainty	25%	\$ (90,584,921)	\$ 724,679,365
9	Downblend Repository Temporary Suspension of Operations	90%	\$ 7,467,710	\$ 59,506,475
10	SRS Overhead Cost Increase	75%	\$ 14,817,818	\$ 37,044,545
11	Feedstock Production Re-Start Delay at LANL	25%	\$ 13,631,475	\$ 64,732,383
12	Exceed Downblend Repository TRU Allowable Storage Volume	25%	\$ 55,996,010	\$ 171,373,411
13	Need for Additional Storage Space	10%	\$ 28,930,025	\$ 231,440,204
14	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	75%	\$ 4,353,370	\$ 17,413,480
15	Feedstock Milling and Blending Not Needed/Quality Control Reductions	90%	\$ (62,673,563)	\$ (17,417,963)
16	Feedstock Production Consolidated at LANL (Remove HB-Line)	90%	\$ (653,374,020)	\$ (270,017,246)

The following items were either eliminated or added to the Option 4 discrete risks from the Aerospace report as shown in **Exhibit 4.3.2**:

- **Risk Item Number 12** was eliminated because the High Bridge analysis showed that WIPP capacity will be exceeded if Option 4 is selected. This becomes a part of the High Bridge ETC for Option 4.
- **Risk Item Number 13** was eliminated by High Bridge because this becomes a part of the High Bridge estimate for licensing, constructing, and operating the WIPP to accommodate the additional weapons grade Pu 239.
- **Risk Item Numbers 17, 18, and 19** were added by High Bridge as risks arising from High Bridge's estimate for licensing, constructing, and continued operation of the WIPP to accommodate the additional weapons grade Pu 239.

Details of the Monte Carlo outputs, including the rationale used to evaluate the Low and High financial impacts, are in **Appendix F**. The Monte Carlo analysis resulted in a contingency of \$5.0B in FY14\$ at the 85% confidence level. The cumulative cost risk (contingency) probability is displayed in **Exhibit 4.3.3**.

Exhibit 4.3.3 – Cumulative Cost-Risk Probability Option 4 Downblend (FY14\$)

Confidence Level	Contingency
0%	\$ (772,017,233)
5%	\$ (567,537,742)
10%	\$ (349,263,282)
15%	\$ 224,511,167
20%	\$ 411,223,726
25%	\$ 779,347,312
30%	\$ 1,713,102,458
35%	\$ 1,863,462,823
40%	\$ 1,981,621,154
45%	\$ 2,085,304,141
50%	\$ 2,680,261,329
55%	\$ 3,250,758,619
60%	\$ 3,486,820,078
65%	\$ 3,683,364,978
70%	\$ 3,865,351,348
75%	\$ 4,046,257,088
80%	\$ 4,722,003,758
85%	\$ 5,043,565,992
90%	\$ 5,381,117,767
95%	\$ 5,814,334,766
100%	\$ 6,818,919,092

The top six risk items that contributed to the \$5.0B contingency are displayed in **Exhibit 4.3.4**

Exhibit 4.3.4 – Top 6 Risk Items for Option 4 Downblend

Risk Item Number	Description of Discrete Risk
1	Feedstock Production Rate Lower Than Expected
3	Feedstock Temporary Suspension of Operations
2	SRS Downblend Facility Start Delay
8	MFFF Project Termination Cost Uncertainty
17	NEPA Revision to WIPP EIS process takes longer than expected
4	Downblend Production Rate is Lower Than Expected

The Option 4 Downblend contingency in the Aerospace report is \$4.0B RY\$ at 85% confidence level. High Bridge de-escalated the Aerospace Min and Max values from Option 1 MOX Fuel to make a comparison. The resulting contingency is \$3.8B FY14\$ versus \$5.0B FY14\$ from High Bridge’s independent Monte Carlo analysis.

4.4 Program Status and Design Maturity Methodology

The Option 1 MOX Fuel programmatic technical risks are not as high or as likely as characterized in the Aerospace report. Processes involved in Option 1 MOX Fuel are not new. The design is based on similar facilities operating in France. The Option 1 MOX project is at a CD-3 status of complete design/construction and Aerospace generally evaluates risk/cost impacts as high impact and high likelihood of occurrence. The Option 4 Downblend is at a pre-conceptual design status and Aerospace generally evaluated risk/cost impacts as low impact and low POO. High Bridge finds this illogical, incorrect, and inconsistent with the guidance outlined in DOE Order 413.3.

In 1999, the DOE requested that the National Research Council conduct a study to review the policies, procedures, and practices used by DOE to identify, plan, design, and manage its portfolio of projects. The goal of the study was to develop recommendations to improve DOE’s oversight and management of projects. The National Research Council Report “Improving Project Management in the Department of Energy” was issued in November 1999.

A major outcome from this National Research Council report was the development and implementation of a comprehensive DOE Project Management policies and procedures, as outlined in DOE Order 413.3 (**Reference 18**). This included the definition and adoption of a five-step Critical Decision (CD) Milestone and Authorization process on which all DOE projects are executed.

Exhibit 4.4.1 provides an overview of this five-step Critical Decision process. It involved a structured and rigorous approach to move through the various project life cycle steps and the

progressive stages of design maturity of Pre-Conceptual, Conceptual, Preliminary, and Final with the following Milestone Gates:

•	CD-0	Approve Mission Need	Option 4
•	CD-1	Approve Preliminary Baseline Range	
•	CD-2	Approve Performance Baseline	
•	CD-3	Approve Start of Construction	Option 1
•	CD-4	Approve Start of Operations	

The design maturity and relatively low risk posture for Option 1, and the design immaturity and relatively high risk posture for Option 1, do not appear to have been understood by the Aerospace report against these DOE Order 413.3 Criteria.

Exhibit 4.4.2 is an extracted page from DOE Order 413.3 providing guidance concerning relative estimate accuracy ranges as a function of the Critical Decision Milestone status

•	CD-0	Estimate Accuracy Range -20% to +100%	Option 4
•	CD-1	Estimate Accuracy Range -15% to +50%	
•	CD-2	Estimate Accuracy Range -10% to +30%	
•	CD-3	Estimate Accuracy Range -5% to +20%	Option 1
•	CD-4	Estimate Accuracy Range -3% to +15%	

High Bridge understands and has evaluated Option 1 and Option 4 through these criteria.

Exhibit 4.4.1 – Critical Decision Process Overview

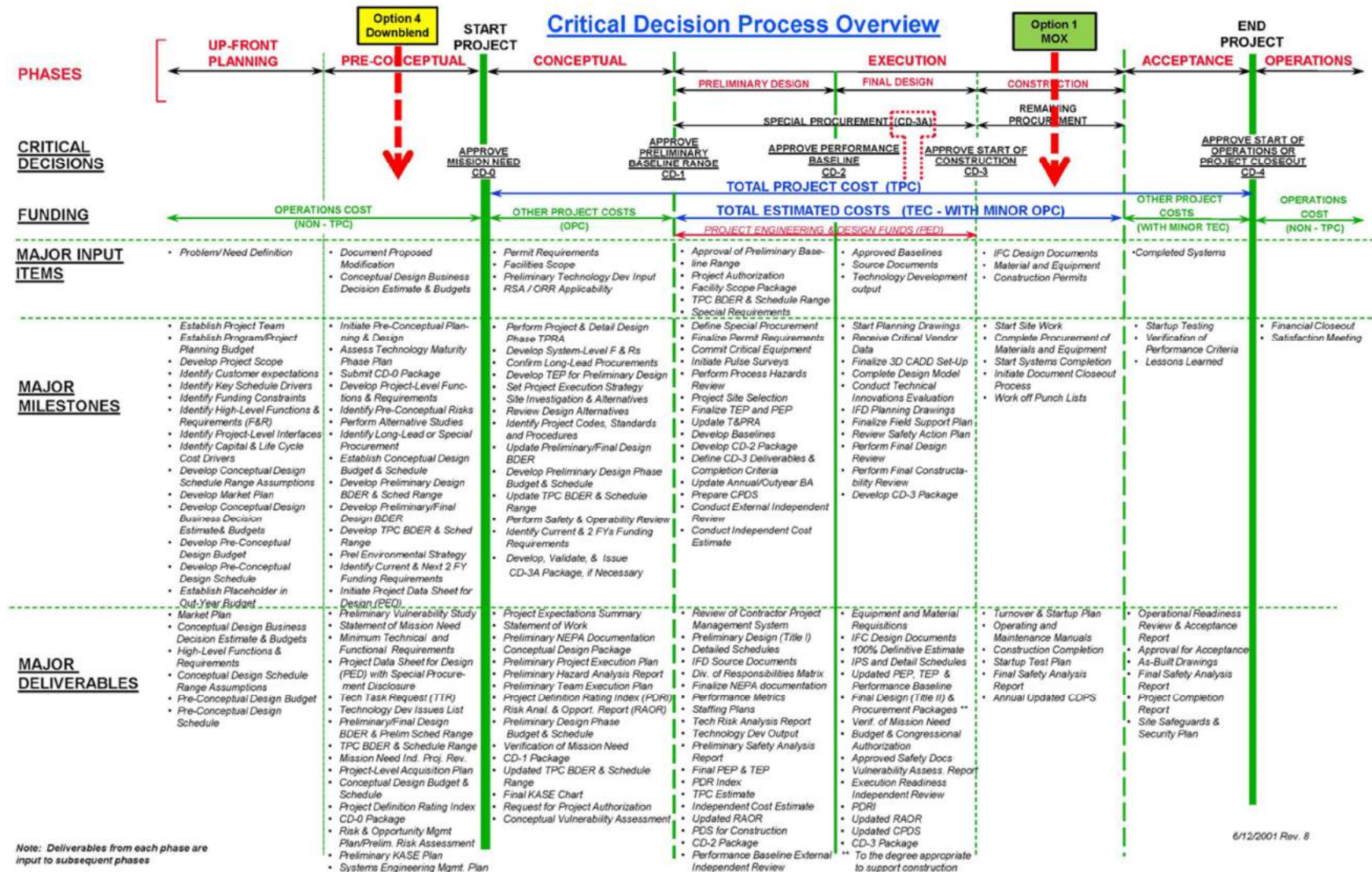


Exhibit 4.4.2 – DOE Order 413.3 ExcerptDOE G 413.3-21
5-9-2011

15

ESTIMATE CLASS	Primary Characteristic	Secondary Characteristic		
	DEGREE OF PROJECT DEFINITION Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges ^[a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 70%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	70% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

Table 4.3 – Cost Estimate Classification for Process Industries

Critical Decision	Suggested Estimate	AACEI Estimate Classification
CD-0	Cost estimate range	Class 5
	Estimate of costs to be incurred prior to CD-1	Class 3
CD-1	Estimate of near term preliminary design cost	Class 3
	LCC of likely alternatives that are being considered	Class 5
	TPC range	Class 4
CD-2	Single point estimate representing entire project:	
	Low risk projects	Class 3
	High risk projects	Class 2
CD-3	Cost estimate based on Final Design [or sufficiently mature to start construction]:	
	Low risk and final design complete	Class 1
	Low risk and final design not complete	Class 2
	High risk (final design or not)	Class 2
CD-4		N/A

Table 4.4 – Generic Suggested Types of Estimates for DOE Critical Decisions

5 OPTION 4 DOWNBLEND AND IMPACTS ON WIPP

5.1 Overview

Much of the 25-year history of the design and construction of the WIPP was devoted to developing a better understanding of the size of the Transuranic Waste (TRU) waste problem and of the geological subtleties of this deep salt deposit. The final design was summarized in the Waste Isolation Pilot Plant Land Withdrawal Act of 1992 which authorized the placement of waste in the completed facility. Among other requirements, it sets the maximum size of the WIPP repository at 6.2 million cubic feet or approximately 175,600 cubic meters of TRU waste. Nothing in the law or in any of the licensing submittals has mentioned the possibility of disposing of weapons plutonium in WIPP, which suggests at least the possibility that an unanalyzed licensing issue may exist.

The Aerospace report includes the following passage on page 8:

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 the Downblend Options (**Reference 1**).

Not assessing these technical parameters reflects a deficiency in the Aerospace analysis process. Since these options are both inherently complex and the facilities being used by Option 4 Downblend are beyond their design life and need to be repurposed for that option, the failure to assess the scientific and technical aspects of the two options is a significant flaw in their methodology.

An intrinsic assumption of the Aerospace analysis of Option 4 Downblend is that there is adequate capacity at WIPP for the additional loading of TRU represented by 34 MT of excess weapons plutonium. Moreover, it is further assumed that no other organization has the right to use that available capacity. In fact, WIPP was created to support the DOE Environmental Management (EM) mission to clean up the legacy TRU wastes from the Cold War weapons production. This is an important effort that can only be accomplished with unimpeded access to WIPP.

In the Aerospace report risk table for Option 4 (**Reference 1**), risk 12 is entitled “Exceed Downblend Repository TRU Allowable Storage Volume.” It lists a probability of 10% with a predicted impact of \$22M. Risk 13 on the same risk table is entitled, “Need for Additional Storage Volume.” It lists a probability of 25% with a predicted impact of \$12.7M. It is difficult to reconcile these two risks and even more difficult to understand how they may have been quantified without at least examining the physical constraints of WIPP. In the absence of any technical rigor in the analysis, Aerospace has assumed that there is:

1. Space available for the waste to be placed in WIPP not needed for anything else, and
2. Only 34 MT of surplus weapons plutonium.

As demonstrated in **Section 5.3** below, the existing capacity of WIPP will be exceeded by using Option 4 Downblend for the 34 MTs of surplus plutonium. Moreover, DOE/NNSA is not in possession of 34 MTs of surplus weapons plutonium; they are in possession of over 51 MTs of surplus weapons plutonium. So, the Risk Assessment by Aerospace of the Option 4 Downblend approach is flawed by the approach they used that did not evaluate the technologies. The probability of Option 4 exceeding the volume allowed at WIPP is 100% and the cost would be significantly greater than the \$22M and the \$12.7M cited in the Aerospace report.

Exhibit 5.1.1 provides a summary analysis of WIPP capacity and projected loads based on the latest TRU Waste Projection, the latest excess Plutonium projection of 51 MT, and a realistic allowance for future growth of projected loads of TRU-waste and Plutonium. It reflects that the legislated volume capacity of WIPP will be exceeded by approximately 49% and that the 1,000-year Curie inventory will increase by 843%.⁵

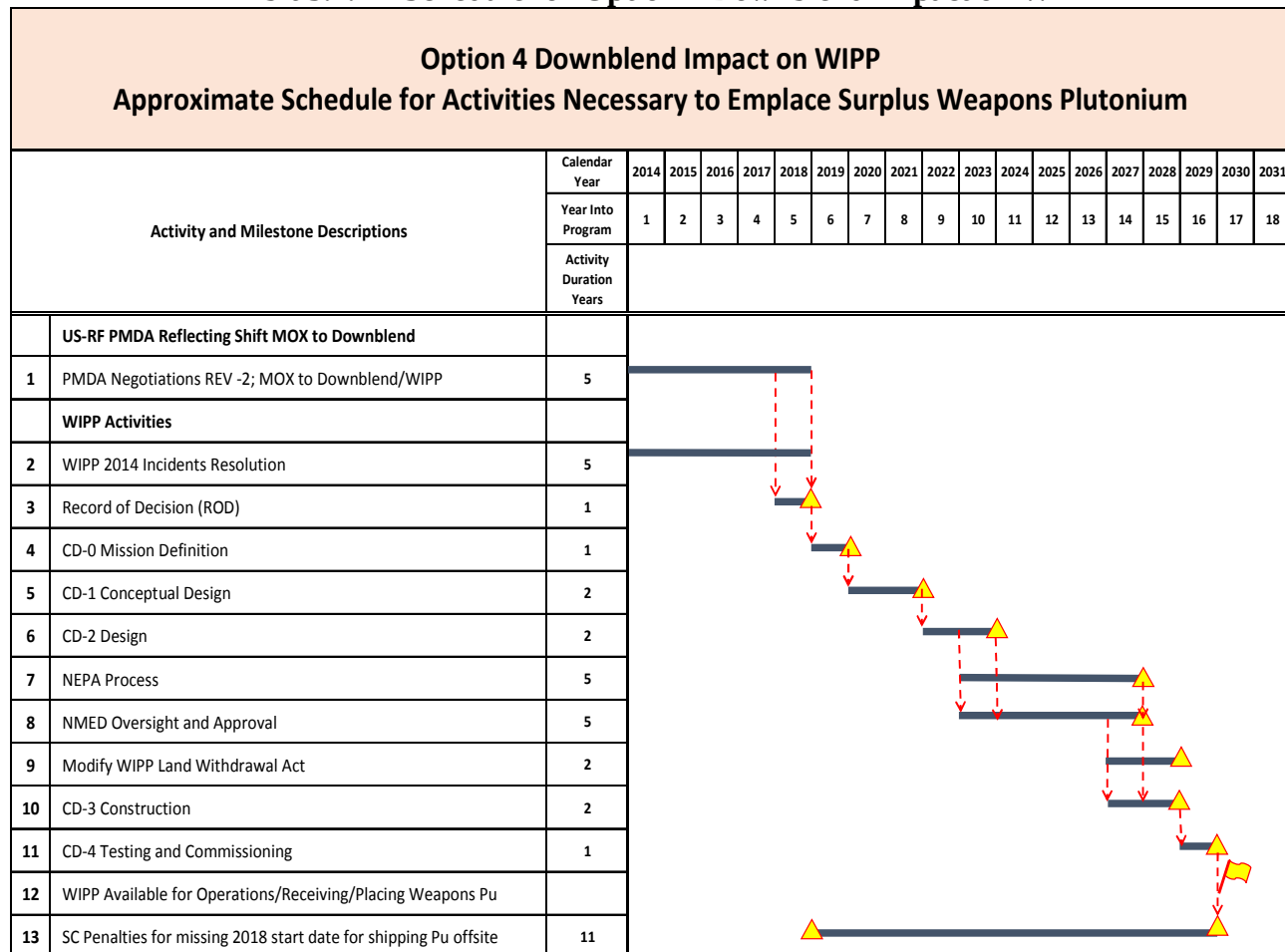
Exhibit 5.1.1 – WIPP Capacity and Projected Loads

WIPP Facility Capacity and Projected Loads TRU Waste and Plutonium Approximate Impacts						
Capacity and Projected Load Element		Cubic Meters	Cubic Meters/ 55 Gal. Drum	Number of 55 Gal. Drums	Plutonium Metric Tons	Curies *
1	Capacity per 1992 Land Act Law Low Level & Mixed TRU Waste	175,600	0.208	844,231	0	539,000
2	2014 DOE EM TRU Waste Projection	156,000	0.208	750,000	0	0
3	2015 NNSA Excess Plutonium Projection	<u>30,300</u>	0.208	<u>145,673</u>	<u>51</u>	<u>2,300,000</u>
4	Sub Total Projection	186,300	-	895,673	51	2,300,000
5	25% Freeboard for Future Identified Waste Projection	46,575	0.208	223,918		575,000
6	Allowance for additional surplus weapons plutonium	29,112	0.208	139,960	49	2,209,804
7	Capacity Basis for NEPA, New Mexico, & CD-1 to CD-4 Amendments	261,987	-	1,259,552	100	5,084,804
8	Approximate % Increase in Capacity/Load	49%	-	49%		843%
* - These are 1000 year curies, i.e., curies remaining in 1000 years.						

⁵ The Waste Isolation Pilot Project Land Withdrawal Act does not have an overall curie limit for TRU. It only has a curie limit for remote handled TRU to ensure that WIPP does not become a de facto High-Level Waste repository. This increase was measured against the value used to calculate the 1000 year source term for the NEPA FEIS.

Based on this capacity and projected waste inventory load analysis, the WIPP facility will require a NEPA Amendment, Revised Legislation, and a full Critical Decision (CD) 0 through 4 process in accordance with DOE Order 413.3. High Bridge also concludes that the resolution of WIPP corrective actions to address the 2014 incidents will require approximately five years to complete. Additionally, High Bridge believes that the PMDA Amendment with the Russian Federation needs to be completed prior to beginning this NEPA and CD process. As reflected in **Exhibit 5.1.2** these steps add approximately eleven years to the WIPP availability date to begin receiving Plutonium under the Option 4 Downblend approach.

Exhibit 5.1.2 – Schedule for Option 4 Downblend Impact on WIPP



As reflected in **Exhibit 5.1.2** above, there will be penalties owed the State of South Carolina for 11 years for missing the start date for shipping Plutonium out of state.

Exhibit 5.1.3 provides a cost estimate for the activities and steps reflected on **Exhibit 5.1.2**. High Bridge concludes that approximately \$2.0B in additional costs will be incurred to follow the Option 4 Downblend approach. High Bridge considers this as a 100% certainty to occur and added this to the estimated base costs for Option 4.

Exhibit 5.1.3 - Option 4 Downblend Impact on PMDA, WIPP, and SC Fines

Option 4 Downblend Impact on PMDA, WIPP, and SC Fines Approximate Cost Estimate			
	PMDA, and WIPP Activities/Steps	Cost Estimate	Basis
	<u>PMDA Amendment Activities</u>		
1	PMDA Negotiations REV -2; MOX to Downblend/WIPP	\$83,750,000	Average 40 FTE for duration and a Team of 10 National Lab SMEs
	<u>WIPP Activities</u>		
2	WIPP 2014 Incidents Resolution	\$360,000,000	Current published estimate is the Low Est. Worst case estimate offered a public meeting by DOE of 5 years is the high (not included in the Total Option 4 Impact below)
3	Record of Decision (ROD)	\$2,406,250	Staff and DOE manager's time to organize and obtain necessary approvals for ROD - 5 FTEs
4	CD-0 Mission Definition	\$11,811,250	DOE management team procuring the services of a Contractor to develop the technical basis
5	CD-1 Conceptual Design	\$28,875,000	DOE management team overseeing the services of a Contractor that prepares the CDR
6	CD-2 Design	\$61,875,000	DOE management team overseeing the services of a Contractor that prepares the design packages
7	NEPA Process	\$326,562,500	DOE management team overseeing the services of a Contractor that prepares the design packages
8	NMED Oversight and Approval	\$18,906,250	5 NMED officials and a 10 person consultant firm 1/2 time
9	Modify WIPP Land Withdrawal Act	\$6,875,000	DOE Officials and staff briefings with staffers and legislators
10	CD-3 Construction	\$284,375,000	DOE management team overseeing the services of Contractors that prepare the procurement packages and actual construction services
11	CD-4 Testing and Commissioning	\$37,109,375	DOE management team overseeing the services of Contractors that conduct the startup testing and the readiness reviews to begin operations with surplus weapons Pu.
12	WIPP Total	\$778,795,625	
13	SC Penalties for missing 2018 start date for shipping Pu offsite	\$1,100,000,000	\$100M/yr starting in 2019
	Total Option 4 Impact	\$1,962,545,625	

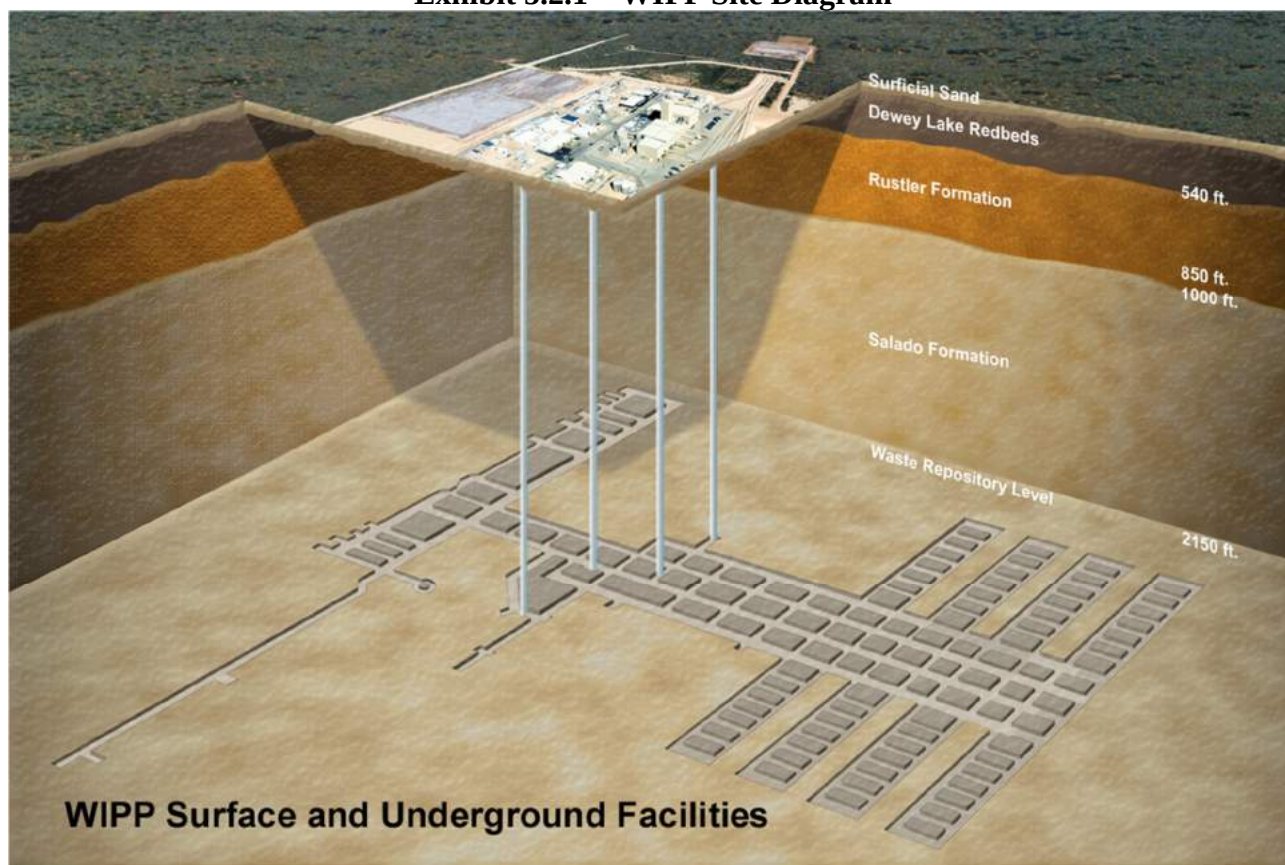
The Aerospace report identified the increase in the cost of WIPP operations for placing Option 4 Downblend plutonium at WIPP is \$360M and provided no backup. The increase in the cost of disposal operations at WIPP for the surplus weapons plutonium would be proportional to the number of extra shipments that result from Option 4 operations. Using 350 Fissile Gram Equivalents (FGE) per CCO, it would take more than 97,000 drums to package all of the plutonium. At 42 CCOs per shipment (i.e., three TRUPACT-II overpacks per shipment), this converts to approximately 2,300 shipments. If SRS could ship 17 shipments per week, it would take about 2.6 years to emplace the entire 34 tons of plutonium at WIPP.

The National TRU Waste Management Plan prepared by the DOE Carlsbad office provided an estimate of operational costs for WIPP (**Reference 14**). It identified the cost for disposal of TRU over the life of the EM TRU program. The values vary yet the projection for the disposal costs, not including transportation costs, are within 95.6% of the cost of preparing the waste packages. The resulting approximate WIPP costs for waste placement and for other mission critical activities is 95.6% of the Option 4 Downblend costs of \$2.094B or approximately \$2.0B. This would represent a net increase of nearly \$1.64B more than the Aerospace report predicted.

5.2 Background

The Waste Isolation Pilot Plant is a waste repository for TRU wastes located near Carlsbad New Mexico. It originated as a pilot project to demonstrate the effectiveness of using “salt domes” as geologic formations to store long-lived nuclear waste. Over time, it evolved into the TRU repository for the U.S.’s legacy wastes from the Cold War’s weapons production. The site is an arid scrub-covered surface beneath which lies about 1,000 feet of clay, silt, and sedimentary rock. Below that, there is nearly 2,000 feet of salt, undisturbed for 250 million years. It is essential for the DOE’s Environmental Management (EM) program. **Exhibit 5.2.1** is a diagram of the WIPP site.

Exhibit 5.2.1 – WIPP Site Diagram



(Reference 33)

TRU waste is waste containing more than 100 nanocuries per gram of radioactive isotopes of elements higher in the periodic table than uranium, i.e., *transuranic*. These elements include Plutonium,

Americium and others that resulted from developing nuclear weapons. TRU isotopes typically have long half-lives and emit alpha particles as their major decay product. These characteristics make these isotopes extremely persistent and potentially damaging to flora and fauna if allowed into the environment. The DOE had been segregating the TRU waste from other low-level wastes since the 1970s and ensuring that it was stored in a manner that would permit retrieval once the repository was available. Preliminary test drilling was done in 1973 and resulted in the final decision to select current site over others. The original Final Environmental Impact Statement (FEIS), issued in January of 1980, described the materials to be disposed of at WIPP as “a wide variety of physical forms, ranging from unprocessed general trash (e.g., absorbent papers, protective clothing, plastics, rubber, and wood) to decommission tools and glove boxes” (**Reference 24**). A more recent Supplemental EIS finalized in 1997 added “solidified sludges from wastewater treatment” (**Reference 25**).

About 60% of the TRU waste is mixed-waste because it also contains hazardous substances that are controlled by the Resource Conservation and Recovery Act (**Reference 26**). Lead is the major contributor to this characterization since it was used for shielding in gloveboxes and in personnel protection clothing. In addition, there are a number of industrial cleaners, solvents, lubricants and other industrial RCRA wastes in the TRU waste forms.

TRU wastes are classified for handling purposes as either contact-handled (CH) or remote-handled (RH). RH waste has a dose rate in excess of 100 R/hr and must be handled using shielded overpacks and robotic machines. RH wastes are placed in holes drilled into the walls of the drifts. No wastes with contact dose rates greater than 1000 R/hr can be placed in WIPP. CH wastes can safely be handled more easily and are stacked directly on the floor of the drifts.

Salt is “plastic” and acts to close holes mined into it. Consequently, the entire site is not mined as might be the case in a hard rock repository. Instead, the drifts are mined and secured continuously as the repository is filled. WIPP has already experienced some cave-ins and floor upheavals that require continuous mining operations to keep the facility operational. In February 2014, a mining truck in the repository caught fire and forced a shutdown of operations. Subsequent to that event, a waste drum packaged at LANL experienced a chemical reaction that over pressurized a waste container causing the release of plutonium and americium. WIPP has been shutdown since that event while cleanup and a root-cause determination is conducted. Current planning has estimated that it may take between two and five years to recover operations, and it could be expected to be under new operating protocols with uncertain impact on waste placement rates.

5.3 WIPP Capacity: Original versus Modified Mission

The maximum volume of TRU waste permitted in WIPP was set into law by the Waste Isolation Pilot Project Land Withdrawal Act at 6.2 million cubic feet, or 175,600 cubic meters. (**Reference 12**) An intrinsic assumption of the Option 4 Downblend alternative is that there is adequate capacity at WIPP for the additional loading of TRU represented by 34 MT of excess weapons plutonium. There are two challenges with this assumption:

- There is adequate available space for the waste to be placed in WIPP that is not needed for anything else.
- There are only 34 MT of surplus weapons plutonium.

Every year, the DOE issues a report called the Annual Transuranic Waste Inventory Report. The latest revision was issued December 31, 2014. **(Reference 13)** It identifies that the volume of TRU waste emplaced or identified for emplacement is 156,000 cubic meters. That leaves approximately 19,600 cubic meters of capacity available for the disposal of the surplus weapons plutonium. Using the latest disposal container incorporating a Criticality Control Overpack, a 55-gallon drum is permitted to dispose of 380 FGE per drum.⁶ The actual wording in the NRC limit for the CCO design container is “shall not exceed” 380 FGE. The Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement published in April 2015 **(Reference 28)**, uses a value of 350 FGE per CCO for its assessment to ensure that no waste container is overloaded. Using 350 FGE per container, it would require 97,143 drums to package 34 MT of plutonium. At 0.208 cubic meters per 55-gallon drum, that is equivalent to 20,200 cubic meters or approximately 600 cubic meters above the maximum capacity permitted for WIPP.

While the most recent report suggests that approximately 12% of the rated capacity is freeboard, a review of the Annual Transuranic Waste Inventory reports suggests that the EM mission will continue to require more of that space. **Exhibit 5.3.1** is a table that shows the projected total TRU inventory over time. It is obvious that the trend is generally up with more TRU being identified and packaged for disposal at WIPP over time. If all of the excess capacity in WIPP is taken up by redirecting the surplus weapons plutonium to the repository, it will do so at the expense of the DOE-EM mission of WIPP, i.e., to clean up the Weapons Complex and to provide a disposal pathway for the continuing efforts maintaining weapons every year.

Exhibit 5.3.1 – WIPP Identified TRU Volume

WIPP Identified TRU Volume Cubic Meters			
Calendar Year	Emplaced Waste	Anticipated Waste	Total Waste Inventory
2007	46,000	103,000	149,000
2009	64,500	81,800	146,000
2010	72,400	80,100	153,000
2011	79,700	71,500	151,000
2012	85,200	66,200	151,000
2013	90,400	65,900	156,000

(See **Reference 26**.)

The second assumption underpinning Option 4 Downblend is that there is only 34 MT of surplus plutonium. Currently, the NNSA is planning to dispose of approximately four MT of excess weapons grade plutonium that is currently being treated at SRS. DOE has also identified 13.1 MTs of plutonium for which a Final Supplemental Environmental Impact Statement (SEIS) was issued in April of 2015 without a preferred disposal option selected **(Reference 28)**. Without MOX, these two inventories of surplus plutonium would need to be disposed of at WIPP. Taken together, these identified sources of surplus weapons plutonium account for 51 MT of plutonium. If MFFF is completed, these could be processed into nuclear fuel and be used to generate revenue for the Treasury. This would convert the plutonium into a form that is undesirable for a state nuclear

⁶ FGE stands for fissile gram equivalent and is a unit that permits all waste generators to convert the grams of other fissile isotopes into an equivalent number of grams of plutonium 239. This simplifies criticality calculations at WIPP. For weapons plutonium, 1 FGE is approximately equal to 1 gram of plutonium.

weapons designer and is undesirable from a diversion point of view due to the extreme radiation dose rate associated with used nuclear fuel. Using Option 4 Downblend and the average of 350 FGE per can to ensure that no waste package exceeds the 380 FGE limit, the currently identified 51 MTs of plutonium would require about 145,700 drums that would occupy 30,300 cubic meters of WIPP capacity. As described earlier, there are only about 19,600 cubic meters available without impacting the EM mission as currently defined.

In conclusion, the Option 4 Downblend does not fit in WIPP as currently configured, it also cannot accommodate additional surplus weapons plutonium that could be identified as a result of future arms control agreements. Original discussions with the Russian Federation made mention of potentially as much as 100 MTs of surplus plutonium. Option 4 not only effectively precludes the disposition of the 34 MTs of surplus plutonium, as currently agreed in an international agreement with the Russian Federation, but it also eliminates the potential expansion of nuclear weapons dismantling programs by effectively discarding the United States' flexibility as represented by the MFFF project under the MOX Program.

5.4 Impacts of Modifying WIPP's Design Basis

In order for Option 4 Downblend to be pursued, the design basis for WIPP would need to be re-engineered and relicensed to ensure that it meets the new requirements. The agreement by New Mexico did not provide for the acceptance of any sort of waste that the DOE/NNSA decides to bring there. It precluded the disposal of spent nuclear fuel and commercial wastes from West Valley and other sites that were not connected to the weapons complex. Arguably, disposing of surplus weapons components also falls outside of the agreement. Especially in the light of renewed scrutiny after the 2014 incidents, there may be less willingness by New Mexico stakeholders to accept the increase of the radioisotopic source term by nearly an order of magnitude. As a minimum, however, the entire program would need to be reevaluated and revised to accommodate the new larger inventory of TRU at WIPP. This represents a major delay in the schedule suggested by Aerospace for Option 4.

Since beginning this process means abandoning the disposition method agreed to in the PMDA, the first step must be renegotiating the PMDA with the Russian Federation. Since beginning the dilution process would represent a semi-irreversible step, it would be unwise to begin those steps prior to reaching an agreement with the Russian Federation regarding the new approach. Papers written by A. Diakov and V. Rybachenkov, both of the prestigious Center for Arms Control, Energy and Environmental Studies, in Moscow, have suggested that Option 4 Downblend represents a potential deal breaker. The Russian Federation has always insisted on isotopic conversion of the plutonium to render it undesirable for a State weapons designer. This is achieved only by reducing the amount of Pu239 while increasing the amount of Pu240 in the plutonium. While this does not render the plutonium unusable in a weapon, it does make it unreliable for a State produced weapon because the spontaneous fission rate of Pu240 makes it difficult to impossible to predict the performance of the final weapon.

Diakov and Rybachenkov suggest that the only point that would attract the Russian Federation to accept the ineffective deterrence approach represented by Option 4 Downblend is the possible use of a breeding blanket in their fast reactors. The current revision of the PMDA specifies that the Russian Federation can "burn" the plutonium in their fast reactors as long as the breeding ratio in each reactor

is less than one.⁷ While this is possible in a fast reactor, it requires replacing the “blanket” region of the core with materials other than depleted uranium. This causes the nuclear core designers some difficulties and does not enable the plant operators to optimize performance until the 34 MTs of plutonium has been consumed. In other words, for the Russian Federation to accept the use of Option 4 Downblend, they would insist in using the weapons plutonium to breed more reactor grade plutonium than consumed. This is an elegant use of the plutonium from their point of view but an extremely difficult position for the U.S.-side to accept.

The previous renegotiation of the PMDA was over essentially minor, mutually agreeable points. These included the effective start date, the agreed to throughput, the elimination of the Russian Federation’s LWR MOX program and the elimination of immobilization on the U.S.-side. Negotiations started in 2007 and did not result in a ratified agreement until 2011.⁸ That five-year effort is not likely to be duplicated for this proposed change. The Russian Federation has always been adamant that the plutonium remains weapons-ready unless the isotopic makeup of the plutonium is irrevocably altered. The U.S.-side has always maintained that plutonium inventories should be reduced by this effort and not increased. While an agreement that was a collection of minor issues took five years to execute, it is unrealistic to assume that this revision of the PMDA could be accomplished in a shorter period of time. It is likely to take significantly longer and cost a lot more than Aerospace assumed for Option 4. High Bridge assumed optimistically that this can be achieved in an aggressive five-year period for a cost of approximately \$84M.

The record of decision (ROD) process could be initiated once the agreement has been reached on the new PMDA language but the actual design effort would probably not be authorized until the PMDA is ratified. This process would require a critical decision process for modifying WIPP for its new enlarged mission and authorizations for the other activities necessary for Option 4. The major problem for the redesign, retrofit, and relicensing of WIPP is the definition of the new mission. Not only would it need to be resized for the 51 MT identified already, it would also need to be enlarged to address expansion of the EM mission and the largest credible amount of surplus plutonium that might result from START talks in the future.

Exhibit 5.1.2 above provides an approximate schedule for the activities necessary to emplace surplus weapons plutonium. Critical Decision 0 (CD-0) would take 6 to 12 months and would result in a defined mission and scope for the revised WIPP design and a separate effort to identify the modifications necessary at SRS and LANL to accommodate the Option 4 modifications.

Following the approval of the CD-0 package, a CD-1 effort would be required to develop a conceptual design report and the other deliverables necessary to set the range estimates for the project. Following approval of the CD-1 effort deliverables, the CD-2 effort would be necessary to develop the preliminary design to a state that could support the beginning of the NEPA process and deliver a Draft Supplemental EIS for review.

⁷ Breeding ratio is a measure of how much plutonium is created in the blanket compared to the amount that was loaded in the driver region of the core. A breeding ratio of less than one means that the reactor makes less plutonium than was originally loaded. Normally, the BN-600 and the new BN-800 would have breeding ratios greater than 1.0. This could be accomplished only by designing a special blanket region of the core that does not contain uranium.

⁸ While the PMDA protocol was signed in 2010, the agreement did not enter into effect until the Russian Duma ratified it in 2011.

Since the disposal of pure weapons plutonium from pits has never been addressed, the NEPA process is certain to be at the higher end of the range of effort both in terms of time and money than a minor supplement DEIS review. Indeed, in the wake of the incidents in February 2014, it is almost certain that the effort to obtain the approval for the revised design of the WIPP will be significant and possibly contentious. Finally, WIPP was originally proposed as a “pilot project.” It had a 25-year design life and a narrowly defined mission. Opening its licensing up to a new mission and a significant increase in size and environmental impact could be problematic.

Finally, upon successful issuance and approval of the FEIS for the revised WIPP design, an act of Congress is required to expand the area impacted by the WIPP Land Withdrawal Act before any CD-3 Construction or CD-4 Operations could begin.

As a result, Option 4 requires a reconfiguration of WIPP with a complete licensing effort to expand the capacity significantly. The size increase would need to consider the amount of space required for all conceivable weapons plutonium disposal in addition to enough capacity to ensure that the existing EM mission is not impacted. This means a CD-0 process, a CD-1 process, a CD-2 process, a NEPA process including obtaining the approval of the State of New Mexico, an amendment to the existing WIPP Land Withdrawal Act a CD-3 process and a CD-4 process. The minimum time that this is estimated to be is 11 years.

In conclusion, instead of being more expedient than the current plan to use MOX, Option 4 Downblend will be significantly longer. This brings into focus the current law authorizing the use of South Carolina to host this activity. Instead of being able to begin operations before the end of 2018 as suggested in the Aerospace report, the more credible likelihood is that Option 4 Downblend could not begin operations until the start of 2030; eleven years later. 50 U.S. Code § 2566 – “Disposition of weapons-usable plutonium at Savannah River Site” as amended in 2005 identifies a fine of \$1M per day up to \$100M per year for every year that plutonium is not removed from South Carolina. It is not clear if the wording of the law is forceful enough to enforce this fine, or if the operation of Option 4 actually is effective enough to remove the enforcement of the fine due to the slow rate of processing plutonium. But since WIPP is unlikely to be able to start receipt and emplacement of surplus weapons plutonium as prepared in Option 4 until 2030, it is clear that Option 4 will cost DOE/NSA approximately \$1.1B in fines before operations can begin.⁹

Exhibit 5.1.3 above is an approximate rollup of the costs associated with the impact of Option 4 Downblend on WIPP. These are unintended consequences of Option 4 and are not risks, but rather, they are part of the base cost of the pursuing Option. They represent a present day cost of approximately \$2B that was not recognized in the Aerospace or the PWG reports.

Indeed, this cost could be considered a cost avoidance benefit of proceeding with of Option 1 since it is likely that WIPP would be able to support its current mission without major modification. The identified surplus weapons plutonium beyond the 34 MTs in the PMDA will easily fit into WIPP without the need for major revisions. Indeed, the 13.1 MTs were the subject of a FEIS issued in April of 2015 entitled “Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement.” (**Reference 28**). While the FEIS did not identify a preferred alternative, clearly the work

⁹ This assumes that no Option 4 wastes are shipped prior to the completion of the WIPP modifications and passage of a revised WIPP Land Withdrawal Act.

necessary to process that plutonium via Option 4 is not nearly as onerous as would be the case if MOX is abandoned. First, it is not included in the quantity in the PMDA, so there is no need to reopen negotiations with the Russian Federation. Second, 13.1 MTs does not represent a volume of waste that threatens the EM Mission or impacts the legal and licensing basis of WIPP. Using the technical approach described as Option 4 for small amounts of plutonium currently identified surplus would not result in nearly as much cost and schedule delay.

5.5 WIPP Operations

The Aerospace report projected an increase in the cost of operations at WIPP of \$360M. There was no granularity provided for the value. The increase in the cost of disposal operations at WIPP for the surplus weapons plutonium would be proportional to the number of extra shipments that result from Option 4 operations. Using 350 FGE per CCO, it would take more than 97,000 drums to process all of the plutonium. At 42 CCOs per shipment (i.e., three TRUPACT-II overpacks per shipment), this converts to approximately 2,300 shipments. If SRS could ship 17 shipments per week, it would take about 2.6 years to emplace the entire 34 tons of plutonium at WIPP.

The National TRU Waste Management Plan prepared by the DOE Carlsbad office provided an estimate of operational costs for WIPP (**Reference 14**) and identifies the cost for disposal of TRU over the life of the EM TRU program. The projection is for the disposal costs, not including transportation costs, are within 95.6% of the cost of preparing the waste package. This indicates that the WIPP cost for waste placement and for other mission critical activities should be 95.6% of the Option 4 Downblend costs of \$2.094B or approximately \$2.0B. This would represent a net increase of nearly \$1.7B more than the Aerospace report predicted. The total impact of these costs was summarized in Section 3 above.

6 VALUE OF MOX FUEL SALES AND CLEAN ENERGY

6.1 Overview

The Aerospace Report identified no net income credit for the Option 1 MOX Fuel alternative, provided little discussion of the status, and exhibited limited understanding of the fuel sales process and approach. The Aerospace report provided no analysis or identified cost benefit for the economic contribution to the GNP or Clean Energy Production. High Bridge finds this lack of analysis to be an important omission.

MOX Fuel Sales - The goal of the MOX project is to transmute the isotopic makeup of the surplus weapons plutonium into a form that makes it less usable by a weapons state for weapons. This is done by incorporating the plutonium into fuel for use in commercial nuclear reactors. The surplus stockpile can produce approximately 2,000 PWR fuel assemblies. AREVA began MOX fuel marketing activities in the 2009 timeframe and was successfully building a list of interested nuclear operating companies. By 2013, AREVA had several letters of intent or expressions of interest and several more being developed to strengthen their negotiating position for future discussions.

The core of a nuclear reactor is “reloaded” every 18 or 24 months¹⁰ and about a third of the total core is replaced with fresh fuel assemblies. Overall, the 34 MT of plutonium would produce approximately 30 core reloads for a 1,200 MWe reactor. The approximate cost for a replacement uranium fuel reactor core is \$100M. The value of the displaced uranium fuel assemblies would cost approximately \$3B. Assuming a 20% discount to the nuclear utilities and a 40% to 50% cost of materials supplied by AREVA, the net revenue for the U.S. Treasury for fuel sales would be approximately \$1B over the life of the project.

Contribution to GNP and Clean Energy - An ancillary benefit of the MOX program is the production of clean, green-house gas free, electrical energy. A nuclear reactor currently “burns” its nuclear fuel at a rate of 45,000 MW-Days/Metric Ton. The 34 MTs of surplus weapons plutonium will result in approximately 875 MT of fuel. This fuel would generate 15,300 MW-Days of electricity. At an average retail price of electricity of \$110 per MW-Hr, that amount of electricity is worth \$35B. This would be done without consuming uranium from the normal fuel cycle, so it would be accomplished with no new mining, milling, converting, or enriching processes. In addition, it consumes depleted uranium that would otherwise be deposited in a radioactive waste dump, would cost the DOE several hundred million dollars in disposal fees, and would pose an environmental risk for years to come. The value to the gross national product of the electricity sales (\$35B) from the MOX fuel is greater than the Option 1 capital cost and the total life-cycle cost (\$19.4) in FY14\$. Therefore this investment by the DOE yields considerably greater value than its cost. Unlike Option 4 that produces no trickle-down revenue or GNP contribution and represents a net loss to the taxpayers, Option 1 represents a net improvement in the GNP wealth of the U.S. and creates >10,000 U.S. jobs driven by the availability and consumption of clean electricity. Using the 34 MT of Plutonium converted to approximately 30 nuclear power reactor MOX Fuel core loads will eliminate approximately 335 million tons of carbon emissions, 420,000 tons of NOx emissions, and 675,000 tons of SO₂ emissions. **(Reference 29).**

Exhibit 6.1.1 provides a summary comparison of revenue, cost impact items, and value considerations for key elements of the Option 1 and Option 4 Alternatives.

Overall jobs creation for Option 1 MOX Fuel is estimated at >5,000 job during construction and >2,000 jobs during operation. As identified on **Exhibit 6.1.1** above, it is estimated that >10,000 jobs will result from the consumption of clean electricity over 20 years.

¹⁰ The variability of the existing core designs makes the following analysis qualitative. It assumes a PWR and provides indicative values to make a point. It is not intended to be a rigorous treatment of fuel costs. AREVA will seek to get the most value for the MOX fuel consistent with finding host nuclear operating companies.

Exhibit 6.1.1 – Comparison of Plutonium Disposition Program Alternatives

Comparison of Plutonium Disposition Program Alternatives Approximate Revenue, Cost Impact, and Value Contribution Metrics MOX Fuel Sales, Clean Energy, and GNP Parameters Option 1 MOX Fuel vs. Option 4 Downblend				
#	Option 1 - MOX Fuel		Option 4 - Downblend	
	Program Element		Program Element	
1	Metric Tonnes of Plutonium Pu 239	34	34	Metric Tonnes of Plutonium Pu 239
2	Pounds of Plutonium Pu 239	74,956	74,956	Pounds of Plutonium Pu 239
3	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved	Yes	No	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved
4	Approximate Product Output Nuclear Fuel PWR Assembly Approx. 8.5" x 8.5" x 13.5' Long Each Containing Approx. 264 Zircalloy Clad Fuel Rods	2,000	97,000	Approximate Waste Form Output Plutonium Diluted/Mixed with Stardust Inert Material in 6" Diameter x 2' Long Container Packed Inside a 55 Gallon Drum
5	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales	\$1,000,000	\$0	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales
6	Approximate Number of Shipments in Casks with 2 Fuel Assemblies/Cask, 4 Casks/Truck, and 3 Trucks/Shipment	80	2,300	Approximate Number of Shipments in TRUPACT-II Containers with 14 Drums/Container and 3 Containers/Truck
7	Approximate WIPP Storage Capacity Volume Consumed	~0	20,200 Cu. Meters	Approximate WIPP Storage Capacity Volume Consumed
8	Approximate Megawatt Hours of Clean Electricity Produced	285 Million	0	Approximate Megawatt Hours of Clean Electricity Produced
9	Approximate Value of Clean Electricity Produced	\$35 Billion	\$0	Approximate Value of Clean Electricity Produced
10	Approximate State/Local Tax Revenues Generated	>\$5 Billion	\$0	Approximate State/Local Tax Revenues Generated
11	Approximate Life Cycle Cost of MOX Program	\$19.4 Billion	\$19.9 Billion	Approximate Life Cycle Cost of Downblend Program
12	Approximate US Jobs Created for 20 Years	>10,000	0	Approximate US Jobs Created for 20 Years
13	Avoided Carbon Emissions	335 Million Tons	0	Avoided Carbon Emissions
14	Avoided NOx Gas Emissions	420,000 Tons	0	Avoided NOx Gas Emissions
15	Avoided SO2 Gas Emissions	675,000 Tons	0	Avoided SO2 Gas Emissions
NOTE: The values identified in this Exhibit are approximate based on the analysis performed during the High Bridge Phase 2 Report Review.				

6.2 MOX Fuel Sales

The Aerospace Report identified no net income credit for the Option 1 MOX Fuel alternative, provided little discussion of the status, and exhibited limited understanding of the fuel sales process and approach. The Aerospace report provided no analysis or identified cost benefit for the economic contribution to the GNP or Clean Energy Production. High Bridge finds this lack of analysis to be an important omission.

The goal of the MOX project is to make fuel for commercial power reactors in order to transmute the isotopic makeup of the weapons plutonium into a form that makes it less usable by a nuclear state for weapons. In order to make the fuel attractive to potential nuclear operators, it will probably need to be sold at a discount to recognize the increased cost to the utility for managing MOX fuel. DOE/NNSA realized that they are not the organizations to involve themselves in commercial fuel sales, so they asked AREVA to provide a sales and marketing service for the project.

AREVA is a major fuel supplier to the American nuclear fleet and they produce fuel for all types and models of nuclear reactors in operation today. They began MOX fuel marketing activities in the 2009 timeframe and were successfully building a list of interested nuclear operating companies. By 2013, AREVA had several letters of intent and several more being developed to strengthen their negotiating position for future discussions. When DOE was forced to curtail the program funding in 2013 due to budget constraints, the AREVA team was fairly confident that selling the MOX fuel would not be a problem. AREVA's nuclear fuels group would provide the hardware to the MOX project so that the QA/QC of the materials would be assured. DOE/NNSA would provide the materials for the MOX fuel, i.e., depleted uranium and the plutonium and the work necessary to convert these raw materials into feedstock for fuel pellets. The MFFF would sinter the uranium and plutonium oxides into fuel pellets of the correct metal ratio for the specific reactor and fabricated the fuel assemblies.

MOX fuel has slightly different nuclear performance than uranium fuel. Some reactors can use a complete MOX core while others would require modifications (slightly different control rod materials and/or core instrumentation) while most of the fleet could only use partial core loads of MOX fuel. This makes the negotiations potentially difficult because no organization but a major fuel supplier understands the variables. A light water reactor (BWR or PWR) typically replaces only 1/3 of their core with each fuel load. Depending on the enrichment and a range of other variables, the core is "reloaded" every 18 or 24 months.¹¹ A typical PWR reload is about 60 assemblies with approximately 461 kilograms of uranium each, assuming a metal ratio of approximately 4% results in approximately 1,100 kilograms of plutonium in each core reload. So, the 34 MT of plutonium would produce approximately 30 core reloads.

Assuming that the reactor can operate on a 100% MOX core, the typical cost of replacement uranium fuel for a 1,200 MWe reactor core is approximately \$100M. The value of the 30 displaced uranium fuel reloads would be cost approximately \$3B. Assuming a 20% discount to the nuclear utilities and 40% to 50% cost of materials supplied by AREVA, the net revenue to the DOE for fuel sales would be approximately \$1B over the life of the project.

Some have said that the government is "subsidizing" the MOX sales. This is incorrect. A subsidy implies a cost to the government when, in fact, DOE will be selling the MOX fuel at a to-be-negotiated discount. It is important to remember that the purpose of the MOX Program is to transmute surplus weapons plutonium in the U.S. to reduce the costs of safeguards while at the same time encouraging the Russian Federation to do the same. The revenue from fuel sales is a benefit to the government not a subsidy.

¹¹ The variability of the existing core designs makes the following analysis qualitative. It assumes a PWR and provides indicative values to make a point. It is not intended to be a rigorous treatment of fuel costs. AREVA will seek to get the most value for the MOX fuel consistent with finding host nuclear operating companies.

It will be the responsibility of AREVA's fuel sales staff to get the best deal possible. The nuclear operating companies are currently not negotiating this deal because they lack the confidence that this fuel will be available, given the reduced and uncertain funding status for the program. The savings of approximately \$20M per fuel load is a compelling incentive to negotiate once the utilities are convinced that DOE will actually complete the project and produce qualified nuclear fuel. The cost to cover AREVA's efforts is not a subsidy but rather a direct cost to a major component supplier. The residual for the government is expected to be 30% - 40% of the cost of the uranium fuel displaced by the MOX fuel.

The MOX project fuel sales will net approximately \$1B dollars to defray operational costs. Certainly, that is not full cost recovery, but that was never the intention of the U.S. selecting the Option 1 MOX Fuel approach and solution. The federal government is not going into competition with the American nuclear fuel suppliers. It is disposing of a strategic nuclear material in the most cost effective manner possible consistent with the PMDA.

6.3 GNP and Clean Energy

An ancillary benefit of the MOX program is the production of clean, green-house gas free, electrical energy. A nuclear reactor currently "burns" its nuclear fuel at a rate of 45,000 MW-Days/Metric Ton. The 34 MTs of surplus weapons plutonium will result in approximately 875 MT of fuel. This fuel would generate 15,300 MW-Days of electricity. At an average retail price of electricity of \$110 per MW-Hr, that amount of electricity is worth \$35B. This would be done without consuming uranium from the normal fuel cycle, so it would be accomplished with no new mining, milling, converting, or enriching processes. In addition, it consumes depleted uranium that would otherwise be deposited in a radioactive waste dump, would cost the DOE several hundred million dollars in disposal fees, and would pose an environmental risk for years to come. The value to the gross national product of the electricity sales (\$35B) from the MOX fuel is greater than the Option 1 capital cost and the total life-cycle cost (\$19.4) in FY14\$. Therefore this investment by the DOE yields considerably greater value than its cost. Unlike Option 4 that produces no trickle-down revenue or GNP contribution and represents a net loss to the taxpayers, Option 1 represents a net improvement in the GNP wealth of the U.S. and creates >10,000 U.S. jobs driven by the availability and consumption of clean electricity. Using the 34 MT of Plutonium converted to approximately 30 nuclear power reactor MOX Fuel core loads will eliminate approximately 335 million tons of carbon emissions, 420,000 tons of NOx emissions, and 675,000 tons of SO₂ emissions. **(Reference 29).**

It is noteworthy that this contribution to the U.S. is realized without the production of greenhouse gases. The enrichment of uranium is an energy intensive process and much of the electricity consumed in this process comes from coal fired power plants.¹² The remainder of the front end of the fuel cycle uses a modest amount of electricity and is of the same order as the MFFF. However, the substitution of Plutonium 239 for Uranium 235 in the fuel is a huge energy reduction and therefore a net improvement in the U.S.'s goal to reduce greenhouse gas emissions.

¹² This is an academic point at present because most of the uranium fuel used in U.S. today comes from the downblending of weapons grade uranium into low enriched uranium for fuel supplies. This is only a temporary perturbation of the market place and this point will be valid in the future when the MOX plant comes on line.

The use of nuclear power in the generation of electricity contributes significantly to greenhouse gas reductions. Using the 34 MT of Plutonium converted to approximately 30 nuclear power reactor core loads will eliminate approximately 335 million tons of carbon emissions, and prevents 420,000 tons of NO_x and 675,000 tons of SO₂ emissions. **(Reference 29).**

7 GEO-POLITICAL CONSIDERATIONS

7.1 Overview

Significant geo-political risks are associated with abandoning Option 1 MOX Fuel and transitioning to Option 4 Downblend. Replacing the Non-Proliferation partnership embraced in the PMDA between the United States and the Russian Federation could result in undesired outcomes. These issues, risks, and costs were not addressed by Aerospace, either quantitatively or qualitatively:

- a. In the past, the Russian Federation has rejected any option that does not convert weapons Plutonium to a non-weapons transuranic form, including immobilization. The Option 4 Downblend process is less rigorous than the Immobilization Option that was rejected by the Russian Federation in the past. The Plutonium 239 isotopic signature is not altered to a non-weapons form.
- b. Transitioning to the Option 4 Downblend approach would at best require many years of negotiation and/or result in Russia withdrawing from the Plutonium Management and Disposition Agreement (PMDA). This in turn would delay the Option 4 start and significantly increase overall costs.
- c. There is no recognition or discussion of the strategic value of Option 1 and its key role in the 2000 PMDA between the U.S. and the Russian Federation.

Option 4 has been mischaracterized as Downblending. The term downblending implies blending non-fissile plutonium isotopes with the weapons plutonium to fundamentally alter its nuclear characteristics as was done in the High-Enriched Uranium (HEU) U-235 Uranium Downblending Program. This is not possible with plutonium since there is no source of non-fissile plutonium available to mix with the weapons plutonium to achieve a similar goal. The Downblending option is actually a simplified Dilution and Immobilization process that would mix small amounts of the plutonium with an inerting agent referred to as “Stardust.” This provides a means of lowering the attractiveness level of the dilute plutonium bearing wastes so that the material could be handled as normal contact handled TRU waste. While this approach has been used to lower the Attractiveness Level of plutonium bearing wastes in the past, High Bridge finds that the actual safeguards may require additional security because the resulting waste form is a mechanical mixture that has not altered the chemical or isotopic form of the Plutonium.

In a recent paper written by V. Rybachenkov (a Senior Research Scientist, Center for Arms Control, Energy & Environment Studies, Moscow), he offered a concise commentary regarding Russian Federation expectations and insights concerning the U.S. adopting Option 4 Downblending. From his perspective, the Russian Federation would want U.S. concessions for option 4 to be acceptable. It is not clear what these concessions could be but in the past the Russian Federation has made

statements that they would like to operate their fast reactors in a "breeding" configuration while burning the PMDA 34 MT of weapons plutonium. This would move the Russian Federation and the U.S. away from a strong Non-Proliferation Partnership founded on the PMDA.

Former Secretary of Energy Bill Richardson (under President Clinton at the time of PMDA execution in 2000) recently had an Op Ed news clip in January 2015 **Appendix E**. He emphasizes the critical strategic importance of the PMDA and MOX Project in maintaining a dialogue with the Russian Federation and continuing a Non-Proliferation Partnership.

The Aerospace Report discusses the PMDA in Section 9 but only mentions that it will need to be discussed with the Russian Federation. It downplays the difficulty and time required to negotiate a mutually satisfactory PMDA Amendment that maintains a geo-political partnership. The first revision to the PMDA completed in 2010 addressed uncontentious issues and yet it required five years of effort to consummate. This revision involves extremely contentious issues that are likely to take an extremely long time to reach agreement, or to result in both parties abandoning the PMDA as unworkable. The Aerospace Report did not address the geo-political value and potential cost impacts, and the PWG likewise did not address this.

In summary, Option 1 MOX Fuel is an important DOE program and needs to be evaluated in the greater context that formed it. The DOE proceeding unilaterally in a new direction with the Option 4 Downblend approach when the Congress/United States have evaluated and selected Option 1 MOX Fuel approach could have undesired consequences.

7.2 SALT II Evolution to PMDA (2000)

The MOX project can trace its beginnings to the Strategic Arms Limitation Talks II (SALT II) that began in 1974 and culminated in an arms limitation agreement in June of 1979. This agreement removed several classes of nuclear weapons from each country's arsenal and was followed even though it was never ratified by the U.S.. It resulted in both the United States and the then Soviet Union declaring many tons of weapons plutonium to be surplus and placed into storage. In 1994, Presidents Clinton and Yeltsin issued a Joint Statement by the President of the Russian Federation and the President of the United States of America on Non-Proliferation of Weapons of Mass Destruction and the Means of Their Delivery (**Reference 30**). This joint statement began a five-year technical cooperation program that identified about 50 MT of surplus plutonium in each country's inventory for disposal.

The Joint Statement of Principles for Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes was signed by the President of the United States of America and the President of the Russian Federation on September 2, 1998. It affirmed the intention of each country to remove by stages approximately 50 MT of plutonium from their nuclear weapons programs and to convert this plutonium into forms unusable for nuclear weapons (**Reference 7**).

This resulted in the development of the PMDA between the Russian Federation and the United States of America. The original goal of 50 MTs was reduced by the negotiations process first to 38.2 MT and then to 34 MT. The PMDA was signed in 2000.

Article II of the PMDA identifies the goal of disposing of 34 MT as a start and commits to remove more plutonium from the inventory going forward. It identifies the means of disposal as one or more of the following:

- a) Irradiation of disposition plutonium as fuel in nuclear reactors;
- b) Disposition of plutonium into immobilized forms i.e. in a high level nuclear waste form product. A Stardust Downblend mixture was not identified. (**Reference 7**)
- c) Any other methods that may be agreed by the Parties in writing.

Subsequent to the initial PMDA, the Russian Federation and the United States began negotiations to amend the PMDA in 2007. In 2010, a protocol was signed that summarized the revisions to the agreement. The agreement entered into force on July 13, 2011, after the exchange of diplomatic notes in Washington by Sergey Lavrov and Hillary Clinton. It lowered the annual target for plutonium disposition from 2 MT a year to 1.3 MT per year. It enabled the Russian Federation to delete the use of VVER reactors for plutonium irradiation and substituted fast reactors with breeding ratios less than one, i.e., burner reactors, not breeder reactors.

The revised agreement set the goal for starting the disposition of the surplus plutonium at 2018. In summary, the MOX Fuel program is the result of nearly 40 years of effort of arms reduction talks, agreements and work. The PMDA established expectations that the isotopic content of the surplus plutonium will be downgraded. A great deal of infrastructure has already been put into place at great expense to achieve this goal.

7.3 Non-viability of Ignoring PMDA and Adopting Downblending

Option 4 has been mischaracterized as Downblending. The term downblending implies blending non-fissile plutonium isotopes with the weapons plutonium to fundamentally alter its nuclear characteristics. Since isotopes are chemically identical, the only way to return a down blended strategic nuclear material to weapons status is to enrich the fissile isotope using the techniques used to enrich uranium.

However, there are no significant isotopes of plutonium that are non-fissile. Additionally, there is no supply of plutonium isotopes available for downblending. The downblending option is actually a simplified dilution and immobilization process that would mix small amounts of the plutonium with an inerting agent referred to as Stardust. Stardust was first used at the Rocky Flats weapons plant decontamination and demolition project as a means of lowering the attractiveness level of plutonium bearing wastes so that the material could be handled as normal CH TRU waste. While it is suitable for that purpose, it does not alter the nuclear characteristics of the plutonium. The Russian Federation has always been suspicious of simple immobilization as an appropriate means of plutonium disposition. This view was witnessed first-hand by one of the High Bridge Review Team experts that served as part of a DOE-contractor negotiation support team and made numerous visits to attend PMDA coordination meetings in Moscow in 1999 to 2000. The Russian Federation has always contended that the radio-isotopic character of the surplus plutonium should be fundamentally altered to ensure its irreversible disposition.

Placing the surplus weapons plutonium into nuclear fuel and allowing it to be consumed in the reactor does two things. First, it converts plutonium 239 into fission products and energy. Second, it simultaneously increases the amount of plutonium 240 and 241. The presence of Pu 240 causes a weapon to experience degradation due to the spontaneous fission rate of Pu 240 which, in turn, causes random fissions in the rest of the warhead components. This causes the weapon's yield to be significantly lower than designed. This is the only protection against the Russian Federation or the U.S. from returning the plutonium to the weapons arsenal. It is clear that if the U.S. wished to recover the Pu 239 from the Option 4 waste form, it would be able to do so. This approach would be far cheaper than rebuilding the now defunct U.S. plutonium production infrastructure from scratch.

The proposed Option 4 Downblend does not meet the expectations the Russian Federation and is inconsistent with the PMDA as agreed to in the 2010 protocol. The Russian Federation is not primarily concerned with terrorists or rogue States obtaining strategic nuclear materials. They are more concerned with the United States government returning the plutonium surreptitiously to our arsenal. This view was witnessed first-hand by one of the High Bridge Review Team experts that served as part of a DOE-contractor negotiation support team and made numerous visits to attend PMDA coordination meetings in Moscow in 1999 to 2000.

Option 1, on the other hand, is expressly referenced in the PMDA 2000 and revision to the PMDA in 2010 as the premier means of rendering the plutonium unattractive for a weapons State. Exposure to the neutron flux in an operating core achieves the strategic objective of fundamentally altering the isotopic composition of the plutonium. Option 4 cannot be simply substituted for the MOX option. A revision to the existing PMDA needs to be renegotiated before the U.S. can begin to employ Option 4 or run the risk of undesired outcomes. If MOX is cancelled before achieving agreement on this new approach, the U.S. would be in violation of an agreement that went into effect only four years ago. This would have adverse impacts on various PMDA related issues.

Immobilization of plutonium in a high level waste form is a physically more robust method of safeguarding the plutonium than the Option 4 Downblend approach. It was considered and specifically rejected by DOE and the NRC. The rationale was described in the FEIS for the MOX project in the following quote:

The NRC has now determined for two reasons that immobilization is no longer a reasonable alternative to the proposed action. First, immobilization of the 34 MT (37.5 tons) of surplus plutonium would not meet a key element of the purpose and need for the proposed action... Due to budgetary constraints, the DOE decided to cancel the immobilization portion of the surplus plutonium disposition program and adopt a MOX-only approach. The DOE determined that in order to make progress with available funds, only one approach could be supported. The DOE stated that after evaluating the feasibility of implementing two disposition approaches, it believed that the best way to make the most progress with available funds while maintaining the Russian Federation's interest in and commitment to surplus plutonium disposition was to pursue a MOX-only disposition strategy (DOE 2002a).

The DOE further stated that the Russian Federation does not consider immobilization alone to be an acceptable approach. In the DOE's judgment, reliance by the U.S. on

immobilization would therefore cause the Russian Federation to abandon its plutonium disposition efforts. Because immobilization fails to degrade the isotopic composition of the plutonium, the Russian Federation distrusts the immobilization alternative, as it would leave open the possibility of future retrieval and reuse of the plutonium in nuclear weapons (DOE 2002a). The DOE therefore concluded that reliance on a MOX-only approach is the key to successfully completing the September 2000 agreement between Russia and the U.S. **(Reference 31)**

Therefore, no Option 4 activity can begin until the State Department can organize and conduct negotiations on another modification to the PMDA. These State Department activities began in 2013.

7.4 PMDA Renegotiation Realities

A 2014 paper written by V. Rybachenkov, a Senior Research Scientist at the Moscow Center for Arms Control, Energy & Environment Studies, suggests that the Russian Federation may be open to accepting any program that the U.S. suggests, but that they see it as a fundamental threat to the entire arms control agreement. Rybachenkov wrote:

The question however arises regarding what effect the American decisions will have on the destiny of the Agreement and whether the sides would be in a position to find mutually accepted solutions for its preservation. One can guess with a certain degree of probability that even in the case of repudiation by Americans of the previously agreed upon disposition method the two sides will do their best to preserve the Agreement...

Taking this into account we are of the view that Russia may agree with any disposition method, which the US would deem acceptable. In return Russia would have the right to repudiate the provision of the Agreement prohibiting spent fuel and blanket reprocessing till the full disposition of 34 tons of excess plutonium is over. Moreover, taking into consideration the opinion of American experts about equivalence of weapon grade and civil reactor plutonium for weapons purposes, Russia could also insist on the increase of the plutonium disposition share in the form of dioxide. **(Reference 16)**

The Russian Federation would want U.S. concessions allowing their irradiation fast reactors to operate as breeder reactors while burning the PMDA 34 MT of weapons plutonium and creating more weapons plutonium. This position is likely to be a difficult one for the U.S. to accept. This would move the Russian Federation and U.S. away from a strong Non-Proliferation Partnership founded on the PMDA. As a result, if the PMDA is to survive, it will take a great deal of time and effort. In contrast, the earlier revision to the PMDA started in 2007 and was not in full effect until 2011 was to address fairly minor points (i.e., elimination of MOX in the Russian Federation light water reactors, reduction of the disposition rates, revisions of the effective dates, etc). There was no major disagreement between the two countries and the process still required nearly five years to complete. This new revision to the PMDA although tentatively begun in 2013 could conceivably take far longer to complete. Indeed, it is possible that no agreement would be reached and the entire 40-year effort scrapped.

As former Secretary of Energy Bill Richardson stated in an Op-Ed in the U.S. News and World Report in January of 2015:

There's no glossing over President Vladimir Putin's behavior, and the West must stand against the first forced redrawing of European borders since World War II. It's certainly ugly in the short term, but work and cooperation endures on some critical long-term concrete initiatives.

The most important of these is the Mixed Oxide Fuel Fabrication Facility, known as MOX, being built by Department of Energy's National Nuclear Security Administration in South Carolina. During its life, the facility will transform 34 metric tons of U.S. surplus weapons grade plutonium into commercial nuclear reactor fuel. MOX is a first-of-a-kind facility in the U.S., and has reached a 64 percent total project completion level with exemplary reviews by the Nuclear Regulatory Commission....

The decision to build MOX came only after a couple of very extensive disposition analyses. Both DOE and the National Academy of Sciences looked at the issue during 1994-1995, and came up with 37 different possibilities for dealing with the plutonium. Many were exotic, such as shooting it into space or burying it beneath the deep ocean floor.

Ultimately, DOE decided on a two-track strategy in 1997: A combination of proven MOX technology, and a program for "immobilization," in which the plutonium is barricaded in a ceramic material that is then surrounded by vitrified high-level nuclear waste. The latter would have required the construction of a Plutonium Immobilization Plant with undeveloped technology.

The new Bush administration decided in 2002 to go exclusively for MOX, and abandon "immobilization," largely because of cost. Also, Russia objected to any disposition pathway that preserved the isotopic content of the plutonium, leaving it "weapons grade," no matter how barricaded it might be.

MOX needs to be evaluated in the greater context that formed it. In summary, DOE proceeding unilaterally in a new direction with the Option 4 Downblend approach when the Congress/United States have evaluated and selected Option 1 MOX Fuel approach could have extremely undesired consequences.

8 REVIEW TEAM CREDENTIALS

8.1 High Bridge Associates

High Bridge Associates, Inc. (High Bridge) is a Certified Woman Owned Business. It is a planning, integration, and project management company providing consulting and project staffing support services to the commercial nuclear power generation, Department of Energy (DOE), petro-chemical, and industrial business sectors. **Appendix G** provides an Overview of High Bridge Corporate

Qualifications. Commercial nuclear power represents over 60% of High Bridge business, with DOE and other Federal programs forming about 20% of our activities. In summary:

Customers

- 70% Utility, Industrial, & Federal Government Owners
- 20% Engineering, Procurement, & Construction Contractors
- 10% Original Equipment Manufacturers

Industries

- 90% Commercial Power Generation
 - 70% Nuclear
 - 20% Fossil (Coal/CGTG) & Renewable (Wind/Solar/Biofuel)
 - 10% Government, Science/R&D, Industrial, & Petro Chemical

High Bridge experts are intimate with and understand the technical design and regulatory licensing requirements that drive the parameters for program planning and project execution for complex nuclear and process facilities. It has supported many First of a Kind (FOAK) projects providing a broad cadre of project management and planning services. **Exhibit 8.1.1** below provides a summary of selected High Bridge customers spanning owners, EPC, and OEM organizations.

Exhibit 8.1.1 – Summary of Selected High Bridge Customers

<u>Selected Owner & Agency Customers</u>	<u>Selected EPC Customers</u>	<u>Selected OEM Customers</u>
Ameren Energy, Amoco, American Electric Power, Arizona Public Service, British Energy/UK, BNFL, Chevron, Constellation Energy, Dominion Energy, Duke Energy, Entergy, Exelon, Exxon, Florida Power & Light/NextEra, Honeywell, International Atomic Energy Agency (IAEA), ITER International Fusion Project, Luminant Energy, Magnox Electric UK, Nebraska Public Power District, Nuclear Management Corp., Nuclear Management Partners/Sellafield, Ontario Power/Canada, Southern California Edison, STPNOC/NRG, Tennessee Valley Authority, Louisiana Energy Services/URENCO, & US DOE/National Nuclear Security Agency/National Labs at Albuquerque, Argonne, Fermi, Idaho, Kansas City Plant, Los Alamos, Oak Ridge, Princeton, Richland, Savannah River, & Stanford	Alberici, Altran Mediterranee, Bechtel, Burns and Roe, CH2MHill, Fluor, Graycor, Jacobs, Kiewit, Parsons, Sachs Electric, SAIC, Sargent & Lundy, Shaw Environmental, CB&I Shaw Nuclear, Tetra Tech, URS/Washington Group, Worley Parsons	Alstom, Areva, Babcox & Wilcox, Cogema, Framatome, Foster Wheeler, GE Power, Holtec, Mitsubishi, NuScale, SPX Technologies, Toshiba, Voith Power, Westinghouse

8.2 Independent Review Selection, Charter, and Approach

On June 10, 2015 MOX Services Board of Governors requested High Bridge to perform an Independent Review of the Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Plutonium Disposition Study Options Independent Assessment (Aerospace Assessment Report). The purpose of

this High Bridge task is to provide an independent and objective analysis of the approach, process, and results that Aerospace used for its Assessment of the Option 1 MOX Fuel Project and Option 4 Down-Blending approach Life Cycle Cost Estimates (LCCE) provided in the April 2014 Plutonium Working Group (PWG) Report of Disposition Options. High Bridge was selected based on its unique corporate qualifications and Team Expert experience including:

- Experience supporting Plutonium Disposition Program activities in the 1990's leading to the January 21, 1997 Record of Decision (ROD 62 FR 3014) and Final Programmatic Environmental Impact Statement for the Storage and Disposition of Weapons-Usable Fissile Materials, including fabrication of surplus plutonium into MOX fuel for use in existing domestic commercial reactors.
- Experience and DOE team member in the 1990's for negotiating the September 2000 PMDA Plutonium Disposition Agreement between the Russian Federation and the U.S.
- Relevant insights and experience supporting the MOX FUEL project with planning, scheduling, risk assessment, and earned value activities since 1999. This included independent assessments to provide realistic construction labor hours, schedule duration, and contingency inputs for the MOX FUEL 2012 Revised Baseline.
- Best in class commercial nuclear power and FOAK project experience dealing with the requirements and parameters for planning and executing complex projects.

A reference material eRoom was established to provide High Bridge experts with access to the Aerospace Assessment Report and other relevant information. A two-phase approach is being used by High Bridge to provide this Independent Review:

- Phase 1 – Conduct a high level Independent Review in two weeks and produce an Executive Summary Report of key findings, analyses, and conclusions by June 24, along with a plan and approach to continue with a more detailed Phase 2 independent review and analysis.
- Phase 2 – Continue the Independent Review with a more detailed analysis of Aerospace and other program information over seven weeks and produce a Detail Report of issues, analyses, and conclusions by August 14, 2015. This Phase 2 will include interviews with MOX Services stakeholders and digging into the 2012 MOX Revised Baseline that served as the basis for the Plutonium Working Group (PWG) April 2014 Plutonium Options Report and the Aerospace Assessment Report.

8.3 Review Team Organization and Experience

High Bridge organized a Review Team of industry experts in several days and began review and analysis of the Aerospace Assessment Report and other information in the eRoom.

- Detail Review Experts – Ken Aupperle, Rick Drake, Charlie Hess, Dr. Mike High, and Barth Loney
- Peer Review Experts – Charlie Anderson, Dr. Andy Kadak, and Steve Maehr

The High Bridge Review Team members have an average of 40 years of relevant commercial nuclear power and DOE program experience spanning power generation, plutonium disposition, environmental/waste management, and complex FOAK facilities. Most of the Review Team members have worked together in the past performing similar Independent Reviews and Assessments, allowing

for a quick start and efficient communications/analyses to perform this task in an expedited and intense fashion. **Exhibit 8.3.1** below provides a summary of High Bridge Review Team Expert Experience.

Exhibit 8.3.1 – Summary of High Bridge Review Team Experience

High Bridge Independent Review of Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Summary of High Bridge Review Team Expert Experience						
Name	Years Nuclear/DOE Experience	Past Experience Working Together	MOX Project Experience	Plutonium Disposition Program Experience	FOAK Project Experience	Specific Unique/Relevant Experience
<u>Detail Review Experts</u>						
1 Ken Aupperle (Task Lead)	>40	X	X	X	X	Task Lead for Fissile Material Disposition Program (FMDP), DOE HQ Office, Historical Cost Estimating Program Review & Support, Assessment of Technology Cost Impacts/Trends (2000 to 2002).
2 Rick Drake	>35	X	X	X	X	Assessment Team Member for review of MOX 2012 Re-Baseline construction labor hours, schedule duration, & contingency. Member of other MOX Assessment Teams since 2010.
3 Charlie Hess	>35	X	X	X	X	Was DOE team member in the 1990's that negotiated the Plutonium Disposition Agreement between Russia & the USA. He was responsible for developing/integrating the schedule of activities for the Russian MOX facilities & for coordinating with the US MOX program.
4 Dr. Mike High	>50	X	X	X	X	Assessment Team Member for review of MOX 2012 Re-Baseline construction labor hours, schedule duration, & contingency. MOX schedule/risk assessment team member 2000-2002.
5 Barth Loney	>35	X	X	X	X	Performed multiple Independent Project Reviews of the MOX project for the Office of Environmental Management (EM) in 2007-2009. Worked with EM from 2003-present on all of their waste disposition projects. Experience with other FOAK project for DOE such as the Waste Treatment Plant (WTP) at Hanford. Was on original recovery team from HQ for WTP in 2005-2006.
<u>Peer Review Experts</u>						
6 Charlie Anderson	>35	X	X	X	X	Currently serving as General Manager of the TRU Waste Processing Center (TWPC), Oak Ridge, for processing and extended storage. Prior to this, supported Nuclear Waste Partners in recovery efforts at the WIPP.
7 Dr. Andy Kadak	>40	X			X	Served on the DOE Nuclear Waste Technology Review Board regarding high-level waste disposal. Is familiar with the challenges of WIPP and HLW waste disposal as well as NRC nuclear licensing and construction experience.
8 Steve Maehr	>35	X	X	X	X	Mr. Maehr is president, CEO, and co-founder of High Bridge Associates. He has led or participated in over 50 independent assessments of complex nuclear and process facilities.

One-page Experience Biographies for each Review Team Expert are provided in **Appendix H**.

Detailed Experience Resumes for each Review Team Expert are provided in **Appendix I**.

One-paragraph Experience Summaries for each Review Team Expert are provided below.

Ken Aupperle (Task Lead) - Mr. Aupperle is a High Bridge Senior Vice President and Management Consultant. He has over 40 years of experience in project and construction management, cost estimating, planning, scheduling, project controls, earned value, and risk management. His experience spans the design, construction, operation/maintenance, and outage/modification of commercial nuclear/fossil power, industrial, environmental, and U.S. Department of Energy (DOE)

projects. He has managed/performed numerous high level consulting assignments providing independent detailed cost estimates; independent high level cost reviews, schedule and risk assessments; and due diligence reviews for large capital projects, Life Cycle Cost Estimates, operating/maintenance activities, and decommissioning/waste management programs. *He was Task Lead for the DOE Fissile Material Disposition Program (FMDP) HQ Office to perform a Historical Cost Estimating Program Review and Support Task to compile and analyze Disposition Technology Cost Impacts/Trends (2000 to 2002).* Mr. Aupperle leads High Bridge development and maintenance of its nuclear industry cost and schedule data base, and its analysis of industry risk issues and contingency considerations. He has conducted research of cost/schedule/risk performance records for more than 100 U.S. commercial nuclear and DOE science projects, and presented numerous Industry Lessons Learned presentations/papers at the American Nuclear Society and other industry forums. He consults as a Subject Matter Expert (SME) for the International Atomic Energy Agency (IAEA) for Project Management, Program Planning, and Integration on IAEA Planning/Training Missions for Member Nations.

Rick Drake - Mr. Drake has over 35 years of experience in the commercial nuclear power industry spanning design, construction, procurement, Project Management, startup, operation/maintenance, and outage/modification phases. He began his career working for Bechtel Power and held positions of increasing responsibility in support of construction, start up, outage, and continuing maintenance activities during the construction, commissioning, and operation of Palo Verde Nuclear Plant from 1978 to 1990. He held key department line management positions with the Tennessee Valley Authority Nuclear (TVAN) organization from 1990 to 2005 at each of the TVA Nuclear Sites and the corporate headquarters. He served as the construction manager for the completion of Watts Bar Unit 1 and Browns Ferry Unit 1 restart. Since 2006, Mr. Drake has been a Vice President and Senior Consultant with High Bridge Associates. He has led multi-discipline teams of personnel spanning numerous locations and contractor organizations, producing effective results in dynamic environments amid multiple priorities and aggressive deadlines. He has worked supporting various Project Assessments and Project Management/Controls Deployment Planning Reviews for New Nuclear Projects. He led the High Bridge activities for STPNOC STP 3 & 4 supporting independent cost and schedule assessments of Toshiba and Fluor. Mr. Drake was Co-Lead on an Independent Project Assessment Team for Toshiba to review and critique Fluor's estimates for STP Units 3&4, which identified more than \$1B in potential reductions to the Fluor Estimate, and developed alternative strategies for contractual approaches for future contracting.

Charlie Hess - Mr. Hess has over 35 years of experience in the power industry and has been involved with development, design, engineering, construction, operation, and decommissioning of various nuclear facilities. He is active with industry programs in preparation for new large and small reactor nuclear facilities, and is familiar with all nuclear technologies and NRC requirements. He is a recognized expert in light water reactors, sodium cooled fast reactors, and high temperature gas cooled reactors. He also has worked on pool-type research reactors, homogeneous aqueous reactors and Thorium based fuel cycles. He has designed fuel fabrication facilities, reprocessing facilities high-level waste vitrification facilities, and fuel storage facilities. He managed completion of engineering, operational support, and decommissioning projects for large and small energy facilities. With nearly 20 years in responsible positions for nuclear industry, he has a thorough understanding of owner and regulatory issues balanced with extensive EPC experience and constructability/maintainability issues. He is a Registered Professional Engineer in Pennsylvania,

with a BS degree in Nuclear Engineering and has been a Certified Project Management Professional. *Mr. Hess was part of the DOE team that negotiated the Plutonium Disposition Agreement between the Russians and the U.S.. He was responsible for developing and integrating the schedule of activities for developing the Russian MOX facilities and for coordinating with the U.S. MOX program in the 1990s. He understands the issues surrounding plutonium disposition.*

Dr. Mike High - Dr. High has over 50 years of experience with advanced technology and first-of-a-kind (FOAK) projects spanning research, development, demonstration, engineering, construction, operations, and maintenance in the power generation, environmental, and aeronautical industries. He has testified before various congressional subcommittees regarding environmental issues, acid rain legislation, and the U.S. Department of Energy's fossil and nuclear energy budgets. He chaired the Electric Power Research Institute's (EPRI) Environmental Research Division Advisory Committee and served for five (5) years as a member of the EPRI Research Advisory Committee. As a member of the EPRI Ad Hoc Committee on Advanced Reactor Programs (ARP), he provided policy and technical guidance on making light water reactors simpler and enhancing their safety features through the Advanced Light Water Reactor (ALWR) Utility Steering Committee. Dr. High practiced in the field of aeronautical and aerospace engineering for nearly twenty years, first at Pratt & Whitney Aircraft Company and more extensively at the U.S. Air Force Arnold Engineering and Development Center located near Tullahoma, Tennessee. He joined the Tennessee Valley Authority (TVA) in 1980 and served as Division Director for nine years where he was responsible for all aspects of Research, Development, and Demonstration (RD&D) for the TVA electric power system. Since 2000, Dr. High has worked extensively with High Bridge Associates as a Management Consultant providing consulting services, technology assessments, and independent reviews. He has extensive technical, scientific, and financial analytical skills, and is accustomed to supporting large, complex, and multi-disciplined projects with numerous participants. He has performed independent project reviews, risk assessments, feasibility/due-diligence and life cycle cost studies for various commercial and Department of Energy (DOE) projects.

Barth Loney - Mr. Loney has more than 35 years of experience in program / project / engineering management serving in various positions with increasing responsibilities. As a Senior Vice President with High Bridge Associates, Inc., he has a history of successful project/program completions, implementations, reengineering and process improvements. He is an adept professional with the ability to work comfortably in diverse environments, handle multiple tasks simultaneously, and creatively address root causes to develop innovative solutions that have improved processes and contributed directly to bottom line performance. He is a Subject Matter Expert with extensive experience in Project Management, Earned Value Management, Risk Management, and Engineering and Construction Management. His industry experience includes nuclear power, construction and utility background, both in private and federal sectors. He has ten years of experience leading and participating in project reviews for the Department of Energy. He is familiar with multiple standards and requirement, including, but not limited to, DOE Order 413, PMBOK, and ANSI 748. Some recent assignments for High Bridge supporting multiple DOE Offices include:

- Oak Ridge National Lab (WAI) – TRU Waste Processing Center, Support General Manager in areas of Risk, Earned Value and Budget/Proposal development. Evaluating waste stream trends and cost for the project and budget forecasting options

- Office of Acquisition Project Management (Headquarters) – Led External Independent Review (EIR) team for the CD2/3 submittal of the K-27 D&D project at Oak Ridge. Also served as Risk SME for the review.
- Office of Environmental Management (Headquarters) – provided project controls expertise for a project involving research reactor fuels disposition.

Charlie Anderson - Over 33 years with increasing responsibilities in executive, technical, operations, program, and project management of nuclear materials disposition, nuclear materials production, nuclear waste management, and nuclear and coal fired power generation programs with *Los Alamos National Lab, Nuclear Management Partners, URS Corporation, Washington Group International, the Department of Energy* and the *Tennessee Valley Authority* covering laboratories and complex operating facilities from construction through decommissioning and demolition. He served in senior management positions as a key member of these organizations with responsibilities in leadership, management, oversight, strategic planning, and execution of startups, transitions, and problematic programs. Responsibilities have included annual budgets of \$6.2B and workforces of 3,000 Federal and 30,000 contractor personnel. Work has typically involved bridging technical, business, and political agendas to solve problems in order to achieve programmatic and operational goals and objectives. Performance has always demonstrated a focus on progress and personal commitment. He lead key cross cutting initiatives in most of these organizations, which includes commercial, government, international, and government contractor. He served as Principal Deputy Assistant Secretary of Environmental Management, with the DOE in Washington, DC. Provided innovative and sound leadership in a number of management positions at the Savannah River Site for the Department of Energy including Deputy Site Manager, Assistant Manager for High Level Waste; Director, Office of Defense Nuclear Nonproliferation; Director, Nuclear Materials Disposition; Director, Reactors and Spent Fuel Division; Director, High Level Waste Programs Division; and Director, Liquid Waste Division.

Dr. Andy Kadak - Dr. Kadak has over 40 years of commercial nuclear experience and is President of Kadak Associates, Inc., a consulting firm specializing in management issues and nuclear energy. Prior to resuming his private consulting practice, Dr. Kadak was Principal and Director of Nuclear Services at Exponent, a worldwide company offering multidisciplinary expertise and rapid response capabilities to provide stewardship in addressing complex engineering and scientific problems. Dr. Kadak served on the IAEA special team assessing earthquake and tsunami damage of the Onagawa Nuclear Plant in Japan and has performed extensive studies of the Fukushima Dai-ichi Nuclear Plant. Dr. Kadak was a Professor of the Practice in the Nuclear Engineering Department of the Massachusetts Institute of Technology. His research interests include the development of advanced reactors, in particular the high temperature pebble bed gas reactor, space nuclear power systems, improved technology neutral licensing standards for advanced reactors and operations and management issues of existing nuclear power plants. Recently he was asked to serve on the Small Modular Reactor subcommittee of the Secretary of Energy's Advisory Board. His expertise ranges from reactor physics, power conversion, safety analysis and engineering systems. Dr. Kadak was President and CEO of Yankee Atomic Electric Company. In this capacity, he was responsible for overseeing all Yankee operations, including the decommissioning of the Yankee plant in Rowe, Massachusetts and engineering, licensing, environmental and operational support to all eight nuclear plants in New England and many other national and international clients. Dr. Kadak was President of the American Nuclear Society in 1999/2000. He was appointed by the President to serve on the U.S.

Nuclear Waste Technology Review Board. He has made more than 70 lectures and speeches on topics related to the technical and business aspects of nuclear power.

Steve Maehr - Mr. Maehr is President, CEO, and co-founder of High Bridge Associates. He has more than 35 years of experience in Engineering, Project Management, and Executive leadership positions in the electric utility and management services industries. His principal areas of expertise include Strategic Planning, Business Development and Sales, Planning and Scheduling, Budgeting, Financial Planning and Accounting, Maintenance, Outage Management, Management Information Systems, Licensing, Engineering and System Testing. With degrees in Mathematics, Nuclear Engineering (BS) and Industrial Management (MS), he has held positions of increasing responsibility with electric utilities, management service contractors, and consulting/project management companies. Mr. Maehr has a demonstrated record of accomplishment in developing opportunities and assisting customers with managing their projects, programs, and corporate operations. He is an entrepreneurial and strategic thinker, an excellent communicator, and a versatile leader. With his network of resources developed over the years by working with hundreds of owners, specialty contractors, and staff resources, he has an exceptional proficiency in assembling project teams to deliver “Just in Time” skills to customers, when and where they are needed.

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APPENDIX A

**High Bridge’s “Phase 1 Executive Summary &
Overview with No Appendices” submitted
June 29, 2015**

High Bridge Associates, Inc.

June 29, 2015

Phase 1 Executive Summary & Overview prepared for the MOX Services Board of Governors

**High Level Independent Review of
Aerospace April 13, 2015 LCCE Report TOR-2015-01848
Plutonium Disposition Study Options Independent Assessment**



“Connecting Vision and Plans with Performance and Execution”

**Phase 1 Executive Summary and Overview
High Level Independent Review of
Aerospace April 13, 2015 LCCE Report TOR-2015-01848
Plutonium Disposition Study Options Independent Assessment**

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1. EXECUTIVE SUMMARY

High Bridge Associates, Inc. (High Bridge) performed an Independent Review of the Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Plutonium Disposition Study Options Independent Assessment. High Bridge preliminary key findings and conclusions regarding the Aerospace Assessment Report include:

- A. The Option 1 MOX project is at a CD-3 status of complete design/construction and Aerospace generally evaluates risk/cost impacts as high impact and high likelihood of occurrence. The Option 4 Downblend is at a CD-0 status of pre-conceptual design and Aerospace generally evaluates risk/cost impacts as low impact and low likelihood of occurrence. High Bridge finds this illogical and incorrect.
- B. The identification and analysis of risk issues/contingency impacts identified in Appendix B for Option 1 MOX Fuel and Option 4 Downblend is flawed. High Bridge concludes that several Option 1 MOX risk elements and resulting impact costs are overstated and inconsistent. High Bridge also concludes that several Option 4 Downblend risk elements and resulting impact costs are understated, and that technical/licensing requirements do not appear to be well understood.
- C. Base costs, contingency/risks, funding limits, escalation, and real year (RY) costs for Options 1 and 4 were presented in a manner that was difficult to follow. This provided an apparent focus on escalated RY costs which are highly influenced by the assumed funding levels in the report. High Bridge performed a preliminary evaluation of risks/contingency base costs excluding escalation. **Table E1** reflects that the \$FY14 LCCE for Option 1 MOX and Option 4 Downblend are nearly the same after incorporating the High Bridge assessment of risks and contingency cost impacts:

Table E1 (Same as Exhibit 5)

High Bridge Cost Comparison		
Option 1 MOX Fuel and Option 4 Downblend Alternatives		
Cost Element	Option 1 - MOX (\$B FY14)	Option 4 - Downblend (\$B FY14)
Unescalated Base Cost (with Contingency)	24.3	13.0
Aerospace Evaluation of Risks/Contingency	7.4	2.3
High Bridge Evaluation of Risks/Contingency	3.7	9.3
Aerospace and High Bridge Differences	-3.7	7.0
Evaluated Cost Reflecting Differences	20.6	20.0

- D. Without adequate funding levels, no NNSA/DOE project will have an optimum schedule as a basis to proceed effectively and to achieve its mission efficiently. The funding levels evaluated in the Aerospace Report were below the levels that allow for efficient completion of the Option 1 MOX project and result in longer schedules and higher costs. Aerospace also utilized inconsistent assumptions in calculating the impacts of reduced funding in that they used escalated costs but did not escalate funding to match. High Bridge also concludes that the funding levels for Option 4 Downblend will need to be higher and include MOX termination costs.
- E. The programmatic risks associated with abandoning Option 1 MOX Fuel and transitioning to Option 4 Downblend are enormous and are not addressed, either qualitatively or quantitatively. The geo-political and non-proliferation value for Option 1 MOX Fuel that is defined in the original 2000 Plutonium Management and Disposition Agreement (PMDA) remain relevant today and cannot be ignored.
- F. As a new project at CD-0 status, there are significant Option 4 Downblend production facility and WIPP issues and risks that have not been adequately considered or evaluated in the Option 4 LCCE. Commencing Downblend operations in 2018 would require moving from CD 0 to CD 4 in less than three years. High Bridge concludes this is extremely unrealistic and not achievable.

2. REPORT OVERVIEW

Background - On June 10, 2015, the MOX Services LLC Board of Governors (MOX Services) requested High Bridge Associates, Inc. (High Bridge) to perform an Independent Review of the Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Plutonium Disposition Study Options Independent Assessment (Aerospace Assessment Report). The purpose of this High Bridge task is to provide an objective analysis of the approach/process used by Aerospace, and of the results contained in its Assessment of the April 2014 Plutonium Working Group (PWG) Report of Disposition Options for the Option 1 MOX Fuel Project and Option 4 Downblend Life Cycle Cost Estimates (LCCE).

High Bridge is a planning and project management company providing consulting and project staffing support services to the commercial nuclear power generation, Department of Energy (DOE), petro-chemical, and industrial business sectors. High Bridge experts are intimate with and understand the technical design and regulatory licensing requirements that drive the parameters for program planning and project execution for complex nuclear and process facilities. It has performed hundreds of 3rd party reviews of cost estimates/schedules/risk contingency assessments developed by others. High Bridge organized a Review Team of industry experts with an average of 40 years of relevant commercial nuclear power and DOE program experience spanning power generation, plutonium disposition, and complex FOAK facilities. This report provides its initial key findings and conclusions.

Overview of Findings and Conclusions - Given the Aerospace charter began with the PWG Analysis To-Go values, High Bridge found the Aerospace Assessment Report to be organized and professional. However, based on its preliminary two-week review, High Bridge finds that various aspects of the Aerospace assessment approach, analysis, and presented results were unclear, inconsistent, and unsupported. Some key findings and conclusions include:

1. The programmatic risks associated with abandoning Option 1 MOX Fuel and transitioning to Option 4 Downblend are enormous and are not addressed, either qualitatively or quantitatively:
 - a. In the past, Russia has rejected any option that does not convert weapons Plutonium to a non-weapons transuranic form, including immobilization. The Option 4 Downblend process is less rigorous than the Immobilization Option that was rejected by Russia in the past.
 - b. Transitioning to the Option 4 Downblend approach would at best require years of negotiation and/or result in Russia withdrawing from the PMDA. This in turn would delay the start and significantly increase overall costs.
 - c. For Option 1 MOX Fuel, there is no identification or discussion of its strategic value that is consistent with the ROC 62 and the 2000 Plutonium Management and Disposition Agreement (PMDA) between the US and Russia.

High Bridge concludes that the geo-political and non-proliferation value for Option 1 MOX Fuel that is defined in the original 2000 United States-Russia Plutonium Management and Disposition Group (PMDA) remain relevant today and cannot be ignored.

2. There are significant Option 4 Downblend production facility and WIPP issues and risks:
 - a. There are very high risks for proceeding with Downblend Production Facility and WIPP activities without a revised agreement and concurrence from Russia (see Item 1 above).
 - b. The assumptions of a fast track schedule and no funding restraints for the Option 4 Downblend Facility and WIPP are very unrealistic and unlikely. Commencing Downblend operations in 2018 would require moving from CD 0 to CD 4 in less than three years.
 - c. Inadequate time exists for licensing/design of the Downblend Production Facility.
 - d. Option 4 will require a license amendment, have related impacts on WIPP operations, and require a modification approval of the Waste Acceptance Criteria.
 - e. The likelihood for an increase in physical size of the Waste Isolation Treatment Plant (WIPP) is higher than presented by Aerospace. Various issues will drive this like criticality, concentration, and waste acceptance criteria. Transportation and material handling costs are also likely understated.
 - f. The requirements for the National Environmental Policy Act (NEPA) Environmental Impact Statement process for the Downblend and WIPP facilities were not addressed.

High Bridge concludes these above issues and risks have not been adequately considered or evaluated in the Option 4 LCCE. The schedule impact on escalation and the contingency risk exposure window is significant. Commencing Downblend operations in 2018 would require moving from CD 0 to CD 4 in less than three years. High Bridge concludes this is extremely unrealistic and not achievable.

3. Without adequate annual funding levels, no NNSA/DOE project will have an optimum schedule as a basis to proceed effectively and to achieve its mission efficiently:
 - a. For Option 1, the To-Go cost estimate outcome is distorted by the extended project schedule due to the assumed funding constraints.
 - b. For Option 1, project costs were escalated but annual funding was not escalated, which is an inconsistent approach to the LCCE. This approach exacerbated the impact on the project schedule and the ultimate cost of funding constraints. The normal practice would be to evaluate an investment decision based on constant year dollars.
 - c. For Option 1, it is not clear why a LCCE case was not developed for full funding consistent with the 2012 Re-Baseline proposal. If fully funded, the MOX project construction would complete years earlier than the Aerospace report stated with a reduction in total cost.
 - d. For Option 4, the funding levels will need to be higher and include MOX termination costs.

High Bridge will evaluate full funding outcomes during its Phase 2 detailed review.

4. Base costs, contingency/risks, funding limits, escalation, and real year (RY) costs for Options 1 and 4 were presented in a manner that was difficult to follow. This provided an apparent focus on escalated RY costs. High Bridge developed the below **Exhibit 1** (Option 1) and **Exhibit 2**

(Option 4) to provide a simple breakdown of FY2014 \$ costs for construction, operations, other programs, and total. This provides a clearer picture for these key decision making cost elements.

Exhibit 1

OPTION 1 MOX AEROSPACE REPORT COSTS (\$FY14 - ETC Unconstrained)						
	MFFF Construction	Operations	MIFT and Other	Changes Since PWG 2014	Total	% of Total
Base	\$ 4,342.0	\$ 6,255.4	\$ 5,924.2	\$ 1,136.0	\$ 17,657.6	73%
Contingency	\$ 2,113.8	\$ 2,249.2	\$ 2,310.2	\$ -	\$ 6,673.2	27%
Total	\$ 6,455.8	\$ 8,504.6	\$ 8,234.4	\$ 1,136.0	\$ 24,330.8	100%
Escalation	\$ 1,255.0	\$ 3,551.0	\$ 1,864.0	\$ 4,340.0	\$ 11,010.0	
	\$ 7,710.8	\$ 12,055.6	\$ 10,098.4	\$ 5,476.0	\$ 35,340.8	

In comparison to the constrained Aerospace funding model, the \$35.3 billion compares to the \$47.5 billion, illustrating the tremendous impact of the assumed funding limitation on contingency and escalation. **Exhibit 1** utilizes the Aerospace data with only the assumed funding level adjusted.

Exhibit 2

OPTION 4 DOWNBLEND AEROSPACE REPORT COSTS (\$FY14 - ETC)							
	MFFF Termination	WIPP Capital	Operations	MIFT and Other	Changes Since PWG 2014	Total	% of Total
Base	\$ 1,492.0	\$ 214.0	\$ 2,094.0	\$ 4,444.0	\$ 1,873.0	\$ 10,117.0	78%
Contingency	\$ 571.5	\$ -	\$ 1,142.9	\$ 1,205.7	\$ -	\$ 2,920.1	22%
Sub Total	\$ 2,063.5	\$ 214.0	\$ 3,236.9	\$ 5,649.7	\$ 1,873.0	\$ 13,037.1	100%
Escalation	\$ 34.0	\$ 73.0	\$ 912.0	\$ 1,082.0	\$ 1,547.0	\$ 3,648.0	
Total	\$ 2,097.5	\$ 287.0	\$ 4,148.9	\$ 6,731.7	\$ 3,420.0	\$ 16,685.1	

Exhibit 2 reflects the Aerospace data presented consistently for comparison with **Exhibit 1**.

5. The identification and analysis of risk issues/impacts identified in Appendix B for Option 1 MOX Fuel and Option 4 Downblend is flawed:
 - a. Risk elements and resulting impact costs for Option 1 MOX Fuel appear to be overstated, redundant, and inconsistent.
 - b. Risk elements and resulting impact costs for Option 4 Downblend appear understated and technical/licensing requirements do not appear to be well understood. Some specific risks were not identified.

High Bridge developed **Exhibit 3** (Option 1) and **Exhibit 4** (Option 4) to provide a preliminary parametric assessment (no Monte Carlo simulation performed) of key risks, likelihood of occurrence, and approximate cost impacts. These indicate that Option 1 MOX Fuel evaluated risk/cost impacts are significantly overstated and that Option 4 Downblend evaluated risk/cost impacts are significantly understated. The added risk values in **Exhibit 4** are rough order-of-magnitude based on experience. High Bridge will review and evaluate these risk/cost impacts in greater detail during Phase 2 of the High Bridge independent review.

Exhibit 3

Option 1, MOX Fuel Risk Table Comparison from Aerospace 2015 Assessment, Appendix B					
Rank	Title	Aerospace		High Bridge	
		Likelihood	Total Impact (\$M)	Likelihood	Total Impact (\$M)
1	Fuel Production Rate Lower Than Expected	75%	\$ 3,111.50	75%	\$ 3,111.50
2	Feedstock Production Rate Lower Than Expected	75%	\$ 1,362.80	0%	\$ -
3	MFFF Construction Cost Uncertainty / Growth	75%	\$ 998.60	0%	\$ -
4	MFFF Temporary Suspension of Operations	90%	\$ 697.30	0%	\$ -
5	MFFF Full Construction Re-Start Delay	50%	\$ 641.60	10%	\$ 100.00
6	Feedstock Temporary Suspension of Operations	90%	\$ 283.20	25%	\$ 75.00
7	SRS Overhead Cost Increases	75%	\$ 194.10	25%	\$ 50.00
8	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	90%	\$ 157.00	90%	\$ 157.00
9	LANL Overhead Cost Increases	25%	\$ 118.10	25%	\$ 118.10
10	MFFF Hot Operations Delay after CD-4 Complete	50%	\$ 100.00	0%	\$ -
11	MFFF Integrated Functional Testing Delay Before CD-4	25%	\$ 96.70	50%	\$ 175.00
12	Needs for Additional Storage	50%	\$ 46.10	0%	\$ -
13	LANL Feedstock Production Re-Start Delay	25%	\$ 30.40	25%	\$ 30.40
14	Funding for Depleted Uranium	10%	\$ 2.10	10%	\$ 2.10
15	Feedstock Production Consolidated at LANL (Remove HB-Line)	75%	\$ (396.10)	25%	\$ (130.00)
	Total		\$ 7,443.40		\$ 3,689.10
High Bridge - Aerospace = (\$3.7 billion)					
	Gray = Project Cost Risk		\$ 1,736.90		\$ 275.00
	White = Federal Cost Risk		\$ 5,706.50		\$ 3,414.10

- The Option 1 MOX technical risks are not as high or as likely as characterized. The MOX process is not new. The design is based on similar facilities operating in France. The Option 1 MOX project is at a CD-3 status of complete design/construction and Aerospace generally evaluates risk/cost impacts as high impact and high likelihood of occurrence. The Option 4 Downblend is at a CD-0 status of pre-conceptual design and Aerospace generally evaluates risk/cost impacts as low impact and low likelihood of occurrence. High Bridge finds this illogical and incorrect. High Bridge will review the LCCE operating campaigns, throughput, availability, and other basis parameters in the 2012 Re-Baseline in greater detail during Phase 2 of the High Bridge independent review.
- High Bridge identified no apparent duplication of risk between the Aerospace report and the PWG report. Overall, the PWG identified risks were more technical in nature and the risks identified by Aerospace were more programmatic in nature. However, within the Aerospace risk list there appear to be risks that are duplicative, or additive of other risk within the Aerospace list. The Aerospace risks were used to calculate cost and schedule contingency and

added to the earlier PWG estimated values. This results in larger than necessary cost and schedule contingency impacts. It should be noted that the majority of Aerospace identified risks are federal/programmatic and not project. The risk/contingency costs for Option 1 will be evaluated and reconciled during Phase 2 of the High Bridge independent review.

Exhibit 4

Option 4, Downblend Risk Table Comparison from Aerospace 2015 Assessment, Appendix B					
Rank	Title	Aerospace		High Bridge	
		Likelihood	Total Impact (\$M)	Likelihood	Total Impact (\$M)
1	Feedstock Production Rate Lower Than Expected	75%	\$ 1,341.50	75%	\$ 1,341.50
2	SRS Downblend Facility Start Delay	25%	\$ 338.50	90%	\$ 1,500.00
3	Feedstock Temporary Suspension of Operations	90%	\$ 247.00	90%	\$ 247.00
4	Downblend Production Rate is Lower Than Expected	25%	\$ 188.10	75%	\$ 600.00
5	Downblend Facility Temporary Suspension of Operations	90%	\$ 175.90	90%	\$ 175.90
6	Downblend Construction Cost Estimate Uncertainty/Growth	75%	\$ 174.70	75%	\$ 174.70
7	LANL Overhead Cost Increase	25%	\$ 119.20	75%	\$ 420.00
8	MFFF Project Termination Cost Uncertainty	25%	\$ 81.10	25%	\$ 81.10
9	Downblend Repository Temporary Suspension of Operations	90%	\$ 41.60	90%	\$ 41.60
10	SRS Overhead Cost Increase	75%	\$ 31.40	75%	\$ 31.40
11	Feedstock Production Re-Start Delay at LANL	25%	\$ 30.10	25%	\$ 30.10
12	Exceed Downblend Repository TRU Allowable Storage Volume	10%	\$ 22.00	50%	\$ 1,000.00
13	Need for Additional Storage Volume	25%	\$ 12.70	25%	\$ 12.70
14	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	75%	\$ 8.60	75%	\$ 8.60
15	Feedstock Milling and Blending Not Needed/Quality Control Reductions	90%	\$ (44.10)	50%	\$ (22.10)
16	Feedstock Production Consolidated at LANL (Remove HB-Line)	90%	\$ (479.30)	10%	\$ (100.00)
	Sub Total		\$ 2,289.00		\$ 5,542.50
17	Programmatic failure of PMDA Due to Russian Federation Rejection of Op 4		\$ -	90%	\$ 1,000.00
18	Inability to address Licensing issues at WIPP due to recovery program for 2/14 accident until after restart (~FY2017)		\$ -	90%	\$ 250.00
19	NEPA Process for Dilution and Disposal Option takes more than expected		\$ -	50%	\$ 250.00
20	NEPA Revision to WIPP EIS process takes longer than expected		\$ -	75%	\$ 250.00
21	NMED Disputes Land Use Issues		\$ -	50%	\$ 250.00
22	High risk of proceeding with Downblend production facility and WIPP without revised agreement and concurrence from Russia (see Item 17 above).		\$ -	90%	\$ 500.00
23	Fastrack Licensing not permitted		\$ -	50%	\$ 500.00
24	Funding Constraints imposed on dilution option		\$ -	50%	\$ 500.00
25	Potential licensing impact on WIPP operations and modification/acceptance of Waste Acceptance Criteria.		\$ -	25%	\$ 250.00
	Sub Total		\$ -		\$ 3,750.00
	Total		\$ 2,289.00		\$ 9,292.50
High Bridge - Aerospace = \$7.0 billion					
	Gray = Project Cost Risk		\$ 525.90		\$ 1,687.40
	White = Federal Cost Risk		\$ 1,763.10		\$ 7,605.10

For Option 4, the project risks for constructing the facilities are notably absent, which is inconsistent with a CD 0 program.

High Bridge's evaluation of these risks/impacts indicates the LCCE costs for Options 1 and 4 are nearly the same.

8. Base costs, contingency/risks, funding limits, escalation, and real year (RY) costs for Options 1 and 4 were presented in a manner that was difficult to follow. This provided an apparent focus on escalated RY costs. High Bridge performed a preliminary evaluation of risks/contingency cost impacts. **Exhibit 5** reflects that the \$FY14 LCCE for Option 1 MOX and Option 4 Downblend are nearly the same after incorporating the High Bridge assessment of risks and contingency cost impacts:

Exhibit 5 (Same as Table E1)

High Bridge Cost Comparison		
Option 1 MOX Fuel and Option 4 Downblend Alternatives		
Cost Element	Option 1 - MOX (\$B FY14)	Option 4 - Downblend (\$B FY14)
Unescalated Base Cost (with Contingency)	24.3	13.0
Aerospace Evaluation of Risks/Contingency	7.4	2.3
High Bridge Evaluation of Risks/Contingency	3.7	9.3
Aerospace and High Bridge Differences	-3.7	7.0
Evaluated Cost Reflecting Differences	20.6	20.0

9. The Aerospace values presented and added for “changes” to the PWG To-Go costs lacked visibility, formal discussion, and back up. High Bridge concludes that a significant cost element like this (~\$5 Billion RY) should have been covered in more detail.
10. The Aerospace and PWG values presented and added for “MIFT” to the To-Go costs lacked visibility, formal discussion, and back up. High Bridge concludes that a significant cost element like this (~\$10 Billion RY) should have been covered in more detail.
11. As reflected on **Exhibits 1 and 2**, escalation represents a significant portion of the total RY LCCE with full annual funding levels, and an even greater portion under the Option 1 MOX Fuel constrained funding levels/extended schedules presented in the Aerospace Assessment Report. High Bridge preliminary conclusions indicate that:
- Escalation indices for Options 1 and 4 applied by Aerospace for capital costs were higher than industry guidance/High Bridge experience would apply.
 - Escalation for Option 1 MOX Fuel construction-to-complete duplicated what the PWG had already calculated.

High Bridge will review this item in greater detail during Phase 2 of the independent review.

12. The Aerospace Assessment Report references the potential for revenue generation from the sale of MOX fuel elements, but provides no analysis or credit to offset LCCE costs. High Bridge will review this item in greater detail during Phase 2 of the High Bridge independent review.
13. The Aerospace Assessment Report provides no mention or analysis of value for the generation of clean/non carbon emitting electric energy, or of the GNP and federal tax revenue value related to electricity generation sales. High Bridge will review these items in greater detail during Phase 2 of the High Bridge independent review.

3. BACKGROUND

3.1 High Bridge Associates

High Bridge Associates, Inc. (High Bridge) is a Certified Woman Owned Business. It is a planning, integration, and project management company providing consulting and project staffing support services to the commercial nuclear power generation, Department of Energy (DOE), petrochemical, and industrial business sectors. **Appendix A** provides an Overview of High Bridge Qualifications. Commercial nuclear power represents over 60% of High Bridge business, with DOE and other Federal programs forming about 20% of our activities. In summary:

Customers

- 70% Utility, Industrial, & Federal Government Owners
- 20% Engineering, Procurement, & Construction Contractors
- 10% Original Equipment Manufacturers

Industries

- 90% Commercial Power Generation
 - 70% Nuclear
 - 20% Fossil (Coal/CGTG) & Renewable (Wind/Solar/Biofuel)
 - 10% Government, Science/R&D, Industrial, & Petro Chemical

High Bridge experts are intimate with and understand the technical design and regulatory licensing requirements that drive the parameters for program planning and project execution for complex nuclear and process facilities. It has supported many First of a Kind (FOAK) projects providing a broad cadre of project management and planning services. **Exhibit 6** below provides a summary of selected High Bridge customers spanning owners, EPC, and OEM organizations.

Exhibit 6

<u>Selected Owner & Agency Customers</u>	<u>Selected EPC Customers</u>	<u>Selected OEM Customers</u>
Ameren Energy, Amoco, American Electric Power, Arizona Public Service, British Energy/UK, BNFL, Chevron, Constellation Energy, Dominion Energy, Duke Energy, Entergy, Exelon, Exxon, Florida Power & Light/NextEra, Honeywell, International Atomic Energy Agency (IAEA), ITER International Fusion Project, Luminant Energy, Magnox Electric UK, Nebraska Public Power District, Nuclear Management Corp., Nuclear Management Partners/Sellafield, Ontario Power/Canada, Southern California Edison, STPNOC/NRG, Tennessee Valley Authority, Louisiana Energy Services/URENCO, & US DOE/National Nuclear Security Agency/National Labs at Albuquerque, Argonne, Fermi, Idaho, Kansas City Plant, Los Alamos, Oak Ridge, Princeton, Richland, Savannah River, & Stanford	Alberici, Altran Mediterranee, Bechtel, Burns and Roe, CH2MHill, Fluor, Graycor, Jacobs, Kiewit, Parsons, Sachs Electric, SAIC, Sargent & Lundy, Shaw Environmental, CB&I Shaw Nuclear, Tetra Tech, URS/Washington Group, Worley Parsons	Alstom, Areva, Babcox & Wilcox, Cogema, Framatome, Foster Wheeler, GE Power, Holtec, Mitsubishi, NuScale, SPX Technologies, Toshiba, Voith Power, Westinghouse

3.2 Independent Review Selection, Charter, and Approach

On June 10, 2015 MOX Services Board of Governors requested High Bridge to perform an Independent Review of the Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Plutonium Disposition Study Options Independent Assessment (Aerospace Assessment Report). The purpose of this High Bridge task is to provide an independent and objective analysis of the approach, process, and results that Aerospace used for its Assessment of the Option 1 MOX FUEL Project and Option 4 Down-Blending approach Life Cycle Cost Estimates (LCCE) provided in the April 2014 Plutonium Working Group (PWG) Report of Disposition Options. High Bridge was selected based on its unique corporate qualifications and Team Expert experience including:

- Experience supporting Plutonium Disposition Program activities in the 1990's leading to the January 21, 1997 Record of Decision (ROD 62 FR 3014) and Final Programmatic Environmental Impact Statement for the Storage and Disposition of Weapons-Usable Fissile Materials, including fabrication of surplus plutonium into MOX fuel for use in existing domestic commercial reactors.
- Experience and DOE team member in the 1990's for negotiating the September 2000 PMDA Plutonium Disposition Agreement between Russia and the USA.
- Relevant insights and experience supporting the MOX FUEL project with planning, scheduling, risk assessment, and earned value activities since 1999. This included independent assessments to provide realistic construction labor hours, schedule duration, and contingency inputs for the MOX FUEL 2012 Revised Baseline.
- Best in class commercial nuclear power and FOAK project experience dealing with the requirements and parameters for planning and executing complex projects.

A reference material eRoom was established to provide High Bridge experts with access to the Aerospace Assessment Report and other relevant information. A two-phase approach is being used by High Bridge to provide this Independent Review:

- Phase 1 – Conduct a high level Independent Review in two weeks and produce an Executive Summary Report of key findings, analyses, and conclusions by June 24, along with a plan and approach to continue with a more detailed Phase 2 independent review and analysis.
- Phase 2 – Continue the Independent Review with a more detailed analysis of Aerospace and other program information over seven weeks and produce a Detail Report of issues, analyses, and conclusions by August 14, 2015. This Phase 2 will include interviews with MOX Services stakeholders and digging into the 2012 MOX Revised Baseline that served as the basis for the Plutonium Working Group (PWG) April 2014 Plutonium Options Report and the Aerospace Assessment Report.

3.3 Review Team Organization and Experience

High Bridge organized a Review Team of industry experts in several days and began review and analysis of the Aerospace Assessment Report and other information in the eRoom.

- Detail Review Experts – Ken Aupperle, Rick Drake, Charlie Hess, Dr. Mike High, and Barth Loney
- Peer Review Experts – Charlie Anderson, Dr. Andy Kadak, and Steve Maehr

The High Bridge Review Team members have an average of 40 years of relevant commercial nuclear power and DOE program experience spanning power generation, plutonium disposition, environmental/waste management, and complex FOAK facilities. Most of the Review Team members have worked together in the past performing similar Independent Reviews and Assessments, allowing for a quick start and efficient communications/analyses to perform this task in an expedited and intense fashion. **Exhibit 7** below provides a summary of High Bridge Review Team Expert Experience.

Exhibit 7

High Bridge Independent Review of Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Summary of High Bridge Review Team Expert Experience						
Name	Years Nuclear/DOE Experience	Past Experience Working Together	MOX Project Experience	Plutonium Disposition Program Experience	FOAK Project Experience	Specific Unique/Relevant Experience
<u>Detail Review Experts</u>						
1 Ken Aupperle (Task Lead)	>40	X	X	X	X	Task Lead for Fissile Material Disposition Program (FMDP), DOE HQ Office, Historical Cost Estimating Program Review & Support, Assessment of Technology Cost Impacts/Trends (2000 to 2002).
2 Rick Drake	>35	X	X	X	X	Assessment Team Member for review of MOX 2012 Re-Baseline construction labor hours, schedule duration, & contingency. Member of other MOX Assessment Teams since 2010.
3 Charlie Hess	>35	X	X	X	X	Was DOE team member in the 1990's that negotiated the Plutonium Disposition Agreement between Russia & the USA. He was responsible for developing/integrating the schedule of activities for the Russian MOX facilities & for coordinating with the US MOX program.
4 Dr. Mike High	>50	X	X	X	X	Assessment Team Member for review of MOX 2012 Re-Baseline construction labor hours, schedule duration, & contingency. MOX schedule/risk assessment team member 2000-2002.
5 Barth Loney	>35	X	X	X	X	Performed multiple Independent Project Reviews of the MOX project for the Office of Environmental Management (EM) in 2007-2009. Worked with EM from 2003-present on all of their waste disposition projects. Experience with other FOAK project for DOE such as the Waste Treatment Plant (WTP) at Hanford. Was on original recovery team from HQ for WTP in 2005-2006.
<u>Peer Review Experts</u>						
6 Charlie Anderson	>35	X	X	X	X	Currently serving as General Manager of the TRU Waste Processing Center (TWPC), Oak Ridge, for processing and extended storage. Prior to this, supported Nuclear Waste Partners in recovery efforts at the WIPP.
7 Dr. Andy Kadak	>40	X			X	Served on the DOE Nuclear Waste Technology Review Board regarding high-level waste disposal. Is familiar with the challenges of WIPP and HLW waste disposal as well as NRC nuclear licensing and construction experience.
8 Steve Maehr	>35	X	X	X	X	Mr. Maehr is president, CEO, and co-founder of High Bridge Associates. He has led or participated in over 50 independent assessments of complex nuclear and process facilities.

One-page Experience Biographies for each Review Team Expert are provided in **Appendix B**.

Detailed Experience Resumes for each Review Team Expert are provided in **Appendix C**.

One-paragraph Experience Summaries for each Review Team Expert are provided below.

Ken Aupperle (Task Lead) - Mr. Aupperle is a High Bridge Senior Vice President and Management Consultant. He has over 40 years of experience in project and construction management, cost estimating, planning, scheduling, project controls, earned value, and risk management. His experience spans the design, construction, operation/maintenance, and outage/modification of commercial nuclear/fossil power, industrial, environmental, and U.S. Department of Energy (DOE) projects. He has managed/performed numerous high level consulting assignments providing independent detailed cost estimates; independent high level cost reviews, schedule and risk assessments; and due diligence reviews for large capital projects, Life Cycle Cost Estimates, operating/maintenance activities, and decommissioning/waste management programs. *He was Task Lead for the DOE Fissile Material Disposition Program (FMDP) HQ Office to perform a Historical Cost Estimating Program Review and Support Task to compile and analyze Disposition Technology Cost Impacts/Trends (2000 to 2002).* Mr. Aupperle leads High Bridge development and maintenance of its nuclear industry cost and schedule data base, and its analysis of industry risk issues and contingency considerations. He has conducted research of cost/schedule/risk performance records for more than 100 US commercial nuclear and DOE science projects, and presented numerous Industry Lessons Learned presentations/papers at the American Nuclear Society and other industry forums. He consults as a Subject Matter Expert (SME) for the International Atomic Energy Agency (IAEA) for Project Management, Program Planning, and Integration on IAEA Planning/Training Missions for Member Nations.

Rick Drake - Mr. Drake has over 35 years of experience in the commercial nuclear power industry spanning design, construction, procurement, Project Management, startup, operation/maintenance, and outage/modification phases. He began his career working for Bechtel Power and held positions of increasing responsibility in support of construction, start up, outage, and continuing maintenance activities during the construction, commissioning, and operation of Palo Verde Nuclear Plant from 1978 to 1990. He held key department line management positions with the Tennessee Valley Authority Nuclear (TVAN) organization from 1990 to 2005 at each of the TVA Nuclear Sites and the corporate headquarters. He served as the construction manager for the completion of Watts Bar Unit 1 and Browns Ferry Unit 1 restart. Since 2006, Mr. Drake has been a Vice President and Senior Consultant with High Bridge Associates. He has led multi-discipline teams of personnel spanning numerous locations and contractor organizations, producing effective results in dynamic environments amid multiple priorities and aggressive deadlines. He has worked supporting various Project Assessments and Project Management/Controls Deployment Planning Reviews for New Nuclear Projects. He led the High Bridge activities for STPNOC STP 3 & 4 supporting independent cost and schedule assessments of Toshiba and Fluor. Mr. Drake was Co-Lead on an Independent Project Assessment Team for Toshiba to review and critique Fluor's estimates for STP Units 3&4, which identified more than \$1 billion in potential reductions to the Fluor Estimate, and developed alternative strategies for contractual approaches for future contracting.

Charlie Hess - Mr. Hess has over 35 years of experience in the power industry and has been involved with development, design, engineering, construction, operation, and decommissioning of various nuclear facilities. He is active with industry programs in preparation for new large and small reactor nuclear facilities, and is familiar with all nuclear technologies and NRC requirements. He is a recognized expert in light water reactors, sodium cooled fast reactors, and high temperature gas cooled reactors. He also has worked on pool-type research reactors, homogeneous aqueous reactors and Thorium based fuel cycles. He has designed fuel fabrication facilities, reprocessing

facilities high-level waste vitrification facilities, and fuel storage facilities. He managed completion of engineering, operational support, and decommissioning projects for large and small energy facilities. With nearly 20 years in responsible positions for nuclear industry, he has a thorough understanding of owner and regulatory issues balanced with extensive EPC experience and constructability/maintainability issues. He is a Registered Professional Engineer in Pennsylvania, with a BS degree in Nuclear Engineering and has been a Certified Project Management Professional. *Mr. Hess was part of the DOE team that negotiated the Plutonium Disposition Agreement between the Russians and the USA. He was responsible for developing and integrating the schedule of activities for developing the Russian MOX facilities and for coordinating with the US MOX program in the 1990s. He understands the issues surrounding plutonium disposition.*

Dr. Mike High - Dr. High has over 50 years of experience with advanced technology and first-of-a-kind (FOAK) projects spanning research, development, demonstration, engineering, construction, operations, and maintenance in the power generation, environmental, and aeronautical industries. He has testified before various congressional subcommittees regarding environmental issues, acid rain legislation, and the U.S. Department of Energy's fossil and nuclear energy budgets. He chaired the Electric Power Research Institute's (EPRI) Environmental Research Division Advisory Committee and served for five (5) years as a member of the EPRI Research Advisory Committee. As a member of the EPRI Ad Hoc Committee on Advanced Reactor Programs (ARP), he provided policy and technical guidance on making light water reactors simpler and enhancing their safety features through the Advanced Light Water Reactor (ALWR) Utility Steering Committee. Dr. High practiced in the field of aeronautical and aerospace engineering for nearly twenty years, first at Pratt & Whitney Aircraft Company and more extensively at the U.S. Air Force Arnold Engineering and Development Center located near Tullahoma, Tennessee. He joined the Tennessee Valley Authority (TVA) in 1980 and served as Division Director for nine years where he was responsible for all aspects of Research, Development, and Demonstration (RD&D) for the TVA electric power system. Since 2000, Dr. High has worked extensively with High Bridge Associates as a Management Consultant providing consulting services, technology assessments, and independent reviews. He has extensive technical, scientific, and financial analytical skills, and is accustomed to supporting large, complex, and multi-disciplined projects with numerous participants. He has performed independent project reviews, risk assessments, feasibility/due-diligence and life cycle cost studies for various commercial and Department of Energy (DOE) projects.

Barth Loney - Mr. Loney has more than 35 years of experience in program / project / engineering management serving in various positions with increasing responsibilities. As a Senior Vice President with High Bridge Associates, Inc., he has a history of successful project/program completions, implementations, reengineering and process improvements. He is an adept professional with the ability to work comfortably in diverse environments, handle multiple tasks simultaneously, and creatively address root causes to develop innovative solutions that have improved processes and contributed directly to bottom line performance. He is a Subject Matter Expert with extensive experience in Project Management, Earned Value Management, Risk Management, and Engineering and Construction Management. His industry experience includes nuclear power, construction and utility background, both in private and federal sectors. He has ten years of experience leading and participating in project reviews for the Department of Energy. He is familiar with multiple standards and requirement, including, but not limited to, DOE Order 413,

PMBOK, and ANSI 748. Some recent assignments for High Bridge supporting multiple DOE Offices include:

- Oak Ridge National Lab (WAI) – TRU Waste Processing Center, Support General Manager in areas of Risk, Earned Value and Budget/Proposal development. Evaluating waste stream trends and cost for the project and budget forecasting options
- Office of Acquisition Project Management (Headquarters) – Led External Independent Review (EIR) team for the CD2/3 submittal of the K-27 D&D project at Oak Ridge. Also served as Risk SME for the review.
- Office of Environmental Management (Headquarters) – provided project controls expertise for a project involving research reactor fuels disposition.

Charlie Anderson - Over 33 years with increasing responsibilities in executive, technical, operations, program, and project management of nuclear materials disposition, nuclear materials production, nuclear waste management, and nuclear and coal fired power generation programs with *Los Alamos National Lab, Nuclear Management Partners, URS Corporation, Washington Group International, the Department of Energy* and the *Tennessee Valley Authority* covering laboratories and complex operating facilities from construction through decommissioning and demolition. He served in senior management positions as a key member of these organizations with responsibilities in leadership, management, oversight, strategic planning, and execution of startups, transitions, and problematic programs. Responsibilities have included annual budgets of \$6.2 Billion and workforces of 3,000 Federal and 30,000 contractor personnel. Work has typically involved bridging technical, business, and political agendas to solve problems in order to achieve programmatic and operational goals and objectives. Performance has always demonstrated a focus on progress and personal commitment. He lead key cross cutting initiatives in most of these organizations, which includes commercial, government, international, and government contractor. He served as Principal Deputy Assistant Secretary of Environmental Management, with the DOE in Washington, DC. Provided innovative and sound leadership in a number of management positions at the Savannah River Site for the Department of Energy including Deputy Site Manager, Assistant Manager for High Level Waste; Director, Office of Defense Nuclear Nonproliferation; Director, Nuclear Materials Disposition; Director, Reactors and Spent Fuel Division; Director, High Level Waste Programs Division; and Director, Liquid Waste Division.

Dr. Andy Kadak - Dr. Kadak has over 40 years of commercial nuclear experience and is President of Kadak Associates, Inc., a consulting firm specializing in management issues and nuclear energy. Prior to resuming his private consulting practice, Dr. Kadak was Principal and Director of Nuclear Services at Exponent, a worldwide company offering multidisciplinary expertise and rapid response capabilities to provide stewardship in addressing complex engineering and scientific problems. Dr. Kadak served on the IAEA special team assessing earthquake and tsunami damage of the Onagawa Nuclear Plant in Japan and has performed extensive studies of the Fukushima Di-iachi Nuclear Plant. Dr. Kadak was s a Professor of the Practice in the Nuclear Engineering Department of the Massachusetts Institute of Technology. His research interests include the development of advanced reactors, in particular the high temperature pebble bed gas reactor, space nuclear power systems, improved technology neutral licensing standards for advanced reactors and operations and management issues of existing nuclear power plants. Recently he was asked to serve on the Small Modular Reactor subcommittee of the Secretary of Energy's Advisory Board. His expertise ranges

from reactor physics, power conversion, safety analysis and engineering systems. Dr. Kadak was President and CEO of Yankee Atomic Electric Company. In this capacity, he was responsible for overseeing all Yankee operations, including the decommissioning of the Yankee plant in Rowe, Massachusetts and engineering, licensing, environmental and operational support to all eight nuclear plants in New England and many other national and international clients. Dr. Kadak was President of the American Nuclear Society in 1999/2000. He was appointed by the President to serve on the US Nuclear Waste Technology Review Board. He has made more than 70 lectures and speeches on topics related to the technical and business aspects of nuclear power.

Steve Maehr - Mr. Maehr is President, CEO, and co-founder of High Bridge Associates. He has more than 35 years of experience in Engineering, Project Management, and Executive leadership positions in the electric utility and management services industries. His principal areas of expertise include Strategic Planning, Business Development and Sales, Planning and Scheduling, Budgeting, Financial Planning and Accounting, Maintenance, Outage Management, Management Information Systems, Licensing, Engineering and System Testing. With degrees in Mathematics, Nuclear Engineering (BS) and Industrial Management (MS), he has held positions of increasing responsibility with electric utilities, management service contractors, and consulting/project management companies. Mr. Maehr has a demonstrated record of accomplishment in developing opportunities and assisting customers with managing their projects, programs, and corporate operations. He is an entrepreneurial and strategic thinker, an excellent communicator, and a versatile leader. With his network of resources developed over the years by working with hundreds of owners, specialty contractors, and staff resources, he has an exceptional proficiency in assembling project teams to deliver “Just in Time” skills to customers, when and where they are needed.

APPENDIX B

PowerPoint Summary of Report

High Bridge Associates

Phase 2 Presentation Option 1 MOX Fuel Program Compared to Option 4 Downblend Alternative



"Connecting Vision and Plans with Performance and Execution"



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Executive Summary

- Aerospace used escalated real year dollars to compare projects which violates good practice & exaggerates costs
- Converting the Aerospace costs to current year dollars and correcting for errors, the total project costs are comparable
 - Option 1 MOX Fuel $\simeq$ \$19B
 - Option 4 Downblend $\simeq$ \$20B
- Option 1 MOX Fuel fully meets PMDA requirements while Option 4 Downblend
- Option 4 will exceed the capacity of WIPP and will require a complete redesign/relicensing of WIPP to proceed



Executive Summary

- High Bridge estimates average annual costs for MFFF are < \$500M
- High Bridge confidence in the Option 1 MOX Fuel ETC is greater than for Option 4 Downblend ETC costs due to the Program Maturity
- MFFF Project experienced significant cost increases resulting from scope changes caused by the MOX Program consolidating the Pit Disassembly and Conversion Facility and the Immobilization Facility into the MFFF Project
 - This reduced the overall MOX Program costs while increasing the MFFF Project costs.
- The Aerospace Option 1 MOX Fuel 20% annual funding reduction resulted in a 400% construction schedule duration increase
 - This analysis is flawed and resulted in exaggerated escalation cost

Executive Summary

- Funding the MFFF Project at the baseline level will reduce construction cost by more than \$1B the schedule by more than 10 years compared to the Aerospace report
- Aerospace underestimated the transportation cost of Option 4 Downblend by approximately \$1B
 - Option 1 MOX Fuel: approx. 80 shipments/2,000 fuel assemblies
 - Option 4 Downblend: approx. 2,300 truck shipments/97,000 drums
- Aerospace ignored the value of the MOX Fuel in Option 1
 - Approximately 285B kilowatt hours of electricity generating an economic value of approximately \$35B compared to the estimated MFFF cost of \$20B.
- Option 4 would reverse a policy based on 20 years of study and analysis



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Real Year Dollars (RY\$)

- All Federal references require constant year dollars for capital asset comparisons
 - DOE Order DOE 413.3B
 - DOE Guideline 413.3-21
 - GAO Cost Estimating/Assessment Guide, GAO-09-3SP
 - Guidelines for Benefit-Cost Analysis of Federal Programs, OMB A-94
- RY\$ inflates the costs and exaggerates differences
 - Option 1 (RY\$) = \$47B; Option 1 (FY14\$) = \$27B

Evaluated Cost Comparison

Comparison of Options 1 and 4 Life Cycle Costs (B-FY14\$)				
	Option 1 - MOX		Option 4 - Downblend	
Element	High Bridge	Aerospace	High Bridge	Aerospace
Base Costs	\$ 15.1	\$ 16.7	\$ 13.0	\$ 7.4
Contingency/Risk	\$ 3.2	\$ 7.8	\$ 5.0	\$ 3.8
Changes	\$ 1.1	\$ 2.7	\$ 1.9	\$ 1.9
Total	\$ 19.4	\$ 27.2	\$ 19.9	\$ 13.1



Evaluated Option 1 Costs

HIGH BRIDGE EVALUATED OPTION 1 MOX FUEL COSTS (M-FY14\$) - ETC Unconstrained)							
	MFFF Construction	Operations	MIFT and Other	Changes Since PWG 2014	Penalties ²	Revenue ³	Total
Base ¹	\$ 4,342.0	\$ 6,255.4	\$ 5,924.2	\$ 1,136.0			\$ 17,657.6
Penalties ²					\$ 400.0		\$ 400.0
Revenue ³						\$ (1,000.0)	\$ (1,000.0)
Operations/Security ⁴	\$ -	\$ (800.0)	\$ -	\$ -	\$ -	\$ -	\$ (800.0)
Subtotal	\$ 4,342.0	\$ 5,455.4	\$ 5,924.2	\$ 1,136.0	\$ 400.0	\$ (1,000.0)	\$ 16,257.6
Contingency	\$ 900.0	\$ 1,070.0	\$ 1,220.0	\$ -	\$ -	\$ -	\$ 3,190.0
Total	\$ 5,242.0	\$ 6,525.4	\$ 7,144.2	\$ 1,136.0	\$ 400.0	\$ (1,000.0)	\$ 19,447.6
Notes							
1	Base Cost of \$18.6B from PWG has \$1.9B contingency in FY14\$; High Bridge did not distribute.						
2	Penalty payment to South Carolina for non-shipment of weapons grade Pu239 from SRS.						
3	Sales of MOX fuel to electric utilities - based on the sale of approximately 2,000 PWR fuel assemblies.						
4	Overestimate of SRS shared infrastructure, for example, MOX Services operational cost estimate of \$50M/year vs HBA estimate of \$15M/year (saving of \$800M on project).						



Evaluated Option 4 Costs

High Bridge Evaluated Option 4 Downblend Costs (M-FY14\$ - ETC)							
	MFFF Termination	WIPP Capital	Operations	"MIFT" and Other	Changes Since PWG 2014	Penalties ²	Total
Base ¹	\$ 1,492	\$ 214	\$ 2,094	\$ 4,444	\$ 1,873		\$ 10,117
Penalties ²						\$ 1,100	\$ 1,100
PMDA & WIPP ³		\$ 863					\$ 863
Operations - WIPP ⁴			\$ 1,640				\$ 1,640
MIFT-Trans/Pkg's ⁵			\$ -	\$ 1,150			\$ 1,150
Subtotal	\$ 1,492	\$ 1,077	\$ 3,734	\$ 5,594	\$ 1,873	\$ 1,100	\$ 14,870
Contingency	\$ 430	\$ -	\$ 512	\$ 4,101	\$ -	\$ -	\$ 5,043
Sub Total	\$ 1,922	\$ 1,077	\$ 4,246	\$ 9,695	\$ 1,873	\$ 1,100	\$ 19,913
Notes							
1	Base Cost of \$8.2B from PWG has \$0.8B contingency in FY14\$; High Bridge did not distribute.						
2	Penalty payment to South Carolina for non-shipment of weapons grade Pu239 from SRS.						
3	High Bridge estimate for PMDA amendments and WIPP revised federal legislation, NEPA, NMED, and CD-0 to CD-4 activities.						
4	High Bridge re-estimate for the resources required for 30 years of WIPP operations (PWG = \$360M vs HBA = \$2,000M).						
5	High Bridge estimate for additional transportation costs (80 for MOX vs 2300 for Downblend Shipments) and material costs (Shipping Containers) for MIFT.						



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WIPP

- WIPP was created as a demonstration project for the weapons complex legacy wastes
- It has a statutory limit of 6.2 million cubic feet of TRU wastes (~175,600 cubic meters)
- Current EM activities have committed to use all but 19,600 cubic meters of that capacity
- Aerospace identified the risk of needing more space at WIPP at only 10%

Impacts of Option 4

- Option 4 Downblend will exceed the available capacity of WIPP for only 34 MT of Pu
- DOE/NNSA has 51 MT of surplus Pu
 - Option 4 eliminates all disposal options
 - 51 MTs requires over 30,300 cubic meters at WIPP
- EM has an enormous backlog of TRU wastes
 - Law suits at many sites due to failure to perform
 - Option 4 would slow down EM waste disposal
- Option 4 requires that WIPP be redesigned and relicensed for a revised mission



Potential WIPP Impacts

	Capacity and Projected Load Element	Cubic Meters	Cubic Meters/ 55 Gal. Drum	Number of 55 Gal. Drums	Plutonium Metric Tons	Curies *
1	Capacity per 1992 Land Act Law Low Level & Mixed TRU Waste	175,600	0.208	844,231	0	539,000
2	2014 DOE EM TRU Waste Projection	156,000	0.208	750,000	0	0
3	2015 NNSA Excess Plutonium Projection	<u>30,300</u>	0.208	<u>145,673</u>	<u>51</u>	<u>2,300,000</u>
4	Sub Total Projection	186,300	-	895,673	51	2,300,000
5	25% Freeboard for Future Identified Waste Projection	46,575	0.208	223,918		575,000
6	Allowance for additional surplus weapons plutonium	29,112	0.208	139,960	49	2,209,804
7	Capacity Basis for NEPA, New Mexico, & CD-1 to CD-4 Amendments	261,987	-	1,259,552	100	5,084,804
8	Approximate % Increase in Capacity/Load	49%	-	49%		843%
* - These are 1000 year curies, i.e., curies remaining in 1000 years.						



Relicensing WIPP

- Need a Complete NEPA Process
- Need a CD-3 Package and Construction Effort
 - Might interrupt current WIPP activities
- Need New Mexico Environmental Department Concurrence
- Need a revised Waste Isolation Pilot Project Land Withdrawal Act passed by Congress and signed into law



PMDA & WIPP Schedule

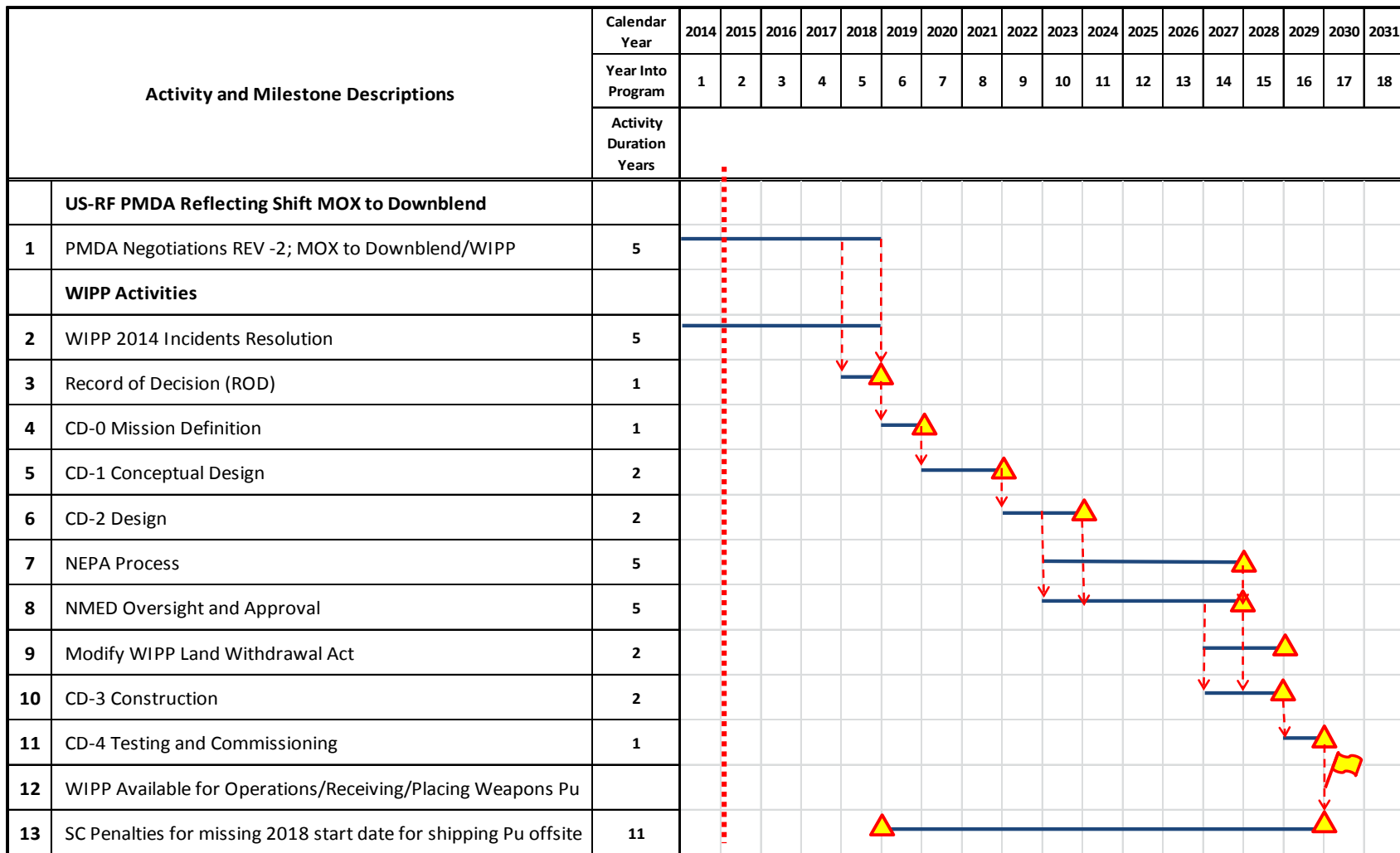




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Option 1 Schedule Growth

- Aerospace did not review the proposed MFFF funding level
- Aerospace considered only constrained funding for Option 1 MOX Fuel
- This 20% reduction in funding resulted in a 400% increase in schedule
- This is a flawed analysis that resulted in extremely exaggerated escalation costs

Annual Costs of MOX

- Critics have suggested that the cost of MOX is over \$1 billion per year
 - This is the result of Aerospace using escalated real year dollars in their cost estimate
- High Bridge estimates the project cost of MOX averages less than \$500 million per year – less than the cost of security for our Pu supply
 - \$19.4B over 40 years



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MOX vs MFFF

- Confusion exists between comparisons of the MOX Program and MFFF Project
 - MOX is a program consisting of many parts
 - MFFF is a project within MOX
- MOX Program consolidated two planned facilities into MFFF to reduce program costs
- These revisions to MFFF design during construction resulted in cost increases
- Overall MOX Program costs were reduced

MOX History

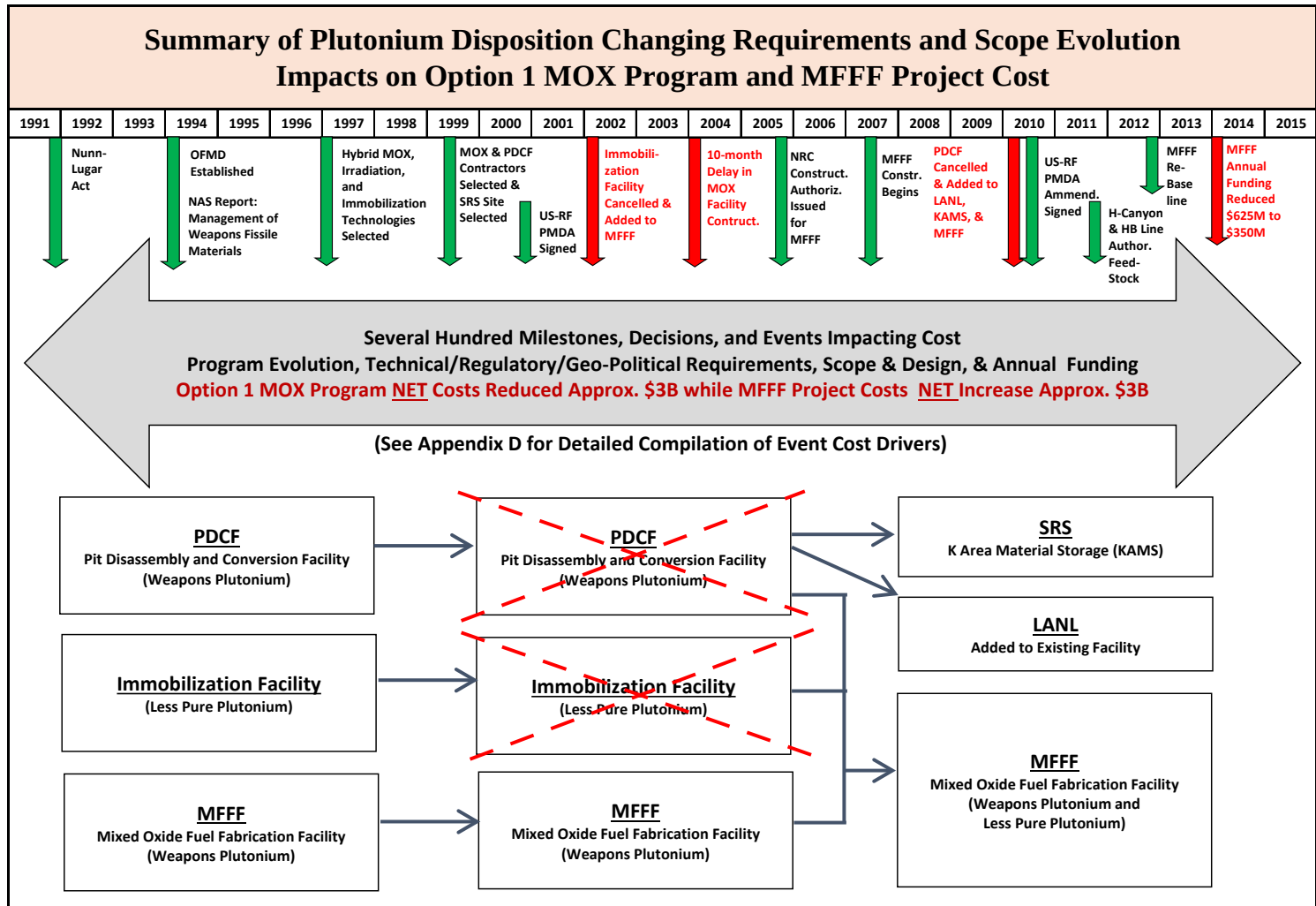
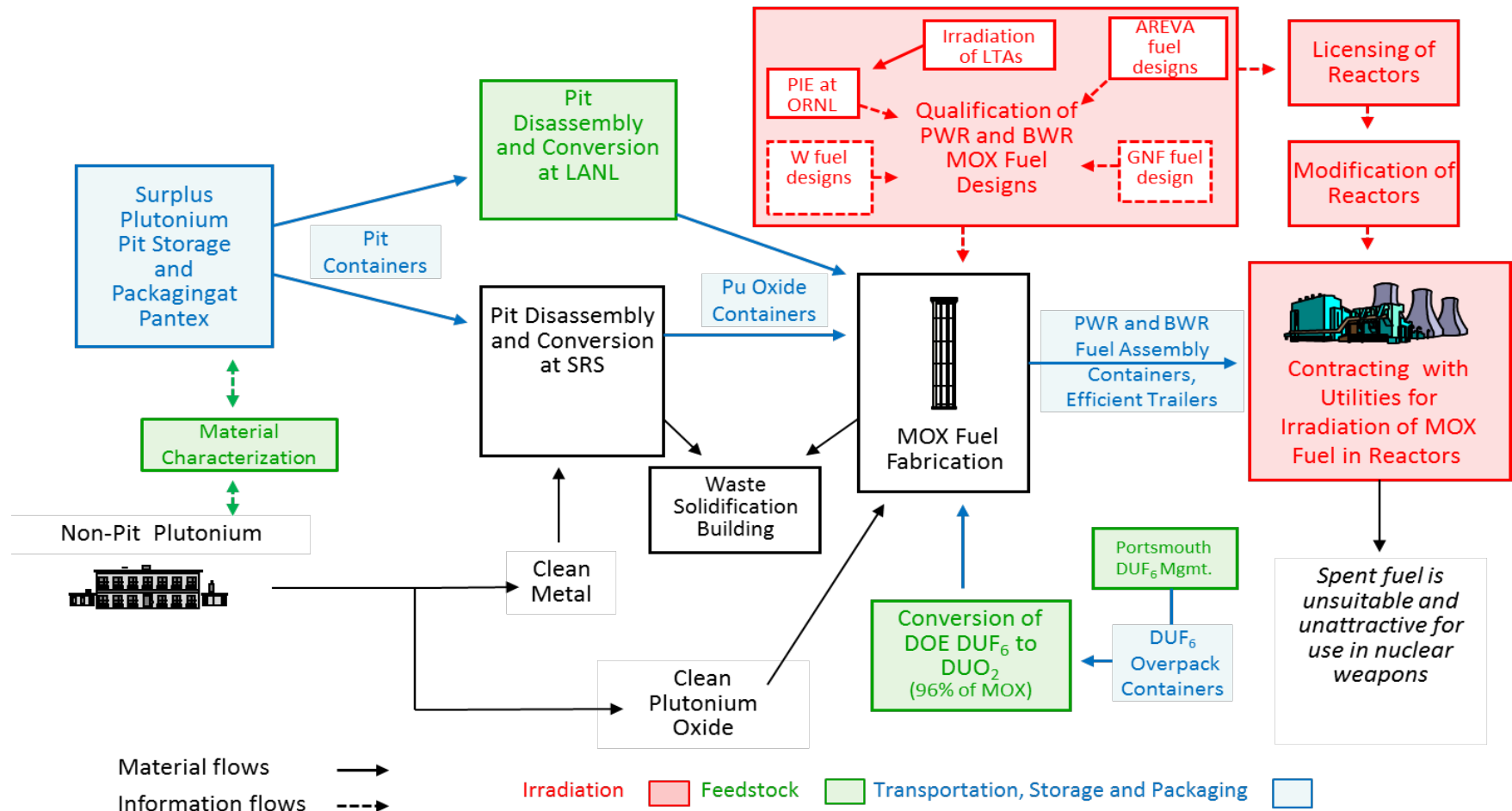




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MOX Irradiation Feedstock and Transportation - MIFT



MIFT Cost Increases

- Aerospace allocated a \$10B to \$35B increase to MIFT for both options with no supporting data
- De-escalated costs were calculated
 - \$4.1B for Option 1
 - \$3.4B for Option 4
- Not clear why MIFT for Option 1 is > than Option 4

MIFT Costs

- MI stands for MOX Irradiation
 - Option 4 does not require MI
 - Option 4 has costs not captured by Aerospace
 - Option 4 missing costs are $\geq$ the MI Option 1 costs
- F stands for Feedstock Preparation
 - Pu Oxide production is slower for Option 4 therefore more expensive
 - U Oxide costs are comparable to Stardust costs

MIFT Costs

- T stands for transportation costs
 - Option 1 MOX Fuel will have 80 total shipments
 - Option 4 Downblend will have 2,300 total shipments
 - Option 1 would need approximately 20 reusable fuel shipping containers ~\$3.2M
 - Option 4 Transport costs would include 97,000 single use Criticality Control Overpacks at \$2,200 each ~\$210M
- Option 4 would cost ~\$1.0B more than Option 1



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Comparison of Options

Comparison of Plutonium Disposition Program Alternatives Approximate Revenue, Cost Impact, and Value Contribution Metrics MOX Fuel Sales, Clean Energy, and GNP Parameters Option 1 MOX Fuel vs. Option 4 Downblend

#	Option 1 - MOX Fuel		Option 4 - Downblend	
	Program Element		Program Element	
1	Metric Tonnes of Plutonium Pu 239	34	34	Metric Tonnes of Plutonium Pu 239
2	Pounds of Plutonium Pu 239	74,956	74,956	Pounds of Plutonium Pu 239
3	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved	Yes	No	Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved
4	<u>Approximate Product Output</u> Nuclear Fuel PWR Assembly Approx. 8.5" x 8.5" x 13.5' Long Each Containing Approx. 264 Zircalloy Clad Fuel Rods	2,000	97,000	<u>Approximate Waste Form Output</u> Plutonium Diluted/Mixed with Stardust Inert Material in 6" Diameter x 2' Long Container Packed Inside a 55 Gallon Drum
5	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales	\$1,000,000	\$0	Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales
6	Approximate Number of Shipments in Casks with 2 Fuel Assemblies/Cask, 4 Casks/Truck, and 3 Trucks/Shipment	80	2,300	Approximate Number of Shipments in TRUPACT-II Containers with 14 Drums/Container and 3 Containers/Truck



Comparison of Options

Comparison of Plutonium Disposition Program Alternatives				
#	Option 1 - MOX Fuel		Option 4 - Downblend	
	Program Element		Program Element	
7	Approximate WIPP Storage Capacity Volume Consumed	~0	20,200 Cu. Meters	Approximate WIPP Storage Capacity Volume Consumed
8	Approximate Megawatt Hours of Clean Electricity Produced	285 Million	0	Approximate Megawatt Hours of Clean Electricity Produced
9	Approximate Value of Clean Electricity Produced	\$35 Billion	\$0	Approximate Value of Clean Electricity Produced
10	Approximate State/Local Tax Revenues Generated	>\$5 Billion	\$0	Approximate State/Local Tax Revenues Generated
11	Approximate Life Cycle Cost of MOX Program	\$19.4 Billion	\$19.9 Billion	Approximate Life Cycle Cost of Downblend Program
12	Approximate US Jobs Created for 20 Years	>10,000	0	Approximate US Jobs Created for 20 Years
13	Avoided Carbon Emissions	335 Million Tons	0	Avoided Carbon Emissions
14	Avoided NOx Gas Emissions	420,000 Tons	0	Avoided NOx Gas Emissions
15	Avoided SO2 Gas Emissions	675,000 Tons	0	Avoided SO2 Gas Emissions
NOTE: The values identified in this Exhibit are approximate based on the analysis				



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Option 4 - Downblend

- Option 4 is not downblend
 - Downblending fundamentally changes the isotopic characteristics of the material
 - Downblending is impossible with Plutonium because there is no source of non-fissile Plutonium
 - Option 4 is dilution with a substance (“Stardust”) designed to foil diversion attempts
 - The waste packages are readily handle able
- Immobilization was reluctantly accepted by RF for minor amounts of Plutonium

Option 4 - Downblend

- Option 4 is almost certainly not acceptable to the Russian Federation
- Major concessions would be needed for them to accept it
- Option 4 could not begin without obtaining the acceptance of the Russian Federation
- Option 1 – MOX Fuel is both acceptable to the Russian Federation and the best solution available to USA

Policy Level Decision

- United States/Congress selected the Option 1 MOX Fuel approach in 1997 as the solution for Pu Disposition
- MOX is named in the PMDA between the Russian Federation and the USA
- DOE/NNSA is proceeding as if this is a budgetary decision
- Adopting Option 4 Downblend would be a major policy reversal of a decision based on 20 years of study and analysis

APPENDIX C

Admiral Rickover's 1953 Letter to Congress: Paper vs. Practical Reactors

June 5, 1953

Important decisions about the future development of atomic power must frequently be made by people who do not necessarily have an intimate knowledge of the technical aspects of reactors. These people are, nonetheless, interested in what a reactor plant will do, how much it will cost, how long it will take to build and how long and how well it will operate. When they attempt to learn these things, they become aware of confusion existing in the reactor business. There appears to be unresolved conflict on almost every issue that arises.

I believe that this confusion stems from a failure to distinguish between the academic and the practical. These apparent conflicts can usually be explained only when the various aspects of the issue are resolved into their academic and practical components. To aid in this resolution, it is possible to define in a general way those characteristics which distinguish the one from the other.

An academic reactor or reactor plant almost always has the following basic characteristics: (1) It is simple. (2) It is small. (3) It is cheap. (4) It is light. (5) It can be built very quickly. (6) It is very flexible in purpose (“omnibus reactor”). (7) Very little development is required. It will use mostly “off-the-shelf” components. (8) The reactor is in the study phases. It is not being built now.

On the other hand, a practical reactor plant can be distinguished by the following characteristics: (1) It is being built now. (2) It is behind schedule. (3) It is requiring an immense amount of development on apparently trivial items. Corrosion, in particular, is a problem. (4) It is very expensive. (5) It takes a long time to build because of the engineering development problems. (6) It is large. (7) It is heavy. (8) It is complicated.

The tools of the academic-reactor designer are a piece of paper and a pencil with an eraser. If a mistake is made, it can always be erased and changed. If the practical-reactor designer errs, he wears the mistake around his neck; it cannot be erased. Everyone can see it.

The academic-reactor designer is a dilettante. He has not had to assume any real responsibility in connection with his projects. He is free to luxuriate in the elegant ideas, the practical shortcomings of which can be relegated to the category of “mere technical details.” The practical-reactor designer must live with these same technical details. Although recalcitrant and awkward, they must be solved and cannot be put off until tomorrow. Their solutions require manpower, time and money.

Unfortunately for those who must make far-reaching decisions without the benefit of an intimate knowledge of reactor technology and unfortunately for the interested public, it is much easier to get the academic side of an issue than the practical side. For a large part those involved with the academic reactors have more inclination and time to present their ideas in reports and orally to those who will listen. Since they are innocently unaware of the real but hidden difficulties of their plans, [t]hey speak with great facility and confidence. Those involved with practical reactors, humbled by their experiences, speak less and worry more.

Yet it is incumbent on those in high places to make wise decisions, and it is reasonable and important that the public be correctly informed. It is consequently incumbent on all of us to state

the facts as forthrightly as possible. Although it is probably impossible to have reactor ideas labelled as “practical” or “academic” by the authors, it is worthwhile for both the authors and the audience to bear in mind this distinction and to be guided thereby.

Yours faithfully,

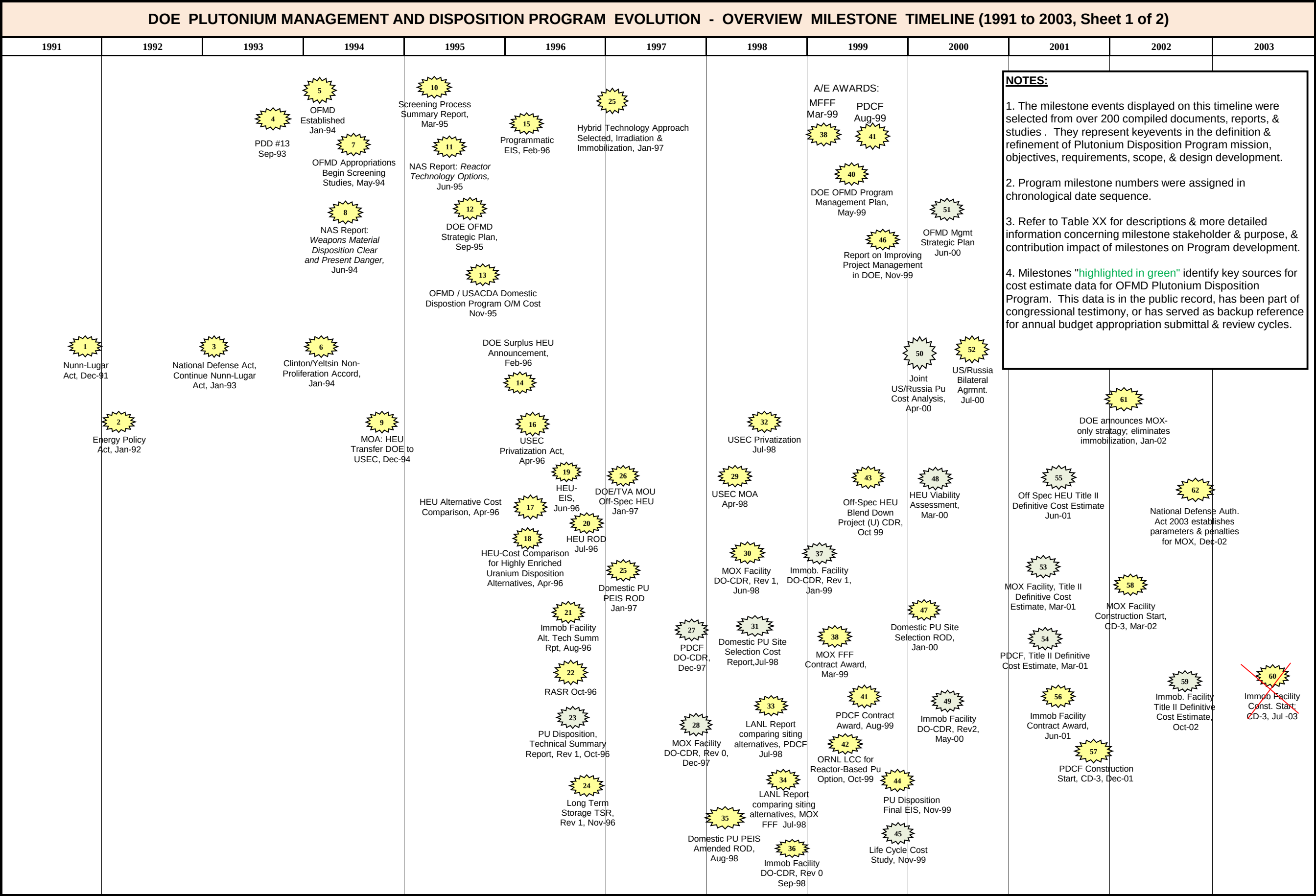
*H. G. Rickover
Naval Reactors Branch
Division of Reactor Development
U.S. Atomic Energy Commission*

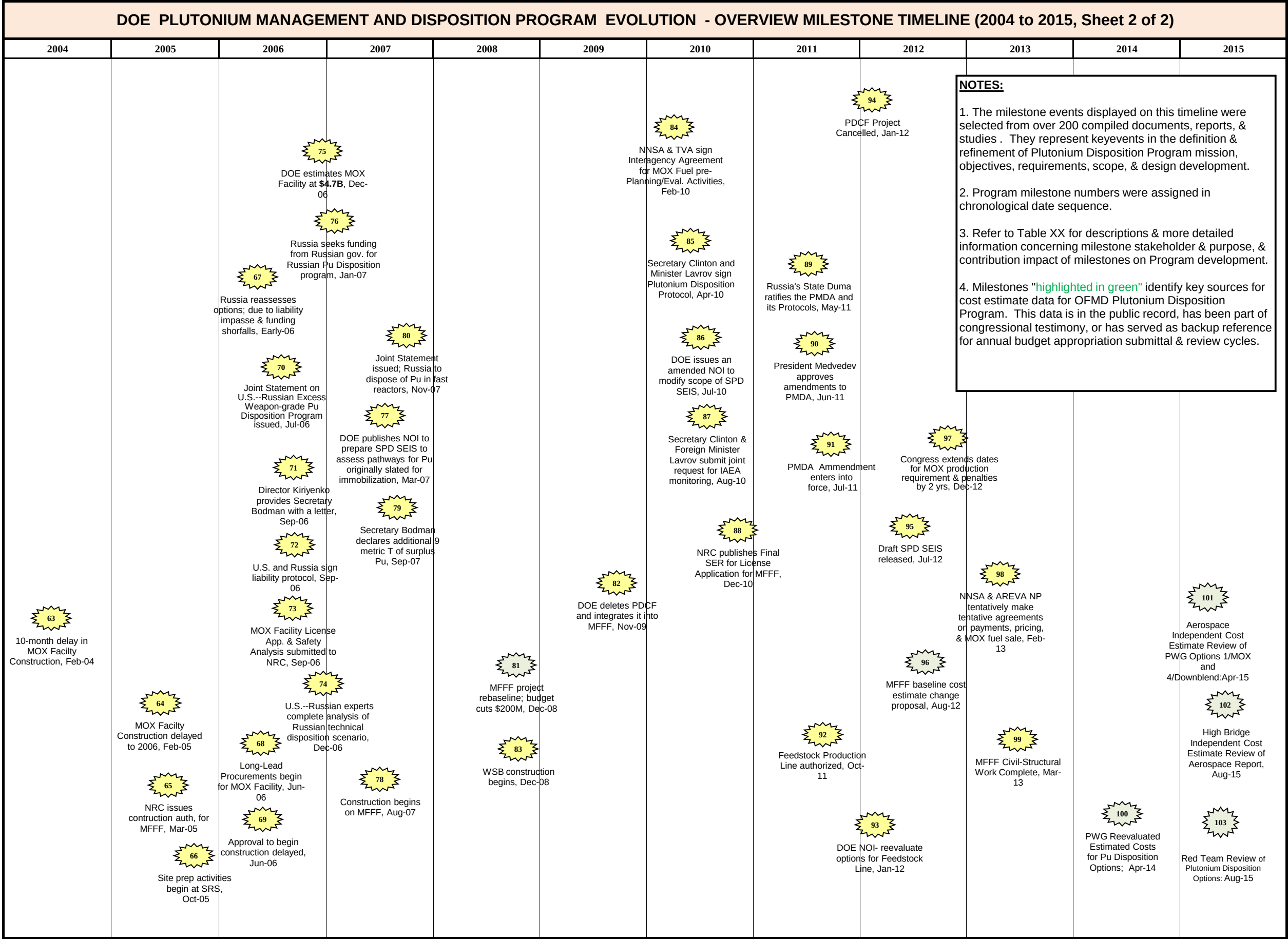
http://ecolo.org/documents/documents_in_english/Rickover.pdf,

Accessed on July 7, 2015.

APPENDIX D

Detailed Compilation of Milestones and Events Impacting Plutonium Disposition Program Costs, Timeline Spreadsheet and Chronological List





DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
1	Nunn-Lugar Act	Dec-91		
2	Energy Policy Act	Jan-92		
3	National Defense Authorization Act	Jan-93		
4	Presidential Decision Directive-13	Sep-93		
5	Office of Fissile Material Disposition Established	Jan-94	N/A	
6	Clinton/Yeltsin Non-Proliferation Accord	Jan-94		
7	OFMD Appropriations To Begin Screening Studies	May-94		
8	Management of Disposition of Excess Weapons	Jun-94	National Academy of Sciences	The primary goal of this document was to choose options for management and disposition of excess nuclear weapons and fissile materials that would minimize the risks to national and international security posed by the existence of this material.
9	MOA HEU Transfer DOE to USEC	Dec-94		
10	Summary Report of the Screening Process To Determine Reasonable Alternatives for Long-Term Storage and Disposition of Weapons-Usable Fissile Materials	29-Mar-95	DOE-OFMD	The purpose of this screening document was to consider potential options and to identify reasonable alternatives for a subsequent detailed evaluation to support Records of Decision.
11	Management of Disposition of Excess Weapons - Reactor-Related Options	Jun-95	National Academy of Sciences	The purpose of this document was to choose options for management and disposition of Wpu beyond interim storage to measures that involve irradiation of the plutonium in nuclear reactors or its immobilization with reactor wastes.
12	DOE OFMD Strategic Plan	Sep-95	DOE-OFMD	The purpose of this Strategic Plan is to Describe the top-level mission, objectives and strategies of the Department to manage the storage and disposition of weapons-usable fissile materials.
13	OFMD/USACDA Domestic Disposition Program O/M Cost	Nov-95	Michael Rosenthal, U.S. Arms Control & Disarmament Agency	The purpose of this letter was to provide additional information on an alternative in which plutonium is vitrified without radionuclides.
14	DOE Surplus HEU Announcement	Feb-96		
15	Storage and Disposition of Weapons-Usable Fissile Materials Draft Programmatic Environmental Impact Statement	Feb-96	DOE-OFMD	The purpose of this draft Storage and Disposition PEIS was to identify reasonable long-term storage alternatives as: upgrade at multiple sites, consolidation of plutonium at a single site, and collocation of plutonium and highly enriched uranium at a single site.
16	USEC Privatization Act	Apr-96	DOE - USEC	United States Enrichment Corporation established as a private company.

DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
17	Cost Comparison for Highly Enriched Uranium Disposition Alternatives	Apr-96	Oak Ridge Y-12 Plant for DOE	The purpose of this report was to provide estimates of the potential costs for blending HEU by using each of the technological blending approaches, and it compares the economic impact for disposition of the excess HEU according to the various alternatives for the extent of commercial fuel use.
18	HEU Cost Comparison for Highly Enriched Uranium Disposition Alternatives.	Apr-96		
19	HEU EIS	Jun-96		
20	Record of Decision for the Disposition of Surplus Highly Enriched Uranium Final Environment Impact Statement	29-Jul-96	Hazel R. O'Leary, Secretary	The purpose of this ROD was to render decision on alternatives for a program to reduce global nuclear proliferation risks by blending up to 200 metric tons of United States-origin surplus HEU down to LEU to make it non-weapons-usable.
21	FMDP Alternative Technical Summary Report: Ceramic Can-in-Can Variant	26-Aug-96	Lawrence Livermore National Laboratory	The purpose of this report is to provide the required information for one of the immobilization variants: the ceramic can-in-canister variant with dry feed at the Savannah River Site using HLW glass to surround the plutonium-ceramic cans. Other approaches considered in this document are a wet feed to replace the dry feed preparation operation in the immobilization step, and substitution of a hot press operation for the cold press and sinter operation.
22	FMDP Reactor Alternative Summary Report (RASR), Vol. 1 - Existing LWR Alternative	7-Oct-96	Oak Ridge National Laboratory	The purpose of this report was to conduct and summarize extensive analyses of the cost, schedule, technical maturity, S&S, and other characteristics of reactor-based plutonium disposition.
23	Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition, Rev. 1	31-Oct-96	DOE-OFMD	The purpose of this report was to summarize representative technical, cost, and schedule data for the reasonable alternatives being considered for the disposition of plutonium declared surplus to national security requirements in the <i>Storage and Disposition of Weapons-Usable Fissile Materials Draft Environmental Impact Statement</i> .
24	Technical Summary Report for Long-Term Storage of Weapons-Usable Fissile Materials, Rev. 1	29-Nov-96	DOE-OFMD	The purpose of this report was to provide technical, cost, and schedule information for storage alternatives analyzed in the MD-PEIS.

DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
25	Record of Decision for the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement	14-Jan-97	DOE-OFMD	The purpose of this ROD was to render decision on disposition of surplus plutonium by pursuing a strategy that allows: 1) immobilization of surplus plutonium for disposal in a repository pursuant to the Nuclear Waste Policy Act, and 2) fabrication of surplus plutonium into MOX fuel, for use in existing domestic commercial reactors (and potentially CANDU reactors, depending on future agreements with Russia and Canada). (Milestone #20 was written in support of this ROD).
26	DOE/TVA Memorandum of Understanding (MOU) Off-Spec HEU	Jan-97		
27	Design-Only Conceptual Design Report for Pit Disassembly and Conversion Facility, Rev. 0	12-Dec-97	University of California, LANL, Fluor Daniel, Inc.	The purpose of this DO-CDR was to support a funding request by the DOE-OFMD for line-item funds for engineering design of the Pit Disassembly and Conversion Facility.
28	Design-Only Conceptual Design Report for a Generic Mixed Oxide Fuel Fabrication Facility, Rev. 0	15-Dec-97	Los Alamos National Laboratory, Fluor Daniel, Inc., Westinghouse Savannah River Company	The purpose of this DO-CDR was to support a line-item funding request for engineering design of the Mixed Oxide (MOX) Fuel Fabrication Facility (FFF).
29	USEC Memorandum of Agreement (MOA)	1-Apr-98		
30	Design-Only Conceptual Design Report for a Generic Mixed Oxide Fuel Fabrication Facility, Rev. 1	30-Jun-98	Los Alamos National Laboratory	The purpose of this DO-CDR was to support a line-item funding request for engineering design of the Mixed Oxide (MOX) Fuel Fabrication Facility (FFF).
31	Cost Analysis in Support of Site Selection for Surplus Weapons-Usable Plutonium Disposition	22-Jul-98	DOE-OFMD	The purpose of this report was to provide cost information and analyses to support the selection of a preferred alternative from the alternatives considered in the <i>Surplus Plutonium Disposition Environmental Impact Statement</i> for plutonium disposition for three types of facilities: A Pit Disassembly and Conversion Facility, a Mixed Oxide Fuel Fabrication Facility, and an Immobilization Facility.
32	USEC Privatization	Jul-98		
33	Cost Estimates of Pit Disassembly and Conversion Facility Siting Alternatives, LA-13486-MS	Jul-98	Los Alamos National Laboratory, Fluor Daniel, Inc.	The purpose of this report was to support a siting decision for the PDCF by providing site-specific cost estimates and comparisons of costs between siting alternatives.
34	Cost Estimates of Generic Mixed Oxide Fuel Fabrication Facility Alternatives, LA-13485-MS	Jul-98	Los Alamos National Laboratory, Fluor Daniel, Inc.	The purpose of this report was to support a siting decision for the MOX FFF by providing site-specific cost estimates and comparisons of costs between siting alternatives.

DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
35	Amended Record of Decision for Storage and Disposition of Weapons-Usable Fissile Materials	6-Aug-98	DOE-OFMD	The purpose of this amended ROD was to allow the 1) accelerated shipment of all non-pit surplus weapons-usable plutonium from the RFETS (about 7 metric tons) to the SRS beginning in about 2000, in advance of completion of the APSF in 2001, and 2) relocation of all Hanford surplus weapons-usable plutonium (about 4.6 metric tons) to the SRS between 2002 and 2005, pending disposition.
36	Design-Only Conceptual Design Report Plutonium Immobilization Plant, Rev. 0		Bechtel for Lawrence Livermore National Laboratory	The purpose of this DO-CDR was to support a funding request by the DOE-OFMD for engineering and design of the Plutonium Immobilization Plant, which will be used to immobilize up to 50 tonnes of surplus plutonium and provided cost for a Plutonium Immobilization Plant which would process and immobilize 18.2 tonnes of plutonium in 10 years
37	Design-Only Conceptual Design Report Plutonium Immobilization Plant, Rev. 1	1-Jan-99	Bechtel for Lawrence Livermore National Laboratory	The purpose of this DO-CDR was to support a funding request by the DOE-OFMD for engineering and design of the Plutonium Immobilization Plant, which will be used to immobilize up to 50 tonnes of surplus plutonium and provided cost for a Plutonium Immobilization Plant which would process and immobilize 18.2 tonnes of plutonium in 10 years
38	Contract Award: Reactor Disposition of Plutonium Irradiation Services Consortium	Mar-99		
39	US / Russian Feed Material Transaction Agreement	Mar-99	Bill Richardson / Yevgeny Adamov	A "historic" contract between three Western uranium companies - Cameco, Cogema, and Nukem - and Russia's Techsnabexport (Tenex) - for the purchase of 260-million pounds of uranium from downblended Russian warhead high-enriched uranium (HEU). The agreement stipulated that the US will maintain a stock of no less than 22,000 metric tons of natural uranium equivalent.
40	Program Management Plan	May-99	Laura S. H. Holgate, Director, OFMD	The purpose of this Plan is to define the OFMD organization, staff responsibilities, and procedures for planning and managing work in support of the Fissile Materials Disposition Program (FMDP). The Plan also contains an appendix of OFMD administrative procedures covering general office operations
41	PDCF Design Contract Award	Aug-99		
42	ORNL Life Cycle Costs for the Domestic Reactor-Based Plutonium Disposition Option	Oct-99	Oak Ridge National Laboratory	The purpose of this report was to update several previous documents that provided life-cycle cost (LCC) estimates for reactor-based plutonium disposition through the use of mixed-oxide (MOX) fuel.

DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
43	Off-Spec HEU Blend Down Project (U) CDR	Oct-99	Westinghouse Savannah River Corporation (WSRC)	
44	Surplus Plutonium Disposition Final Environmental Impact Statement	Nov-99	DOE-OFMD	The purpose of this SPD EIS is to address the extent to which each of the two plutonium disposition approaches (immobilization and MOX) would be implemented and to analyze candidate sites for plutonium disposition facilities and activities (i.e. lead assembly fabrication and postirradiation examination), as well as alternative technologies for immobilization.
45	Plutonium Disposition Life Cycle Costs and Cost-Related Comment Resolution Document	Nov-99	DOE-OFMD	The purpose of this cost report was to update the costs in the 1998 <i>Site Selection Cost Report</i> with adjustments to account for changes in the size of the PDCF and MOX FFF facilities and to refine the costs for the Immobilization Facility based on the DO-CDR.
46	Improving Project Management in the Department of Energy Report	Nov-99	National Research Council	The purpose of this report was to assess DOE's ability to manage projects, develop cost estimates and develop designs.
47	Record of Decision for the Surplus Plutonium Disposition Final Environmental Impact Statement	4-Jan-00	DOE-OFMD	The purpose of this ROD was to select the Savannah River Site in South Carolina as the location for all three disposition facilities, to authorize DCS to fully implement the base contract, to select Los Alamos National Laboratory in New Mexico as the location for lead assembly fabrication, and Oak Ridge National Laboratory in Tennessee as the site for post-irradiation examination of lead assemblies. (Milestone #39 was written in support of this ROD)
48	Surplus Highly Enriched Uranium Disposition Program Viability Assessment	31-Mar-00	HEU Disposition Program Office for DOE	The purpose of this assessment was to evaluate the technical and economic viability of current and planned disposition activities under the <u>Surplus HEU Disposition Program</u> .
49	Design-Only Conceptual Design Report Plutonium Immobilization Plant, Rev. 2	May-00	Bechtel for Lawrence Livermore National Laboratory	The purpose of this DO-CDR was to support a funding request by the DOE-OFMD for engineering and design of the Plutonium Immobilization Plant, which will be used to immobilize up to 50 tonnes of surplus plutonium and provided cost for a Plutonium Immobilization Plant which would process and immobilize 17 tonnes of plutonium in ten years.
50	Report of the Joint U.S.-Russian Working Group On Cost Analysis and Economics in Plutonium Disposition	Apr-00	DOE-OFMD	The purpose of this report was to address the additional costs of disposing of 34 MT of Russian weapon-grade plutonium.

DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
51	OFMD Strategic Plan	Jun-00	DOE-OFMD	The purpose of this plan is to define DOE's strategies and critical role in meeting national and international security initiatives.
52	US/Russia BiLateral Agreement (PMDA)	Sep-00		
53	MOX FFF Title II Definitive Cost Estimate	Mar-01		
54	PDCF Title II Definitive Cost Estimate	Mar-01		
55	Off-Spec HEU Title II Definitive Cost Estimate	Jun-01		
56	Immobilization Contract Award	Sep-01		
57	PDCF Construction Start CD3	Dec-01		Level I Master Schedule, Revision 5, October 1999
58	MOX FFF Construction Start CD3	Mar-02		Level I Master Schedule, Revision 5, October 1999
59	Immobilization Facility Title II Definitive Cost Estimate	Oct-02		Level I Master Schedule, Revision 5, October 1999
60	Immobilization Facility Construction Start CD3	Jul-03		Level I Master Schedule, Revision 5, October 1999
61	DOE announce MOX-only strategy; eliminates immobilization	Jan-02		After completing the reviewing of nonproliferation programs in January 2002, the DOE announces that it intends to pursue a MOX-only plutonium disposition strategy, halting further work on immobilization. The new approach saves time and money over the previous strategy and is acceptable to Russia, whereas a U.S. immobilization-only approach strategy is not.
62	National Defense Auth. Act 2003 establishes parameters & penalties for MOX	Dec-02		In December 2002, the National Defense Authorization Act for Fiscal Year 2003 is enacted. The law sets dates for achieving the MOX production objective (production of MOX fuel at an average rate of one metric ton per year), requires the Secretary to report annually to Congress on the status of meeting these dates, and establishes various penalties for failure, including the payment of up to \$100 M/ year to South Carolina.
63	10-month Delay in MOX Construction	Feb-04	DOE	In February 2004, DOE announces a ten-month delay in starting construction of the U.S. MOX Facility. The delay is a result of the prolonged impasse over liability protections for the U.S. for work performed in Russia. Construction is rescheduled for May 2005, assuming liability is resolved and adequate funding is available.
64	MOC Facility Constr Delayed to 2006	Feb-05	DOE	In February 2005, the U.S. and Russia renew negotiations on liability protections for U.S. work performed in Russia, based on a new U.S. proposal. However, as a result of the delays due to the liability issue, the President's annual budget request states that the start of construction of the MOX facility has been further delayed to 2006.

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DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
65	NRC issue Constr Auth. For MFFF	Mar-05		In March 2005, the Nuclear Regulatory Commission (NRC) issues a construction authorization for the U.S. MOX Fuel Fabrication Facility.
66	Site Prep activities begin at SRS	Oct-05		In October 2005, the U.S. begins site preparation activities for the MOX facility and the Pit Disassembly and Conversion Facility at the Savannah River Site.
67	Russia reassesses options; due to liability impasse & funding shortfalls	2006		In early 2006, the Russian Government begins a reassessment of the technical options for the Russian plutonium disposition program in light of delays caused by the liability impasse and funding shortfalls.
68	Long-Lead Procurements begin for MOX Facility	Jun-06		In June 2006, long-lead procurements begin for construction of the U.S. MOX Facility including: engineered fill, rebar, embedments, process tanks, sintering furnaces, and security barriers.
69	Approval to begin construction delayed	Jun-06	DOE	In June 2006, the DOE Energy Systems Acquisition Advisory Board (ESAAB) chaired by the Deputy Secretary of Energy meet to review the request for approval of the MOX Project performance baseline (Critical Decision 2) and to start construction (Critical Decision 3). Approval to begin construction is delayed pending resolution of the FY 2007 funding.
70	Joint Statement on U.S.--Russian Excess Weapon-grade Pu Disposition Program issued	Jul-06		In July 2006, Energy Secretary Bodman and Rosatom Director Kiriienko issue a Joint Statement on the U.S.—Russian Excess Weapon-grade Plutonium Disposition Program that, inter alia, reaffirmed each country's commitment to dispose of weapon-grade plutonium and directed a joint U.S. and Russian experts group to describe plans for the long-term implementation of the Russian technical program by December 25, 2006.
71	Director Kiriienko provides Secretary Bodman with a letter	Sep-06		In September 2006, Director Kiriienko provides Secretary Bodman with a letter concerning Rosatom's plans for implementing its disposition program, noting that U.S. and Russian experts had completed a preliminary joint analysis of the Russian program, which would begin with the BN-600 and continue with VVER-1000s once a MOX Fuel Fabrication Facility is built in Russia.
72	U.S. and Russia sign liability protocol	Sep-06		In September 2006, the United States and Russia formally sign the liability protocol that had long delayed progress on the plutonium disposition program.

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DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
73	MOX Facility License App. & Safety Analysis submitted to NRC	Sep-06		In September 2006, the MOX Facility Operating License Application and Integrated Safety Analysis Summary is submitted to the NRC.
74	U.S.-Russian experts complete analysis of Russian technical disposition scenario	Dec-06		In December 2006, a U.S.-Russian experts group completes an analysis of a Russian technical disposition scenario, which is provided to the Secretary of Energy and the Director of Rosatom in December 2006 in accordance with their July 2006 Joint Statement. This Russian-proposed technical plan is based on using the BN-600 fast reactor as a plutonium burner and VVER-1000 reactors to disposition 34 metric tons of Russia's weapons plutonium.
75	DOE estimates MOX Facility at \$4.7B	Dec-06	DOE	In December 2006, the Department advises Congress that the estimated cost to design, construct, and start up the MOX Facility is \$4.7 billion based on what is essentially level funding in the outyears and timely appropriation of the Administration's future year budget requests. The report also states that MOX fuel production is planned to begin in March 2016 and one metric ton of fuel is scheduled to be produced by March 2017.
76	Russia seeks funding from Russian gov. for Russian Pu Disposition program	Jan-07		In January 2007, during meetings with U.S. officials, the Rosatom Deputy Director indicates the Russian Government is in the process of determining its technical plutonium disposition approach and seeking a budget line item from the Russian Duma in order to help finance its program.

DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
77	DOE publishes NOI to prepare SPD SEIS to assess pathways for Pu originally slated for immobilization	Mar-07		In March 2007, DOE publishes a Notice of Intent (NOI) to prepare the Surplus Plutonium Disposition (SPD) Supplemental Environmental Impact Statement (SEIS) to evaluate environmental impacts of disposition pathways for the plutonium at SRS originally planned for immobilization. DOE identifies vitrification in K-Area as the preferred alternative.
78	Construction begins on MFFF	Aug-07		In August 2007, construction begins on the MOX Fuel Fabrication Facility (MFFF).
79	Secretary Bodman declares additional 9 metric T of surplus Pu	Sep-07		In September 2007, Secretary Bodman declares an additional 9 metric tons of surplus plutonium while speaking to the IAEA General Conference in Vienna.
80	Joint Statement issued; Russia to dispose of Pu in fast reactors	Nov-07		In November 2007, Secretary Bodman and Director Kiriyeenko issue a Joint Statement on Mutual Understandings concerning Cooperation on the Program for the Disposition of Excess Weapon-Grade Plutonium where Russia commits to dispose of its plutonium in fast reactors.
81	MFFF Project Rebaseline; budget cuts of \$200M	Dec-08		In December 2008 the MFFF project was rebaselined to account for the budget cuts of ~\$200M.
82	DOE deletes PDCF and integrates it into MFFF	Nov-09		"On November 22, 2009, DOE approved combining the Pit Disassembly and Conversion Facility [PDCF] Project and the Plutonium Preparation Project into a new project called the Pit Disassembly and Conversion Project." from http://www.dnfsb.gov/sites/default/files/Board%20Activities/Reports/Reports%20to%20Congress/2012/qr_20121224_21001.pdf , p. E2-5, Defense Nuclear Safety Board. December, 24, 2012. from "Report to Congress on the Status of Significant Unresolved Issues with the Department of Energy's Design and Construction Projects"
83	Construction of WSB Begins	Dec-08	NNSA	In December 2008, NNSA begins construction of the Waste Solidification Building to receive and treat liquid waste streams generated by the MFFF and pit disassembly and conversion operations.

DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
84	NNSA & TVA sign Interagency Agreement for MOX Fuel pre-Planning/Eval. Activities	Feb-10		In February 2010, NNSA and the Tennessee Valley Authority (TVA) sign an Interagency Agreement for Mixed Oxide Fuel pre-Planning/Evaluation Activities. Under the agreement, NNSA pays TVA for expenses incurred for studying Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) fuel design and core design analyses to cover the transition from all low-enriched uranium (LEU) cores to mixed LEU/MOX cores, as well as the necessary project management expenses and any expenses incurred by TVA as a cooperating agency in support of the SPD SEIS.
85	Secretary Clinton and Minister Lavrov sign Plutonium Disposition Protocol	Apr-10		In April 2010, U.S. Secretary of State Hillary Clinton and Russian Foreign Minister Sergey Lavrov sign the Plutonium Disposition Protocol. This protocol enables each Party to proceed with completing and operating facilities to dispose of at least 34 metric tons of weapon-grade plutonium by using it as fuel in civilian power reactors producing electricity. The Protocol: 1) caps U.S. support for Russian disposition activities at \$400 million; 2) includes certain non-proliferation conditions for Russian fast reactors; 3) removes all references to the immobilization option; 4) retains the language from the 2000 PMDA allowing for disposition using “any other methods that may be agreed by the Parties in writing”; and 5) removes language that makes implementation of the Russian program dependent on additional donor funding.
86	DOE issues an amended NOI to modify scope of SPD SEIS	Jul-10		In July 2010, DOE issues an amended NOI to modify the scope of the SPD SEIS, where DOE would refine the types and quantities of surplus plutonium, evaluate additional alternatives, no longer consider in detail one of the alternatives identified in the 2007 NOI, and analyze an alternative to install and operate the pit disassembly and conversion capabilities in an existing building in K-Area at SRS.
87	Secretary Clinton & Foreign Minister Lavrov submit joint request for IAEA monitoring	Aug-10		In August 2010 Secretary Clinton and Foreign Minister Lavrov submit a joint request to International Atomic Energy Agency (IAEA) Director General Amano for consultation regarding an agreement whereby the IAEA will monitor the Parties’ disposition activities and conduct on-site inspections to verify compliance with the PMDA.

DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
88	NRC publishes Final SER for License Application for MFFF	Dec-10		In December 2010, the NRC publishes its Final Safety Evaluation Report (SER) for the License Application to possess and use radioactive material at the Mixed Oxide Fuel Fabrication Facility.
89	Russia's State Duma ratifies the PMDA and its Protocols	May-11		In May 2011 Russia's State Duma ratifies the PMDA and its Protocols.
90	President Medvedev approves amendments to PMDA	Jun-11		In June 2011 Russian President Medvedev approves the amendments to the PMDA.
91	PMDA enters into force	Jul-11		In July 2011, the PMDA enters into force.
92	Feedstock Production Line Authorized	Oct-11	NNSA	In October 2011, Administrator D'Agostino authorized the use of H-Canyon and HB-Line at SRS to provide feedstock for the MFFF.
93	DOE NOI to reevaluate options for MOX Feedstock Line	Jan-12	DOE	In January 2012, DOE issues a second amended NOI to further modify the scope of the SPD SEIS to evaluate additional options for pit disassembly and conversion of plutonium metal to oxide including potential use of PF-4 at LANL, and potential use of K-Area, H-Canyon/HB-Line and MFFF at SRS. DOE identifies the MOX Fuel ~~Alternative as DOE's Preferred Alternative~~
94	PDCF Project Cancelled	Jan-12	NNSA	In January 2012, NNSA makes the decision to cancel the PDCF project.
95	Draft SPD SEIS released	Jul-12	DOE	In July 2012, DOE announces the availability of the Draft SPD SEIS and announces the dates, times, and locations for the public hearings to receive comments on the draft document.
96	MFFF Baseline Change Proposal inc. \$4.8B to \$7.7B	Aug-12	MOX Services	In August 2012, MOX Services submits to NNSA a baseline change proposal to increase the total project cost from \$4.8B to \$7.7B for the MOX Fuel Fabrication Facility.
97	Congress extends dates for MOX production requirement & penalties by 2 yrs	Dec-12		In December 2012, Congress passes the National Defense Authorization Act for FY 2013 which includes an amendment to the MOX legislation, extending the dates for the MOX production requirement and penalties by two years.
98	NNSA & AREVA NP tentatively make tentative agreements on payments, pricing, & MOX fuel sale	Feb-13		In February 2013, NNSA and AREVA NP tentatively agree on the terms and conditions, including the payments by AREVA NP to the US Treasury and other pricing terms under which AREVA NP will facilitate the sale of MOX fuel produced at the MFFF to commercial utility customers
99	MFFF Civil-Structr Work Complete	Mar-13		In March 2013, construction of the roof of the MOX Fuel Fabrication Facility is complete, marking the completion of the civil-structural work on the building.

DOE Office of Fissile Material Disposition ~ Plutonium Disposition Evolution

DOE PLUTONIUM MANAGEMENT AND DISPOSITION PROGRAM EVOLUTION 1991 TO 2015 MILESTONE DESCRIPTIONS				
Milestone No.	Title	Date	Author	Purpose
100	PWG Reevaluated Pu Disposition Options	Apr-14		Plutonium Working Group (PWG) reevaluates plutonium disposition options.
101	Aerospace Independent Review of PWG report complete	Apr-15		Aerospace Independent Review of PWG report complete.
102	High Bridge independent evaluation complete	Aug-15		On July 31, 2015, High Bridge Associates completes the Final Phase 2 Evaluation of Plutonium Disposition Option 1 - Mox and Option 4 - Downblend/Dilution.
103	Red Team review completion anticipated first week of Aug	Aug-15		Red Team Review is anticipated to be complete during the first week of August, 2015.

APPENDIX E

**Bill Richardson’s “Don't Kill a Non-
Proliferation Success Story.”**

U.S. News and World Report. January 31, 2015.

U.S. News and World Report

“Don't Kill a Non-Proliferation Success Story: Finishing the MOX facility in South Carolina will enhance global security”

By Bill Richardson

Jan. 31, 2015 | 9:00 a.m. EST

The 114th Congress is finally underway, and all eyes are now on the White House, which will soon reveal the policy priorities of its fiscal 2016 budget request. Pundits and bloggers alike expect, and sometimes cheer, stalemate: the president's veto pen versus anything substantive passed by Republicans who now control both houses of Capitol Hill.

This may be true for many issues that resonate with each side's base, but there are issues of safety and security on which we can all agree. Nuclear non-proliferation is one of them, and there's a lot in the short term to make us forget that real and concrete on-the-ground progress endures in concrete actions, not paper promises, that will make us all safer in the years ahead.

There's no glossing over President Vladimir Putin's behavior, and the West must stand against the first forced redrawing of European borders since World War II. It's certainly ugly in the short term, but work and cooperation endures on some critical long-term concrete initiatives.

The most important of these is the Mixed Oxide Fuel Fabrication Facility, known as MOX, being built by Department of Energy's National Nuclear Security Administration in South Carolina. During its life, the facility will transform 34 metric tons of U.S. surplus weapons grade plutonium into commercial nuclear reactor fuel. MOX is a first-of-a-kind facility in the U.S., and has reached a 64 percent completion level with exemplary reviews by the Nuclear Regulatory Commission.

And, under an agreement first signed in 2000, the Russians are matching us ton-for-ton, so that, together, we will have destroyed enough plutonium for about 17,000 nuclear warheads.

The decision to build MOX came only after a couple of very extensive disposition analyses. Both DOE and the National Academy of Sciences looked at the issue during 1994-95, and came up with 37 different possibilities for dealing with the plutonium. Many were exotic, such as shooting it into space or burying it beneath the deep ocean floor. Some would never fly politically, such as “deep borehole” burial in states that would surely reject it. Even new advanced “fast” reactors were considered, but nobody who remembers the 1970s would ever countenance the cost.

So, DOE decided on a two-track strategy in 1997: A combination of proven MOX technology, and a program for “immobilization,” in which the plutonium is barricaded in a ceramic material that is then surrounded by vitrified high-level nuclear waste. The latter would have required the construction of a Plutonium Immobilization Plant with undeveloped technology.

In January 2000, it was my decision as energy secretary, after extensive environmental and economic analyses and public comment, to consolidate the surplus plutonium disposition program at South Carolina's Savannah River Site. (Urban myth has it that Congressional Republicans

steered the program to South Carolina to bolster Republican Gov. Mark Sanford, who only first took office in 2003.)

Later in 2000, the U.S. and Russia signed the historic Plutonium Management and Disposition Agreement that formally committed each side to the 34 metric ton threshold.

The new Bush administration decided in 2002 to go exclusively for MOX, and abandon “immobilization,” largely because of cost. Also, the Russians objected to any disposition pathway that preserved the isotopic content of the plutonium, leaving it “weapons grade,” no matter how barricaded it might be.

But costs escalated when contractors were pushed into beginning construction before the facility’s design was complete. That was the original sin of the last generation of nuclear construction in the U.S., and it was repeated here to the usual accompaniment of torrents of change orders. And the special regulatory requirements of the Nuclear Regulatory Commission prevented any off-the-shelf replication of successful European MOX facilities.

Another urban myth holds that the cost of MOX has zoomed from \$1.7 billion to about \$10 billion, a 488 percent increase. That would be astounding, were it true, even for a complex first-of-a-kind nuclear facility. But, there was never any real engineering to support the low baseline number that makes the oft-repeated percentage increase so offensively large. Succeeding management teams at DOE just ran with somebody’s rough stab at finding a starting number. It stuck.

MOX has been on track for a long time, with its design and growing pains behind it. When ground was broken in 2007, there hadn’t been any new nuclear construction begun in the U.S. in 30 years. A sophisticated labor force and supply chain had to be built from scratch at great expense, and the president’s all-of-the-above energy policy will benefit for decades.

MOX is nearly two-thirds done, and the roughly \$4 billion spent already is sunk and gone. We should use our brief freedom from election year politics to think long term, and not waste the next two years trying to kill what will surely be non-proliferation success story.

Bill Richardson is a former two-term, Democratic governor of New Mexico and served as secretary of energy and ambassador to the United Nations during the Clinton administration.

<http://www.usnews.com/opinion/articles/2015/01/31/finish-the-mox-facility-enhance-security-with-nuclear-non-proliferation>

Accessed 7.22.2015

APPENDIX F

Risk/Opportunities Analysis and Backup

- **High Bridge Values – Option 1 MOX Fuel**
- **High Bridge Values – Option 4 Downblend**
- **Aerospace Values – Option 1 MOX Fuel**
- **Aerospace Values – Option 4 Downblend**



**High Bridge Monte Carlo Input
Aerospace April 13, 2015 Report Review
Option 1 MOX Fuel**

Form 1.6B

Row	Estimator Initials	Project	Risk Description	Risk Specifics/Details	\$ Impact Range			% Probability of Occurrence	# of Times Risk Could Occur Per Project
					Expected	Low	High		
1		MOX	Fuel Production Rate Lower Than Expected	Assumed a Low of 18 months and a High of 45 month schedule slip; Ops cost used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency (\$318.6M per year)	\$ 836,325,000	\$ 477,900,000	\$ 1,194,750,000	75%	1
2			Feedstock Production Rate Lower Than Expected	HBA believes that this a subset of Item 1 and eliminated in Monte Carlo analysis by assigning a POO of 0%.	\$ -	\$ -	\$ -	0%	1
3			MFFF Construction Cost Uncertainty / Growth	MFFF Construction cost increases due to design changes, etc., evaluated as a percent of 2012 re-base line ETC. (Low is 2% increase and High is a 5% increase of 2012 ET C.) (USACE MFFF Construction ICE escalated to 2014, 6 yrs construction - ETC = \$3.74B.)	\$ 131,390,000	\$ 75,080,000	\$ 187,700,000	75%	1
4			MFFF Temporary Suspension of Operations	MFFF Operating factor of 35% is so low it makes the probability of temporary suspension part of the baseline as opposed a risk. HBA eliminated in Monte Carlo analysis by assigning a POO of 0%.	\$ -	\$ -	\$ -	0%	1
5			MFFF Full Construction Re-Start Delay	Assumes that a suspension of MFFF construction due to FY16 de-funding and subsequent re-start in FY17 causes a Low of 6 months slip and a High of 12 months slip. USACE MFFF Construction ICE escalated to 2014, 6 yrs construction - ETC = \$3.74B.	\$ 469,250,000	\$ 312,833,333	\$ 625,666,667	50%	1
6			Feedstock Temporary Suspension of Operations	Ops cost used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency (318.6M per year)	\$ 212,400,000	\$ 106,200,000	\$ 318,600,000	25%	1
7			SRS Overhead Cost Increases	MOX O.H. assumed Ops cost; used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency minus labor-capital items from MOX (LCCE 2008)(15 yrs of ops)	\$ 280,485,000	\$ 73,170,000	\$ 487,800,000	50%	1
8			Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Adopted the Aerospace Low and High values but changed the POO. HBA assumed this is an item meant to address the risk that the older facilities needed by the MOX project will need to be up-graded and maintenance costs will be incurred.	\$ 187,500,000	\$ 75,000,000	\$ 300,000,000	50%	1
9			LANL Overhead Cost Increases	LANL O.H. assumed Ops minus labor-capital items from PWG Page C-F-12 SUBJECTED :HBA Est.(28 YEARS)	\$ 126,868,000	\$ 33,096,000	\$ 220,640,000	50%	1
10			MFFF Hot Operations Delay after CD-4 Complete	Ops cost used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency (318.6M per year)	\$ 92,925,000	\$ 26,550,000	\$ 159,300,000	50%	1
11			MFFF Integrated Functional Testing Delay Before CD-4	H.L. from delay from incomplete construction activities; Low of 2 months and High of 6 month delay (assumes USACE MFFF Construction ICE escalated to 2014, 6 yrs construction - ETC = \$3.74B.)	\$ 104,277,778	\$ 52,138,889	\$ 156,416,667	25%	1



**High Bridge Monte Carlo Input
Aerospace April 13, 2015 Report Review
Option 1 MOX Fuel**

Form 1.6B

Row	Estimator Initials	Project	Risk Description	Risk Specifics/Details	\$ Impact Range			% Probability of Occurrence	# of Times Risk Could Occur Per Project
					Expected	Low	High		
12			Needs for Additional Storage	Adopted the Aerospace Low, High, and POO values since HBA could not interpret what this risk was related.	\$ 119,650,000	\$ 74,800,000	\$ 164,500,000	50%	1
13			LANL Feedstock Production Re-Start Delay	Assumed a Low of 4 months and a High of 12 month schedule slip; Ops cost used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency (\$318.6M per year)	\$ 212,400,000	\$ 106,200,000	\$ 318,600,000	25%	1
14			Funding for Depleted Uranium	Aerospace assumed that the needed depleted Uranium feedstock has to be purchased from the two DOE facilities that produce the feedstock; this production goes on regardless of whether or not MOX is pursued. This should be as avoided cost credited to MOX hence viewed as an opportunity. Used Aerospace evaluated financial impacts and HBA's POO.	\$ (19,800,000)	\$ (29,700,000)	\$ (9,900,000)	10%	1
15			Feedstock Production Consolidated at LANL (Remove HB-Line)	Assumes feedstock can be produced at LANL instead of SRS; used Aerospace's evaluated High and Low financial impacts and HBA's probability of occurrence because LANL throughput too low to maintain a reasonable MOX fuel production schedule.	\$ (546,950,000)	\$ (774,900,000)	\$ (319,000,000)	10%	1
16			Estimate accuracy/uncertainty as a function of design maturity for construction completion and hot start up (known unknowns)	Assumes design maturity at five years past CD 3 Milestone for a similar design proven in France. Uncertainty is \$3.74B ETC at this design status is assumed to be 2% for Low and 5% for High.	\$ 130,900,000	\$ 74,800,000	\$ 187,000,000	75%	1
17									



High Bridge Review of Pu Disposition Options
MOX Risks - Option 1
Discrete Risk Model
(2015 Updated Evaluations)

Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

Item	Description of Discrete Risk	Risk Specifics/Details	Remarks	Estimated Impact	Probability of Occurrence	# of Occurences Possible	(P1) Value	(P99) Value	Item
1	Fuel Production Rate Lower Than Expected	Assumed a Low of 18 months and a High of 45 month schedule slip; Ops cost used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency (\$318.6M per year)		836,325,000	75%	1.00	\$ 477,900,000	\$ 1,194,750,000	1
2	Feedstock Production Rate Lower Than Expected	HBA believes that this a subset of Item 1 and eliminated in Monte Carlo analysis by assigning a POO of 0%.		-	0%	1.00	\$ -	\$ -	2
3	MFFF Construction Cost Uncertainty / Growth	MFFF Construction cost increases due to design changes, etc., evaluated as a percent of 2012 re-base line ETC. (Low is 2% increase and High is a 5% increasse of 2012 ET C.) (USACE MFFF Construction ICE escalated to 2014, 6 yrs construction - ETC = \$3.74B.)		131,390,000	75%	1.00	\$ 75,080,000	\$ 187,700,000	3
4	MFFF Temporary Suspension of Operations	MFFF Operating factor of 35% is so low it makes the probability of temporary suspension part of the baseline as opposed a risk. HBA eliminated in Monte Carlo analysis by assigning a POO of 0%.		-	0%	1.00	\$ -	\$ -	4
5	MFFF Full Construction Re-Start Delay	Assumes that a suspension of MFFF construction due to FY16 de-funding and subsequent re-start in FY17 causes a Low of 6 months slip and a High of 12 months slip. USACE MFFF Construction ICE escalated to 2014, 6 yrs construction - ETC = \$3.74B.		469,250,000	50%	1.00	\$ 312,833,333	\$ 625,666,667	5
6	Feedstock Temporary Suspension of Operations	Ops cost used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency (318.6M per year)		212,400,000	25%	1.00	\$ 106,200,000	\$ 318,600,000	6
7	SRS Overhead Cost Increases	MOX O.H. assumed Ops cost; used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency minus labor-capital items from MOX (LCCE 2008)(15 yrs of ops)		280,485,000	50%	1.00	\$ 73,170,000	\$ 487,800,000	7
8	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Adopted the Aerospace Low and High values but changed the POO. HBA assumed this is an item meant to address the risk that the older facilities needed by the MOX project will need to be up-graded and maintenance costs will be incurred.		187,500,000	50%	1.00	\$ 75,000,000	\$ 300,000,000	8
9	LANL Overhead Cost Increases	LANL O.H. assumed Ops minus labor-capital items from PWG Page C-F-12 SUBJECTED :HBA Est.(28 YEARS)		126,868,000	50%	1.00	\$ 33,096,000	\$ 220,640,000	9

Model Results		
Expected Value	Occurrence	85%
836,325,000	1.00	964,600,147
0	-	-
131,390,000	1.00	151,639,621
0	-	-
469,250,000	1.00	504,099,705
212,400,000	1.00	198,576,130
280,485,000	1.00	324,886,142
187,500,000	1.00	212,513,951
126,868,000	1.00	148,787,008



High Bridge Review of Pu Disposition Options
MOX Risks - Option 1
Discrete Risk Model
(2015 Updated Evaluations)

Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

10	MFFF Hot Operations Delay after CD-4 Complete	Ops cost used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency (318.6M per year)		92,925,000	50%	1.00	\$ 26,550,000	\$ 159,300,000	10	92,925,000	1.00	107,969,208
11	MFFF Integrated Functional Testing Delay Before CD-4	H.L. from delay from incomplete consstruction activities; Low of 2 months and High of 6 month delay (assumes USACE MFFF Construction ICE escalated to 2014, 6 yrs construction - ETC = \$3.74B.)		104,277,778	25%	1.00	\$ 52,138,889	\$ 156,416,667	11	104,277,778	1.00	98,173,679
12	Needs for Additional Storage	Adopted the Aerospace Low, High, amd POO values since HBA could not interpret what this risk was related.		119,650,000	50%	1.00	\$ 74,800,000	\$ 164,500,000	12	119,650,000	1.00	129,558,472
13	LANL Feedstock Production Re-Start Delay	Assumed a Low of 4 months and a High of 12 month schedule slip; Ops cost used MOX 2008 est.; escalated to 2014 at 2%; subtracted the 32.2 contingency (\$318.6M per year)		212,400,000	25%	1.00	\$ 106,200,000	\$ 318,600,000	13	212,400,000	1.00	200,635,113
14	Funding for Depleted Uranium	Aerospace assumed that the needed depleted Uranium feedstock has to pruchased from the two DOE facilities that produdce the feedstock; this production goes on regardless of whether or not MOX is pursued. This should be as avoided cost credited to MOX hence viewed as an opportunity. Used Aerospace evaluated financial impacts and HBA's POO.		(19,800,000)	10%	1.00	\$ (29,700,000)	\$ -	14	0	-	-
15	Feedstock Production Consolidated at LANL (Remove HB-Line)	Assumes feedstock can be produced at LANLinstead of SRS; used Aerospace's evaluated High and Low financial impacts and HBA's probability of occurrence because LANL throughput too low to maintain a reasonable MOX fuel production schedule.		(546,950,000)	10%	1.00	\$ (774,900,000)	\$ (319,000,000)	15	(546,950,000)	-	-
16	Estimate accuracy/uncertainty as a function of design maturity for construction completion and hot start up (known unknowns)	Assumes design maturity at five uears past CD 3 Milestone for a similar design proven in France. Uncertainty is \$3.74B ETC at this design status is assumed to be 2% for Low and 5% for High.		130,900,000	75%	1.00	\$ 74,800,000	\$ 187,000,000	16	130,900,000	1.00	151,005,161
17				-	0%	-	\$ -	\$ -	17	0	-	-
18				-	0%	-	\$ -	\$ -	18	0	-	-
19				-	0%	-	\$ -	\$ -	19	0	-	-
20				-	0%	-	\$ -	\$ -	20	0	-	-
											3,192,444,337	

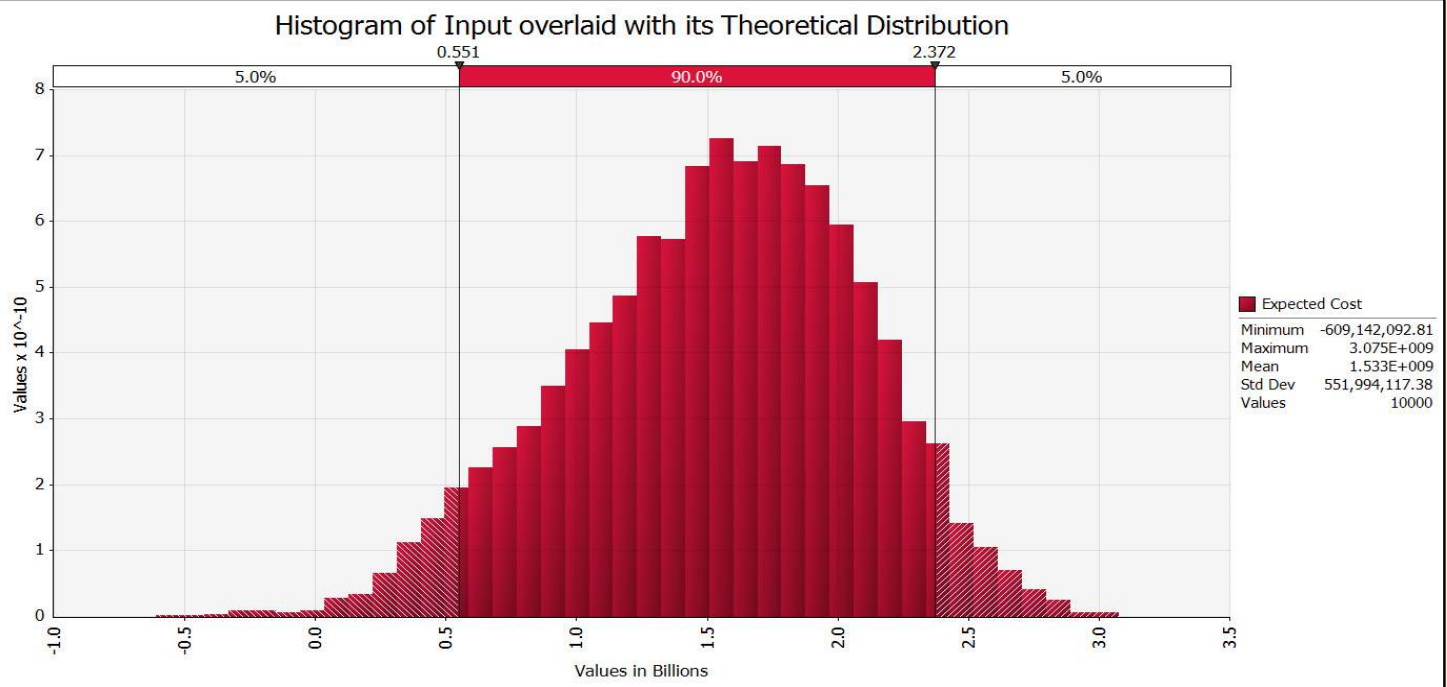


High Bridge Review of Pu Disposition Options
MOX Risks - Option 1
Discrete Risk Model
(2015 Updated Evaluations)

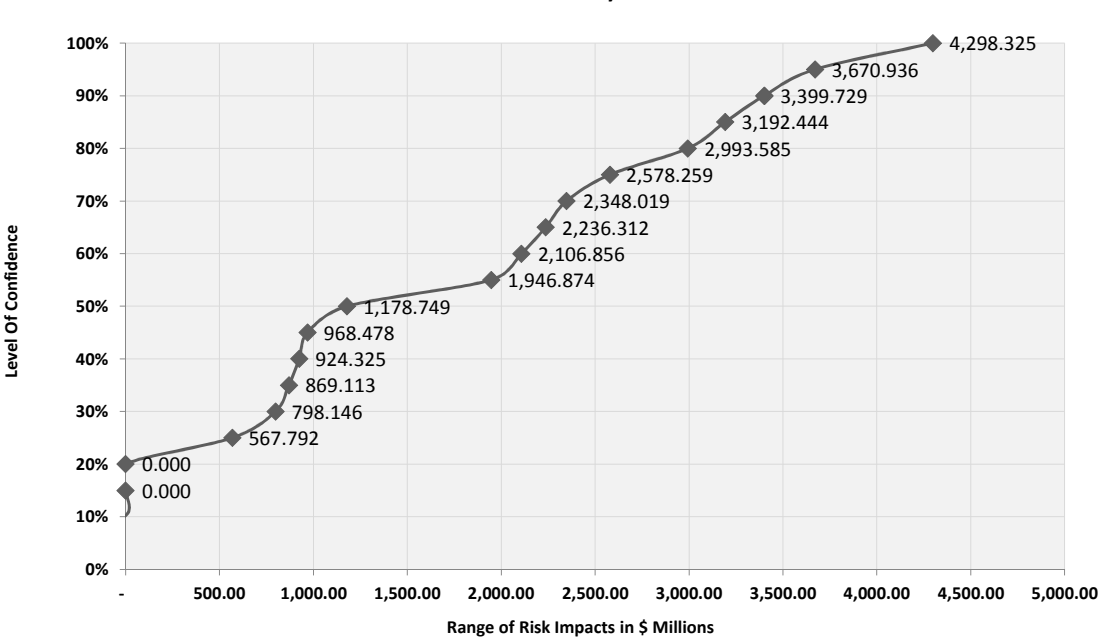
Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

Histogram of Input overlaid with its Theoretical Distribution



Discrete Risk Analysis



Results Summary

Confidence Level	Contingency	% of Project Estimate
0%	\$ (801,037,932)	-10%
5%	\$ (561,089,733)	-7%
10%	\$ (10,862,326)	0%
15%	\$ -	0%
20%	\$ -	0%
25%	\$ 567,791,668	7%
30%	\$ 798,146,165	10%
35%	\$ 869,112,864	11%
40%	\$ 924,324,875	12%
45%	\$ 968,477,927	12%
50%	\$ 1,178,749,360	15%
55%	\$ 1,946,874,480	24%
60%	\$ 2,106,856,325	26%
65%	\$ 2,236,311,855	28%
70%	\$ 2,348,018,847	29%
75%	\$ 2,578,259,191	32%
80%	\$ 2,993,585,024	37%
85%	\$ 3,192,444,337	40%
90%	\$ 3,399,729,102	42%
95%	\$ 3,670,936,231	46%
100%	\$ 4,298,324,746	54%

Notes:

P1 (Percentile 1) represents the extreme low end of the possible risk values, also known as the "Best Case".

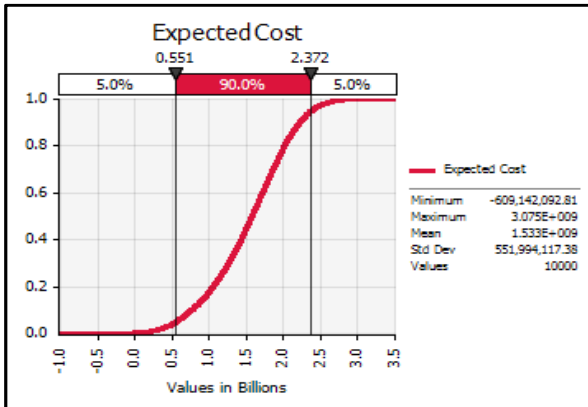
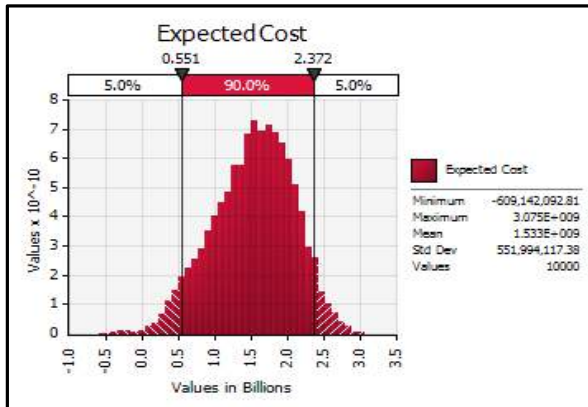
P99 (Percentile 99) represents the extreme high end of the possible risk values, also known as the "Worst Case".

Reference: AACE International Recommended Practice No. 41R-08 - Risk Analysis And Contingency Determination Using Range Estimating

@RISK Output Report for Expected Cost

Performed By: HBA

Date: Monday, July 27, 2015 9:14:00 AM

**Simulation Summary Information**

Workbook Name	1.6B_HBA_Discrete_15-0727_MOX Opt-
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	40
Number of Outputs	1
Sampling Type	Monte Carlo
Simulation Start Time	7/27/2015 9:13
Simulation Duration	00:00:06
Random # Generator	Mersenne Twister
Random Seed	735132105

Summary Statistics for Expected Cost

Statistics	Percentile
Minimum	5% 551,190,210
Maximum	10% 763,729,332
Mean	15% 929,065,826
Std Dev	20% 1,054,776,641
Variance	25% 1,163,035,373
Skewness	30% 1,262,698,419
Kurtosis	35% 1,348,650,803
Median	40% 1,431,810,636
Mode	45% 1,504,862,086
Left X	50% 1,573,752,577
Left P	55% 1,645,311,030
Right X	60% 1,717,128,294
Right P	65% 1,786,845,376
Diff X	70% 1,859,758,273
Diff P	75% 1,933,642,713
#Errors	80% 2,010,883,013
Filter Min	85% 2,105,604,165
Filter Max	90% 2,215,763,803
#Filtered	95% 2,372,199,807



**High Bridge Monte Carlo Input
Aerospace April 13, 2015 Report Review
Option 4 Downblend**

Form 1.6B

Row	Estimator Initials	Project	Risk Description	Risk Specifics/Details	\$ Impact Range			% Probability of Occurrence	# of Times Risk Could Occur Per Project
					Expected	Low	High		
1	(HBA Assumed Register Values)		Feedstock Production Rate Lower Than Expected	H.L. for downblend operations; assumed a Low of 24 month and High of 72 month schedule increase. (From USACE input to PWG, Downblend (Option 4) de-escalated costs of operation, mift, prog inte and capital of ~\$6.7 Billion.)	\$ 895,600,000	\$ 447,800,000	\$ 1,343,400,000	75%	1
2			SRS Downblend Facility Start Delay	H.L. for downblend Program delayed; assumed a Low of 6 month and High of 24 month schedule increase. (From USACE input to PWG, de-escalated costs for MFFF Term, MIFT, DB partial ops out to FY35; ~7.1B \$.)	\$ 420,833,333	\$ 168,333,333	\$ 673,333,333	75%	1
3			Feedstock Temporary Suspension of Operations	H.L. for downblend Program delayed; assumed a Low of 12 month and High of 36 month schedule increase. (From USACE input to PWG, Downblend (Option 4) de-escalated costs of operation, mift, prog inte and capital of ~\$6.7 Billion.)	\$ 447,800,000	\$ 223,900,000	\$ 671,700,000	90%	1
4			Downblend Production Rate is Lower Than Expected	H.L. for downblend operations delayed; assumed a Low of 24 month and High of 120 month schedule increase. (From PWG report; Downblend (Option4) cost de-escalated costs of operations, ~\$ 2.1B.)	\$ 419,000,000	\$ 139,666,667	\$ 698,333,333	25%	1
5			Downblend Facility Temporary Suspension of Operations	H.L. for downblend operations delayed; assumed a Low of 24 month and High of 60 month schedule increase. (From PWG report; Downblend (Option4) cost de-escalated costs of operations, ~\$ 2.1B.)	\$ 105,082,540	\$ 60,522,222	\$ 149,642,857	90%	1
6			Downblend Construction Cost Estimate Uncertainty/Growth	Construction cost increases due to design changes, more stringent reqm'ts,etc., evaluated as a percent of Option 4 of ~\$0.25B EAC. Assumed a Low of 25% and a High of 100% cost increase of the EAC.	\$ 156,250,000	\$ 62,500,000	\$ 250,000,000	90%	1
7			LANL Overhead Cost Increase	LANL staffing needed to accommodate additional site activities; evaluated as a % of the estimated Option 4 operating costs of ~\$0.915B; assumed a Low of 20% increase in site overhead and a High of 50% increase in site overhead.	\$ 320,250,000	\$ 183,000,000	\$ 457,500,000	50%	1
8			MFFF Project Termination Cost Uncertainty	MFFF termination cost increases, evaluated as a percent of the estimated cost from the USACE input to PWG of ~\$1.49B. Assumed a Low of -5% (comes in less than estimate) to a High of 50% increase in estimate.	\$ 335,700,000	\$ (74,600,000)	\$ 746,000,000	50%	1



**High Bridge Monte Carlo Input
Aerospace April 13, 2015 Report Review
Option 4 Downblend**

Form 1.6B

Row	Estimator Initials	Project	Risk Description	Risk Specifics/Details	\$ Impact Range			% Probability of Occurrence	# of Times Risk Could Occur Per Project
					Expected	Low	High		
9			Downblend Repository Temporary Suspension of Operations	WIPP Outage Hotel Load; Suspension of WIPP operations ; 28 yrs @ a Total of ~\$0.360B. Assumed a Low of 12 month and a High of 36 month schedule increase.	\$ 308,571,429	\$ 154,285,714	\$ 462,857,143	90%	1
10			SRS Overhead Cost Increase	SRS staffing needed to accommodate additional and mix of site activities; evaluated as a % of the estimated Option 4 operating costs of ~\$0.90B; assumed a Low of 3% increase in site overhead and a High of 15% increase in site overhead.	\$ 81,000,000	\$ 27,000,000	\$ 135,000,000	50%	1
11			Feedstock Production Re-Start Delay at LANL	H.L. for downblend operations; assumed a Low of 6 month and High of 18 month schedule increase. (From USACE input to PWG, Downblend (Option 4) de-escalated costs of operation, mift, prog inte and capital of ~\$6.7 Billion.)	\$ 223,900,000	\$ 111,950,000	\$ 335,850,000	25%	1
12			Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Adopted the Aerospace Low, High, and the POO. HBA assumed this is an item meant to address the risk that the older facilities needed by the MOX project will need to be up-graded and maintenance costs will be incurred.	\$ 10,883,425	\$ 4,353,370	\$ 17,413,480	75%	1
13			Feedstock Milling and Blending Not Needed/Quality Control Reductions	Adopted the Aerospace Low and High values. HBA changed the POO because it seems unlikely that the need for Quality Control will be eliminated.	\$ (44,800,000)	\$ (62,673,563)	\$ (17,417,963)	25%	1
14			Feedstock Production Consolidated at LANL (Remove HB-Line)	Adopted the Aerospace Low and High values. HBA changed the POO because it seems unlikely that LANL site will be able to produce enough feedstock to satisfy program objectives.	\$ (461,695,633)	\$ (653,374,020)	\$ (270,017,246)	20%	1
15			NEPA Revision to WIPP EIS process takes longer than expected	From HBA estimate for cost increases that the Downblend (Option 4) will incur if it is selected as the preferred option.	\$ 326,562,500	\$ 261,250,000	\$ 391,875,000	50%	1
16			NMED Disputes Land Use Issues	From HBA estimate for cost increases that the Downblend (Option 4) will incur if it is selected as the preferred option.	\$ 18,906,250	\$ 15,125,000	\$ 22,687,500	50%	1
17			Additional licensing impacts on WIPP operations as a result to the 2014 incidents	From HBA estimate for cost increases that the Downblend (Option 4) will incur if it is selected as the preferred option.	\$ 360,000,000	\$ 220,000,000	\$ 500,000,000	50%	1



High Bridge Review of Pu Disposition Options
Downblend Risks - Option 4
Discrete Risk Model
(2015 Updated Evaluations)

Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

Item	Description of Discrete Risk	Risk Specifics/Details	Remarks	Estimated Impact	Probability of Occurrence	# of Occurrences Possible	(P1) Value	(P99) Value	Item
1	Feedstock Production Rate Lower Than Expected	H.L. for downblend operations; assumed a Low of 24 month and High of 72 month schedule increase. (From USACE input to PWG, Downblend (Option 4) de-escalated costs of operation, mift, prog inte and capital of ~\$6.7 Billion.)	MIFT	895,600,000	75%	1.00	\$ 447,800,000	\$ 1,343,400,000	1
2	SRS Downblend Facility Start Delay	H.L. for downblend Program delayed; assumed a Low of 6 month and High of 24 month schedule increase. (From USACE input to PWG, de-escalated costs for MFFF Term, MIFT, DB partial ops out to FY35; ~7.1B \$.)	CON	420,833,333	75%	1.00	\$ 168,333,333	\$ 673,333,333	2
3	Feedstock Temporary Suspension of Operations	H.L. for downblend Program delayed; assumed a Low of 12 month and High of 36 month schedule increase. (From USACE input to PWG, Downblend (Option 4) de-escalated costs of operation, mift, prog inte and capital of ~\$6.7 Billion.)	MIFT	447,800,000	90%	1.00	\$ 223,900,000	\$ 671,700,000	3
4	Downblend Production Rate is Lower Than Expected	H.L. for downblend operations delayed; assumed a Low of 24 month and High of 120 month schedule increase. (From PWG report; Downblend (Option4) cost de-escalated costs of operatioons, ~\$ 2.1B.)	OPS	419,000,000	25%	1.00	\$ 139,666,667	\$ 698,333,333	4
5	Downblend Facility Temporary Suspension of Operations	H.L. for downblend operations delayed; assumed a Low of 24 month and High of 60 month schedule increase. (From PWG report; Downblend (Option4) cost de-escalated costs of operatioons, ~\$ 2.1B.)	OPS	105,082,540	90%	1.00	\$ 60,522,222	\$ 149,642,857	5
6	Downblend Construction Cost Estimate Uncertainty/Growth	Construction cost increases due to design changes, more stringent rqm'ts,etc., evaluated as a percent of Option 4 of ~\$0.25B EAC. Assumed a Low of 25% and a High of 100% cost increase of the EAC.	CON	156,250,000	90%	1.00	\$ 62,500,000	\$ 250,000,000	6
7	LANL Overhead Cost Increase	LANL staffing needed to accommodate additional site activities; evaluated as a % of the estimated Option 4 operating costs of ~\$0.915B; assumed a Low of 20% increase in site overhead and a High of 50% increase in site overhead.	OTHER	320,250,000	50%	1.00	\$ 183,000,000	\$ 457,500,000	7
8	MFFF Project Termination Cost Uncertainty	MFFF termination cost increases, evaluated as a percent of the estimated cost from the USACE input to PWG of ~\$1.49B. Assumed a Low of -5% (comes in less than estimate) to a High of 50% increase in estimate.	CON	335,700,000	50%	1.00	\$ (74,600,000)	\$ 746,000,000	8
9	Downblend Repository Temporary Suspension of Operations	WIPP Outage Hotel Load; Suspension of WIPP operations ; 28 yrs @ a Total of ~\$0.360B. Assumed a Low of 12 month and a High of 36 month schedule increase.	MIFT	308,571,429	90%	1.00	\$ 154,285,714	\$ 462,857,143	9
10	SRS Overhead Cost Increase	SRS staffing needed to accommodate additional and mix of site activities; evaluated as a % of the estimated Option 4 operating costs of ~\$0.90B; assumed a Low of 3% increase in site overhead and a High of 15% increase in site overhead.	OTHER	81,000,000	50%	1.00	\$ 27,000,000	\$ 135,000,000	10

Model Results		
Expected Value	Occurrence	85%
895,600,000	1.00	1,059,246,647
420,833,333	1.00	511,837,332
447,800,000	1.00	540,250,462
419,000,000	1.00	388,088,040
105,082,540	1.00	123,553,137
156,250,000	1.00	195,259,026
320,250,000	1.00	349,975,207
335,700,000	1.00	430,129,251
308,571,429	1.00	375,426,338
81,000,000	1.00	93,097,084



High Bridge Review of Pu Disposition Options
Downblend Risks - Option 4
Discrete Risk Model
(2015 Updated Evaluations)

Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

11	Feedstock Production Re-Start Delay at LANL	H.L. for downblend operations; assumed a Low of 6 month and High of 18 month schedule increase. (From USACE input to PWG, Downblend (Option 4) de-escalated costs of operation, mift, prog inte and capital of ~\$6.7 Billion.)	MIFT	223,900,000	25%	1.00	\$ 111,950,000	\$ 335,850,000	11	223,900,000	1.00	209,991,000
12	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Adopted the Aerospace Low, High, and the POO. HBA assumed this is an item meant to address the risk that the older facilities needed by the MOX project will need to be up-graded and maintenance costs will be incurred.	OTHER	10,883,425	75%	1.00	\$ 4,353,370	\$ 17,413,480	12	10,883,425	1.00	13,337,619
13	Feedstock Milling and Blending Not Needed/Quality Control Reductions	Adopted the Aerospace Low and High values. HBA changed the POO because it seems unlikely that the need for Quality Control will be eliminated.	MIFT	(44,800,000)	25%	1.00	\$ (62,673,563)	\$ (17,417,963)	13	(41,630,509)	1.00	-
14	Feedstock Production Consolidated at LANL (Remove HB-Line)	Adopted the Aerospace Low and High values. HBA changed the POO because it seems unlikely that LANL site will be able to produce enough feedstock to satisfy program objectives.	MIFT	(461,695,633)	20%	1.00	\$ (653,374,020)	\$ (270,017,246)	14	(461,695,633)	1.00	-
15	NEPA Revision to WIPP EIS process takes longer than expected	From HBA estimate for cost increases that the Downblend (Option 4) will incur if it is selected as the preferred option.	MIFT	326,562,500	50%	1.00	\$ 261,250,000	\$ 391,875,000	15	326,562,500	1.00	340,795,144
16	NMED Disputes Land Use Issues	From HBA estimate for cost increases that the Downblend (Option 4) will incur if it is selected as the preferred option.	MIFT	18,906,250	50%	1.00	\$ 15,125,000	\$ 22,687,500	16	18,906,250	1.00	19,812,226
17	Cost uncertainty for WIPP modifications for life extension	From HBA estimate for cost increases that the Downblend (Option 4) will incur if it is selected as the preferred option.	MIFT	360,000,000	50%	1.00	\$ 220,000,000	\$ 500,000,000	17	360,000,000	1.00	392,767,480
											5,043,565,992	

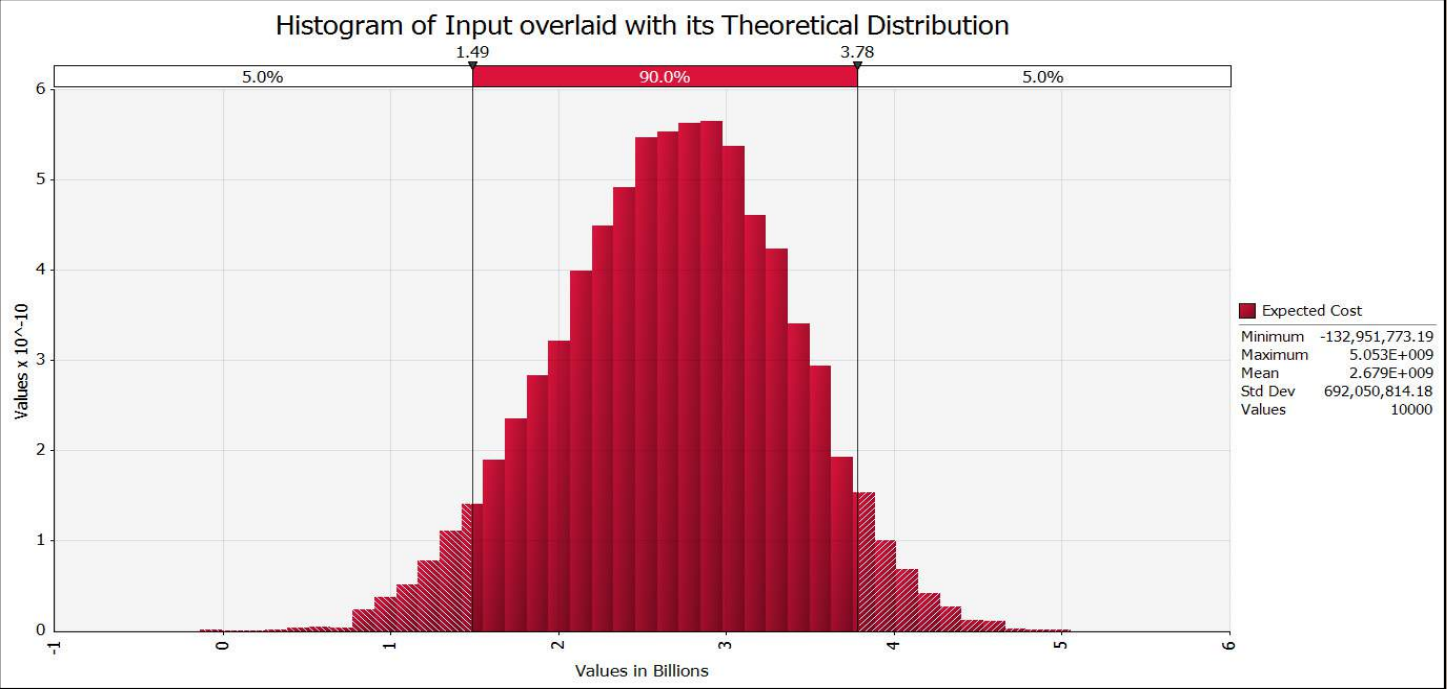


High Bridge Review of Pu Disposition Options
Downblend Risks - Option 4
Discrete Risk Model
(2015 Updated Evaluations)

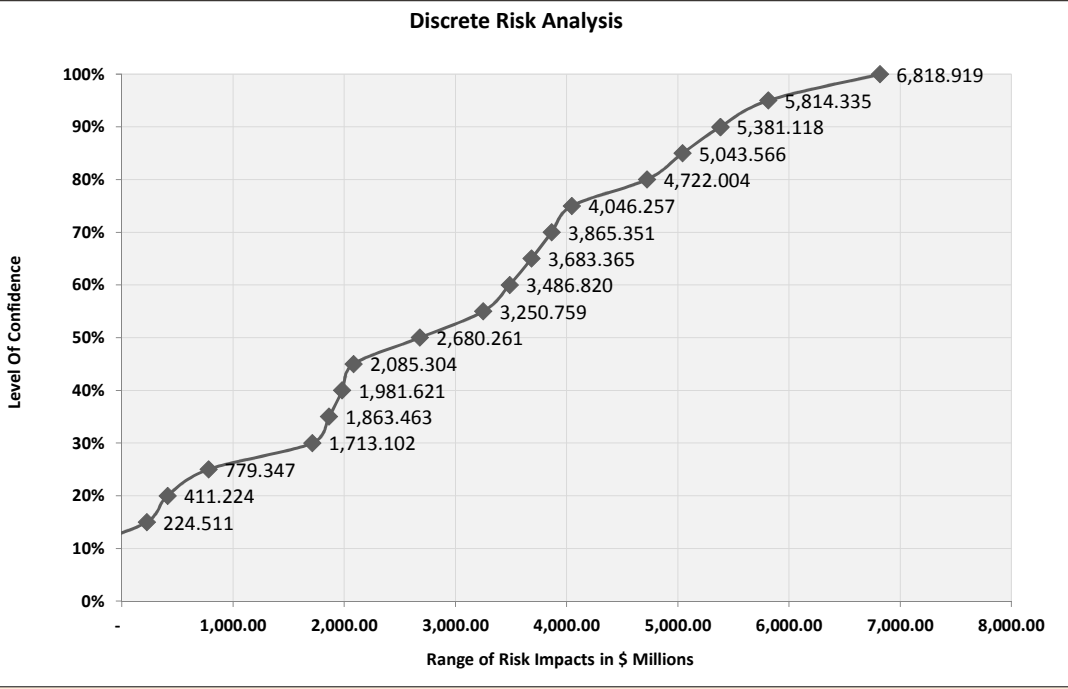
Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$ 8,000,000,000		\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

Histogram of Input overlaid with its Theoretical Distribution



Discrete Risk Analysis



Results Summary

Confidence Level	Contingency	% of Project Estimate
0%	\$ (772,017,233)	-10%
5%	\$ (567,537,742)	-7%
10%	\$ (349,263,282)	-4%
15%	\$ 224,511,167	3%
20%	\$ 411,223,726	5%
25%	\$ 779,347,312	10%
30%	\$ 1,713,102,458	21%
35%	\$ 1,863,462,823	23%
40%	\$ 1,981,621,154	25%
45%	\$ 2,085,304,141	26%
50%	\$ 2,680,261,329	34%
55%	\$ 3,250,758,619	41%
60%	\$ 3,486,820,078	44%
65%	\$ 3,683,364,978	46%
70%	\$ 3,865,351,348	48%
75%	\$ 4,046,257,088	51%
80%	\$ 4,722,003,758	59%
85%	\$ 5,043,565,992	63%
90%	\$ 5,381,117,767	67%
95%	\$ 5,814,334,766	73%
100%	\$ 6,818,919,092	85%

Notes:

P1 (Percentile 1) represents the extreme low end of the possible risk values, also known as the "Best Case".

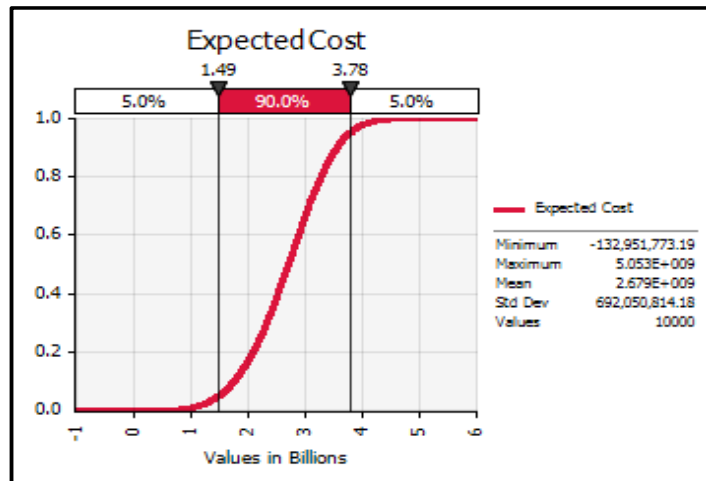
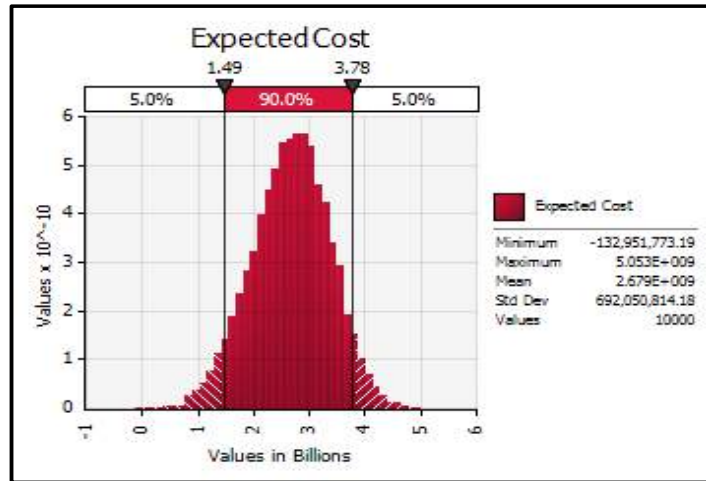
P99 (Percentile 99) represents the extreme high end of the possible risk values, also known as the "Worst Case".

Reference: AACE International Recommended Practice No. 41R-08 - Risk Analysis And Contingency Determination Using Range Estimating

@RISK Output Report for Expected Cost

Performed By: HBA

Date: Monday, July 27, 2015 9:19:16 AM

**Simulation Summary Information**

Workbook Name	1.6B_HBA_Discrete_15-0727_Downblend
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	40
Number of Outputs	1
Sampling Type	Monte Carlo
Simulation Start Time	7/27/2015 9:18
Simulation Duration	00:00:05
Random # Generator	Mersenne Twister
Random Seed	620454978

Summary Statistics for Expected Cost

Statistics		Percentile	
Minimum	(132,951,773)	5%	1,488,737,664
Maximum	5,052,722,748	10%	1,759,976,022
Mean	2,679,321,351	15%	1,938,910,397
Std Dev	692,050,814	20%	2,090,416,459
Variance	4.78934E+17	25%	2,216,832,289
Skewness	-0.140135316	30%	2,325,150,908
Kurtosis	2.836696361	35%	2,428,805,072
Median	2,704,966,430	40%	2,521,276,830
Mode	2,942,992,753	45%	2,612,914,113
Left X	1,488,737,664	50%	2,704,966,430
Left P	5%	55%	2,794,762,790
Right X	3,779,439,448	60%	2,882,684,925
Right P	95%	65%	2,969,727,315
Diff X	2,290,701,783	70%	3,061,678,726
Diff P	90%	75%	3,162,030,356
#Errors	0	80%	3,275,125,353
Filter Min	Off	85%	3,397,406,252
Filter Max	Off	90%	3,553,908,602
#Filtered	0	95%	3,779,439,448



High Bridge Review of Aerospace April 13, 2015 Report
Option 1 MOX Fuel
Discrete Risk Model
AEROSPACE VALUES - 2015 Updated Evaluations

Form 1.6B

Row	Estimator Initials	Project	Risk Description	Risk Specifics/Details	\$ Impact Range			% Probability of Occurrence	# of Times Risk Could Occur Per Project
					Expected	Low	High		
1			Fuel Production Rate Lower Than Expected	Use Aerospace POO, Min, and Max values.	\$ 3,291,588,577	\$ 799,434,896	\$ 3,586,388,527	75%	1
2			Feedstock Production Rate Lower Than Expected	Use Aerospace POO, Min, and Max values.	\$ 1,237,278,054	\$ 475,124,327	\$ 1,999,431,781	75%	1
3			MFFF Construction Cost Uncertainty / Growth	Use Aerospace POO, Min, and Max values.	\$ 1,054,827,612	\$ (161,368,308)	\$ 2,271,023,532	75%	1
4			MFFF Temporary Suspension of Operations	Use Aerospace POO, Min, and Max values.	\$ 564,285,574	\$ 125,423,175	\$ 1,003,147,972	90%	1
5			MFFF Full Construction Re-Start Delay	Use Aerospace POO, Min, and Max values.	\$ 1,006,806,141	\$ 314,255,556	\$ 1,699,356,727	50%	1
6			Feedstock Temporary Suspension of Operations	Use Aerospace POO, Min, and Max values.	\$ 302,987,019	\$ 67,105,812	\$ 538,868,226	90%	1
7			SRS Overhead Cost Increases	Use Aerospace POO, Min, and Max values.	\$ 161,143,770	\$ 92,082,154	\$ 230,205,385	75%	1
8			Facilities and Infrastructure Life-cycle/Sustainment	Use Aerospace POO, Min, and Max values.	\$ 136,601,444	\$ 54,640,578	\$ 218,562,311	90%	1
9			LANL Overhead Cost Increases	Use Aerospace POO, Min, and Max values.	\$ 391,904,164	\$ 261,269,443	\$ 522,538,886	25%	1
10			MFFF Hot Operations Delay after CD-4 Complete	Use Aerospace POO, Min, and Max values.	\$ 146,003,823	\$ 41,048,559	\$ 250,959,086	50%	1
11			MFFF Integrated Functional Testing Delay Before CD-4	Use Aerospace POO, Min, and Max values.	\$ 223,172,596	\$ 17,238,356	\$ 429,106,836	25%	1
12			Needs for Additional Storage	Use Aerospace POO, Min, and Max values.	\$ 70,137,887	\$ 24,551,778	\$ 115,723,997	50%	1
13			LANL Feedstock Production Re-Start Delay	Use Aerospace POO, Min, and Max values.	\$ 113,684,710	\$ 55,996,010	\$ 171,373,411	25%	1
14			Funding for Depleted Uranium	Use Aerospace POO, Min, and Max values.	\$ 15,669,368	\$ 7,834,684	\$ 23,504,052	10%	1
15			Feedstock Production Consolidated at LANL	Use Aerospace POO, Min, and Max values.	\$ (462,965,306)	\$ (655,913,367)	\$ (270,017,246)	75%	1
16									
17									
18									
19									
20									



High Bridge Review of Pu Disposition Options
MOX Risks - Option 1
Discrete Risk Model
(Aerospace Values - 2015 Updated Evaluations)

Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

Model Results									
Expected Value	Occurrence	85%							
2,559,137,333	1.00	3,160,715,335	1	Fuel Production Rate Lower Than Expected	Use Aerospace POO, Min, and Max values.		3,291,588,577	75%	1.00
1,237,278,054	1.00	1,531,947,757	2	Feedstock Production Rate Lower Than Expected	Use Aerospace POO, Min, and Max values.		1,237,278,054	75%	1.00
1,054,827,612	1.00	1,487,568,584	3	MFFF Construction Cost Uncertainty / Growth	Use Aerospace POO, Min, and Max values.		1,054,827,612	75%	1.00
564,285,574	1.00	753,071,637	4	MFFF Temporary Suspension of Operations	Use Aerospace POO, Min, and Max values.		564,285,574	90%	1.00
1,006,806,141	1.00	1,167,384,756	5	MFFF Full Construction Re-Start Delay	Use Aerospace POO, Min, and Max values.		1,006,806,141	50%	1.00
302,987,019	1.00	402,671,821	6	Feedstock Temporary Suspension of Operations	Use Aerospace POO, Min, and Max values.		302,987,019	90%	1.00
161,143,770	1.00	186,535,838	7	SRS Overhead Cost Increases	Use Aerospace POO, Min, and Max values.		161,143,770	75%	1.00
136,601,444	1.00	171,109,759	8	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Use Aerospace POO, Min, and Max values.		136,601,444	90%	1.00
391,904,164	1.00	377,312,451	9	LANL Overhead Cost Increases	Use Aerospace POO, Min, and Max values.		391,904,164	25%	1.00
146,003,823	1.00	170,096,564	10	MFFF Hot Operations Delay after CD-4 Complete	Use Aerospace POO, Min, and Max values.		146,003,823	50%	1.00



High Bridge Review of Pu Disposition Options
MOX Risks - Option 1
Discrete Risk Model
(Aerospace Values - 2015 Updated Evaluations)

Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

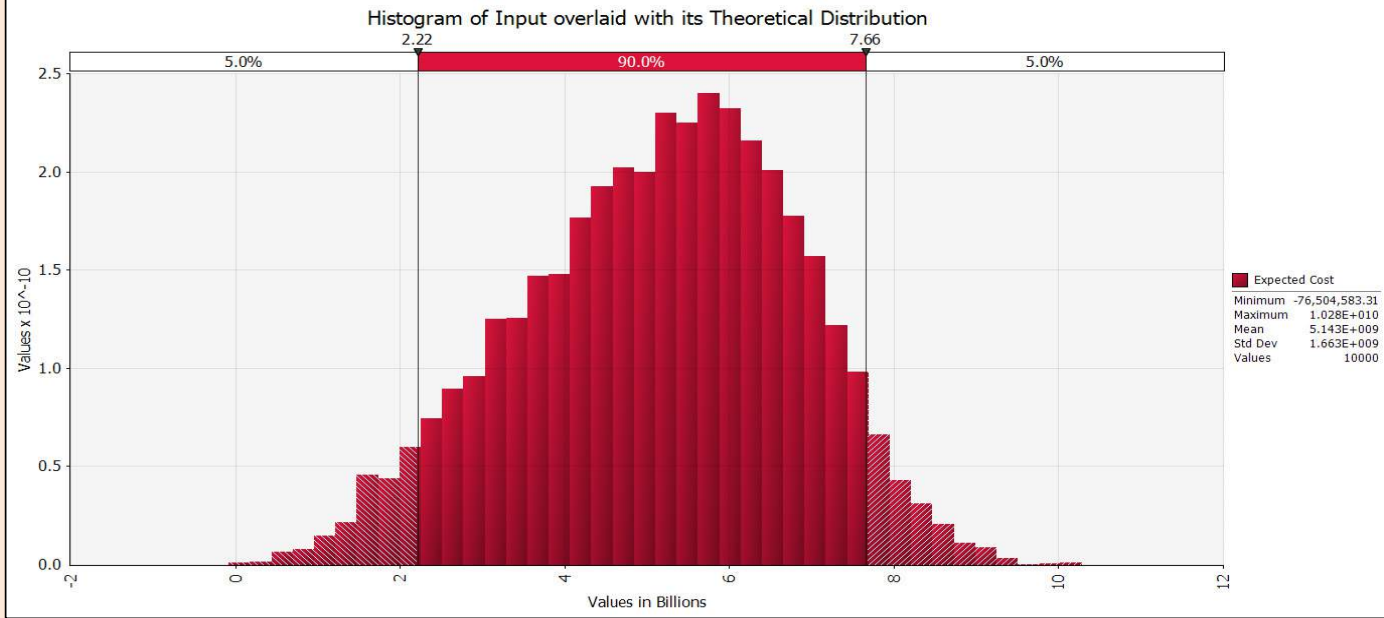
11	MFFF Integrated Functional Testing Delay Before CD-4	Use Aerospace POO, Min, and Max values.		223,172,596	25%	1.00	\$ 17,238,356	\$ 429,106,836	11
12	Needs for Additional Storage	Use Aerospace POO, Min, and Max values.		70,137,887	50%	1.00	\$ 24,551,778	\$ 115,723,997	12
13	LANL Feedstock Production Re-Start Delay	Use Aerospace POO, Min, and Max values.		113,684,710	25%	1.00	\$ 55,996,010	\$ 171,373,411	13
14	Funding for Depleted Uranium	Use Aerospace POO, Min, and Max values.		15,669,368	10%	1.00	\$ 7,834,684	\$ 23,504,052	14
15	Feedstock Production Consolidated at LANL (Remove HB-Line)	Use Aerospace POO, Min, and Max values.		(462,965,306)	75%	1.00	\$ (655,913,367)	\$ (270,017,246)	15

223,172,596	1.00	201,240,888
70,137,887	1.00	80,032,118
113,684,710	1.00	108,000,721
15,669,368	-	-
(462,965,306)	1.00	-
		9,797,688,228



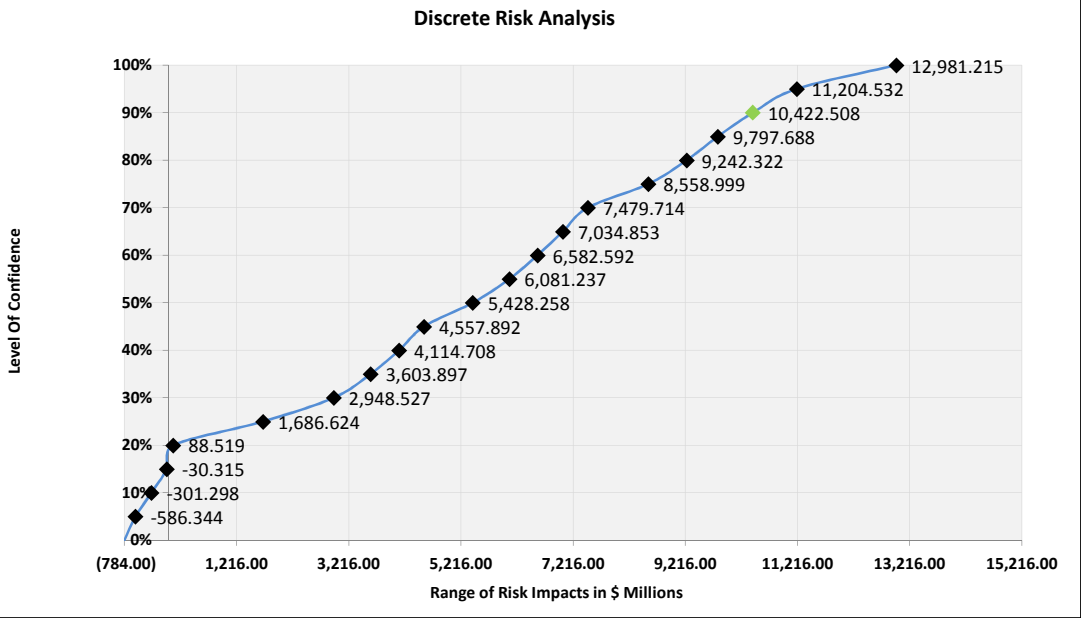
High Bridge Review of Pu Disposition Options
MOX Risks - Option 1
Discrete Risk Model
(Aerospace Values - 2015 Updated Evaluations)

Histogram of Input overlaid with its Theoretical Distribution



Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception



Results Summary		
% Conf.	Contingency	% of Project Estimate
0%	\$ (784,768,311)	-10%
5%	\$ (586,343,586)	-7%
10%	\$ (301,298,027)	-4%
15%	\$ (30,314,746)	0%
20%	\$ 88,518,674	1%
25%	\$ 1,686,623,946	21%
30%	\$ 2,948,527,088	37%
35%	\$ 3,603,897,232	45%
40%	\$ 4,114,707,566	51%
45%	\$ 4,557,892,185	57%
50%	\$ 5,428,258,383	68%
55%	\$ 6,081,236,741	76%
60%	\$ 6,582,591,640	82%
65%	\$ 7,034,852,604	88%
70%	\$ 7,479,713,844	93%
75%	\$ 8,558,999,019	107%
80%	\$ 9,242,321,856	116%
85%	\$ 9,797,688,228	122%
90%	\$ 10,422,508,460	130%
95%	\$ 11,204,531,566	140%
100%	\$ 12,981,215,361	162%

Notes:

P1 (Percentile 1) represents the extreme low end of the possible risk values, also known as the "Best Case".

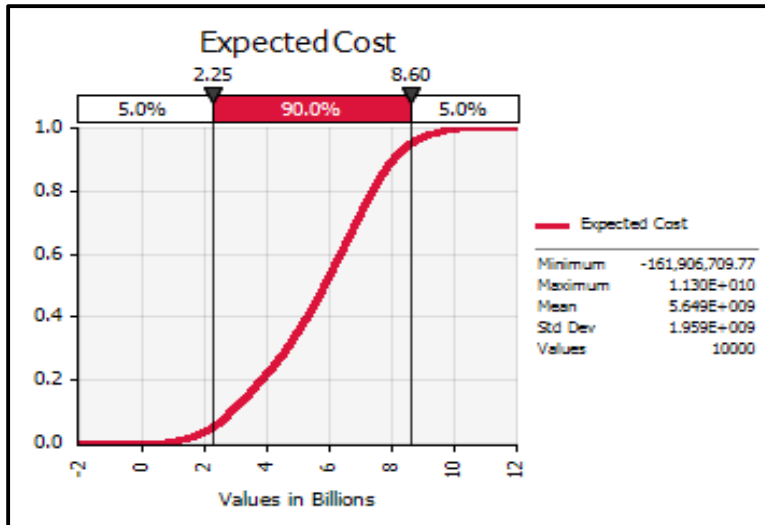
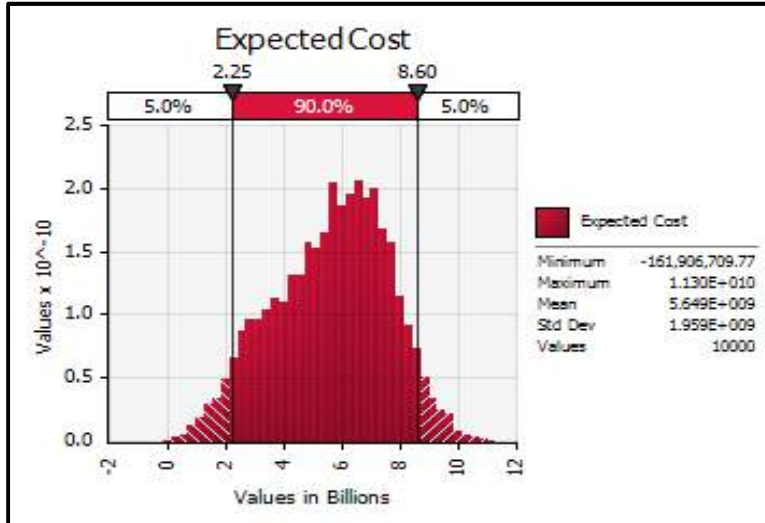
P99 (Percentile 99) represents the extreme high end of the possible risk values, also known as the "Worst Case".

Reference: AACE International Recommended Practice No. 41R-08 - Risk Analysis And Contingency Determination Using Range Estimating

@RISK Output Report for Expected Cost

Performed By: HBA

Date: Monday, July 27, 2015 9:26:47 AM

**Simulation Summary Information**

Workbook Name	1.6B_HBA_Discrete_15-0727_MOX Op
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	40
Number of Outputs	1
Sampling Type	Monte Carlo
Simulation Start Time	7/27/2015 9:26
Simulation Duration	00:00:06
Random # Generator	Mersenne Twister
Random Seed	1794918410

Summary Statistics for Expected Cost

Statistics		Percentile	
Minimum	(161,906,710)	5%	2,247,972,594
Maximum	11,297,124,738	10%	2,842,708,421
Mean	5,648,813,198	15%	3,366,168,195
Std Dev	1,959,198,021	20%	3,808,618,314
Variance	3.83846E+18	25%	4,247,460,124
Skewness	-0.242219802	30%	4,635,171,058
Kurtosis	2.464148535	35%	4,961,469,797
Median	5,837,322,531	40%	5,285,759,947
Mode	6,726,153,732	45%	5,588,724,662
Left X	2,247,972,594	50%	5,837,322,531
Left P	5%	55%	6,100,051,257
Right X	8,601,889,092	60%	6,354,314,689
Right P	95%	65%	6,605,525,604
Diff X	6,353,916,497	70%	6,859,021,387
Diff P	90%	75%	7,112,058,227
#Errors	0	80%	7,380,451,032
Filter Min	Off	85%	7,679,077,158
Filter Max	Off	90%	8,056,339,005
#Filtered	0	95%	8,601,889,092



High Bridge Review of Aerospace April 13, 2015 Report
Option 4 Downblend
Discrete Risk Model
AEROSPACE VALUES - 2015 Updated Evaluations

Form 1.6B

Row	Estimator Initials	Project	Risk Description	Risk Specifics/Details	\$ Impact Range			% Probability of Occurrence	# of Times Risk Could Occur Per Project
					Expected	Low	High		
1	HBA with Aero Values	Downblend	Feedstock Production Rate Lower Than Expected	Uses Aerospace Option 4 Min & Max Values	\$ 1,210,030,218	\$ 464,627,467	\$ 1,955,432,968	75%	1
2			SRS Downblend Facility Start Delay	Uses Aerospace Option 4 Min & Max Values	\$ 1,106,247,908	\$ 345,243,049	\$ 1,867,252,767	25%	1
3			Feedstock Temporary Suspension of Operations	Uses Aerospace Option 4 Min & Max Values	\$ 263,330,050	\$ 58,552,348	\$ 468,107,752	90%	1
4			Downblend Production Rate is Lower Than Expected	Uses Aerospace Option 4 Min & Max Values	\$ 347,176,321	\$ 93,230,907	\$ 601,121,735	25%	1
5			Downblend Facility Temporary Suspension of	Uses Aerospace Option 4 Min & Max Values	\$ 157,872,654	\$ 35,082,812	\$ 280,662,497	90%	1
6			Downblend Construction Cost Estimate Uncertainty/Growth	Uses Aerospace Option 4 Min & Max Values	\$ 184,151,228	\$ 73,660,491	\$ 294,641,965	75%	1
7			LANL Overhead Cost Increase	Uses Aerospace Option 4 Min & Max Values	\$ 391,904,164	\$ 261,269,443	\$ 522,538,886	25%	1
8			MFFF Project Termination Cost Uncertainty	Uses Aerospace Option 4 Min & Max Values	\$ 317,047,222	\$ (90,584,921)	\$ 724,679,365	25%	1
9			Downblend Repository Temporary Suspension of	Uses Aerospace Option 4 Min & Max Values	\$ 33,487,092	\$ 7,467,710	\$ 59,506,475	90%	1
10			SRS Overhead Cost Increase	Uses Aerospace Option 4 Min & Max Values	\$ 25,931,181	\$ 14,817,818	\$ 37,044,545	75%	1
11			Feedstock Production Re-Start Delay at LANL	Uses Aerospace Option 4 Min & Max Values	\$ 113,684,710	\$ 55,996,010	\$ 171,373,411	25%	1
12			Exceed Downblend Repository TRU Allowable Storage	Uses Aerospace Option 4 Min & Max Values	\$ 130,185,114	\$ 28,930,025	\$ 231,440,204	10%	1
13			Need for Additional Storage Volume	Uses Aerospace Option 4 Min & Max Values	\$ 39,181,929	\$ 13,631,475	\$ 64,732,383	25%	1
14			Facilities and Infrastructure Life-cycle/Sustainment	Uses Aerospace Option 4 Min & Max Values	\$ 10,883,425	\$ 4,353,370	\$ 17,413,480	75%	1
15			Feedstock Milling and Blending Not Needed/Quality	Uses Aerospace Option 4 Min & Max Values	\$ (40,045,763)	\$ (62,673,563)	\$ (17,417,963)	90%	1
16			Feedstock Production Consolidated at LANL (Remove HB-Line)	Uses Aerospace Option 4 Min & Max Values	\$ (461,695,633)	\$ (653,374,020)	\$ (270,017,246)	90%	1



High Bridge Review of Pu Disposition Options
Downblend Risks - Option 4
Discrete Risk Model
(Aerospace Values - 2015 Up-dated Evaluations)

Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

Item	Description of Discrete Risk	Risk Specifics/Details	Remarks	Estimated Impact	Probability of Occurrence	# of Occurrences Possible	(P1) Value	(P99) Value	Item
1	Feedstock Production Rate Lower Than Expected	Uses Aerospace Option 4 Min & Max Values		1,210,030,218	75%	1.00	\$ 464,627,467	\$ 1,955,432,968	1
2	SRS Downblend Facility Start Delay	Uses Aerospace Option 4 Min & Max Values		1,106,247,908	25%	1.00	\$ 345,243,049	\$ 1,867,252,767	2
3	Feedstock Temporary Suspension of Operations	Uses Aerospace Option 4 Min & Max Values		263,330,050	90%	1.00	\$ 58,552,348	\$ 468,107,752	3
4	Downblend Production Rate is Lower Than Expected	Uses Aerospace Option 4 Min & Max Values		347,176,321	25%	1.00	\$ 93,230,907	\$ 601,121,735	4
5	Downblend Facility Temporary Suspension of Operations	Uses Aerospace Option 4 Min & Max Values		157,872,654	90%	1.00	\$ 35,082,812	\$ 280,662,497	5
6	Downblend Construction Cost Estimate Uncertainty/Growth	Uses Aerospace Option 4 Min & Max Values		184,151,228	75%	1.00	\$ 73,660,491	\$ 294,641,965	6
7	LANL Overhead Cost Increase	Uses Aerospace Option 4 Min & Max Values		391,904,164	25%	1.00	\$ 261,269,443	\$ 522,538,886	7
8	MFFF Project Termination Cost Uncertainty	Uses Aerospace Option 4 Min & Max Values		317,047,222	25%	1.00	\$ (90,584,921)	\$ 724,679,365	8
9	Downblend Repository Temporary Suspension of Operations	Uses Aerospace Option 4 Min & Max Values		33,487,092	90%	1.00	\$ 7,467,710	\$ 59,506,475	9
10	SRS Overhead Cost Increase	Uses Aerospace Option 4 Min & Max Values		25,931,181	75%	1.00	\$ 14,817,818	\$ 37,044,545	10

Model Results		
Expected Value	Occurrence	85%
1,210,030,218	1.00	1,481,694,704
1,106,247,908	1.00	1,040,594,575
263,330,050	1.00	349,981,722
347,176,321	1.00	318,593,869
157,872,654	1.00	209,347,269
184,151,228	1.00	224,815,558
391,904,164	1.00	376,094,249
317,047,222	1.00	268,853,726
33,487,092	1.00	44,478,547
25,931,181	1.00	30,090,638



High Bridge Review of Pu Disposition Options
Downblend Risks - Option 4
Discrete Risk Model
(Aerospace Values - 2015 Up-dated Evaluations)

Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$	8,000,000,000	\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

11	Feedstock Production Re-Start Delay at LANL	Uses Aerospace Option 4 Min & Max Values		113,684,710	25%	1.00	\$ 55,996,010	\$ 171,373,411	11	113,684,710	1.00	107,635,628
12	Exceed Downblend Repository TRU Allowable Storage	Uses Aerospace Option 4 Min & Max Values		130,185,114	10%	1.00	\$ 28,930,025	\$ 231,440,204	12	130,185,115	-	-
13	Need for Additional Storage Volume	Uses Aerospace Option 4 Min & Max Values		39,181,929	25%	1.00	\$ 13,631,475	\$ 64,732,383	13	39,181,929	1.00	36,800,832
14	Facilities and Infrastructure Life-cycle/Sustainment (Recapitalization)	Uses Aerospace Option 4 Min & Max Values		10,883,425	75%	1.00	\$ 4,353,370	\$ 17,413,480	14	10,883,425	1.00	13,217,163
15	Feedstock Milling and Blending Not Needed/Quality Control Reductions	Uses Aerospace Option 4 Min & Max Values		(40,045,763)	90%	1.00	\$ (62,673,563)	\$ (17,417,963)	15	(40,045,763)	1.00	(25,196,941)
16	Feedstock Production Consolidated at LANL (Remove HB-Line)	Uses Aerospace Option 4 Min & Max Values		(461,695,633)	90%	1.00	\$ (653,374,020)	\$ (270,017,246)	16	(461,695,633)	1.00	(335,602,057)
											4,141,399,481	

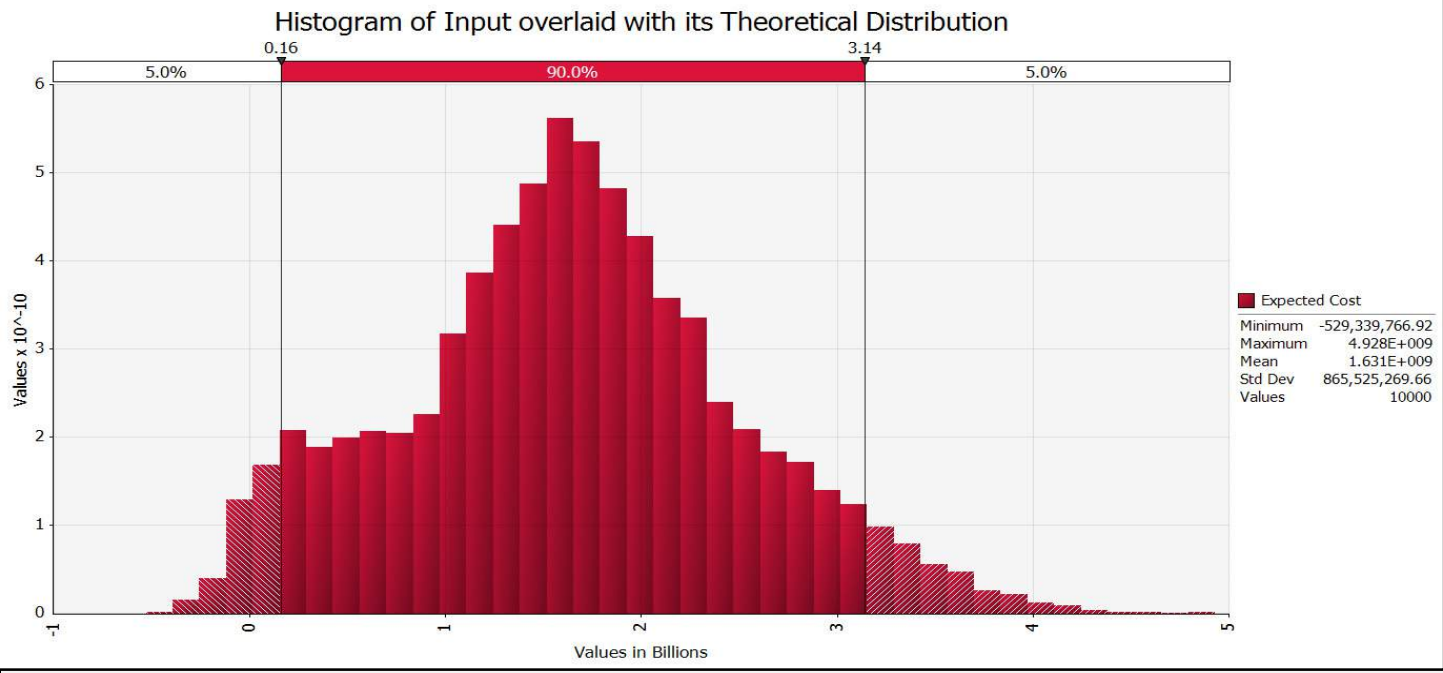


High Bridge Review of Pu Disposition Options
Downblend Risks - Option 4
Discrete Risk Model
(Aerospace Values - 2015 Up-dated Evaluations)

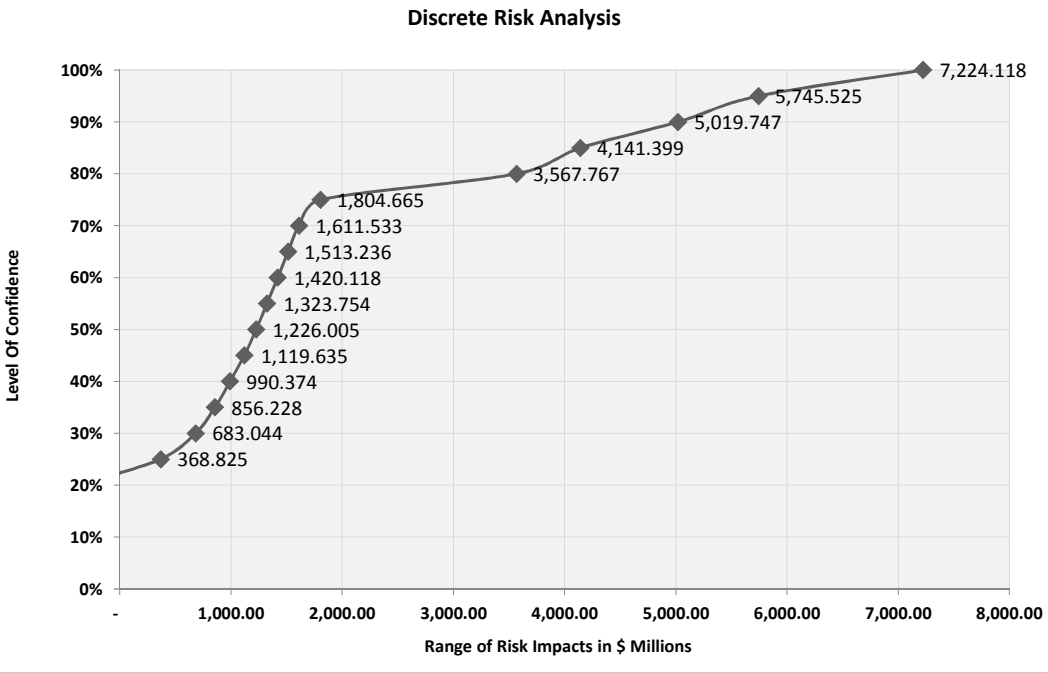
Risk Severity Map		Consequence of Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Cost Estimate Value		0.1%	0.2%	0.5%	2.0%	5.0%
\$ 8,000,000,000		\$8,000,000	\$16,000,000	\$40,000,000	\$160,000,000	\$400,000,000
Probable	90.0%	7,200,000	14,400,000	36,000,000	144,000,000	360,000,000
High	75.0%	6,000,000	12,000,000	30,000,000	120,000,000	300,000,000
Medium	50.0%	4,000,000	8,000,000	20,000,000	80,000,000	200,000,000
Low	25.0%	2,000,000	4,000,000	10,000,000	40,000,000	100,000,000
Unlikely	10.0%	800,000	1,600,000	4,000,000	16,000,000	40,000,000

Risk Severity Key	
Catastrophic	Beyond boundary of project assumptions
Major	Must identify additional project controls
Moderate	Likely identify additional project controls
Minor	Consider additional project controls
Insignificant	Mitigate by exception

Histogram of Input overlaid with its Theoretical Distribution



Discrete Risk Analysis



Results Summary

% Conf.	Contingency	% of Project Estimate
0%	\$ (798,989,586)	-10%
5%	\$ (643,658,346)	-8%
10%	\$ (533,887,967)	-7%
15%	\$ (368,434,829)	-5%
20%	\$ (300,517,024)	-4%
25%	\$ 368,825,366	5%
30%	\$ 683,044,057	9%
35%	\$ 856,228,113	11%
40%	\$ 990,373,665	12%
45%	\$ 1,119,634,857	14%
50%	\$ 1,226,005,428	15%
55%	\$ 1,323,753,619	17%
60%	\$ 1,420,117,592	18%
65%	\$ 1,513,236,445	19%
70%	\$ 1,611,533,488	20%
75%	\$ 1,804,665,037	23%
80%	\$ 3,567,766,710	45%
85%	\$ 4,141,399,481	52%
90%	\$ 5,019,747,370	63%
95%	\$ 5,745,525,276	72%
100%	\$ 7,224,118,388	90%

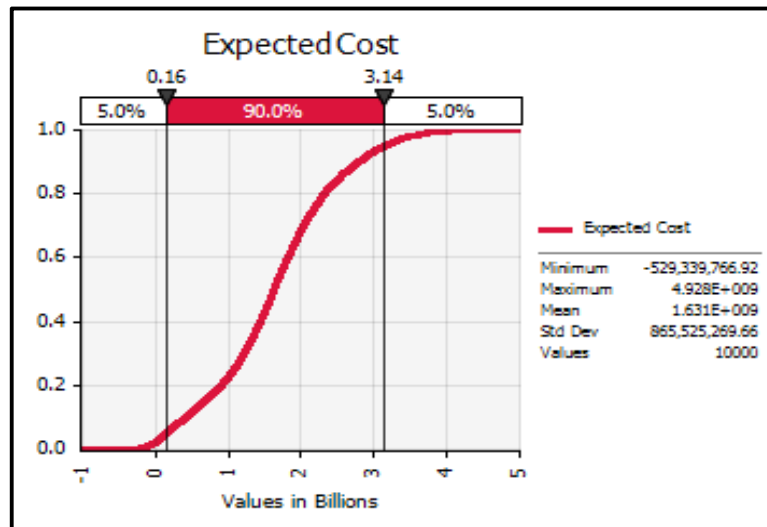
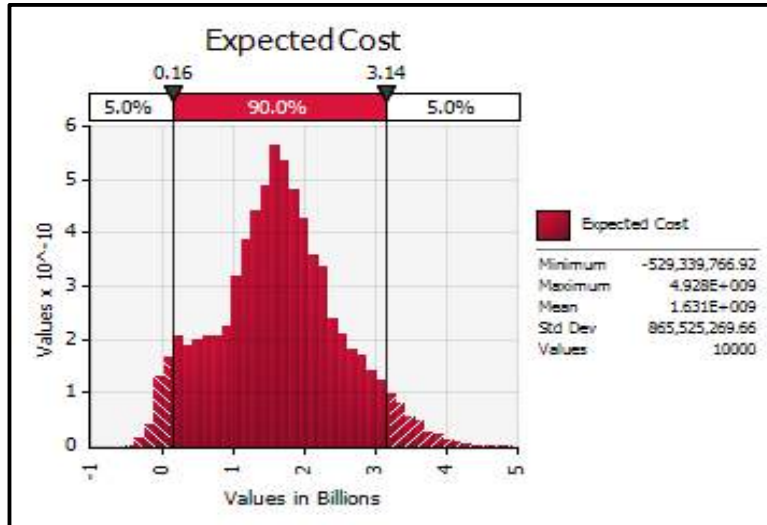
Notes:

P1 (Percentile 1) represents the extreme low end of the possible risk values, also known as the "Best Case".
P99 (Percentile 99) represents the extreme high end of the possible risk values, also known as the "Worst Case".
Reference: AACE International Recommended Practice No. 41R-08 - Risk Analysis And Contingency Determination Using Range Estimating

@RISK Output Report for Expected Cost

Performed By: HBA

Date: Monday, July 27, 2015 9:34:25 AM

**Simulation Summary Information**

Workbook Name	1.6B_HBA_Discrete_15-0727_Downblend
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	40
Number of Outputs	1
Sampling Type	Monte Carlo
Simulation Start Time	7/27/2015 9:34
Simulation Duration	00:00:06
Random # Generator	Mersenne Twister
Random Seed	378723591

Summary Statistics for Expected Cost

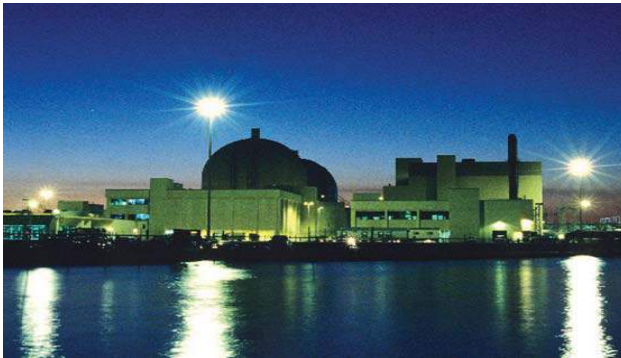
Statistics	Percentile
Minimum	5% 159,866,453
Maximum	10% 413,514,049
Mean	15% 667,357,369
Std Dev	20% 902,865,186
Variance	25% 1,081,586,916
Skewness	30% 1,216,084,830
Kurtosis	35% 1,334,572,375
Median	40% 1,440,319,518
Mode	45% 1,539,764,654
Left X	50% 1,629,302,805
Left P	55% 1,717,445,547
Right X	60% 1,811,493,825
Right P	65% 1,919,139,929
Diff X	70% 2,030,980,768
Diff P	75% 2,166,061,699
#Errors	80% 2,314,336,644
Filter Min	85% 2,517,141,100
Filter Max	90% 2,788,237,873
#Filtered	95% 3,142,648,556

APPENDIX G

High Bridge Corporate Qualifications

June 2015

High Bridge Qualifications Overview



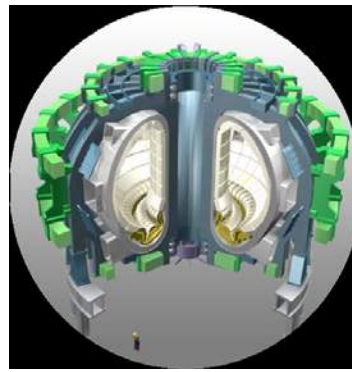
Vogtle Nuclear Power Plant, Georgia



Nuclear Waste Management Complex, Idaho



Sellafield Nuclear Facility, England



ITER Fusion Research Facility, France



Oconee Nuclear Power Plant, South Carolina



“Connecting Vision and Plans with Performance and Execution”

High Bridge Associates



- High Bridge Associates, Inc. (High Bridge) provides project management consulting & staff augmentation services
- We assist owners, engineer/constructors, & manufacturers with new projects & operating plant modifications/O&M
- 2008 through 2014:
 - Average revenue ~ \$50M per year
 - Average 200 employees in >30 states and 8 countries
- Offices in Greensboro, GA and Chattanooga, TN



High Bridge Corporate Evolution

Team Associates 1994 to 2003

- Founders from utilities and EPC firms
- Commercial nuclear, fossil, and DOE EM focus
- Project controls, planning/scheduling, & cost estimating “niche”
- Sold business in 2001 to major customer...GE Power Systems
 - Developed “Web/PC-Based” global project controls/reporting system

High Bridge Associates 2004 to Present

- Expanded staff augmentation support to consulting services
- Established Work Management Inc. (WMI) for operating nuclear plant “niche”
- Developed detailed project scope definition & cost estimating process
 - Best in industry process for scope definition & detailed cost estimating
 - Establishes comprehensive basis for effective change management
 - Data base covering nuclear quantity, U/R, hours, \$, & schedule metrics
- Established High Bridge Energy Development (HBED) to capture Small Modular Reactor (SMR) project development/integration opportunities



3

Customers, Industries, & Business Model

Customers

- 70% Utility, Industrial, & Federal Government **Owners**
- 20% Engineering, Procurement, & Construction **Contractors**
- 10% Original Equipment **Manufacturers**

Industries

- 90% Commercial Power Generation
 - 70% Nuclear
 - 20% Fossil (Coal/CGTG) & Renewable (Wind/Solar/Biofuel)
 - 10% Government, Science/R&D, Industrial, & Petro Chemical

Business Model

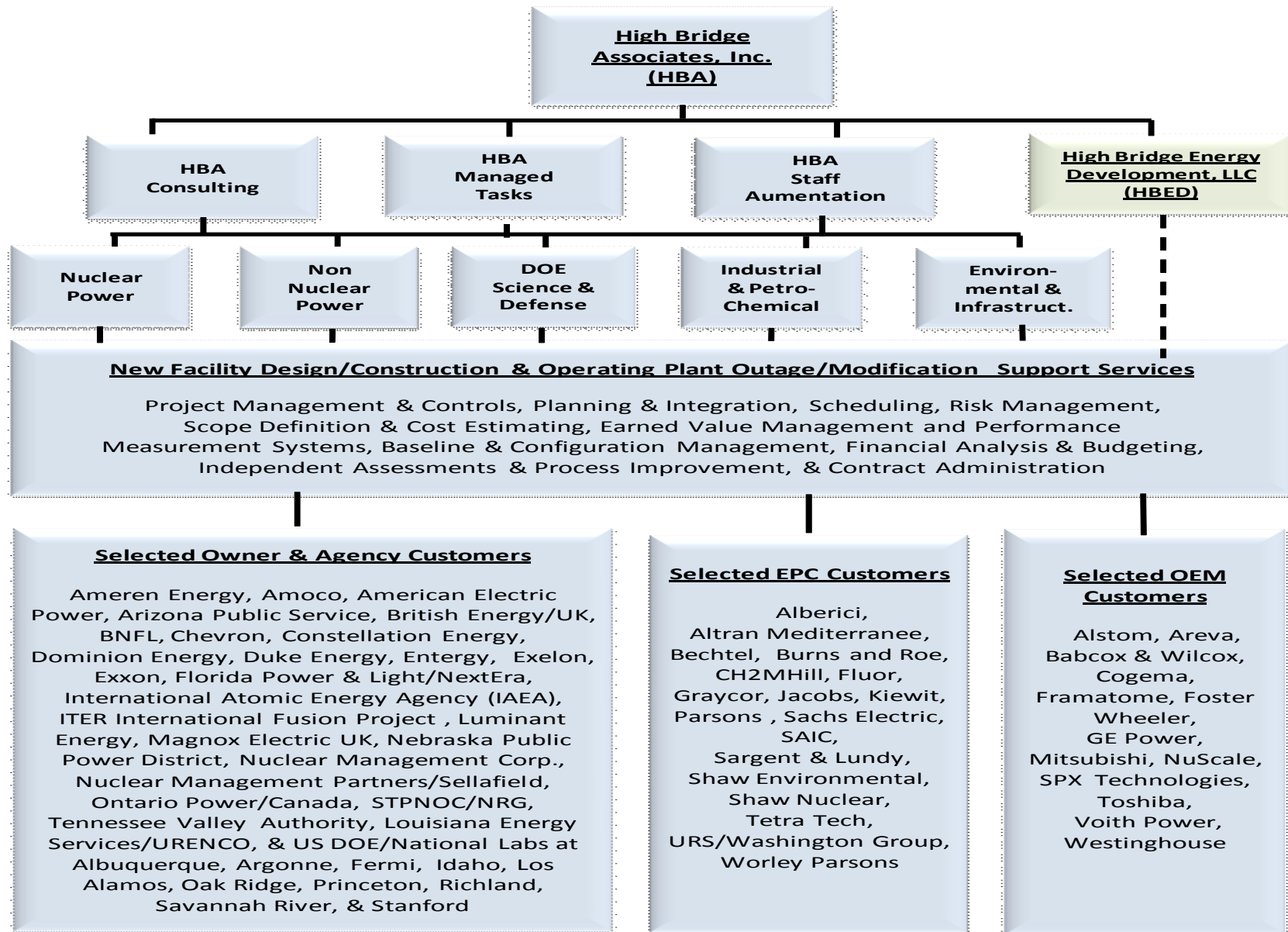
- Since 1994, >90% of our business is sole source negotiated
- Prior working relationships with customer decision makers
- Trust & proven track record for value added services



4



High Bridge Associates, Inc. (HBA) Industries, Capabilities, and Customer Overview





High Bridge Associates

Representative Ongoing & Recent Nuclear Projects

Reference	1	2	3	4	5	6	7
Customer and Project	<u>Spallation Neutron Source (SNS) Project - ORNL</u> Project Mgt. & Controls Support to Owner/Operator Team	<u>International Atomic Energy Agency (IAEA)</u> Senior Consulting & Subject Matter Expert Emerging Commercial Nuclear Program Support to Member Nations	<u>Entergy Grand Gulf #2</u> Owner's Team Project Controls Support to Evaluate LLWR Supplier Options; Evaluated Price, Technical, & Risk Parameters for OEM/EPC Consortia	<u>Dominion Energy, North Anna #3</u> Owner's Team to Support Open Competition for LLWR OEM/EPC Supplier & Services; Developed Financial Submittal Templates & Evaluated Proposals	<u>24 Units & 17 Sites - Dominion, Entergy, & NextEra/FP&L</u> US Operating Nuclear Fleet, Post-Fukushima Support for NRC Orders & Initiatives	<u>>20 Utilities and >50 Nuclear Units</u> US Operating Nuclear Fleet Outage/Mod Support for EPU/Major/Minor Projects	<u>Sellafield UK Nuclear Management Partners/NMP</u> Site cleanup, risk & hazards reduction
Services	Project Controls, Planning, Scheduling, Integration, Cost Estimating, Risk Assessment, Plans & Procedures, Training	Program Planning, Project Organizing, Project Management, Project Controls, & Integration	Project Controls, Planning, Scheduling, Integration, Cost Estimating, & Risk Assessment	Support RFP Development for Cost/Price/Schedule Templates & Evaluation of Supplier Proposals	Scoping Studies, Basis Documentation, Detailed Cost Estimates, & Monte Carlo Risk Assessments	Scoping Studies, Basis Documentation, Detailed Cost Estimates, & Monte Carlo Risk Assessments	Project Mgt., Conduct of Operations Review, Project Controls, Planning, Scheduling, Integration, Plans & Procedures, EVMS
Years	1999 to 2007	2010 to Present	2006 to 2008	2008 to 2011	2011 to Present	2007 to Present	2011 to Present
Reference	8	9	10	11	12	13	14
Customer and Project	<u>ITER IO</u> International (7-Nations) Fusion Demonstration Project, Cadarache France	<u>Tennessee Valley Authority Watts Bar #2</u> Construction Completion & Startup Owner's Team	<u>Westinghouse & CB&I/Shaw AP1000</u> New Nuclear Corporate and Project Support	<u>Duke Power Crystal River #3</u> Owner's Team, Reactor Building Modification Support	<u>Urenco USA Uranium Enrichment Project</u> Owner's Construction Management & Integration Team	<u>Stone & Webster Mixed Oxide Fuel Processing Facility (MOX)</u> Duke Cogema Stone & Webster and Shaw Areva	<u>UniStar</u> Constellation Calvert Cliffs #3, New Nuclear Project Areva EPR, Owner's Team
Services	Proj. Mgt, Risk Mgt., Assessments, Project Controls, Planning, Scheduling, Estimating, EVMS, Training	Project Mgt., Assessments, Project Controls, Planning, Scheduling, Estimating, Risk Mgt., Plans & Procedures	Cost Estimating, Project Controls, Planning/Scheduling, Risk Management, Plans & Procedures, EVMS, IT Hardware Support	Independent Cost, Schedule, & Risk Assessment of Containment Concrete Cracking Repair Options	Independent Cost Estimate, Assessment of Deployment Planning, PMP/PEP, Construction Mgt. Site Staffing	Assessmt of Cost, Schedule, & Risk; Transition Support to Construction; EVMS Plans, Procedures, & Training	Independent Cost Estimate, Deployment Planning, PMP/PEP, Constr. Mgt. Support, Owner Staffing Planning
Years	2006 to Present	2010 to Present	2007 to 2013	2012	2006 to Present	2004 to 2012	2008 to 2011

Commercial Nuclear Plant Description	Units	BWR			Commercial Nuclear Plant Description	Units	PWR			
		Nat1	Nat2	Nat3			Vol	CE	ESV	Grdu
Browns Ferry	3	3			Arkansas	2		1	1	
Brunswick	2	2			Beaver Valley	2	2			
Clinton	1			1	Big Rock	1	1			
Cooper	1	1			Bellefonte	2			2	
Dresden	2	2			Braidwood	2	2			
Fitzpatrick	1	1			Catawba	2	2			
Gina	1	1			Calvert Cliffs	2		2		
Grand Gulf	1			1	Crystal River	1			1	
LaSalle	2		2		DC Cook	2	2			
Nine Mile Point	2	1	1		Indian Point	1	1			
Oyster Creek	1	1			McGuire	2	2			
Peach Bottom	2	2			Millstone #3	1	1			
Perry	1			1	North Anna	2	2			
Pilgrim	1	1			Oconee	3			3	
Quad Cities	2	2			Palo Verde	3		3		
River Bend	1			1	Pickering	10				10
Shoreham	1		1		Rancho Seco	1	1			
Total 17 Sites & 25 Units					Salem	2	2			
New Nuclear Power Facilities, Advanced Reactor Designs, and Uranium Enrichment					Seabrook	1	1			
					Sequoyah	2	2			
					South Texas	2	2			
					Vogtle	2	2			
					Three Mile Island	2			2	
					Waterford	1		1		
					Watts Bar	1	1			
ITER Fusion Project	1				WPPS	1	1			
LES Enrichment Plant	1				Zion	2	2			
Westinghouse AP1000	8									
AEP US APWR	1									
Luminant US APWR	2									
UniStar EPR	1									
Dominion NA3/All NSSS	1									
Entergy ESBWR	1									
South Texas ABWR	2									
Duke AP1000	2									
British Energy/EDF/EPR	10									
NuScale SMR	1									
B&W mPower SMR	1									
Total 20 Sites & 32 Units					Total 27 Sites					
Total Units	57				Total Units	55				
Total 64 Sites and 112 Units										



High Bridge Associates/Work Management Experience Summary US DOE/NNSA, DOD, Advanced Technology, & Science Projects



Facility/Program Location/Description		Facilities/ Projects
1	ITER International Fusion Research & Demonstration Facility, Cadarache France	
a.	Project Management, Planning, Integration, Scheduling, Estimating, Project Controls, & Risk Management	1
2	SMART Park Alternative Energy Project (Sustainable Manufacturing and Recycling Technology)	
a.	Develop, Integrate, Design, Construct, Own, & Operate a Municipal Solid Waste to Ethanol Renewable Fuel fa	1
3	DOE Michigan State University (MSU):	
a.	Facility for Rare Isotope Beams (FRIB): Strategic Planning, Project Management, Preparation, & Organizing	1
4	DOE National Nuclear Security Administration (NNSA)	
a.	Supporting planning, project controls, & program integration for weapons systems development in Albuquerque	1
5	DOE Los Alamos National Laboratory (LANL)	
a.	Weapons Experimental Program: Project Controls, Planning, Scheduling, EVM Reporting, Procedures, & Risk N	1
b.	Accelerator Production of Tritium (APT) Project: Cost Estimating, Planning, & Scheduling	1
6	DOE Fermi National Accelerator Laboratory (FNAL)	
a.	Long Baseline Neutrino Project: Executive Consulting for Integrated Planning, Project and Program Performanc	1
7	Korea National Science Research Center, Rare Isotope Science Project, Daejeon, KR	
a.	Executive Consulting for Planning/Project Management & Member of the International Advisory Committee	1
8	DOE Idaho Site/Idaho National Engineering Laboratory	
a.	Program Planning/Scheduling Support: Primavera Upgrade & Training	1
b.	Pit 9 Waste Management Project: Project Controls, Planning, Scheduling, & Training	1
c.	Advanced Mixed Waste (AMWTP) Project: Project Controls, Scheduling, & Construction Management	1
d.	Idaho Cleanup Project: Project Controls Process Improvement	1
9	Oak Ridge DOE Site/Oak Ridge National Laboratory	
a.	Operating Contractor Support: Executive Consulting for Cost Reduction & Re-Organizing	1
b.	Spallation Neutron Source (SNS) Accelerator: Planning, Organizing, Risk Management, & Scheduling	1
c.	Y-12 Enriched Uranium Project: Independent Estimate/Schedule Review	1
d.	Gaseous Diffusion D&D Project: Planning, Scheduling, Cost Estimating, & Claims	1
e.	Clinch River Breeder Reactor: Project Controls, Planning, Scheduling, & Cost Estimating	1



High Bridge Associates/Work Management Experience Summary US DOE/NNSA, DOD, Advanced Technology, & Science Projects



Facility/Program Location/Description		Facilities/ Projects
10	Savannah River DOE Site	
a.	Mixed Oxide Fuel Facility (MOX): Project Controls, EVMS, Planning, Scheduling, Cost Estimating, Risk Mgt.	1
b.	Regulatory Monitoring/Bioassay Laboratory: Independent Cost Estimate	1
c.	F Canyon Ventilation Upgrade Project: Independent Estimate & Schedule Validation Review	1
d.	High Level Nuclear Waste Tank Farm: Operations Review	1
e.	Environmental Restoration Program: Technology Review & Cost Estimating	1
f.	Defense Waste Processing Facility (DWPF), High Level Nuclear Waste Vitrification: Project Management	1
g.	K-Reactor Upgrade Modifications & Restart: Project Management	1
11	Nevada DOE Test Site	
a.	Yucca Mountain Nuclear Waste Repository: Project Controls & Independent Estimate/Schedule Assessment	1
12	DOE Richland Site	
a.	High Level Waste Treatment Project: Planning & Schedule Integration	1
b.	Reactor D&D Program: Independent Cost Estimate Validation Review	1
c.	K-Basin Spent Fuel Cleanup: Independent Cost Estimate & Construction Management	1
d.	High Level Waste Tank Farm D&D: Cost Estimate/Schedule Independent Assessment	1
e.	High Level Waste Treatment Project: Construction Management	1
13	DOE Argonne National Laboratory (ANL)	
a.	Project Controls Process Improvement, Procedures, Training, & Scheduling	1
14	DOE Lawrence Livermore National Laboratory	
a.	Atomic Vapor Laser Isotope Separation (AVLIS) Project: Cost Estimating & Scheduling	1
15	DOE Headquarters Washington DC/Germantown Office	
a.	Office of Environmental Management (EM): Program Planning, Scheduling, & Integration	6
b.	Weapons Fissile Material Disposition Program: Independent Cost Estimate Review	1
16	DOD US Army COE, Chemical Demilitarization Program	
a.	Pine Bluff Arsenal Project, Estimating and Claims Support	1
b.	Anniston Fort McClellan Project, Estimating and Claims Support	1
Total 16 Sites/Locations		41

High Bridge Commercial Nuclear Power New Build Projects

- Licensee/Owner “New Nuclear” Planning, Organizing, & Project Deployment Programs
 - URENCO LES Enrichment Facility; Watts Bar 2; North Anna 3; Calvert Cliffs 3; Grand Gulf 2; STP 3&4; DC Cook 3; Vogtle 3&4; Summer 2&3; Levy 1&2; Lee 1&2
- OEM/EPC New Nuclear Consortiums & Large Light Water Reactor (LLWR) Technologies:
 - Areva/Bechtel EPR; GE Hitachi/URS ESBWR; Mitsubishi/URS APWR; Toshiba/Shaw/CB&I ABWR; Westinghouse/Shaw/CB&I AP1000
- Small Modular Reactor (SMR) Technologies
- Supporting International Atomic Energy Agency (IAEA)
 - Subject Matter Expert consulting for Project Management & Business Systems Integration for IAEA member nation training & development



10

Independent Assessments & Process Improvement Reviews – Project Management, Organization Roles & Responsibilities, & Integrated EPC Project Teams

- Since 1995, have led/been part of customer assessment teams
 - Over 200 commercial nuclear & government science projects
- Project Management Core Business focus with details including:
 - Engineering & design
 - Procurement & manufacturing
 - Construction & installation
 - Startup testing & commissioning
- Assisted with validating engineering/construction scope
- Have developed Industry Lessons Learned expertise to apply to project assessments & project recovery assignments



11

High Bridge Commercial Nuclear Power Outage/Modification/Cost Estimating

- Since 1995, independent assessments & process improvement studies for >50 projects with total capital cost value > \$300 B
 - Preliminary/conceptual cost, budget & schedule studies
 - Detailed/baseline cost, budget & schedule reviews
 - Independent/Oversight/Third Party assessments
- Compiled extensive industry historical information data base
 - Outage & modification projects for operating fleet
 - New project construction - 20th & 21st centuries
 - Quantities, unit installation rates, wage rates, hours, and \$
 - Nuclear Industry lessons learned insights
- Established Chattanooga Cost Estimating Center in 2007



12

High Bridge Commercial Nuclear Power Outage/Modification/Cost Estimating

- Developed detailed project scope definition & cost estimating process
 - Comprehensive scope/assumptions definition approach & best in industry process for detailed cost estimating and risk assessment
 - Establishes comprehensive basis for effective change management
 - Utilizes user-friendly WinEstimator & Excel platform
 - Facilitates web-based integration, cost effective remote estimate development, & timely task deliverable submittals
- Supporting Multiple Extended Power Up-Rate (EPU) projects
 - NextEra, Constellation, Entergy, & NPPD
- Supporting Post-Fukushima requirements & opportunities
 - Dominion, Entergy, & NextEra



13

High Bridge DOE/DOD Federal Services Planning, Integration, & Project Controls

- Life Cycle support spanning design, construction, startup testing, operation, outage, modification, waste management, decommissioning, & cleanup/closure activities
- DOE Headquarter Programs, National Laboratories, Projects, & Facilities
 - Includes 34 projects/programs for headquarter/site/operation/laboratory activities at Argonne, Idaho, Los Alamos, Lawrence Livermore, Nevada Test Site/Las Vegas, Princeton Plasma Physics Lab, Oak Ridge, Richland/Hanford, and Savannah River
- Current larger contracts include the:
 - ITER 7-Nation International Fusion Power Demonstration Project at Cadarache, France
 - MSU National Cyclotron Facility for Rare Isotope beams (FRIB).
 - ORNL Spallation Neutron Source (SNS) Second Target Station (STS).
 - DOE headquarters Office of Environmental Management.
- We understand how to plan and deliver services in accordance with DOE orders, manuals, and guidelines:
 - Insights regarding FAR and DEAR requirements that drive process, methodology, and related planning and execution details



14

Small Modular Reactors (SMR) Experience, Capabilities, & Services

- ANS SMR Licensing Committee Leadership
- Extensive SMR Consulting/Program Planning since 2008
- Business Case Studies –US Military Base, Government Research, Desalinization, Small Industrial, Mining, Remote Communities, & Other Distributed Settings
- Established High Bridge Energy Development in 2011 to develop, integrate, own, operate SMR ~ 50 MWE facilities
- Planning, Scheduling, & Integration
- Project Controls, Cost Estimating & Risk Management
- Independent Assessments & Process Improvement
- Project and Construction Management



15

High Bridge Recent & Representative Experience Project Management Support & Assessments

- Dominion Power North Anna #3 NNP
- Entergy Grand Gulf #2 NNP
- TVA Watts Bar #2 Startup
- URENCO LES Uranium Enrichment Facility
- Shaw Areva MOX Project
- Duke Energy Crystal River Containment
- ITER International Fusion Project
- Sellafield UK Site Cleanup, Hazards, & Risk Reduction

16

Dominion Power, North Anna #3 NNP Procurement Planning & Management Support Preparation of Bid Invitation & Evaluation of Proposals

- Provided project management/controls support to Owner Team
- Developed proposal pricing/schedule/risk templates for inclusion in Requests for Proposals for NNP OEM/EPC
- Performed evaluation/ranking of proposals for price/schedule/risk
- Supported Owner negotiations & interactions with proposers
- Evaluated/ranked OEM EPC proposed organizations, qualifications, & responsiveness
- Proposals submitted by Areva Bechtel (EPR), GE URS (ESBWR), Westinghouse Shaw (AP1000), Toshiba Shaw (ABWR), & Mitsubishi URS (APWR)



17

Entergy, Grand Gulf #2 NNP Technical & Management Support to Owner's Team

- Provided project management & technical support
- Developed project planning program support for work breakdown structure (WBS), division of responsibilities (DOR), contracting strategy, integrated project schedule, & owner staffing/cost estimate
- Performed evaluation/ranking of proposals for price, schedule, risk, & technical considerations (constructability, operability, maintainability, & reliability)
 - Evaluated designs by Areva Bechtel (EPR), GE URS (ESBWR), Westinghouse Shaw (AP1000), Toshiba Shaw (ABWR), & Mitsubishi URS (APWR)



18

TVA Watts Bar #2 Completion Planning & Management Support Engineering, Procurement & Construction

- Performed initial assessment of project schedule in spring 2011
- Performed follow up assessment, validated engineering/construction scope, & recommended streamlining design package process for support of construction
- Implemented recommendations covering cost control, scheduling, project controls, change management, & engineering work package closure
- Assessed & assisted with developing baseline cost estimate/schedule implementation
- Mobilized project/construction management organization for completion of the project
 - Currently >80 personnel at site as part of Owner's Team



19

URENCO/LES Uranium Enrichment Facility Completion Planning & Management Support Engineering, Procurement & Construction

- Providing Owner's Representative support since 2006
- Assessed/recommended/assisted with implementing integrated owner/EPC project team organization & contracting approach
 - Identified dysfunctional/silo project organization & assisted with implementing Integrated Project Team approach
- Assisted with validating engineering/construction scope
- Developed baseline cost estimate
- Peaked at 70 personnel at NM site as part of Owner's Team
 - Construction managers/superintendents; Field engineering managers/specialists; Procurement managers/specialists; Material managers/specialists; QA managers/specialists



20

Shaw Areva MOX Services Completion Planning & Support Management & Scheduling System Simplification

- Providing Owner's Representative support since 2006
- Assisted with performance baseline revisions & implementation for scope, cost, & schedule
- Led transition & construction readiness team for EVMS Certification
- Developed training program & provided implementation support for project management/EVMS system (Good Practice Pamphlet)
- Presently at request of CB&I Chairman of Board of Governors:
 - Assessment & improvements to EVMS & scheduling system
 - Assessments & improvements in construction management organization
 - Anticipate supporting ETC/EAC development for reduced annual spending
 - Anticipate development of re-baseline schedule & simplified planning system



21

Duke Energy Crystal River #3 Containment Concrete Cracking Repair Assessment Design, Construction, Cost Estimate, Schedule, & Risk

- Selected sole source by Duke based on past experience, capabilities, personnel, & reputation
- Worked with other Duke Team members to assess three design & construction options to repair/replace containment concrete cracking
 - Zapata, Tetra Tech, & Weidlinger
- Performed detailed assessment of EPC contractor estimate & schedule
- Performed detailed assessment of owner scope/cost estimate
- Developed independent cost estimate, schedule, & risk assessment
- Duke utilized High Bridge cost estimate & schedule
- Supported Duke with Florida PUC reviews



22

ITER International Fusion Project (France) Planning & Integration Support

- Providing Owner's Team support since 2008
 - ITER Integrating Organization (IO) is owner/operator/licensee
 - 7-nation collaboration with China, EU, India, Japan, Russia, South Korea, & US
- Planning, organizing, and scoping definition activities, including development and maintenance of the Program/Project Work Breakdown Structure (WBS).
- Program integration, project controls, performance measurement reporting, risk management, and training support activities
- Assessed/recommended/supported implementation for simplified risk management approach.
 - Developed/implemented risk workshops in Japan, China, South Korea, USA
- Assessed/recommended/supported implementation for simplified scheduling/integration approach.
 - Assisted with transition from 200,000 activity project schedule to 20,000 activity project schedule



23

Sellafield UK Nuclear Decommissioning Authority Nuclear Management Partners (NMP) Implementation of Nuclear Performance Model

- Provided two top-down assessments of all facets of the operating organization including:
 - Engineering
 - Operations
 - Maintenance
 - Work Management
 - Outage Management
- Supported development of Management Change Plan to implement the INPO Standard Nuclear Performance Model
- Provided Change Management Team focused on guiding the implementation of process and culture in the above functional areas.



24

High Bridge Commercial Nuclear Power Extended Power Uprate/EPU Cost Estimating

- EPU Projects 2010 to 2012 – Approximately \$3-\$4 Billion
 - NextEra (FP&L) Turkey Point 1&2
 - NextEra (FP&L) Point Beach 1&2
 - Entergy Grand Gulf 1
 - Constellation Nine Mile Point 2
- EPU Projects 2013
 - NPPD Cooper 1
- EPU Estimated costs ranged \$500M to \$1,000M
 - Each EPU comprised of 25-50 individual project modification estimates
 - Individual project modification estimates ranged \$5M - \$50M



25

High Bridge Commercial Nuclear Power Post-Fukushima Studies, Scoping, & Cost Estimating

- NRC Orders & Initiatives: 24 units & 17 sites
 - Dominion : 5 units & 3 sites
 - Entergy: 11 units & 9 sites
 - NextEra (FP&L): 8 units & 5 sites
- Scoping studies & options
- Spent Fuel Pool (SPF) level
- Communications
- GE BWR hardened vents
- FLEX Mods & flexible coping strategies
 - Portable equipment
 - Storage buildings
 - Site connections
 - Staging areas



26

High Bridge Commercial Nuclear and Government O&M Studies – Large, Experimental, & Small Modular Reactors

- Staffing Studies
- Maintenance, Operations, Work Control, and Outage Process Improvement
- PM Optimization
- Asset Management System Implementation
- Work Package Planning



27

APPENDIX H

High Bridge Review Team Biographies

Review Team

Ken Aupperle (Task Lead)

Rick Drake

Dr. Mike High

Charlie Hess

Barth Loney

Peer Review Group

Charlie Anderson

Dr. Andy Kadak

Steve Maehr

High Bridge Independent Review of Aerospace April 13, 2015 LCCE Report TOR-2015-01848 Summary of High Bridge Review Team Expert Experience							
	Name	Years Nuclear/DOE Experience	Past Experience Working Together	MOX Project Experience	Plutonium Disposition Program Experience	FOAK Project Experience	Specific Unique/Relevant Experience
	<u>Detail Review Experts</u>						
1	Ken Aupperle (Task Lead)	>40	X	X	X	X	Task Lead for Fissile Material Disposition Program (FMDP), DOE HQ Office, Historical Cost Estimating Program Review & Support, Assessment of Technology Cost Impacts/Trends (2000 to 2002).
2	Rick Drake	>35	X	X	X	X	Assessment Team Member for review of MOX 2012 Re-Baseline construction labor hours, schedule duration, & contingency. Member of other MOX Assessment Teams since 2010.
3	Charlie Hess	>35	X	X	X	X	Was DOE team member in the 1990's that negotiated the Plutonium Disposition Agreement between Russia & the USA. He was responsible for developing/integrating the schedule of activities for the Russian MOX facilities & for coordinating with the US MOX program.
4	Dr. Mike High	>50	X	X	X	X	Assessment Team Member for review of MOX 2012 Re-Baseline construction labor hours, schedule duration, & contingency. MOX schedule/risk assessment team member 2000-2002.
5	Barth Loney	>35	X	X	X	X	Performed multiple Independent Project Reviews of the MOX project for the Office of Environmental Management (EM) in 2007-2009. Worked with EM from 2003-present on all of their waste disposition projects. Experience with other FOAK project for DOE such as the Waste Treatment Plant (WTP) at Hanford. Was on original recovery team from HQ for WTP in 2005-2006.
	<u>Peer Review Experts</u>						
6	Charlie Anderson	>35	X	X	X	X	Currently serving as General Manager of the TRU Waste Processing Center (TWPC), Oak Ridge, for processing and extended storage. Prior to this, supported Nuclear Waste Partners in recovery efforts at the WIPP.
7	Dr. Andy Kadak	>40	X			X	Served on the DOE Nuclear Waste Technology Review Board regarding high-level waste disposal. Is familiar with the challenges of WIPP and HLW waste disposal as well as NRC nuclear licensing and construction experience.
8	Steve Maehr	>35	X	X	X	X	Mr. Maehr is president, CEO, and co-founder of High Bridge Associates. He has led or participated in over 50 independent assessments of complex nuclear and process facilities.

KENNETH J. AUPPERLE

Mr. Aupperle is a High Bridge Senior Vice President and Management Consultant. He has over 40 years of experience in project and construction management, cost estimating, planning, scheduling, project controls, earned value, and risk management. His experience spans the design, construction, operation/maintenance, and outage/modification of commercial nuclear/fossil power, industrial, environmental, and U.S. Department of Energy (DOE) projects. He has managed/performed numerous high level consulting assignments providing independent detailed cost estimates; independent high level cost reviews, schedule and risk assessments; and due diligence reviews for large capital projects, Life Cycle Cost Estimates, operating/maintenance activities, and decommissioning/waste management programs. He has led multi-discipline teams of personnel spanning numerous locations and contractor organizations, producing effective results in dynamic environments amid multiple priorities and aggressive deadlines. Mr. Aupperle leads High Bridge development and maintenance of its nuclear industry cost and schedule data base, and its analysis of industry risk issues and contingency considerations. He has conducted research of cost/schedule/risk performance records for more than 100 US commercial nuclear and DOE science projects, and presented numerous Industry Lessons Learned presentations/papers at the American Nuclear Society and other industry forums. He is currently supporting or has recently supported various utility owner “New Nuclear” planning, organizing, risk management, and project deployment programs spanning numerous vendor OEM/EPC New Nuclear consortiums including Areva EPR; Mitsubishi APWR; GEH ESBWR; Toshiba ABWR; and Westinghouse AP1000. He consults as a Subject Matter Expert (SME) for the International Atomic Energy Agency (IAEA) for Project Management, Program Planning, and Integration on IAEA Planning/Training Missions for Member Nations. He has held positions of increasing responsibility including:

SENIOR VICE PRESIDENT & MANAGEMENT CONSULTANT: High Bridge Associates, 2004 to present – Responsible for providing planning, scheduling, estimating, project controls, construction management, independent reviews, process improvement, and risk management services to the energy, power, industrial, and government business sectors. He is responsible for developing High Bridge business opportunities, recruiting personnel, and managing contracts/activities for various customer projects.

PRESIDENT (2003/2004) & VICE PRESIDENT: Team Associates, 1995 to August 2004 - Assisted in developing Team as a planning, estimating, project controls, and project management consulting and professional service company. Established in 1994, Team grew to 200 employees working in over 20 states, with more than 40 active contracts and 2002 gross revenues of \$28 million. He managed corporate operations, developed new business, and directed consulting, construction and project management services.

VICE PRESIDENT & REGIONAL MANAGER: Stone and Webster, 1990 to 1994 – Responsible for profit/loss operations of a full-service engineering and construction corporate office in Chattanooga and serving a seven-state southeastern region. He led the development of a corporate business strategy, and managed the expansion of a project office to a 1,200 person regional operation, with 60 projects, 2,400 construction personnel, and an average of over \$500 million in annual gross revenues over four years.

DEPUTY DIRECTOR OF CONSTRUCTION AND MANAGER OF PROJECTS: Stone and Webster, 1988 to 1990 – He was assigned to a full service office in Cherry Hill, NJ and was responsible for the performance, profitability, quality, and safety of various construction projects in the southeast United States.

MANAGER OF CORPORATE COST ESTIMATING: Stone and Webster, 1983 to 1988 – He was assigned to the Boston headquarter office and he was responsible for managing the development and maintenance of project capital cost estimates, life cycle cost estimates, expenditure forecasts, performance measurement systems, and historical cost programs for nuclear projects valued in excess of \$20 billion.

PROJECT CONTROLS MANAGER/ENGINEER/SPECIALIST: Stone and Webster, 1971 to 1983 – He was assigned to various projects to implement construction management and project controls programs for various clients. This included New England Power; Niagara Mohawk; Gulf States Utilities; Illinois Power; TVA; and the DOE at Oak Ridge, Savannah River, Idaho Falls, Richland, and Lawrence Livermore.

RICHARD V. DRAKE

Mr. Drake has over 35 years of experience in the commercial nuclear power industry spanning design, construction, procurement, Project Management, startup, operation/maintenance, and outage/modification phases. He began his career working for Bechtel Power and held positions of increasing responsibility in support of construction, start up, outage, and continuing maintenance activities during the construction, commissioning, and operation of Palo Verde Nuclear Plant from 1978 to 1990. He held key department line management positions with the Tennessee Valley Authority Nuclear (TVAN) organization from 1990 to 2005 at each of the TVA Nuclear Sites and the corporate headquarters. He served as the construction manager for the completion of Watts Bar Unit 1 and Browns Ferry Unit 1 restart.

Since 2006, Mr. Drake has been a Vice President and Senior Consultant with High Bridge Associates. He has led multi-discipline teams of personnel spanning numerous locations and contractor organizations, producing effective results in dynamic environments amid multiple priorities and aggressive deadlines. He has worked supporting various Project Assessments and Project Management/Controls Deployment Planning Reviews for New Nuclear Projects. He led the High Bridge activities for STPNOC STP 3 & 4 supporting independent cost and schedule assessments of Toshiba and Fluor. Mr. Drake was Co-Lead on an Independent Project Assessment Team for Toshiba to review and critique Fluor's estimates for STP Units 3&4, which identified more than \$1 billion in potential reductions to the Fluor Estimate, and developed alternative strategies for contractual approaches for future contracting.

CHARLES W. HESS

Mr. Hess has over 35 years of experience in the power industry and has been involved with development, design, engineering, construction, operation, and decommissioning of various nuclear facilities. He is active with industry programs in preparation for new large and small reactor nuclear facilities, and is familiar with all nuclear technologies and NRC requirements. He is a recognized expert in light water reactors, sodium cooled fast reactors, and high temperature gas cooled reactors. He also has worked on pool-type research reactors, homogeneous aqueous reactors and Thorium based fuel cycles. He has designed fuel fabrication facilities, reprocessing facilities high-level waste vitrification facilities, and fuel storage facilities. He managed completion of engineering, operational support, and decommissioning projects for large and small energy facilities. With nearly 20 years in responsible positions for nuclear industry, he has a thorough understanding of owner and regulatory issues balanced with extensive EPC experience and constructability/maintainability issues. He is a Registered Professional Engineer in Pennsylvania, with a BS degree in Nuclear Engineering and has been a Certified Project Management Professional.

Mr. Hess was the co-chair of the American Nuclear Society (ANS) President's Special Committee on SMR Licensing Issues. The Committee is comprised of ANS members including representatives from SMR designers, developers, academia, industry, and government who are working to develop consensus on issues challenging the deployment of SMR technology. Mr. Hess is a frequent speaker at SMR and other nuclear technical conferences, has been quoted on SMR matters in various publications, and has testified before the House Energy and Commerce Committee regarding SMR issues.

Mr. Hess was the lead technical reviewer for CB&I's support team for the DOE's Advanced Reactor Concepts Program. He provided valuable feedback to National Lab personnel on the commercial implications of the advanced designs. As a result, he is thoroughly knowledgeable in all advanced reactor design concepts in terms of reactor design, fuel cycle development, accident tolerant fuel designs, fuel storage including dry storage options and deep borehole disposal. He was a lead engineer on the Advanced Liquid Metal Reactor program and on the GE-H Team for the Global Nuclear Energy Partnership.

Mr. Hess was part of the DOE team that negotiated the Plutonium Disposition Agreement between the Russians and the USA. He was responsible for developing and integrating the schedule of activities for developing the Russian MOX facilities and for coordinating with the US MOX program in the 1990s. He understands the issues surrounding plutonium disposition.

DR. MICHAEL D. HIGH

Dr. High has over 50 years of experience with advanced technology and first-of-a-kind (FOAK) projects/programs spanning research, development, demonstration, engineering, construction, operations, and maintenance in the power generation, environmental, and aeronautical industries. He has testified before various congressional subcommittees regarding environmental issues, acid rain legislation, and the U.S. Department of Energy's fossil and nuclear energy budgets. He chaired the Electric Power Research Institute's (EPRI) Environmental Research Division Advisory Committee and served for five (5) years as a member of the EPRI Research Advisory Committee (RAC). As a member of the EPRI Ad Hoc Committee on Advanced Reactor Programs (ARP), he provided policy and technical guidance on making light water reactors simpler and enhancing their safety features through the Advanced Light Water Reactor (ALWR) Utility Steering Committee.

Since 2000, Dr. High has worked extensively with High Bridge Associates as an Executive Consultant providing consulting services, technology assessments, and independent reviews. He has extensive technical, scientific, and financial analytical skills, and is accustomed to supporting large, complex, and multi-disciplined projects with numerous participants. He has performed independent project reviews, risk assessments, feasibility/due-diligence and life cycle cost studies for various commercial and Department of Energy (DOE) projects including:

- Evaluation/selection study of next generation nuclear reactor technologies from OEM/EPC suppliers (Areva/EPR, GE/ESBWR; Hitachi GE/ABWR; and Westinghouse/AP 1000), for the New Nuclear Plant Project for Entergy. (Commercial)
- Evaluation/selection study of next generation nuclear reactor technologies from OEM/EPC suppliers (Areva/EPR, GE/ESBWR; Hitachi GE/ABWR; and Westinghouse/AP 1000), for the Dominion Power Corporation. (Commercial)
- Red Team Westinghouse AP1000 Price Certainty review. (Commercial)
- Independent reviews of cost and risks for the NuScale SMR development. (Commercial)
- Feasibility of establishing a privately funded Fast Flux SMR. (Commercial)
- Risk assessment of the United States, Japan, South Korea, and Republic of China scope of work for the International Thermonuclear Experimental Reactor (ITER). (ITER and DOE)
- Development of Project Management Plans and identifying/quantifying project risks for the Mixed Oxide Fuel Fabrication Facility for Shaw Areva located at the DOE Savannah River Site (SRS) in SC.
- Performing an independent risk/contingency assessment of the Spallation Neutron Source (SNS) research accelerator project for the DOE at the Oak Ridge National Laboratory (ORNL).

Dr. High practiced in the field of aeronautical and aerospace engineering for nearly twenty years, first at Pratt & Whitney Aircraft Company and more extensively at the U.S. Air Force Arnold Engineering and Development Center located near Tullahoma, Tennessee. He joined the Tennessee Valley Authority (TVA) in 1980 for nearly nine years as Division Director responsible for all aspects of Research, Development, and Demonstration (RD&D) for the TVA electric power system. Under his direction, TVA pioneered wet limestone scrubbing technologies for the removal of sulfur dioxide. His division carried out the national research, development, and demonstration program for fluidized bed combustion of coals with high sulfur

content, culminating in the construction of a 160-megawatt demonstration power plant at the TVA Shawnee Steam Plant in Kentucky.

In 1988 Dr. High was appointed to the Burkett Miller Chair of Excellence in Management and Technology at the University of Tennessee at Chattanooga (UTC). Dr. High has served on numerous Boards, national committees, and directed several planning studies for the City of Chattanooga and Hamilton County. He served on the State of Tennessee's first Science and Technology Advisory Council being appointed to that council by Governor McWherter. Dr. High is a registered engineer in the State of Tennessee and the Commonwealth of Kentucky. He has over 50 articles published in national and international journals.

BARTH P. LONEY, PE, PMP, CM

Mr. Loney has more than 35 years of experience in program / project / engineering management serving in various positions with increasing responsibilities. As a Senior Vice President with High Bridge Associates, Inc., he has a history of successful project/program completions, implementations, reengineering and process improvements. He is an adept professional with the ability to work comfortably in diverse environments, handle multiple tasks simultaneously, and creatively address root causes to develop innovative solutions that have improved processes and contributed directly to bottom line performance. He is a Subject Matter Expert with extensive experience in Project Management, Earned Value Management, Risk Management, and Engineering and Construction Management. His industry experience includes nuclear power, construction and utility background, both in private and federal sectors. He has ten years of experience leading and participating in project reviews for the Department of Energy. He is familiar with multiple standards and requirement, including, but not limited to, DOE Order 413, PMBOK, and ANSI 748. Some recent assignments for High Bridge supporting multiple DOE Offices include:

- Oak Ridge National Lab (WAI) – TRU Waste Processing Center, Support General Manager in areas of Risk, Earned Value and Budget/Proposal development. Evaluating waste stream trends and cost for the project and budget forecasting options
- Office of Acquisition Project Management (Headquarters) – Led External Independent Review (EIR) team for the CD2/3 submittal of the K-27 D&D project at Oak Ridge. Also served as Risk SME for the review.
- Office of Environmental Management (Headquarters) – provided project controls expertise for a project involving research reactor fuels disposition.

CHARLIE E. ANDERSON

Over 33 years with increasing responsibilities in executive, technical, operations, program, and project management of nuclear materials disposition, nuclear materials production, nuclear waste management, and nuclear and coal fired power generation programs with **Los Alamos National Lab, Nuclear Management Partners, URS Corporation, Washington Group International**, the **Department of Energy** and the **Tennessee Valley Authority** covering laboratories and complex operating facilities from construction through decommissioning and demolition. Served in senior management positions as a key member of these organizations with responsibilities in leadership, management, oversight, strategic planning, and execution of startups, transitions, and problematic programs. Responsibilities have included annual budgets of \$6.2 Billion and workforces of 3,000 Federal and 30,000 contractor personnel. Work has typically involved bridging technical, business, and political agendas to solve problems in order to achieve programmatic and operational goals and objectives. Performance has always demonstrated a focus on progress and personal commitment. Have lead key cross cutting initiatives in most of these organizations, which includes commercial, government, international, and government contractor.

Currently, providing professional management services on an independent basis. Previously served as a Vice President to URS, providing management and programmatic strategic advice on major contracts. Prior to returning to URS corporate offices in Aiken, served as Associate Director of Nuclear & High Hazard Operations at Los Alamos National Lab, with broad responsibility for all facility operations at Los Alamos National Laboratory, including nuclear operations, safety basis, criticality safety, startup and restart, packaging and transportation, fire protection and engineering. Joined URS as General Manager of Nuclear Management Partners, the Management & Operations contractor consortium for the Sellafield operations in the northwest of England. Within the consortium, responsibility included serving as Business Unit Vice President with the Washington Division of the URS Corporation. Prior to joining URS in 2007, served as Principal Deputy Assistant Secretary of Environmental Management, with the DOE in Washington, DC. Provided innovative and sound leadership in a number of management positions at the Savannah River Site for the Department of Energy including Deputy Site Manager, Assistant Manager for High Level Waste; Director, Office of Defense Nuclear Nonproliferation; Director, Nuclear Materials Disposition; Director, Reactors and Spent Fuel Division; Director, High Level Waste Programs Division; and Director, Liquid Waste Division. In 1990, transferred from the Tennessee Valley Authority. Initially started career with the Tennessee Valley Authority as a construction project engineer at the Yellow Creek Nuclear Plant construction site. Relocated to the corporate engineering office in several system engineering positions which lead to Browns Ferry Nuclear Plant leading the system engineering efforts for a three unit operating nuclear plant. Last position with the Tennessee Valley Authority was Special Projects Manager at Browns Ferry Nuclear Plant with responsibility for the site program management of multi-discipline, site-wide problem recovery projects.

ANDREW C. KADAK, Ph.D.

Dr. Kadak has over 40 years of commercial nuclear experience and is President of Kadak Associates, Inc., a consulting firm specializing in management issues and nuclear energy. Prior to resuming his private consulting practice, Dr. Kadak was Principal and Director of Nuclear Services at Exponent, a worldwide company offering multidisciplinary expertise and rapid response capabilities to provide stewardship in addressing complex engineering and scientific problems. Dr. Kadak served on the IAEA special team assessing earthquake and tsunami damage of the Onagawa Nuclear Plant in Japan and has performed extensive studies of the Fukushima Dai-ichi Nuclear Plant.

Prior to joining Exponent, Dr. Kadak was a Professor of the Practice in the Nuclear Engineering Department of the Massachusetts Institute of Technology. His research interests include the development of advanced reactors, in particular the high temperature pebble bed gas reactor, space nuclear power systems, improved technology neutral licensing standards for advanced reactors and operations and management issues of existing nuclear power plants. Recently he was asked to serve on the Small Modular Reactor subcommittee of the Secretary of Energy's Advisory Board. His expertise ranges from reactor physics, power conversion, safety analysis and engineering systems. Dr. Kadak has recently been working on Hybrid Fusion Energy systems and sodium cooled fast reactors. He is also a principal author of the MIT fuel cycle study.

Dr. Kadak was also President and CEO of Yankee Atomic Electric Company. In this capacity, he was responsible for overseeing all Yankee operations, including the decommissioning of the Yankee plant in Rowe, Massachusetts and engineering, licensing, environmental and operational support to all eight nuclear plants in New England and many other national and international clients.

Dr. Kadak's expertise ranges from day to day operations of nuclear plants to senior executive management. In the past, he has lead Yankee Atomic in license renewal of operating reactors, systematic evaluation of older plants to allow them to demonstrate compliance to new regulations, financial rate proceedings to assure adequate capital for safe operation, innovative fuel purchase agreements, high level nuclear waste disposal

and storage solutions. His technical background has allowed him to actively direct the Yankee strategy dealing with reactor vessel embrittlement, boiling water reactor pipe replacements and how to manage aging of nuclear plants. At Yankee he managed the economic analysis of the value of continued operation of the Rowe plant. He presently consults on decommissioning of nuclear plants and has served on safety review boards of nuclear utilities.

Dr. Kadak was President of the American Nuclear Society in 1999/2000. He has served as a board and executive committee member of the Nuclear Energy Institute and the industry's Advisory Committee on High Level Waste. He has served as a member of the National Association of Regulatory Utility Commissioners special panel on high level nuclear waste and the Aspen Institute's "Dialogue on Nuclear Waste Disposal". In 1995, he was a member of the Advisory Committee on External Regulation of Department of Energy Nuclear Safety. He has also conducted several audits of nuclear companies to assess management and served as chairman of a panel providing suggestions to the DOE's Nevada Test Site as to how to make their operations more like commercial industries. Dr. Kadak was appointed by the President to serve on the US Nuclear Waste Technology Review Board. *He also served as a member of the Senior Nuclear Safety Oversight Board of the Daya Bay nuclear power stations in Guangdong Province in China* and served as a member of the Rhode Island Atomic Energy Commission. Dr. Kadak has made more than 70 lectures and speeches on topics related to the technical and business aspects of nuclear power.

STEVE R. MAEHR

Mr. Maehr is President, CEO, and co-founder of High Bridge Associates. He has more than 35 years of experience in Engineering, Project Management, and Executive leadership positions in the electric utility and management services industries. His principal areas of expertise include Strategic Planning, Business Development and Sales, Planning and Scheduling, Budgeting, Financial Planning and Accounting, Maintenance, Outage Management, Management Information Systems, Licensing, Engineering and System Testing. With degrees in Mathematics, Nuclear Engineering (BS) and Industrial Management (MS), he has held positions of increasing responsibility with electric utilities, management service contractors, and consulting/project management companies.

Mr. Maehr has a demonstrated record of accomplishment in developing opportunities and assisting customers with managing their projects, programs, and corporate operations. He is an entrepreneurial and strategic thinker, an excellent communicator, and a versatile leader. With his network of resources developed over the years by working with hundreds of owners, specialty contractors, and staff resources, he has an exceptional proficiency in assembling project teams to deliver "Just in Time" skills to customers, when and where they are needed.

APPENDIX I

High Bridge Review Team Resumes



High Bridge Associates, Inc.

KENNETH J. AUPPERLE

SUMMARY:

Mr. Aupperle is a High Bridge Senior Vice President and Management Consultant. He has over 40 years of experience in project and construction management, cost estimating, planning, scheduling, project controls, earned value, and risk management. His experience spans the design, construction, operation/maintenance, and outage/modification of commercial nuclear/fossil power, industrial, environmental, and U.S. Department of Energy (DOE) projects. He has managed/performed numerous high level consulting assignments providing independent detailed cost estimates; independent high level cost reviews, schedule and risk assessments; and due diligence reviews for large capital projects, Life Cycle Cost Estimates, operating/maintenance activities, and decommissioning/waste management programs. He has led multi-discipline teams of personnel spanning numerous locations and contractor organizations, producing effective results in dynamic environments amid multiple priorities and aggressive deadlines. Mr. Aupperle leads High Bridge development and maintenance of its nuclear industry cost and schedule data base, and its analysis of industry risk issues and contingency considerations. He has conducted research of cost/schedule/risk performance records for more than 100 US commercial nuclear and DOE science projects, and presented numerous Industry Lessons Learned presentations/papers at the American Nuclear Society and other industry forums. He is currently supporting or has recently supported various utility owner “New Nuclear” planning, organizing, risk management, and project deployment programs spanning numerous vendor OEM/EPC New Nuclear consortiums including Areva EPR; Mitsubishi APWR; GEH ESBWR; Toshiba ABWR; and Westinghouse AP1000. He consults as a Subject Matter Expert (SME) for the International Atomic Energy Agency (IAEA) for Project Management, Program Planning, and Integration on IAEA Planning/Training Missions for Member Nations. He has held positions of increasing responsibility including:

SENIOR VICE PRESIDENT & MANAGEMENT CONSULTANT: High Bridge Associates, 2004 to present – He is responsible for providing planning, scheduling, estimating, project controls, construction management, independent reviews, process improvement, and risk management services to the energy, power, industrial, and government business sectors. He is responsible for developing High Bridge business opportunities, recruiting personnel, and managing contracts/activities for various customer projects.

PRESIDENT (2003/2004) & VICE PRESIDENT: Team Associates, 1995 to August 2004 - He assisted in developing Team as a planning, estimating, project controls, and project management consulting and professional service company. Established in 1994, Team grew to 200 employees working in over 20 states, with more than 40 active contracts and 2002 gross revenues of \$28 million. He managed corporate operations, developed new business, and directed consulting, construction and project management services.

VICE PRESIDENT & REGIONAL MANAGER: Stone and Webster, 1990 to 1994 – He was responsible for profit and loss operations of a full-service engineering and construction corporate office, headquartered in Chattanooga and serving a seven-state southeastern region. He led the development of a corporate business strategy, and managed the expansion of a project office to a 1,200 person regional operation, with 60 projects, 2,400 construction personnel, and an average of over \$500 million in annual gross revenues over four years.

DEPUTY DIRECTOR OF CONSTRUCTION AND MANAGER OF PROJECTS: Stone and Webster, 1988 to 1990 – He was assigned to a full service office in Cherry Hill, NJ and was responsible for the performance, profitability, quality, and safety of various construction projects in the southeast United States.

MANAGER OF CORPORATE COST ESTIMATING: Stone and Webster, 1983 to 1988 – He was assigned to the Boston headquarter office and he was responsible for managing the development and maintenance of project capital cost estimates, life cycle cost estimates, expenditure forecasts, performance measurement systems, and historical cost programs for nuclear projects valued in excess of \$20 billion.

PROJECT CONTROLS MANAGER/ENGINEER/SPECIALIST: Stone and Webster, 1971 to 1983 – He was assigned to various projects to implement construction management and project controls programs for various clients. This included New England Power; Niagara Mohawk; Gulf States Utilities; Illinois Power; TVA; and the DOE at Oak Ridge, Savannah River, Idaho Falls, Richland, and Lawrence Livermore Lab.

High Bridge Associates (2004 to Present) and Team Associates (1994 to 2004)

Mr. Aupperle is a Senior Vice President and Management Consultant. He has managed Project Management, Project Controls, and Construction Management consulting assignments and staffing services for owner, engineer/constructor, and original equipment manufacturer customers in the US, United Kingdom, France, Japan, China, and South Korea. He leads the development of a High Bridge Nuclear Industry data base for historical/estimated costs, labor hours, bulk commodities, staffing, and schedule durations. He is responsible for developing High Bridge business opportunities, recruiting personnel, administering contracts, and managing activities for various projects. Representative Corporate Sponsor/Task Consulting assignments have included:

International Atomic Energy Administration (IAEA) – Subject Matter Expert (SME) for Project Management & Program Integration supporting IAEA Planning/Training Missions for Member Nations (2010 – Present)

NuScale Small Modular Reactor – Independent Cost Assessment, Program Planning, Organizing, and Initial Development of Risk Assessment Process (2010 - present)

ITER Fusion Project, ORNL and International Organization (IO) – Program Planning, Project Controls, Scheduling, Cost Estimating, Training, and Risk Management Support in Cadarache France. This included supporting development of the ITER Risk Assessment process and line of questioning, and leading stakeholder meetings and training with ITER representatives in the US, Japan, China, and South Korea. (2006 – Present)

Dominion New Nuclear Program – Program Planning, Organizing, Cost, Schedule, & Risk Studies for Evaluation of Vendor Proposals for Unit #3 at North Anna Station (2008 - 2012)

Duke Power Oconee Nuclear Station - Project Controls, Planning/Scheduling, & Project Management for the Oconee Plant Refurbishment & Life Extension Program (2000 – present)

Shaw Nuclear AP1000 Program – Program Planning, Organizing, Project Controls, Cost Estimating, Scheduling, and Risk Management support for the Westinghouse AP 1000 Program (2007 to 2012)

Westinghouse AP1000 New Nuclear Program – Program Planning, Organizing, Scheduling, and Systems Integration Support for Global Deployment of Eight (8) Plants in China and the US (2008 – 2012)

Unistar Calvert Cliffs #3 New Nuclear Program Support – Independent Assessment/Development of Construction Installation Manhour Unit Rates & Assessment of Owner Organization/Staffing (2008 - 2010)

American Electric Power (AEP), New Nuclear Program Support – Program Planning, Cost, Schedule, & Risk Evaluation Studies for Deployment of a New Unit #3 Nuclear Plant at DC Cook Station (2008 - 2010)

Project Controls Manager, Entergy New Nuclear Project – Program Planning, Organizing, Project Controls, Scheduling, Estimating, Risk Analysis, & Reactor Technology Evaluations for Grand Gulf #2 (2006 – 2008)

Mixed Oxide Fuel Fabrication Facility, Duke Cogema Stone & Webster – Program Planning, Scheduling, & Estimating Support; Earned Value System Readiness for Construction; Independent Schedule/Estimate Assessments; & Development/Implementation of Risk Management Program; (2003 – present)

Idaho Cleanup Project, CH2MHill Washington Group – Project Controls Transition Team & Independent Assessment, Scheduling Integration, Training, & Risk management Support (2005 – 2007)

Yucca Mountain Repository, DOE/Burns & Roe Project Team – Independent Cost Estimating Support & Assessments of Bechtel Project Estimating & Controls Activities (2004 – 2005)

Westinghouse UK, Springfields Fuel Plant & MAGNOX Sites – Developed & conducted orientation program with managers in preparation for transition under government Decommissioning guidelines (2004 – 2005)

Project Controls Process Improvement Initiative for GE Power – Development, Implementation, & Refinement of Global Web-based Project Controls System Platform (2002 – 2004)

British Nuclear Fuels Limited – Corporate Project Management Program Evaluation, Process Improvement, & Policy/Procedure Development Support (2001 – 2002).

Fissile Material Disposition Program (FMDP), Dept. of Energy Headquarters Office – Historical Cost Estimating Program Review & Support, Assessment of Technology Cost Impacts/Trends (2000 to 2002)

Advanced Mixed Waste Treatment Project (AMWTP), British Nuclear Fuels – Program Planning, Independent Estimate/Schedule Assessment of Design, Construction, & Operations (2000 - 2002)

Spallation Neutron Source (SNS) Accelerator Project, Oak Ridge National Lab – Program Planning, Cost Estimate/Contingency Risk Assessment, & Planning/Scheduling Review & Support (1998 – 2002)

Environmental Restoration Division, Savannah River Site - Baseline Estimate Validation Assessments, Project Management Training, & Independent Cost Estimating (1996 – 1998)

Pit 9-Mixed Waste Remediation Project, Idaho National Engineering Laboratory – Independent Assessment, Project Controls, Scheduling, Training, & Start-Up Planning (1995 – 1997)

Stone and Webster Engineering Corporation (1971 to 1994)

Mr. Aupperle had various assignments of increasing responsibility in project controls, estimating, and project/construction management on numerous projects involving power generation, technology research, defense nuclear materials production, and environmental remediation/waste management. In 1990, he was appointed Vice President and Southeast Regional Manager in Stone and Webster's Chattanooga, TN office covering projects and customers in seven states. With full profit and loss (P&L) responsibility, he:

- Exceeded corporate revenue and profitability goals for four consecutive years. Responsible for a \$6 million annual operating budget. Annual gross revenue averaged approximately \$500 million.
- Led a corporate marketing team comprised of managers from four (4) major offices, resulting in the award of contracts for more than three (\$3) billion dollars of new engineering and construction work.
- Surpassed annual marketing goals for new work awards and expanded the southeast regional organization to over 1,200 professional office personnel and 2,400 construction crafts.

In 1988, Mr. Aupperle was assigned as Deputy Director of Construction Operations in Stone and Webster's Cherry Hill, NJ office. In this position he was responsible for the quality and safety of activities on various construction and operating plant modification projects in the southeastern U.S. In 1983, he was assigned as Corporate Manager of Project Cost and Estimating in Stone and Webster's Boston headquarter office. He was responsible for directing the development and maintenance of project construction estimates, expenditure forecasts, earned value performance measurement systems, and actual cost historical programs for nuclear construction projects valued in excess of \$20 billion located around the country.

During the late 1970's, he was assigned to support Stone and Webster's development of the Nuclear Power Construction Stabilization Agreement (NPCSA), a strategic corporate collaboration with Gulf States Utilities, several other engineer/constructors, and the Building and Construction Trades of the AFL/CIO. From 1979 to 1982, he was Superintendent of Project Controls on the River Bend Nuclear Project, the only commercial U.S. nuclear power facility constructed completely under the provisions of the NPCSA. He was responsible for development and implementation of estimating, scheduling, cost control, earned value, performance measurement, and other construction management systems to support a fast track schedule based on utilizing the Alternating 4/10's shift-work approach. River Bend construction/startup was completed in 72 months, representing a 40-month schedule savings compared to industry norms of the time. Significant cost savings were achieved related to reducing escalation, interest during construction, and indirect/distributable activities driven by project duration. Principal assignments and positions have included:

VICE PRESIDENT AND REGIONAL MANAGER - South Regional Office, Chattanooga, TN.; Responsible for Profit and Loss (P&L) Performance of a Full Service Office (1990 – 1994)

DEPUTY DIRECTOR OF CONSTRUCTION AND MANAGER OF PROJECTS – Construction and Project Management Departments, Cherry Hill, NJ; Responsible for Department Activities (1988 – 1990)

MANAGER OF PROJECT COST DIVISION - Boston, MA; Responsible for Managing Project Estimating Cost Reporting, and Maintaining Historical Data for \$20 Billion in Capital Projects (1983 – 1988)

PROJECT MANAGER - US Dept. of Energy, Savannah River Site, Defense Waste Processing Facility, DWPF (1984 – 1990) and K-Reactor Restart and Operations (1988 – 1990). Provided Owner's Technical Engineering and Management Services and Oversight of M&O Contractor (Westinghouse Savannah River)

PROJECT ESTIMATING MANAGER - Lawrence Livermore National Lab; DOE Uranium Enrichment Program, Atomic Vapor Laser Isotope Separation Project, Conceptual Estimating (1984 – 1985)

PROJECT CONTROLS AND SCHEDULING MANAGER - DOE, Clinch River Breeder Reactor Project (CRBRP), Estimate and Schedule Development, Project Controls System Implementation (1982 – 1983)

SUPERINTENDENT OF COST AND SCHEDULING - Gulf States Utilities, River Bend Unit 1, Construction Management System Implementation (1979 – 1982)

CHIEF CONSTRUCTION PLANNING ENGINEER - Niagara Mohawk, Nine Mile Point Nuclear Station Unit 2, Construction Management System Implementation (1975 – 1979)

PROJECT PLANNING/SCHEDULING ENGINEER - New England Power, Salem Station #5, and Indianapolis Power and Light, Stout Station #7, Project Management System Implementation (1971 – 1975)

Department of Energy Summary

Mr. Aupperle has over 20 years of Project Controls, Project Management, and Construction Management experience with DOE programs and projects. He is accustomed to working in large multiple participant organizations involving emerging technologies, various disciplines, and numerous locations. He has a successful background in managing and providing technical, planning, estimating, scheduling, earned value, performance measurement, project management, and business operations support to major prototype projects involving physics research, energy and power generation, defense nuclear material production, high level waste management, and environmental remediation facilities. He held an active DOE “Q” Clearance from 1984 to 1994. He has a comprehensive knowledge of the DOE Savannah River Site (SRS), based on several management assignments supporting Defense Programs and High Level Waste Projects as follows:

- EXECUTIVE SPONSOR - R-Reactor Decontamination and Decommissioning (D&D) Project (1993 to 1994). He led a corporate initiative to develop a D&D Demonstration Project, based on an innovative Partnering and Integrated Organization approach with DOE, Stone and Webster, and BNFL, Inc.
- PROJECT MANAGER - Defense Waste Processing Facility (DWPF) Project (1984 to 1990). He managed a technical support services contract that provided a wide range of specialists to assist DOE with the oversight and management of this high level waste project. This included engineering, design, procurement, construction, startup, and commissioning tasks covering technical and management issues. He performed numerous cost estimate and schedule assessments at various project stages.
- PROJECT MANAGER - K-Reactor Restart and Operations Project (1988 to 1992). He managed a technical support services contract that provided a wide range of specialists to assist DOE with the oversight and management of this Defense Programs Project. This included various engineering, design, procurement, construction, startup, and commissioning tasks covering technical and management issues. He performed numerous cost estimate and schedule assessments at various project stages.

Other DOE Assignments Include the Following:

Principal Consultant, Mixed Oxide Fuel Fabrication Facility, Duke Cogema Stone & Webster – Independent Schedule and Estimate Assessments, Development/Implementation of Risk Management Program; Planning/Scheduling Support; Estimating Support; Project Controls/Earned Value System Readiness Upgrade for Transition to Construction (2003 – 2008)

Weapons Non-Proliferation Fissile Material Disposition Program (FMDP), Department of Energy Headquarters – Project Management, Project Controls, and Independent Estimating Support (2000 to 2002)

Advanced Mixed Waste Treatment Project (AMWTP), Idaho National Engineering Laboratory – Independent Estimate/Schedule Review for Design, Construction, and Operations (2000 -2004)

Spallation Neutron Source (SNS) Accelerator Project, Oak Ridge National Laboratory – Program Planning, Project Controls, Planning/Scheduling, Baseline Control, & Configuration Management (1998 – 2002)

Environmental Restoration Division, Savannah River Site - Baseline Estimate Assessment and Validation Reviews, Project Management Training, and Independent Cost Estimating (1996 – 1998)

Pit 9-Mixed Waste Remediation and Privatization Demonstration Project, Idaho National Engineering Laboratory – Project Controls, Scheduling, and Start Up Planning (1995 – 1997)

Nuclear Materials Production Division (NMPD), Savannah River Site – Assessment of Engineering Organization Functions, Processes, and Staffing (1995)

Hanford Waste Vitrification Plant (HWVP), Hanford Reservation in Richland – Estimate and Schedule Validation Reviews and Assessments (1987 – 1988)

Atomic Vapor Laser Isotope Separation Project (AVLIS), Lawrence Livermore National Laboratory – Estimating and Cost Baseline Development for Balance of Plant Systems (1984 – 1986)

Solvent Refined Coal Project (SRC 1), Alternative Fuel Demonstration Facility, Department of Energy – Schedule and Cost Estimate Development and Integration (1983)

Clinch River Breeder Reactor Plant Project (CRBRP), DOE Oak Ridge – Development and Integration of Cost/Schedule Baselines, and Construction Management System Implementation (1981 – 1983)

EDUCATION

Graduate Level Executive Certificate in Business Administration - Northeastern University, 1987
BS in Construction Management - Syracuse University, Summa cum Laude, 1971
AS in Construction Management - Hudson Valley Community College, Magna cum Laude, 1969
National Honor Society of Phi Kappa Phi, Syracuse University Chapter, 1971

PROFESSIONAL ASSOCIATIONS AND COMMUNITY ACTIVITIES

American Nuclear Society, ANS; -Member 2007 to Present
Association for the Advancement of Cost Engineering, AACE; -Member, 1975 to Present
U.S Department of Energy “Q” Clearance (Top Secret), active from 1984 to 1994
International District Energy Association (IDEA); -Member, 1998 to 2003
Chattanooga State Technical Community College; Curriculum Advisory Board 2010 to 2014; and Technical Advisory Board, Sustainable Technologies, 1999 to 2004
International Congress for Environmental Commerce and Technology (ICONECT)
-Member, Board of Directors and Strategic Planning Committee, 1993 to 1995
National Association of Local Government Environmental Professionals (NALGEP)
-Smart Growth Advisory Council Member, 1997 to 2001
Chattanooga Area Chamber of Commerce; Member, Board of Directors, 1993 to 1996
Greater Chattanooga Area United Way; Member, Board of Directors, 1993 to 1996

SELECTED PAPERS AND PUBLICATIONS

“Nuclear Industry Management Lessons Learned” - An Analysis of 20th and 21st Century New Nuclear Construction Projects; A Digest of Over 150 Industry White Papers and Assessments for Over 100 Projects; presented at the IAEA/Arab Atomic Energy Agency Project Management Workshop; Kuwait, April 2011.

“Developing Nuclear Project Invitations for Tenders and Evaluation of Proposals” – An Analysis and Outline of New Nuclear Power Project OEM/EPC Scope Planning and Preparation Approach; presented at the IAEA/Arab Atomic Energy Agency Project Management Workshop; Kuwait, April 2011.

“Nuclear Project Price/Schedule Definitization and Contract Negotiation” - An Analysis and Outline of New Nuclear Power Project OEM/EPC Scope Planning and Preparation Approach; presented at the IAEA/Arab Atomic Energy Agency Project Management Workshop; Kuwait, April 2011.

“Nuclear Industry Management Lessons Learned” - An Analysis of 20th and 21st Century New Nuclear Construction Projects; A Digest of Over 150 Industry White Papers and Assessments for Over 100 Projects; Nordic Nuclear Conference; Stockholm, December 2010.

“Nuclear Industry Challenges and Insights” - An Analysis of Current Project Controls and Planning Issues; Have We forgotten to Keep Things Simple and Less Is More; presented at the American Nuclear Society (ANS) Winter Meeting; Washington DC, November 2009.

“20th Century Lessons Learned in the Nuclear Industry” - A Critique of Root Causes for Failure and Success Required to Support the 21st Century Nuclear Renaissance; presented at the American Nuclear Society (ANS) Winter Meeting; Washington DC, November 2007.

“Smart Growth, Urban Sprawl, and Sustainable Development” - Partnerships Provide the Foundation for Economic Development and Environmental Stewardship; The Chattanooga Renaissance and SMART Park® Industrial Ecology Model; presented at the Policy Forum on Urban Sprawl for The Center for Environmental Studies; Budapest, Hungary April 2000.

“Keeping the Pace at River Bend” - Fast Track Planning and Construction Management under the Provisions of the Nuclear Power Construction Stabilization Agreement (NPCSA) and the Alternating Four-Tens Shift Work Approach; presented at the American Power Conference; Chicago IL April 1986.



RICHARD V. DRAKE

PROFESSIONAL SUMMARY

Mr. Drake has 32 years of experience in the commercial nuclear power industry spanning design, construction, procurement, Project Management, startup, operation/maintenance, and outage/modification phases. He began his career working for Bechtel Power and held positions of increasing responsibility in support of construction, start up, outage, and continuing maintenance activities during the construction, commissioning, and operation of Palo Verde Nuclear Plant from 1978 to 1990. He held key department line management positions with the Tennessee Valley Authority Nuclear (TVAN) organization from 1990 to 2005 at each of the TVA Nuclear Sites and the corporate headquarters. He served as the construction manager for the completion of Watts Bar Unit 1 and Browns Ferry Unit 1 restart.

Since 2006, Mr. Drake has been a Vice President and Senior Consultant with High Bridge Associates. He has led multi-discipline teams of personnel spanning numerous locations and contractor organizations, producing effective results in dynamic environments amid multiple priorities and aggressive deadlines. He has worked supporting various Project Assessments and Project Management/Controls Deployment Planning Reviews for New Nuclear Projects. He led the High Bridge activities for STPNOC STP 3 & 4 supporting independent cost and schedule assessments of Toshiba and Fluor. Mr. Drake was Co-Lead on an Independent Project Assessment Team for Toshiba to review and critique Fluor's estimates for STP Units 3&4, which identified more than \$1 billion in potential reductions to the Fluor Estimate, and developed alternative strategies for contractual approaches for future contracting.

EMPLOYMENT EXPERIENCE

(May 2006 to Present) High Bridge Associates / Work Management, Inc.

In the position of VICE PRESIDENT, REGIONAL MANAGER, EXECUTIVE MANAGEMENT CONSULTANT

Clients and assignments include:

- **Generation mPower**-TEAM LEAD on an independent assessment and analysis of New Build Nuclear Project oversight costs for completeness, accuracy, appropriateness of methodologies applied, as well as contingency and allowance applications.

- **Florida Power & Light, Turkey Point Nuclear Plant**-TEAM LEAD to provide an independent review and assessment for the Extended Power Uprate project to include cost, schedule, team strengths, outage readiness, and project maturity.
- **NuScale Power** – TEAM LEAD to Develop Program and Project Execution Plan
- **Kiewit Power Constructors** – TEAM LEAD on independent assessment of estimating processes, cost estimate, schedule, and comparative analysis for Small Modular Reactor Project.
- **South Texas Project Nuclear Operating Company, (STPNOC) Unit 3 & 4** – TEAM LEAD for an Independent assessment of cost and schedule of Toshiba America Nuclear Energy (TANE) and Fluor Constructors for the construction two nuclear units in South Texas.
- **Toshiba** – Seconded as CO-LEAD to review and critique the Fluor Constructors cost estimate to construct STP Units 3&4, which identified more than \$1 billion in potential reductions to the Fluor Estimate, and developed alternative strategies for contractual approaches for future contracting.
- **Dominion Power** – Independent assessment and parametric analysis of New Build Nuclear Project to include cost and schedule reviews of five nuclear technologies and EPC companies including Shaw, URS, Fluor, and Bechtel.
- **Riverland BioFuels** – Led Project Management Organization to complete 3 Million gallon ethanol plant.
- **TVA** – Led Project Management Organization to develop and complete a two-year recovery effort for the improvement of the 3-Unit 2500 MWe Paradise Steam Plant.
- **American Electric Power (AEP)** – MANAGEMENT CONSULTANT for the External Independent Review and Assessment of the Sargent and Lundy cost and schedule to construct a New Build Nuclear Plant at the DC Cook site.
- **AEP** – MANAGEMENT CONSULTANT to develop a parametric cost assessment of the current nuclear technologies.
- **Duke Power** – Led a team to review and assess the existing Project Management Organization processes and procedures. Based on findings from the assessment develop organizational and program requirements for the PMO.

(2002 to 2005)Tennessee Valley Authority, Browns Ferry Nuclear Plant, Unit 1 Restart, Decatur, AL

In the position of MAINTENANCE AND MODIFICATIONS MANAGER,

- Design Scheduling Engineering and Planning (DSEP) and Browns Ferry Unit 1 Restart Maintenance and Modifications Manager
- Developed the plan, schedule, resources, and negotiated the contracts for the maintenance and modifications required to restart BFNP Unit 1

Managed the resources for the implementation phase of BFNP Unit 1 Restart (over 1500 craft, 400 non-manual, annual budget greater than \$100M)

(2000 to 2002) Tennessee Valley Authority, Sequoyah Nuclear Plant, Soddy Daisy, TN

As MAINTENANCE AND MODIFICATIONS MANAGER, Units 1/2

- Managed all activities associated with the Maintenance and Modifications department at this dual-unit nuclear plant
- Both units were INPO 1, and during the 2002 evaluation both units were given a strength in maintenance for the period

(1996 to 2000) Tennessee Valley Authority, TVA Nuclear, Chattanooga, TN

In the position OF SENIOR MANAGER OF NUCLEAR PROJECTS AND CAPITAL CONTROLS

- Direct report to the Chief Nuclear Officer TVAN
- Managed the capital budget for TVAN
- Project Management at the TVAN sites reported directly to this position
- Responsible for project approval, project controls, and the development of five-year planning cycles at the TVAN sites

(1995 to 1996) Tennessee Valley Authority, TVAN, Chattanooga, TN

As MANAGER OF PROJECT MANAGEMENT TVAN

- Responsible for developing the project management process and guidelines for TVAN
- Developed project approval processes at the TVAN sites and TVAN corporate office

Direct report to the Vice President of Project Management for the Generating Group at the Tennessee Valley Authority.

(1994 to 1995) Tennessee Valley Authority, Watts Bar Nuclear Plant, Spring City, TN

In the position of CONSTRUCTION MANAGER WBNU1 UNIT 1 responsible for construction activities required to complete WBNU1. Managed construction resources and contracts. Direct report to the Senior Vice President WBNU1 Completion

(1991 to 1994) Tennessee Valley Authority, Sequoyah Nuclear Plant, Soddy Daisy, TN

As MANAGER OF PROJECT MANAGEMENT/PROJECT CONTROLS

- Responsible for project management and project controls, associated capital budget ranging from \$90M - \$120M per year
- Managed 12 – 15 project managers and 22 – 36 project control engineers
- Developed and implemented project approval process and project controls processes and policies

(1990 to 1991) Tennessee Valley Authority, Sequoyah Nuclear Plant, Soddy Daisy, TN

In the position of MODIFICATIONS FIELD SHIFT MANAGER

- Responsible for the implementation of plant modifications
- Developed the processes and procedures for Modifications Task Managers

(1978 to 1990) Bechtel Power Corporation, APS, Palo Verde Nuclear Plant, AZ

Construction, Start up, and Outage Activities

EDUCATION

(1992 to 1995) University of TN at Chattanooga

Attended Courses for a Master's Degree in Mathematics

- 26 course hours completed

(1990) Arizona State University, Tempe, AZ

Bachelor's Degree in Mathematics

- Graduated cum laude
- Lifetime member of Golden Key National Honor Society at Arizona State

PROFESSIONAL AFFILIATIONS

Project Management Institute

Institute of Nuclear Power Operations (INPO) Maintenance Managers



DR. MICHAEL D. HIGH

SUMMARY

Dr. High has over 50 years of experience with advanced technology and first-of-a-kind (FOAK) projects/programs spanning research, development, demonstration, engineering, construction, operations, and maintenance in the power generation, environmental, and aeronautical industries. He has testified before various congressional subcommittees regarding environmental issues, acid rain legislation, and the U.S. Department of Energy's fossil and nuclear energy budgets. He chaired the Electric Power Research Institute's (EPRI) Environmental Research Division Advisory Committee and served for five (5) years as a member of the EPRI Research Advisory Committee (RAC). As a member of the EPRI Ad Hoc Committee on Advanced Reactor Programs (ARP), he provided policy and technical guidance on making light water reactors simpler and enhancing their safety features through the Advanced Light Water Reactor (ALWR) Utility Steering Committee.

Since 2000, Dr. High has worked extensively with High Bridge Associates as an Executive Consultant providing consulting services, technology assessments, and independent reviews. He has extensive technical, scientific, and financial analytical skills, and is accustomed to supporting large, complex, and multi-disciplined projects with numerous participants. He has performed independent project reviews, risk assessments, feasibility/due-diligence and life cycle cost studies for various commercial and Department of Energy (DOE) projects including:

- Evaluation/selection study of next generation nuclear reactor technologies from OEM/EPC suppliers (Areva/EPR, GE/ESBWR; Hitachi GE/ABWR; and Westinghouse/AP 1000), for the New Nuclear Plant Project for Entergy. (Commercial)
- Evaluation/selection study of next generation nuclear reactor technologies from OEM/EPC suppliers (Areva/EPR, GE/ESBWR; Hitachi GE/ABWR; and Westinghouse/AP 1000), for the Dominion Power Corporation. (Commercial)
- Red Team Westinghouse AP1000 Price Certainty review. (Commercial)
- Independent reviews of cost and risks for the NuScale SMR development. (Commercial)
- Feasibility of establishing a privately funded Fast Flux SMR. (Commercial)
- Risk assessment of the United States, Japan, South Korea, and Republic of China scope of work for the International Thermonuclear Experimental Reactor (ITER). (ITER and DOE)
- Development of Project Management Plans and identifying/quantifying project risks for the Mixed Oxide Nuclear Fuel Fabrication Facility for Shaw Areva located at the Savannah River Site (SRS) in SC. (DOE)

MICHAEL D. HIGH

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- Performing an independent risk/contingency assessment of the Spallation Neutron Source (SNS) research accelerator project for the DOE at the Oak Ridge National Laboratory (ORNL).

Dr. High practiced in the field of aeronautical and aerospace engineering for nearly twenty years, first at Pratt & Whitney Aircraft Company and more extensively at the U.S. Air Force Arnold Engineering and Development Center located near Tullahoma, Tennessee. He joined the Tennessee Valley Authority (TVA) in 1980 for nearly nine years as Division Director responsible for all aspects of Research, Development, and Demonstration (RD&D) for the TVA electric power system. Under his direction, TVA pioneered wet limestone scrubbing technologies for the removal of sulfur dioxide. His division carried out the national research, development, and demonstration program for fluidized bed combustion of coals with high sulfur content, culminating in the construction of a 160-megawatt demonstration power plant at the TVA Shawnee Steam Plant in Kentucky.

In 1988 Dr. High was appointed to the Burkett Miller Chair of Excellence in Management and Technology at the University of Tennessee at Chattanooga (UTC). Dr. High has served on numerous Boards, national committees, and directed several planning studies for the City of Chattanooga and Hamilton County. He served on the State of Tennessee's first Science and Technology Advisory Council being appointed to that council by Governor McWherter. Dr. High is a registered engineer in the State of Tennessee and the Commonwealth of Kentucky. He has over 50 articles published in national and international journals.

EXPERIENCE

(2002 to Present) Management Consultant, High Bridge Associates, Inc.

Dr. High provides management consulting and technical support to various projects and FOAK programs. He has supported project development, marketing, and proposal activities for renewable energy, distributed generation, and industrial facilities. He has performed independent project reviews, risk assessments, and feasibility/due-diligence studies for various commercial and Department of Energy (DOE) projects including:

- The New Nuclear Plant Project for Entergy, as part of the Burns and Roe/High Bridge Owner's Engineer team. He was the Task Lead for performing an evaluation/selection study of Reactor Technologies and OEM/EPC suppliers, i.e. Areva/EPR, GE/ESBWR; Hitachi GE/ABWR; and Westinghouse/AP 1000.
- The International Thermonuclear Experimental Fusion Reactor (ITER), a > \$10 billion multi-national (i.e., the US, EU, Japan, China, South Korea, Taiwan, and Russia) facility located in France. He led a high level Risk Assessment for US Team scope of work supporting this project.
- The DOE Mixed Oxide Nuclear Fuel Fabrication Facility for Shaw Areva located at the Savannah River Site (SRS) in SC. This included development of Project Management Plans, identifying/quantifying project risks, and facilitating Risk Mitigation brainstorming and planning.

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- Performing an independent risk/contingency assessment of the Spallation Neutron Source (SNS) research accelerator project for the DOE at the Oak Ridge National Laboratory (ORNL).
- A renewable fuels/clean energy complex (SMART Park) for the City of Chattanooga, Tennessee.

(1996 to 2001) High Technologies Management, Inc. (HITEC)

As CHAIRMAN, CEO, and FOUNDER of a small consulting firm providing management analysis and support to government and private organizations. Some consulting efforts provided by HITEC include:

- Performed an assessment of the technical resources of the Department of Energy's Oak Ridge complex for the Hamilton County and City of Chattanooga. Made recommendations to the community of how to take advantage of those resources.
- Conducted a technical review and management assessment of a USAID project to develop coal research and development facilities in Indonesia. Made recommendations to the USAID Director and Indonesian's Minister of Technology and Science on how to salvage the project to meet the original objective of establishing the R&D facilities within the remaining financial resources.
- Conducted a technology assessment for USAID of the technical and economic readiness of a biomass gasifier feeding an aero-derivative gas turbine combined cycle electric generating plant for Brazil. Made recommendations to the USAID project staff as to the readiness of this technology.
- Conducted a study for the Tennessee Valley Authority for applying global positioning system (GPS) and geographical information systems (GIS) to their electric transmission and communication systems. Made recommendations to the Technology Applications Director of the cost benefit of applying these systems to TVA operations.
- Performed engineering, economic, and technical analyses for Team Associate's SMART Park study for River Valley Partners of Hamilton County and the City of Chattanooga. Analyzed the energy and water needs of industry and commercial buildings in the Southside of the City of Chattanooga. Made recommendations for equipment size and type to support a distributed central energy system for the Southside area. Made recommendations on the technical/economic feasibility of sharing water and energy resources among industries in the Southside area.

(October 1988 to 1996)

Professor and Burkett Miller Chair of Excellence, University of Tennessee (Chattanooga)

Dr. High taught engineering, design, and management courses. As the first holder of the Burkett Miller Chair of Excellence in Management and Technology, developed strategies to assist the University and the community to create new business opportunities, improve operations in existing businesses, and attract new businesses to the Chattanooga region.

As a professor in the School of Engineering, aided the Dean and faculty to define curriculum, exploit research opportunities, and set general strategies that helped UTC Engineering better fulfill its role in preparing engineering students for their profession. In this role participated in

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development of courses for the Master of Science in Engineering Management (MSEM). Personally responsible for development of and teaching the graduate MSEM course in “Technical Project Management.” Personally responsible for development of in the MSEM capstone course “Technology Management”. Lead role in refining the MSEM course “Advanced Engineering Economics” to meet student/industry needs. Was responsible for developing the proposal to establish a Doctor of Philosophy in Engineering program at the University of Tennessee at Chattanooga.

Assisted the Dean and faculty of the School of Business Administration to define curriculum that placed more emphasis on the relation between technology development and management. Maintained an active involvement in appropriate research activities and publication of technology-related matters. He served as a Member on the Board of Directors of the Tennessee Society of Professional Engineers, and as a Member of the Governor’s Advisory Council on Science and Technology, State of Tennessee. As a professor in the School of Computer Science and Engineering, aided the Dean and faculty to define curriculum, exploit research opportunities, and set general strategies that help UTC better fulfill its role in preparing engineering students for their profession. In this role participated in development of courses for the Master of Science in Engineering Management (MSEM). Maintained active participation in appropriate research activities and publication in technology related matters. While a Professor and Chair participated in the following organizations:

- Member of the State Board of Directors of the Tennessee Society of Professional Engineers (July 1989 to July 1992).
- Member, Governor’s Advisory Council on Science and Technology, State of Tennessee.
- General Chairman and Principal Organizer for the conference emphasizing opportunities and technology developments for environmental oriented businesses - Conference on Environment Commerce (CONEC ‘93) held in Chattanooga, Tennessee, October 1993.
- President of the Tennessee World Trade Center Board of Directors, (1991 to 1997).
- Member of the Hamilton County/City of Chattanooga economic development agency (Partners for Economic Progress - PEP) Board of Directors (July 1991 to July 1995).
- Member of the Greater Chattanooga Television Corporation, WTCI-TV, Board of Trustees, (July 1989 to July 1995 and July 1997 to present).
- Chair, community task force for developing long range environmental plans (1992).
- Chair, community task force, recycling plans for unused, urban industrial sites (1991).
- Member of Hamilton County/City of Chattanooga Regional Planning Commission Committee for Downtown Chattanooga Economic Study (January 1990 to July 1990).
- Consultant, U.S. Agency for International Development (USAID) Energy Research Laboratory for Indonesian (1990 - 1991).

(1980 to 1988) Division Director, Division of Energy Demonstrations and Technology, Tennessee Valley Authority (TVA) – Chattanooga, TN

The division was the principal Research, Development, and Demonstration (RD&D) division within the Office of Power of the Tennessee Valley Authority (TVA). Dr. High was responsible for corporate management planning and implementing the TVA power system R&D

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programs including fossil energy, nuclear energy, electricity end use applications, renewable energy sources, electricity transmission, and environment. This included managing internal TVA R&D budgets ranging from \$50 million to \$60 million a year. For several years, with projects funded by outside sources including direct U.S. Government appropriations and funds from the Department of Energy (DOE), the R&D budget was as large as \$100 million a year. Dr. High managed 250 to 350 division employees including 180 technical engineers and scientists. Managed all aspects of TVA's participation in the Electric Power Research Institute (EPRI). TVA's yearly contribution was approximately \$20 million.

A majority of TVA's electric generation capacity is produced by combustion of pulverized coal. A major part of TVA's research program was directed at producing technologies that mitigate the environmental effects associated with the burning of coal. Major research programs were carried out in the areas of reduction of gaseous emissions from burning pulverized coal, particularly sulfur dioxide and nitric oxides and better solid waste disposal technologies. He was responsible for developing the long-range plan, raising the funds, and conducting one of the largest technology efforts by any U.S. electric utility involving the development of atmospheric fluidized bed combustion (AFBC) for coal-burning power plants. This effort included the design, construction, and operation of a \$70 million pilot plant and the design and construction of a \$220 million commercial-size demonstration plant. Testified before several congressional subcommittees on environmental issues, acid rain legislation, and U.S. DOE fossil and nuclear energy budgets.

Dr. High served on several Electric Power Research Institute's Advisory Committee's including chairing the Environmental Research Division, five (5) years as a member of the Research Advisory Committee (RAC) and as a member of the Ad Hoc Committee on Advanced Reactor Programs (ARP). The Research Advisory Committee is responsible for formulating and approving all of the research programs for EPRI. The EPRI ARP was comprised of senior executives from several electric utilities who provided policy, strategy, and technical guidance on the U.S. DOE's Advanced Reactor Programs (SAFR, PRISM, and HGTR). The committee provided policy, strategy, and technical guidance on making current light water reactors simpler and enhancing their safety features through the ALWR Utility Steering Committee (senior vice-president of operations and plant superintendent-level participants).

(1964 to 1979) Engineering Supervisor, Branch Manager, and Research Engineer, Arnold Engineering and Development Center (AEDC) – Tullahoma, TN

From 1965 to 1979, he managed two separate branches, responsible for testing of U.S. Air Force weapons systems including satellite defense, re-entry vehicles, and aircraft. Supervised 50 to 100 technical personnel with approximately 50 to 100 support personnel. Supervised union trades and labor crafts personnel. Participated in developing Sverdrup Corporation business opportunities outside AEDC. (ARO, Inc. was a subsidiary of Sverdrup and Parcels Associates of St. Louis, Missouri, which later became Sverdrup Corporation.) The diversity of these assignments developed technical and personal skills necessary to manage people and highly technical installations from hands-on experience. Began to develop strategic planning capabilities.

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Was responsible for many research areas related to physical phenomena important to air and spacecraft development involving basic aeronautics; high temperature, ionized gases; heat transfer; magneto hydrodynamics; re-entry, ablation and ballistic characteristics; and simulation problems associated with sub-scale testing in ground test facilities. Supervised 7 to 15 scientific personnel with advanced degrees. Was responsible for development of management philosophy to complement technical skills.

As Research Engineer from 1964 to 1968, he worked on and resolved many problems associated with air and spacecraft development. Technical issues required knowledge of fundamental physical phenomena important to air and spacecraft development involving basic aeronautics; high temperature, ionized gases; heat transfer; magneto hydrodynamics; re-entry, ablation and ballistic characteristics; and simulation problems associated with sub-scale testing in ground test facilities. Performed technology assessments critical to technical facilities and organizations. Began publishing and presenting technical papers nationally and internationally.

EDUCATION

Ph.D. in Aeronautical Engineering, University of Oklahoma, **1967**

Masters of Science in Aerospace Engineering, University of Oklahoma, **1962**

Bachelors of Science in Aeronautical Engineering, University of Colorado, **1960**

Associates of Science in Engineering, Mesa Junior College, **1958**

PROFESSIONAL AFFILIATIONS

Registered Professional Engineer, State of Tennessee and Commonwealth of Kentucky

PUBLICATIONS

Selected Publications at the University of Tennessee at Chattanooga:

- Comprehensive View of Electric Utilities R&D Advanced Technologies in the United States, invited paper, Michael D. High and Dale T. Bradshaw, TVA, Japan Central Research Institute of Electric Power, Japan's Seventh Forum of Future Energy Technologies, Tokyo, **(1990)**.
- Assessment of Asbestos Insulation Substitutes in Fossil Fueled Plants, Prakesh Damshala, Michael D. High, Prem S. Chopra, and Phillip M. Kazemersky, EPRI Research Report **(1989)**.

Selected Publications at the Tennessee Valley Authority:

- Status of Atmospheric Fluidized-Bed Combustion for Electricity Generation, invited paper at the Sixth International Conference on Fluidized-Bed Combustion **(1980)**.
- Status of Atmospheric Fluidized-Bed Combustion for Electricity Generation, invited paper at the Ninth International Conference on Fluidized-Bed Combustion **(1986)**.

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- Atmospheric Fluidized-Bed Combustion, invited paper, Second Mid-Western Acid Rain Conference, Chicago, IL **(1986)**.
- Combustion Techniques and Global Warming, invited paper, **1987** Conference on Global Warming, Washington, D.C. **(1987)**.

Also, provided numerous testimonies in the Congressional Record as an expert witness before House of Representatives and Senate Committees and Subcommittees on environmental and energy issues. As the Director of Research and Development for the TVA power system, Dr. High led and provided oversight for the publication of approximately 20 research reports per year for eight years.

Selected Publications at the Arnold Engineering and Development Center:

- Pressure Coefficient on Cones at Large Angles of Attack, AIAA Journal TN, **1963**.
- Similarity Rules for Cones with Mass Injection, AIAA Journal TN, **1963**.
- Analytical Solutions for a Parallel Plate Electrostatic Probe, Ph.D. Thesis, University of Oklahoma **(1967)**.
- Compressible, Turbulent Boundary Layers with MHD Effects and Electron Thermal Nonequilibrium, Ninth Symposium on Engineering Aspects of Magneto hydrodynamics.
- Turbulent Boundary Layers with Electron Thermal Nonequilibrium and Finite Rate Ionization, Eleventh Symposium on Engineering Aspects of Magneto hydrodynamics.
- Turbulent Boundary Layers with Electron Thermal Nonequilibrium and Finite Rate Ionization, AIAA Journal, Vol. 10, No. 1.
- Acceleration of a Spherical Particle in a Uniform Gas Flow, AIAA TN, Vol. 9, No.5.
- Exhaust Plume Temperature and Reynolds Effects on Nozzle After body Performance Over the Transonic Mach Number Range, AGARD-CP-150, Proceedings on Airframe/Propulsion Interference, AGARD Fluid Dynamics Panel Symposium, Rome, Italy.
- Exhaust Plume Temperature and Reynolds Effects on Nozzle After body Performance Over the Transonic Mach Number Range □, AIAA Paper No. 74-481, AIAA/SAE 74 Propulsion Conference, San Diego, C.
- Transition Prediction Technique □, AIAA Journal TN, Vol. 12, No. 1
- Aircraft Turbine Engine Exhaust Emissions Under Simulated High Altitude, Supersonic Free Stream Flight Conditions, AIAA Paper No. 73-507, AIAA/AMS International Conference on Environmental Impact of Aerospace Operations in the High Atmosphere, Denver, CO. (Also article, AIAA Journal of Aircraft, Vol. 11, No.8).
- Velocity Temperature Relationships in Turbulent Boundary Layers with Non-Unity Prandtl Numbers, AIAA 9th Fluid and Plasma dynamics Conference, San Diego, CA (also published article in the International Journal of Mass and Heat Transfer).

Also, author or co-author of seven AEDC technical reports on fluid mechanics and ground testing.

High Bridge Associates, Inc.



CHARLES W. HESS

Summary

Mr. Hess has over 35 years of experience in the power industry and has been involved with development, design, engineering, construction, operation, and decommissioning of various nuclear facilities. He is active with industry programs in preparation for new large and small reactor nuclear facilities, and is familiar with all nuclear technologies and NRC requirements. He is a recognized expert in light water reactors, sodium cooled fast reactors, and high temperature gas cooled reactors. He also has worked on pool-type research reactors, homogeneous aqueous reactors and Thorium based fuel cycles. He has designed fuel fabrication facilities, reprocessing facilities high-level waste vitrification facilities, and fuel storage facilities. He managed completion of engineering, operational support, and decommissioning projects for large and small energy facilities. With nearly 20 years in responsible positions for nuclear industry, he has a thorough understanding of owner and regulatory issues balanced with extensive EPC experience and constructability/maintainability issues. He is a Registered Professional Engineer in Pennsylvania, with a BS degree in Nuclear Engineering and has been a Certified Project Management Professional.

Mr. Hess was the co-chair of the American Nuclear Society (ANS) President's Special Committee on SMR Licensing Issues. The Committee is comprised of ANS members including representatives from SMR designers, developers, academia, industry, and government who are working to develop consensus on issues challenging the deployment of SMR technology. Mr. Hess is a frequent speaker at SMR and other nuclear technical conferences, has been quoted on SMR matters in various publications, and has testified before the House Energy and Commerce Committee regarding SMR issues.

Mr. Hess was the lead technical reviewer for CB&I's support team for the DOE's Advanced Reactor Concepts Program. He provided valuable feedback to National Lab personnel on the commercial implications of the advanced designs. As a result, he is thoroughly knowledgeable in all advanced reactor design concepts in terms of reactor design, fuel cycle development, accident tolerant fuel designs, fuel storage including dry storage options and deep borehole disposal. He was a lead engineer on the Advanced Liquid Metal Reactor program and on the GE-H Team for the Global Nuclear Energy Partnership.

Mr. Hess was part of the DOE team that negotiated the Plutonium Disposition Agreement between the Russians and the USA. He was responsible for developing and integrating the schedule of activities for developing the Russian MOX facilities and for coordinating with the US MOX program in the 1990s. He understands the issues surrounding plutonium disposition.

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Work Experience

(2010 to 2015) CB&I Federal Services (Shaw Environmental and Infrastructure), Senior Project Manager

As a SENIOR PROJECT MANAGER he was the Project Manager for Shaw's participation in the Next Generation Nuclear Plant program working on Pebble Bed Module Reactors. He also was the Project Manager for a medical isotope reactor based on a homogenous aqueous reactor concept developed by B&W. When PBMR, Ltd. collapsed financially, he was responsible for developing, staffing, and managing a team to complete the deliverables needed for DOE to complete their assessment report by producing a Licensing Readiness Assessment and a cost estimate based on the German HTR 200 design. He was the capture manager for Small Modular Reactors to be sold in the Federal Business Sector. He identified the technical issues associated with sodium cooled fast reactors and identified design changes to be performed to better fit the reactor to the needs of the marketplace. He assisted the developer (High Bridge Energy Development, LLC) to conceptualize, develop, integrate, and prepare business cases for SMRs. Made presentations to the Army Corps of Engineers regarding SMRs on military bases. Was the Project Task Manager for the Support to Advanced Reactor Concepts Program to the DOE. Participated in third party reviews of DOE's ARC programs including fuel recycling approaches, Safeguards and Security by Design, advanced reactor concepts. He was the Project Manager for the EM² project with General Atomics that prepared a gap analysis in their design criteria document, developed a construction plan and a capital cost estimate.

(2008 to 2010) Tetra Tech, Director of Nuclear Engineering

In the position of DIRECTOR OF NUCLEAR ENGINEERING he provided direction to the conversion of the Tetra Tech design procedures and policy to make them compatible with the requirements and expectations of the nuclear industry. He was instrumental in identifying the tools necessary to enable a new entrant to the nuclear industry to compete and to prosper. He was responsible for identifying key staff members to position the Tetra Tech engineering in areas of extreme interest to the nuclear industry. Mr. Hess supported the effort to brand Tetra Tech's commercial nuclear capabilities by authoring or co-authoring numerous technical papers that highlighted Tetra Tech's understanding of complex nuclear management and design issues. He led the effort to install and to utilize Intergraph's Smart Plant design tool and used it to develop a detailed proposal to replace the condense at the Columbia Nuclear Stations that was complete with an animated 3D graphics presentation. Mr. Hess served as Co-Chair of the ANS President's Special committee on Small Reactor licensing issues. He was instrumental in advancement of small reactors design criteria and business cases.

(1996 to 2008) Burns and Roe Enterprises, Chief Nuclear Engineer/Program Manager

As CHIEF NUCLEAR ENGINEER, developed and managed the nuclear engineering staff to ensure career and professional development and to assist in the performance of design and modification work. Led the International Nuclear Safety Program for the DOE that provided, updated and improved safety system, structures and components to operating Soviet Era

CHARLES W. HESS

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designed Russian nuclear plants. These plants were in Russia, the Ukraine and Armenia. Modifications included “Flex” items like diesel-driven High Pressure Safety Injection pumps, improved DC Safety Related power systems., and advanced fire detection and suppression systems. Developed engineering tools and management systems to improve the efficiency and quality of engineering products. Took part in many external independent design reviews of DOE programs to ensure that the management systems and engineering approach were both adequate and well applied. Served as the Project Manager of the Entergy Nuclear’s Owner’s Engineering team for their new build program. Was the Project Controls manager for the Plutonium Disposition Program supporting the DOE negotiating team as they attempted to coordinate the technical programs of Russia and the USA in disposing of excess weapons plutonium.

(1976 to 1996) Burns and Roe Enterprises, Nuclear Engineer

As a NUCLEAR ENGINEER performed nuclear shielding analysis and design for various nuclear plants. Also, developed and designed nuclear radioactive waste processing systems for Forked River Nuclear Station and for the post-accident TMI-2 reactor recovery program. Led design teams to make modifications to operating nuclear plants including Oyster Creek, TMI1, Indian Point 3. Developed Design Basis Reconstitution documents for Oyster Creek, Limerick, Cooper and Indian Point 3. Was a lead engineer on the advanced liquid metal reactor program and for the development of several advanced nuclear designs for AP-600 and for the SBWR which were both predecessors to the AP-1000 and the ESBWR reactors. Successfully performed modifications to the Oyster Creek nuclear generating station and for the Indian Point 3 nuclear plants.

Education

B.S., Nuclear Engineering, Pennsylvania State University

Licenses & Certifications

Professional Engineer License, The Commonwealth of Pennsylvania
Certified Project Management Professional (PMI), 2003, Inactive, Nationwide



BARTH P. LONEY, PE, PMP, CM

PROFESSIONAL SUMMARY

Mr. Loney has more than 30 years of experience in program / project / engineering management serving in various positions with increasing responsibilities. As a Senior Vice President with High Bridge Associates, Inc., he has a history of successful project/program completions, implementations, reengineering and process improvements. He is an adept professional with the ability to work comfortably in diverse environments, handle multiple tasks simultaneously, and creatively address root causes to develop innovative solutions that have improved processes and contributed directly to bottom line performance. He is a Subject Matter Expert with extensive experience in Project Management, Earned Value Management, Risk Management, and Engineering and Construction Management. His industry experience includes nuclear power, construction and utility background, both in private and federal sectors. He has ten years of experience leading and participating in project reviews for the Department of Energy. He is familiar with multiple standards and requirement, including, but not limited to, DOE Order 413, PMBOK, and ANSI 748. Some recent assignments for High Bridge supporting multiple DOE Offices include:

- Oak Ridge National Lab (WAI) – TRU Waste Processing Center, Support General Manager in areas of Risk, Earned Value and Budget/Proposal development. Evaluating waste stream trends and cost for the project and budget forecasting options
- Office of Acquisition Project Management (Headquarters) – Led External Independent Review (EIR) team for the CD2/3 submittal of the K-27 D&D project at Oak Ridge. Also served as Risk SME for the review.
- Office of Environmental Management (Headquarters) – provided project controls expertise for a project involving research reactor fuels disposition.
- Office of Environmental Management (Paducah) – Performed review/assessment of project management documents for CD-1 submittal

EMPLOYMENT HISTORY

(2012 to 2014) High Bridge Associates. Invensys, Foxboro, MA/Beijing China

Provide project management expertise to the China Nuclear Project. This includes advising the Senior Management Team on matters regarding all aspects of program management. Personally prepared policy documents in the areas of Project Controls, Earned Value, Configuration Management and Risk Management. Assisted the director and manager of project controls in designing and implementing an integrated schedule for the eight China Nuclear units into a single program schedule, including resources loaded and logically tied. Direct the daily activities of two PMO offices, one in Foxboro and one in Beijing.

(July 2011 to 2012) Edgewater Technical Associates, ADNHHO, Los Alamos National Security

In the position of PROGRAM MANAGEMENT CONSULTANT provided Consulting Expertise for assisting the Nuclear High Hazard Operations Senior Program Management to clearly identify and track all program commitments that were not part of the daily operations activities already in the program schedule for the Los Alamos Nuclear Security, LLC. This includes advising the Assistant Laboratory Director's Staff, the Senior Management Team and Project Directors on matters regarding Program Management. As well as mentoring the members of the senior management team in matters of work control and planning...

(October 2003 to July 2011) High Bridge Associates, Inc., US DOE-EM, EM-62

As SUBJECT MATTER EXPERT provided Expertise for both Project Management and Project Control activities for the Department of Energy's Office of Environmental Management. This includes advising the Assistant Secretary's Staff, the Senior Management Team and Federal Project Directors on matters regarding Project Management, developing and implementing the federal project control program and process, and training for all federal project activities. This also includes direct support to all field offices across the DOE-EM complex as well as participating in multiple project reviews and assessments. All programs and activities are designed based on the Project Management Institutes PMBOK philosophies as well as applicable DOE and federal regulations. Most frequent areas addressed were Risk Management and Contingency analysis, Cost Estimating, Scheduling, Earned Value Management (Per the ANSI standard), and Resource Management. Both prepared policy implementation standards as well as performed audits against implementation methodology for 86 projects ranging in value from \$100M to \$20B.

(2000 to 2003) Varitek Industries, Houston, TX

As Program Manager, managed the development, design, and manufacture and testing of the telematics hardware and software products and services through subcontractors. Program management responsibility including baseline development, performance management and reporting to Senior Management and Board of Directors. Line management responsibility for all activities of the R&D, Product Development, QA, Engineering, Training, Manufacturing plus Customer Integration and Customer Service Departments. Design and implement the work processes for each department. Develop corporate policy for all operational activities. Personally prepared the startup baseline budget and baseline schedule for each division. Prepared integrated startup and business plan for the entire corporation. Drafted the policies and procedures for every department in the corporation.

(1998 to 2000) Triconex Systems, Inc., Houston, TX

In the position of SENIOR PROJECT MANAGER managed Controls Projects in the petrochemical and utility industries. Defined project scope and deliverables with client. Prepared project baseline plans, budgets and schedules. Led project teams of Engineers, Designers, and Technicians while providing technical guidance and approval of the hardware and software products. Presented project plans and status monitoring and reporting to senior management, both internal and customer. Directed Factory Acceptance Test and final customer approval of system. Provided technical oversight for customer at commissioning. Performed project close out and presented to Senior Management, including the final performance and profit analysis.

(1994 to 1998) Houston Light and Power, Wadsworth, TX

As DIRECTOR OF PROJECTS managed Plant Projects Division for utility industry. Designed and implemented the project management process for the plant. Personally managed multiple large capital projects that required executive management skill set due to large cost or high visibility with local municipalities. Also directed the activities of eight other project managers. Responsible for operating budgets of \$12 million and individual project budgets greater than \$20 million. Supervised daily activities of up to 225 employees. Developed and taught teambuilding classes to better network the project teams and to improve the overall project team performance.

(1993 to 1994) AEI, Columbus, GA

As ENGINEERING MANAGER – Engineering and Power Development Managed design evaluation and testing projects at the ***South Texas Nuclear Plant***. Prepared and presented project implementation plans to plant management team for approval. Supervised project teams of up to 25 engineers with project budgets up to \$4 million, including, providing technical direction and oversight. Performed business development activities.

(1991 to 1993) Bechtel Corporation, Athens, AL

In the position of MECHANICAL / NUCLEAR PROJECT ENGINEER managed Design Baseline Verification Project. Prepared project plans and presented them to Executive Management for approval. Directed activities of more than 75 Engineers, from electrical, chemical, mechanical and civil engineering disciplines, in Design Basis Reconciliation activities. Responsible for operating budget in excess of \$2 million with projects scopes up to 150,000 man-hours.

(1989 to 1991) Willo Products Co., Inc. Decatur, AL

As MANUFACTURING MANAGER managed the manufacture of control systems and modular steel products in the detention industry. Duties included long and short range planning, budget and schedule development, plus monitoring, development and implementation of the plant safety and quality programs, staying current on the latest manufacturing techniques and equipment and supervision of support personnel. Prepared and gave presentations on business practices and manufacturing techniques to the Board of Directors of the company and to other companies, community organizations, and business groups. The annual operating budget under my control was \$6-7 million dollars and was consistently ran 5-10% under budget.

(1982 to 1989) Tennessee Valley Authority

LEAD MECHANICAL ENGINEER: managed the Mechanical design organization and assisted the Project Engineer in supervising the activities for each of the various Engineering design groups. Reviewed and approved mechanical design documents to ensure compliance with the appropriate codes and standards.

1980 to 1982) Combustion Engineering, Chattanooga, TN

As ANALYTICAL ENGINEER performed structural engineering analysis on Westinghouse Nuclear Reactor pressure vessels, pressurizers, and piping.

(1976 to 1980) Chattanooga Boiler & Tank Chattanooga, TN

In the position OF PROJECT ENGINEER designed unfired pressure vessels per ASME and API codes. Prepared proposals and presented proposals to customers. Upon closing sale became the

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project manager for manufacturing, delivery and installation of pressure vessels at customer plant site.

EDUCATION

BSE, Mechanical Engineering, Thermal, University of Tennessee, **1982**

SOFTWARE/TOOLS

- Primavera P6 V8.2
- Microsoft Office
- Adobe Professional
- SAP

CLEARANCES / PROFESSIONAL LICENSES / CERTIFICATIONS

- US-DOE Q Clearance
- PMP Certification - PMI
- Registered Professional Engineer, Texas
- Senior Reactor Operator Certification -- NRC
- Certified Manager, Institute of Certified Professional Managers, James Madison University



CHARLIE E. ANDERSON

PROFESSIONAL SUMMARY

Over 33 years with increasing responsibilities in executive, technical, operations, program, and project management of nuclear materials disposition, nuclear materials production, nuclear waste management, and nuclear and coal fired power generation programs with ***Los Alamos National Lab, Nuclear Management Partners, URS Corporation, Washington Group International***, the ***Department of Energy*** and the ***Tennessee Valley Authority*** covering laboratories and complex operating facilities from construction through decommissioning and demolition. Served in senior management positions as a key member of these organizations with responsibilities in leadership, management, oversight, strategic planning, and execution of startups, transitions, and problematic programs. Responsibilities have included annual budgets of \$6.2 Billion and workforces of 3,000 Federal and 30,000 contractor personnel. Work has typically involved bridging technical, business, and political agendas to solve problems in order to achieve programmatic and operational goals and objectives. Performance has always demonstrated a focus on progress and personal commitment. Have lead key cross cutting initiatives in most of these organizations, which includes commercial, government, international, and government contractor.

Currently, providing professional management services on an independent basis. Previously served as a Vice President to URS, providing management and programmatic strategic advice on major contracts. Prior to returning to URS corporate offices in Aiken, served as Associate Director of Nuclear & High Hazard Operations at Los Alamos National Lab, with broad responsibility for all facility operations at Los Alamos National Laboratory, including nuclear operations, safety basis, criticality safety, startup and restart, packaging and transportation, fire protection and engineering. Joined URS as General Manager of Nuclear Management Partners, the Management & Operations contractor consortium for the Sellafield operations in the northwest of England. Within the consortium, responsibility included serving as Business Unit Vice President with the Washington Division of the URS Corporation. Prior to joining URS in 2007, served as Principal Deputy Assistant Secretary of Environmental Management, with the DOE in Washington, DC. Provided innovative and sound leadership in a number of management positions at the Savannah River Site for the Department of Energy including Deputy Site Manager, Assistant Manager for High Level Waste; Director, Office of Defense Nuclear Nonproliferation; Director, Nuclear Materials Disposition; Director, Reactors and Spent Fuel Division; Director, High Level Waste Programs Division; and Director, Liquid Waste Division. In 1990, transferred from the Tennessee Valley Authority. Initially started career with

CHARLIE E. ANDERSON

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the Tennessee Valley Authority as a construction project engineer at the Yellow Creek Nuclear Plant construction site. Relocated to the corporate engineering office in several system engineering positions which lead to Browns Ferry Nuclear Plant leading the system engineering efforts for a three unit operating nuclear plant. Last position with the Tennessee Valley Authority was Special Projects Manager at Browns Ferry Nuclear Plant with responsibility for the site program management of multi-discipline, site-wide problem recovery projects.

PROFESSIONAL HISTORY

(December 2013 to Present) High Bridge Associates, Greensboro, GA
MANAGEMENT CONSULTANT

(May 2013 to November 2013)URS Corporation
VICE PRESIDENT, GLOBAL MANAGEMENT & OPERATING SERVICES

(June 2009 to May 2013)URS Corporation, Los Alamos National Security, LANL, Los Alamos, NM
ASSOCIATE DIRECTOR/DEPUTY ASSOCIATE DIRECTOR, Nuclear & High Hazard Operations

(July 2008 to June 2009)URS Corporation, Nuclear Management Partners, Sellafield, Seascale, United Kingdom
GENERAL MANAGER

(October 2007 to July 2008)URS Corporation, Nuclear Management Partners, Sellafield, Seascale, United Kingdom
VICE PRESIDENT, ENERGY AND ENVIRONMENT

(May 2005 to October 2007)U.S. Department of Energy, Washington, DC Headquarters
PRINCIPAL DEPUTY ASSISTANT SECRETARY, Office of Environmental Management

(December 2004 to May 2005) U.S. Department of Energy, Washington, DC Headquarters
ACTING CHIEF OPERATING OFFICER, Office of Environmental Management

(June 2003 to December 2004)U.S. Department of Energy, Savannah River Operations Office, Aiken, SC
DEPUTY MANAGER FOR CLEANUP

(February 2001 to May 2003)U.S. Department of Energy, Savannah River Operations Office, Aiken, SC
ASSISTANT MANAGER, High Level Waste

(September 2000 to February 2001)U.S. Department of Energy, Savannah River Operations Office, Aiken, SC
DIRECTOR, Office of Defense, Nuclear Nonproliferation, NNSA

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(March 2000 to August 2000) U.S. Department of Energy, Savannah River Operations Office, Aiken, SC

ACTING DEPUTY ASSISTANT MANAGER for Material & Facility Stabilization

(September 1999 to March 2000) U.S. Department of Energy, Savannah River Operations Office, Aiken, SC

DIRECTOR, Nuclear Material Disposition Division

(July 1998 to September 1999) U.S. Department of Energy, Savannah River Operations Office, Aiken, SC

DIRECTOR, Nuclear Material Storage Division

(April 1997 to July 1998) U.S. Department of Energy, Savannah River Operations Office, Aiken, SC

DIRECTOR, Reactors and Spent Fuel Division

(December 1995 to April 1997) U.S. Department of Energy, Savannah River Operations Office, Aiken, SC

DIRECTOR, Programs Division

(February 1995 to December 1995) U.S. Department of Energy, Savannah River Operations Office, Aiken, SC

SPECIAL ASSISTANT to Assistant Manager for High Level Waste

(May 1993 to February 1995) U.S. Department of Energy, Savannah River Operations Office, Aiken, SC

DIRECTOR, Engineering Division

(June 1992 to May 1993) U.S. Department of Energy, Savannah River Operations Office, Aiken, SC

DIRECTOR, Liquid Waste Division

(May 1990 to May 1992) U.S. Department of Energy, Savannah River Operations Office, Aiken, SC

CHIEF, Tank Farm Branch

(April 1989 to May 1990) Tennessee Valley Authority, Browns Ferry Nuclear Plant, Athens, AL

SPECIAL PROJECTS MANAGER

(March 1986 to April 1989) Tennessee Valley Authority, Browns Ferry Nuclear Plant, Athens, AL

LEAD MECHANICAL ENGINEER

CHARLIE E. ANDERSON

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(November 1984 to March 1986) Tennessee Valley Authority, Browns Ferry Nuclear Plant, Athens, AL

STAFF SYSTEMS ENGINEER

(September 1981 to November 1984) Tennessee Valley Authority, Knoxville Corporate Offices

(September 1981 to November 1984)

MECHANICAL SYSTEMS ENGINEER

(December 1980 to September 1981) Tennessee Valley Authority, Yellow Creek Nuclear Plant, Iuka, MS

INSTRUMENTATION & CONTROLS CONSTRUCTION PROJECT ENGINEER

EDUCATION / PROFESSIONAL CERTIFICATIONS

- University of Tennessee - *January 1982 to June 1982*; postgraduate work in electromagnetic fields and transient analyses; no post graduate degree completed.
- Memphis State University - *September 1976 to December 1980*; Bachelor of Science in Mechanical Engineering; 3.41/4.0; cum laude; member of Tau Beta Pi Engineering Honor Society.
- Senior Technical Safety Manager Qualified
- *Q Clearance currently held.*



Andrew C. Kadak, Ph.D.

PROFESSIONAL SUMMARY

Dr. Kadak has over 40 years of commercial nuclear experience and is President of Kadak Associates, Inc., a consulting firm specializing in management issues and nuclear energy. Prior to resuming his private consulting practice, Dr. Kadak was Principal and Director of Nuclear Services at Exponent, a worldwide company offering multidisciplinary expertise and rapid response capabilities to provide stewardship in addressing complex engineering and scientific problems. Dr. Kadak served on the IAEA special team assessing earthquake and tsunami damage of the Onagawa Nuclear Plant in Japan and has performed extensive studies of the Fukushima Di-iachi Nuclear Plant.

Prior to joining Exponent, Dr. Kadak was s a Professor of the Practice in the Nuclear Engineering Department of the Massachusetts Institute of Technology. His research interests include the development of advanced reactors, in particular the high temperature pebble bed gas reactor, space nuclear power systems, improved technology neutral licensing standards for advanced reactors and operations and management issues of existing nuclear power plants. Recently he was asked to serve on the Small Modular Reactor subcommittee of the Secretary of Energy's Advisory Board. His expertise ranges from reactor physics, power conversion, safety analysis and engineering systems. Dr. Kadak has recently been working on Hybrid Fusion Energy systems and sodium cooled fast reactors. He is also a principal author of the MIT fuel cycle study.

Dr. Kadak was also President and CEO of Yankee Atomic Electric Company. In this capacity, he was responsible for overseeing all Yankee operations, including the decommissioning of the Yankee plant in Rowe, Massachusetts and engineering, licensing, environmental and operational support to all eight nuclear plants in New England and many other national and international clients.

Dr. Kadak's expertise ranges from day to day operations of nuclear plants to senior executive management. In the past, he has lead Yankee Atomic in license renewal of operating reactors, systematic evaluation of older plants to allow them to demonstrate compliance to new regulations, financial rate proceedings to assure adequate capital for safe operation, innovative fuel purchase agreements, high level nuclear waste disposal and storage solutions. His technical background has allowed him to actively direct the Yankee strategy dealing with reactor vessel embrittlement, boiling water reactor pipe replacements and how to manage aging of nuclear

plants. At Yankee he managed the economic analysis of the value of continued operation of the Rowe plant. He presently consults on decommissioning of nuclear plants and has served on safety review boards of nuclear utilities.

Dr. Kadak was President of the American Nuclear Society in 1999/2000. He has served as a board and executive committee member of the Nuclear Energy Institute and the industry's Advisory Committee on High Level Waste. He has served as a member of the National Association of Regulatory Utility Commissioners special panel on high level nuclear waste and the Aspen Institute's "Dialogue on Nuclear Waste Disposal". In 1995, he was a member of the Advisory Committee on External Regulation of Department of Energy Nuclear Safety. He has also conducted several audits of nuclear companies to assess management and served as chairman of a panel providing suggestions to the DOE's Nevada Test Site as to how to make their operations more like commercial industries. Dr. Kadak was appointed by the President to serve on the US Nuclear Waste Technology Review Board. *He also served as a member of the Senior Nuclear Safety Oversight Board of the Daya Bay nuclear power stations in Guangdong Province in China* and served as a member of the Rhode Island Atomic Energy Commission. Dr. Kadak has made more than 70 lectures and speeches on topics related to the technical and business aspects of nuclear power.

PROFESSIONAL EXPERIENCE

Kadak Associates, Inc.

1997 to Present

PRESIDENT

- Kadak Associates is a firm that specializes in decommissioning, licensing strategies, management reviews intending to improve competitiveness and effectiveness, organizational strategies for deregulation of the utility industry, safety assessments, license renewal, legal and political strategies, innovative solutions to tough problems, spent fuel management, public relations and communication, and adapting to changing regulatory environments.

Exponent

2010 to 2013

PRINCIPAL AND DIRECTOR OF NUCLEAR SERVICES

- At Exponent, Dr. Kadak applies his extensive experience in the nuclear industry to current problems facing operating nuclear plants and those proposed for construction.
- He leads the Nuclear Services practice to apply Exponent's skills to address problems of national and international significance.
- These areas include engineering fundamentals in mechanical, structural, metallurgical, chemical, electrical engineering.
- Additional areas include executive management consulting, construction, and operations covering such areas as risk, reliability, vulnerability and root cause analyses, and corrective action program development and assessment.
- Of significance to the nuclear industry, Dr. Kadak's responsibilities include regulatory strategy development and compliance assessment.

Massachusetts Institute of Technology

1997 – 2010

PROFESSOR OF THE PRACTICE

- Dr. Kadak supervised the modular high temperature gas reactor project and many graduate and undergraduate theses on many diverse topics from space nuclear power to nuclear powered container ships.
- He taught classes in design, engineering systems, operational reactor safety, and nuclear waste and engineering leadership.
- He also gave invited lectures on topics relevant to commercial nuclear power.

Kadak Associates, Inc.

1997 - 2010

President

- Kadak Associates is a firm that specializes in decommissioning, licensing strategies, management reviews intending to improve competitiveness and effectiveness, organizational strategies for deregulation of the utility industry, safety assessments, license renewal, legal and political strategies, innovative solutions to tough problems, spent fuel management, public relations and communication, and adapting to changing regulatory environments.

Yankee Atomic Electric Company

1979 - 1997

PRESIDENT AND CHIEF EXECUTIVE OFFICER (1989 - 1997)

- Oversaw the Yankee Nuclear Power Station operation and then decommissioning when the plant was permanently shutdown in 1992.
- Yankee also provides engineering and operations support for the Vermont Yankee, Maine Yankee, and Seabrook Nuclear Power Stations and other clients worldwide.
- Yankee was a \$ 100 million revenue company with over 500 professional staff with expertise ranging from engineering, environmental sciences, nuclear safety analysis, quality assurance, fuel procurement, inservice inspection and plant support.

VICE PRESIDENT (1986-88)

- Responsible for Nuclear Engineering, Environmental Engineering, Environmental Laboratory, Computer Services, Generic Licensing, and Commercial Sales.

PROJECT MANAGER, VERMONT YANKEE (1983-85)

- Managed engineering and licensing support for operation of the Vermont Yankee NPS (BWR).

PROJECT MANAGER, YANKEE NPS (ROWE) (1980-83)

- Directed engineering, capital projects, and licensing for the Yankee NPS.
- Managed Yankee's response to the NRC's Systematic Evaluation Program, for the oldest operating plant in the country.

ASSISTANT TO THE VICE PRESIDENT (1979-80)

- Coordinated emergency planning for the Yankee, Vermont Yankee, and Seabrook Nuclear Power Stations, performed post-TMI assessments of operating reactors, and represented Yankee on the Utility Waste Management Group.

New England Power Company

1975-1979

MANAGER, NUCLEAR INFORMATION

- Directed efforts to educate the public on nuclear power. Managed the informational, advertising, citizen coalition and political support for a new power plant project proposed for Rhode Island.

Combustion Engineering Corporation

1972-1975

PRINCIPAL PHYSICIST, PWR PHYSICS (1973-75)

- Concentrated on the operational control aspects of pressurized water reactors; formulated improved methods of reactor control and analysis; developed improved monitoring and safety protection systems; investigated reactor maneuvering capabilities and the application of space-time kinetics to safety analysis.

EDUCATION

Massachusetts Institute of Technology

- Ph.D., Nuclear Engineering - Reactor Physics (1972)
- M.S., Nuclear Engineering (1970)

Northeastern University - M.B.A. (1983)

Union College - B.S., Mechanical Engineering (1967)

PROFESSIONAL AFFILIATIONS AND HONORS

- US Nuclear Waste Technology Review Board, Member (past)
- Commissioner, Rhode Island Atomic Energy Commission
- President, American Nuclear Society, 1999-2000
- Nuclear Energy Institute - Board of Directors (past)
- Nuclear Energy Institute - Nuclear Waste Advisory Committee (past)
- American Nuclear Society (ANS) – President 1999/2000, Board of Directors, (past)
- Advisory Committee on External Regulation of DOE Nuclear Safety (member)
- Electric Power Research Institute Research Advisory Committee (past member)
- The University of Massachusetts Engineering Task Force (past member)
- Edison Electric Institute - past member of the Policy Committee on Energy Resources, past member of the Nuclear Power Executive Advisory Committee
- Electric Council of New England - Board of Directors (past)
- New England Council - Board of Directors (past)
- Nuclear Utility Management and Resources Committee (NUMARC) - past member of the Issues Management Committee Board of Directors, and Executive Committee
- Northeast Section of the American Nuclear Society, Tau Beta Phi, Sigma Xi
- Member of the Industry Review Group on the Chernobyl Accident

SELECTED PAPERS AND LECTURE TOPICS

PAPERS IN REFEREED JOURNALS LIST

1. Kadak, A.C., Freidberg, J.P. “ Fusion-fission hybrids revisited”, *Nature Physics*, June 2009, Vol. 5
2. Kadak, A. “ MIT Pebble Bed Reactor Project”, *Nuclear Engineering and Technology*, 39 (2), 2007, pp. 95-102.
3. Kadak, A.C., “A Future for Nuclear Energy: Pebble Bed Reactors”, *International Journal of Critical Infrastructures*, Vol. 1 No. 4, 2005, pp. 330-345.
4. Kadak, A.C., “Intergenerational Risk Decision Making: A Practical Example”, *Risk*, Vol. 20, No. 6, 2000, pp. 883-894.
5. Kadak, A.C., Matsuo, T., “The Nuclear Industry’s Transition To Risk Informed Regulation and Operation in the United States”, *Reliability Engineering and System Safety*, Vol. 92, Issue 5, May 2007, pp. 609-618.
6. Kadak, A.C., Zhai, T., “Air Ingress Benchmarking with Computational Fluid Dynamics Analysis”, *Nuclear Engineering and Design*, Vol. 236, Issue 5-6, March 2006.
7. Kadak, A.C., Berte M.V., “Advanced Modularity Design for the MIT Pebble Bed Reactor”, *Nuclear Engineering and Design*, Vol. 236, Issue 5-6, March 2006.

OTHER MAJOR PUBLICATIONS

8. Kadak, A.C, Berte, M.V. “Modularity Design of the MIT Pebble Bed Reactor”, American Nuclear Society Meeting, Reno, Nevada. November 2001.
9. Kadak, A.C., “An Advanced Nuclear Power Plant That Can Compete With Natural Gas”, Electric Power 2001 Conference Proceedings, March 21, 2001.
10. Kadak, A.C., “The MIT Modular Pebble Bed Reactor Project”, Seminar on HTGR Application and Development conference proceedings, Beijing, China, March 19, 2001.
11. Zhai, No, Kadak, “LOCA Analysis in a Pebble Bed Reactor”, American Nuclear Society paper submitted for June 2001 meeting in Milwaukee, Wi.
12. Kadak, A.C, Berte, M.V., “Advanced Modularity Design for the MIT Pebble Bed Reactor”, 2nd International Topical Meeting on High Temperature Reactor Technology, September 22-24, 2004, Beijing, China.
13. Kadak, A.C., Zhai, T., “Air Ingress Benchmarking with Computational Fluid Dynamics Analysis”, 2nd International Topical Meeting on High Temperature Reactor Technology, September 22-24, 2004, Beijing, China.
14. Kadak, A.C., Feng, B., “Conceptual Design of an Advanced Breeder Burner Reactor”, American Nuclear Society, June 2007.
15. Kadak, A.C., “Nuclear Power: Made in China”, *The Brown Journal of World Affairs*, Vol. XIII, Issue I, Fall/Winter, 2006.
16. Kadak, A.C., “Reconsidering Nuclear Power”, *Science Year Book* 2003, pp. 68-83.
17. Kadak, A.C., Bazant, M.Z., “Pebble Flow Experiments for Pebble Bed Reactors”, 2nd International Topical Meeting on High Temperature Reactor Technology, September 22-24, 2004, Beijing, China.
18. Kadak, A.C., “Establishing a Safety and Licensing Basis for Generation IV Advanced Reactors”, Workshop on Advanced Reactors, Advisory Committee on Reactor Safeguards, June 4-5, 2001.

19. Kadak, A.C, Brudieu, M.A, “Blind Benchmarking Predictions of NACOK Air Ingress Tests Using Computational Fluid Dynamics, 3rd International Topical Meeting on High Temperature Reactor Technology, October 1-4, 2006, Johannesburg, South Africa.
20. Kadak, A.C., Finan, A.E, Miu, K., “Nuclear Technology & Canadian Oil Sands: Integration of Nuclear Power with In-Situ Oil Extraction”, International Congress on Advances in Nuclear Power Plants, June 4-8, 2006, Reno, Nevada.
21. Kadak, A.C, Finan, A.B, “Integration of Nuclear Energy with Oil Sands Projects for Reduced Greenhouse Gas Emissions and Natural Gas Consumption”, MIT CANES white paper, June 2007.
22. Kadak, A.C., “Licensing and Deployment of Advanced Reactors” , American Nuclear Society Annual Meeting, June 2002.
23. Kadak, A.C., “An Advanced Nuclear Power Plant That Can Compete with Natural Gas”, Electric Power 2001 Conference, March 21, 2001.
24. V. Dostal, K. Gezelius, J. Horng, J. Koser, J.P. Iv, E. Shwageraus, P. Yarsky, and A.C. Kadak, "Mission to Mars: How to Get People There and Back with Nuclear Energy" (September 2004), MIT-NSA-TR-001
25. P. Yarsky, A.C. Kadak, and M.J. Driscoll, "Design of a Sodium-cooled Epithermal Long-term Exploration Nuclear Engine" (September 2004), MIT-NSA-TR-002
26. T. Zhai, A. Kadak, and H-C. No, LOCA and Air Ingress Accident Analysis of a Pebble Bed Reactor (March 2004), MIT- ANP-TR-102.
27. T.A. Galen, D.G. Wilson, and A.C. Kadak, Comparison Between Air and Helium for Use as Working Fluids in the Energy-Conversion Cycle of the MPBR (February 2001)

SELECTED INVITED LECTURES

- Woodrow Wilson International Center for Scholars, May 8, 2008 – Current and Future Prospects for Civilian Nuclear Power: US and Japanese Perspectives”, Washington, D.C.
- Manhattan Institute, New York City – Nuclear Energy Options, March 28, 2007.
- American Physical Society Conference - Nuclear Renaissance, October 31, 2006
- Westinghouse/BNFL, “MIT’s Pebble Bed Reactor Research” May 11, 2001, Monroeville, PA.
- Bettis Atomic Power Laboratory, “MIT Fuel and Safety Research”, May 11, 2001
- New England Council of Public Utility Commissioners, “The Inevitability of Nuclear Energy”, May 21, 2001, Mystic CT.
- Council of Scientific Society Presidents, “Advanced Nuclear Energy Plants – The Pebble Bed Reactor”, May 6, 2001, Washington, DC
- University of Rhode Island, “China’s Nuclear Energy Program”, December 2013
- Nuclear Innovation Alliance Workshop, Washington DC, “Technology Neutral Risk Informed Licensing Approaches and a Proposal”, October 2015
- World Nuclear Fuel Market Conference, New York City, “Nuclear Power Construction Programs – Can We Do It Again?” June 2014
- 45th Annual Meeting on Nuclear Technology, Frankfurt Germany, “US Decommissioning Experience”, May 2014
- Japan Atomic Industrial Forum, “The Environmental Imperative of Nuclear Energy – Despite the Challenges”, Tokyo, Japan, April 2014
- Department of Energy, Nuclear Energy Research Advisory Committee, Washington, DC, “Views and Priorities on Advanced Reactor Research and Development” January 2015.

- MIT Energy Conference, Cambridge MA, “Nuclear Power Plants – Will there be 6 or 60?”, April 2008.
- 6th Annual Technical VHTR Review Meeting 2013, Idaho Falls, “Nuclear Innovation in High Temperature Gas Reactors” May 2013
- SELECTED MANAGEMENT PRESENTATIONS
- "Airplanes Are Different - The Management Challenge," ANS Annual Meeting, New Orleans, Louisiana, June 1994.
- "The Safety Goal as a Regulation," ANS Executive Conference, Washington, D.C., March 1994.
- "Self Assessment - A Challenge to Human Nature," ANS Conference, San Diego, California, November 1993.
- "Engineering Excellence," ANS Executive Conference on Engineering Excellence, Jupiter Beach, Florida, October 1993.
- "The Quality of Management - The Next Self Assessment Challenge," American Nuclear Society Executive Conference, Self Assessment for Self Assurance, La Jolla, California, December 1990.
- "Excellent and Economic Nuclear Plant Performance Conference," ANS/ASME Joint Conference, Newport, Rhode Island, September 1990.
- "Promoting Professionalism and Credibility in the Engineering Organization," INPO Workshop, Atlanta, Georgia, May 1990.
- "What's a Safety Culture? How do I Get It? How Do I Keep It?" Presented to the Nuclear Nonoperating Owner's Group, Boston, September 1989.
- “Is Technology Enough? What About Management?,” 16th Reactor Operations International Topical Meeting, August 1993.

SELECTED OTHER LECTURES AND PRESENTATIONS

- “Generating Companies, An Idea Whose Time Has Come...Again,” Nuclear Engineering International, September 1989.
- “Utilities of the 1990's - Generators of Cash or Electricity?,” American Nuclear Society Executive Conference on Utility Management Strategies of the 1990's, April 1989.
- “Institutional Investors Conference on Economics of Older Nuclear Power Plants,” Lehman Brothers, New York, March 1992.
- “The Atom and Human Values,” 60th Steinmetz Memorial Lecture, Union College, October 1992.
- “How to Decide to Shut Down a Nuclear Plant Prematurely,” NUMARC panel presentation, October 1992.
- “How Long Will the Current Nuclear Power Reactors Operate?,” MIT October 1993.
- “The Safety Goal as a Regulation,” ANS Executive Conference, March 1994.
- “Yankee’s Decommissioning Program,” NRC Regulatory Information Conference, May 1994.
- “High Level Waste Legislation,” New England Conference of Public Utility Commissioners, March 1995
- “The Science and Politics of High Level Waste,” International Conference on High Level Radioactive Waste Disposal, May 1996.



STEVE R. MAEHR

SUMMARY

Mr. Maehr is President, CEO, and co-founder of High Bridge Associates. He has more than 35 years of experience in Engineering, Project Management, and Executive leadership positions in the electric utility and management services industries. His principal areas of expertise include Strategic Planning, Business Development and Sales, Planning and Scheduling, Budgeting, Financial Planning and Accounting, Maintenance, Outage Management, Management Information Systems, Licensing, Engineering and System Testing. With degrees in Mathematics, Nuclear Engineering (BS) and Industrial Management (MS), he has held positions of increasing responsibility with electric utilities, management service contractors, and consulting/project management companies.

Mr. Maehr has a demonstrated record of accomplishment in developing opportunities and assisting customers with managing their projects, programs, and corporate operations. He is an entrepreneurial and strategic thinker, an excellent communicator, and a versatile leader. With his network of resources developed over the years by working with hundreds of owners, specialty contractors, and staff resources, he has an exceptional proficiency in assembling project teams to deliver “Just in Time” skills to customers, when and where they are needed.

PROFESSIONAL SUMMARY

(July 2003 to Present) High Bridge Associates, Inc. and Work Management, Inc.

In the role of PRESIDENT responsible for all aspects of business operations for a management services company providing consulting and project management services to Oil & Gas, Electric Utility, Information Technology and Government industries. Operational control spans all phases of business and new product development, strategic planning, recruiting, management of consulting and service projects, and profit and loss. Provides management consulting for process reengineering and management control system development.

(July 2001 to June 2003) Team Associates, LLC.

As PRESIDENT responsible for all aspects of business operations of a GE affiliate company operating under Granite Services, Inc. and providing consulting and project management services to the utility, architect-engineering, construction and government industries. Operational control spans all phases of business and new product development, strategic planning, recruiting, management of consulting and service projects, and profit and loss.

(December 1994 to June 2001) Team Associates Inc., Norcross, GA

As SENIOR VICE PRESIDENT responsible for project and business management of consulting and management control services company. Grew the company from origination to \$19 MM annual revenue over a six-year period. Operational control spans all phases of business and new

product development, strategic planning, recruiting, management of consulting services and service projects, and profit and loss for assigned business lines. Provides management consulting for process reengineering and management control system development. Recent experience includes: Development of integrated restart schedules, outage management processes, and work control processes for shutdown nuclear power plants (Browns Ferry, Cooper, Dresden, LaSalle, DC Cook); development of a comprehensive baseline estimate and schedule for the demolition and decontamination of DOE's Uranium Enrichment Facility at Oak Ridge, TN; assessments of engineering processes, environmental restoration Life Cycle Cost Estimates, operations & maintenance activities, and project control processes for DOE's Hanford, Savannah River, & Oak Ridge Sites; and numerous management assessments for large electric utilities.

(October 1989 to December 1994) The Spear Group Inc., Norcross, GA

In the position of VICE PRESIDENT responsible to the President to ensure the successful acquisition, control, and execution of all assigned projects. Specific duties included all aspects of day-to-day operations, including client relations and fiscal accountability. Responsible for long-range planning and development of company goals and objectives. Performed consulting services in the power generation, construction, and government defense and energy industries. Specific experience includes project management and technical oversight for the development of an activity based budgeting and accounting process for a major western utility, development of integrated cost and schedule processes for the maintenance and operating contractor for a DOE facility, and development of project cost estimates, schedules, and management control processes for the restart effort of a shutdown nuclear power plant.

(August 1978 to September 1989) TVA, Browns Ferry Nuclear Plant, Decatur, AL

As WORK CONTROL/ OUTAGE SUPERINTENDENT responsible for managing all activities associated with unit outages including defining scope, planning, scheduling and implementation. Orchestrated all plant activities associated with the restart program for the first unit to be brought back into service. Also responsible for defining and implementing the process controlling day-to-day work activities to ensure compliance with plant licensing requirements and the achievement of schedule milestones.

(September 1985 to December 1988) TVA, Browns Ferry Nuclear Plant, Decatur, AL

As MANAGER, SITE PROJECT CONTROLS & FINANCIAL SERVICES was responsible for project management, planning, scheduling, budgeting, materials management and accounting functions for all site organizations. Organized and staffed a department which performed all project control functions for a site of over 6,000 employees and annual budgets to \$500M. Developed and implemented the first procurement engineering group utilized within TVA to ensure material procured for maintenance and modification activities complied with safety and quality requirements of the design basis.

(April 1984 to September 1985) TVA, Browns Ferry Nuclear Plant, Decatur, AL

As PLANNING AND SCHEDULING SUPERVISOR responsible for unit outage, maintenance and periodic test planning and scheduling for a three unit nuclear power plant. Developed and implemented an organization with responsibility for building new scheduling, tracking and management information data bases for all maintenance, engineering, and modification activities on site.

(April 1983 to April 1984) Sequoyah Nuclear Power Plant, Soddy Daisy, TN

STEVE R. MAEHR

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As ASSISTANT OUTAGE DIRECTOR Responsible for the planning, scheduling and implementation of modifications and major maintenance activities for a two-unit nuclear power plant. Developed and implemented new planning programs that resulted in significant improvements in unit outage durations previously experienced. Chattanooga Corporate Office

(May 1981 to April 1983) TVA, Sequoyah Nuclear Power Plant, Soddy Daisy, TN

As REGULATORY GROUP SUPERVISOR responsible for power plant licensing interface with other TVA organizations and with the Nuclear Regulatory Commission. Developed and implemented a program involving technical review of nuclear events and experiences from other utilities. Developed an extensive knowledge of the overall design basis, operating practices, and regulatory framework involved with licensing and operating a nuclear power plant.

(December 1979 to May 1981) TVA, Sequoyah Nuclear Power Plant, Soddy Daisy, TN

In the position of NUCLEAR ENGINEER worked in the plant startup test program, operational and design change safety evaluations and the development and review of the TVA Action program in response to the Three Mile Island accident. Responsible for development of a special test program involving natural circulation tests never before performed at a commercial nuclear plant.

(August 1978 to December 1979) TVA, Sequoyah Nuclear Power Plant, Soddy Daisy, TN

In the position of PRE-OPERATIONAL TEST ENGINEER worked in the pre-op test program including researching, inspecting, coordinating, and testing of nuclear plant systems. Developed an in-depth knowledge of all phases of system testing including mechanical and electrical design verification. Assigned shift coordinator and test director for the plant hot functional test series

EDUCATION

- M.S. - Industrial Administration - Purdue University
- Krannert Graduate School of Management - **1978**
- B.S. - Nuclear Engineering - Purdue University, Lafayette, IN - **1977**
- B.A. - Mathematics - Augustana College, Rock Island, IL - **1977**