High Bridge Associates, Inc.

March 2, 2016

Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel Irradiation

prepared for the
MOX Services Board of Governors

“Connecting Vision and Plans with Performance and Execution”
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Acronyms

CBFO  Carlsbad Field Office
CBOO  Carlsbad Operations Office
CCA  Compliance Certification Application
CCC  Criticality Control Container
CCDF  Complementary Cumulative Distribution Function
CCO  Criticality Control Overpack
CRA  Compliance Recertification Application
DOE  U. S. Department of Energy
EIS  Environmental Impact Statement
EM  Environmental Management
EPA  Environmental Protection Agency
FEIS  Final Environmental Impact Statement
FGE  Fissile Gram Equivalent
HBA  High Bridge Associates
HEU  Highly Enriched Uranium
HSS  Office of Health, Safety, and Security
LEU  Low Enriched Uranium
MFFF  MOX Fuel Fabrication Facility
MgO  Magnesium Oxide
MOX  mixed oxide
MT  Metric Tons
NEPA  National Environmental Policy Act
NNSA  National Nuclear Safety Administration
PA  Performance Assessment
PMDA  Plutonium Management and Disposition Agreement
POC  Pipe Overpack Container
POP  Pipe OverPack
Pu FGE  Plutonium Fissile Gram Equivalent
RCA  Radiologically Controlled Area
SME  Subject Matter Expert
SNM  Special Nuclear Material
SOW  scope of work
SPD  Surplus Plutonium Disposition
SRS  Savannah River Site
TRU  transuranic
WIPP  Waste Isolation Pilot Plant
WIPP/WAC  WIPP Waste Acceptance Criteria
Executive Summary

High Bridge Associates, Inc. performed an assessment of technical parameters and estimated costs for the US DOE surplus plutonium disposition program for the WIPP and MOX alternatives. This included an analysis of the adequacy of the WIPP to accept significant quantities of surplus weapons plutonium in addition to those legacy transuranic (TRU) wastes already committed for storage in the repository. Specifically, we assessed the statutory basis, safety, science, technology, safeguards, nonproliferation, transportation, and cost impacts for storing 51.3 metric tons of surplus weapons plutonium at WIPP. It should be noted that the WIPP facility is a geological repository designed and permitted primarily for disposal of low concentration manufacturing residues of transuranic (TRU) wastes from the weapons complex. It is not permitted to store large quantities of concentrated weapons grade plutonium in WIPP. Weapons plutonium is isotopically identical to that of the TRU waste plutonium currently stored in WIPP (both are $^{239}$Pu). However, the weapons plutonium if stored at WIPP will be significantly more concentrated and will create a much more hazardous condition relative to criticality and safety.

Criticality Safety

The High Bridge team of nuclear experts identified a series of safety and regulatory concerns for the DOE/NNSA plan to store tons of plutonium not originally planned for emplacement in the WIPP repository. The most serious concern is that the plutonium packaging endorsed by the DOE will be crushed over time as the salt chambers in WIPP close up, creating a high likelihood of an uncontrolled criticality.

Criticality refers to a condition in which a nuclear chain reaction is possible. Unlike controlled criticality in a reactor, an uncontrolled criticality can behave in very erratic and unpredictable ways. This will result at a minimum in the release of large amounts of energy and the creation of a large inventory of radioactive fission products that would be available for release to the environment. The extremely high pressures created as the salt cavern closes in on the storage drums will force the plutonium closer together, creating the geometry of crushed storage drums which facilitates a critical chain reaction.

Storing 51.3 metric tons of plutonium in Criticality Control Overpacks (CCOs) endorsed by DOE would require 171,000 55-gallon drums. Our modeling indicates that a ~30% crushing of only a single stack of CCOs (21 drums containing about 8 kg of plutonium) could result in a criticality. We have found no evidence that DOE has analyzed this scenario. This scenario is not evaluated in the environmental impact statements that enabled WIPP to accept TRU waste, nor is it evaluated in any of the National Environmental Protection Act (NEPA) documentation for storage and disposition of weapons plutonium.

High Bridge also analyzed four other storage scenarios which reduced the concentration of plutonium, compared to the packaging identified by DOE, thus reducing or eliminating the likelihood of criticality. In each case, storage volume increased substantially from 1.5 to 3.5 times the limits contained in the WIPP Land Withdrawal Act of 1992 and considered in the Final Environmental Impact Statement.

Other Safety and Regulatory Issues

- Although approved for transportation, CCOs are not currently an acceptable waste package for WIPP. Previous analyses used to qualify WIPP do not consider the impact of the use of CCOs.
- The fissionable plutonium content in CCOs (29.2 kg/m$^3$) exceeds the maximum concentration limit of 7.3 kg/m$^3$ established by the American National Standards Institute to avoid criticality.
Large areas of the WIPP repository will significantly exceed EPA thermal heat load limits. This results in unanalyzed stresses in the geologic strata above the waste.

Safeguards and Security

Weapons-grade plutonium is stored under stringent safeguards intended to prevent theft or diversion. Because of the nature of transuranic materials now stored in WIPP, the facility operates under a much less stringent security program. Plutonium in CCOs is diluted but retains the same isotopic structure and therefore retains its value as a source of weapons material. Terminating safeguards for surplus weapons plutonium in CCOs during transportation to WIPP or after disposal at WIPP is unprecedented and may not be possible. If safeguards are not terminated, the additional security costs would further increase the cost of WIPP operations and require special methods to prevent human intrusion for 10,000 years or longer.

Violation of the U.S.–Russia Plutonium Management and Disposition Agreement (PMDA)

The PMDA specifically identifies the technical approaches for both countries to dispose of their surplus weapons-grade plutonium by irradiating it as mixed oxide (MOX) fuel in nuclear reactors. Once irradiated and converted to spent fuel, the plutonium can no longer be readily used for nuclear weapon purposes. Dilution and storage of this plutonium in a geologic repository such as WIPP has long been opposed by Russia, and a change to the basic disposition approach is likely to result in Russia halting its efforts to dispose of 34 MT of surplus weapons plutonium. If Russia were to reverse its long-standing opposition, Russian nonproliferation experts believe that, as a minimum, Russia would demand relief from the stringent nonproliferation conditions imposed by the PMDA—conditions which are essential to provide the United States with confidence that Russia is disposing of its weapons-grade plutonium in accordance with the terms and conditions of the PMDA.

Inadequacy of WIPP NEPA Environmental Documentation

The High Bridge analysis reveals that any scenario for storing large quantities of weapons-grade plutonium in WIPP would exceed its storage capacity. This would require changes to its statutory authorization as well as its environmental analyses and documentation, a time-consuming and risky process. The NEPA process would also need to be completed before a decision can be made to proceed. Disposal of weapons plutonium at WIPP could also jeopardize WIPP’s current Environmental Management and other DOE programmatic missions and its continued operation.

Comparative Costs of Diluted Plutonium Storage at WIPP vs. MOX Fuel Irradiation

The DOE/NNSA has stated that cost is the major driving force for the plutonium disposition program. It has frequently cited the Aerospace 2015 Assessment of MOX estimated costs of about $1 billion per year (nearly $47.5 billion for about 50 years) as the reason it has decided to follow the plutonium dilution storage path at WIPP with estimated costs of about $400 million per year ($13.1 billion for about 30 years). High Bridge evaluated these Aerospace cost assessments and has concluded that the estimates are based on significantly flawed and incorrect analyses. The Aerospace approach was driven by very narrow parameters that maximized the MOX Fuel Irradiation costs while minimizing the WIPP Dilution Storage costs. Additionally, many significant WIPP cost and schedule elements required to deal with greatly increased plutonium quantities and concentrations (a 243 fold increase over the WIPP design basis) were not analyzed by Aerospace. Most importantly, Aerospace never analyzed the costs associated with these
increased plutonium quantity and concentration levels from a nuclear criticality safety or FEIS regulatory compliance perspective.

As mentioned earlier, High Bridge performed a technical analysis that determined that the proposed disposal option will likely achieve a criticality during the period of regulatory concern. Therefore, five diluted plutonium storage scenarios for WIPP were evaluated based on reducing plutonium concentration levels to avoid criticality and ensure safety. The costs resulting from these scenarios were evaluated. High Bridge concludes that its scenario 5 is the most likely approach that will ensure safe and legal WIPP operations by avoiding nuclear criticality.

Based on these analyses, High Bridge concludes that the life cycle cost for the WIPP diluted storage option is $46.8 billion (not $13.1 billion as estimated by Aerospace) and that the life cycle cost for MOX Fuel Irradiation is $19.4 billion (not $47.5 billion as estimated by Aerospace). This High Bridge MOX estimate represents a cost of about $500 million a year to complete construction and less than $400 million a year for operations. The life cycle costs for completing the MOX program never approaches $1 billion/year.

The WIPP dilution storage option estimated cost of $46.8 billion is more than double the MOX fuel irradiation estimated cost of $19.4 billion. The WIPP dilution storage option estimated duration to dispose of the 51.3 MT of surplus plutonium is 55.3 years and more than double the MOX fuel irradiation estimated duration of about 25 years. None of the High Bridge analysis leading to its estimates have been recognized or evaluated by Aerospace.

About the High Bridge Team

High Bridge is a nuclear industry consulting firm with recognized expertise in providing independent technical and economic assessments of complex facilities and programs. It retained Studsvik Scandpower, an internationally recognized nuclear physics and criticality analysis firm, to assist with this review. High Bridge also retained a nationally recognized legal expert in National Environmental Policy Act (NEPA) compliance to validate our understanding of the existing or new NEPA documentation that could support a decision to store the additional excess weapons plutonium. Other team members included a retired Professor of Nuclear Science and Engineering from MIT; a retired Professor of Engineering and Computer Science from the University of Tennessee and a former Division Director of Research and Development for the Tennessee Valley Authority; and a former Chief Nuclear Engineer for Burns and Roe.

Complete Report that Follows

The Section 1 Overview provides an expanded discussion of analyses and conclusions along with selected graphics to show more insights for Executive Summary key conclusions. The body of the report for sections 3 to 9 provides the more detailed analyses of scientific, regulatory, and estimated cost issues that back up the Executive Summary and Overview. Section 10 References lists over 40 public domain information sources involving over 10,000 pages of data that served as the High Bridge research foundation and basis for this report.
1 Overview

Introduction

The DOE/NNSA has funded numerous studies to find an alternative to the current plan for plutonium disposition that was negotiated with the Russian Federation and signed as a formal MOX Fuel Irradiation agreement in 2000. The PMDA covers fabricating 34 metric tons of weapons grade plutonium into MOX Fuel for subsequent irradiation in nuclear reactors. Once irradiated and converted to spent fuel, the remaining plutonium can no longer be readily used for nuclear weapons purposes. Currently the MOX Fuel Fabrication Facility (MFFF) and supporting facilities are under construction at the Savannah River Site. The plant is approximately 68% complete with a cost to date of $5.2 billion. It is estimated that approximately $3.0 billion is required to complete the plant on an efficiently funded schedule with a completion date of 2022.

The DOE/NNSA is looking at alternatives since the cost of the MOX facility has increased significantly since it was first authorized. This cost increase is due to many factors including and not limited to major scope changes in the program and a lack of fully funding the project that has resulted in cost inefficiencies and extended schedule costs. In their studies, the DOE/NNSA concluded that the least expensive path forward is diluting the plutonium with other materials and disposing it at WIPP. This facility is a geological repository designed and permitted primarily for disposal of low concentration manufacturing residues of transuranic (TRU) wastes from the weapons complex. It is not permitted to store large quantities of concentrated weapons grade plutonium in WIPP. Weapons plutonium is isotopically identical to that of the TRU waste plutonium currently stored in WIPP (both are \(^{239}\text{Pu}\)). However, the weapons plutonium if stored at WIPP will be significantly more concentrated and will create a much more hazardous condition relative to criticality and safety.

In studies, DOE/NNSA made an assumption that WIPP could accept this highly concentrated weapons plutonium without difficulty. High Bridge finds no evidence that DOE rigorously analyzed this assumption in terms of safety, regulatory compliance, technical feasibility, or cost and schedule impacts. Examining other previous DOE/NNSA reports, High Bridge concludes that DOE/NNSA followed an approach that erroneously assumed that past environmental and safety analyses for low concentrations EM TRU waste would apply to the higher concentration of surplus weapons plutonium.

Purpose and Structure of Assessment

The purpose of this High Bridge study was to perform an assessment of technical parameters and estimated costs for the US DOE surplus plutonium disposition program alternatives for the WIPP and MOX alternatives. Additionally, High Bridge investigated in more detail if the WIPP repository can accept the storage of significant quantities of NNSA weapons plutonium in addition to the EM legacy TRU wastes destined for WIPP. Specifically, High Bridge assessed the statutory basis, safety, science, technology, safeguards, transportation, and cost impacts for storing 51.3 metric tons of surplus weapons plutonium.

High Bridge established 51.3 MT of surplus weapons plutonium as the total plutonium quantity that it evaluated for storage at WIPP based on publicly available DOE/NNSA information. This includes 4.2 MT of surplus weapons plutonium currently being packaged at SRS to be shipped to WIPP, 13.1 MT of plutonium under consideration for disposal, and the 34 MTs currently slated to go through the MOX Fuel Fabrication Facility (MFFF) as part of the Plutonium Management and Disposition Agreement (PMDA). The report identifies areas where the proposed action is outside of the current design basis and will be a
violation of the current NEPA FEIS permit for operation. The main areas of concern are nuclear criticality, radiological releases, safeguards security, thermal consequences, and cost impacts. It is not the intention of this report to be a definitive study of these issues, but rather an assessment of the magnitude of the potential impact of the disposal of up to 51.3 MTs of surplus weapons plutonium at WIPP.

This High Bridge report is structured as follows:

- The Executive Summary provides key conclusions regarding this complex program.
- Section 1 Overview – provides an expanded discussion of analyses and conclusions along with selected graphics to show more insights for Executive Summary key conclusions.
- Section 2 Introduction – discusses the High Bridge assessment methodology along with WIPP background and general information.
- Section 3 Criticality – provides analyses and quantification of safety issues considered in the current WIPP FEIS and the impacts created by introducing concentrated weapons plutonium.
- Section 4 Legal and Regulatory – defines current legal compliance parameters in the current WIPP FEIS and what would be violated if surplus weapons plutonium were stored at WIPP.
- Section 5 Radiological Releases – outlines governing regulatory parameters and assesses impacts resulting from nuclear criticality occurring with surplus plutonium stored at WIPP.
- Section 6 Safeguards – explains regulatory standards regarding transportation and storage of special nuclear like weapons plutonium and the security issues created if stored at WIPP.
- Section 7 Thermal Impacts – describes the repository thermal heat load compliance parameters in the WIPP current FEIS and the impacts of criticality energy release on these parameters.
- Section 8 US Russian Plutonium Disposition Program – discusses the PMDA agreement history, current compliance requirements, and impacts resulting from MOX cancelation and WIPP storage.
- Section 9 Economic Analysis – describes prior High Bridge assessments of WIPP and MOX estimated costs performed by Aerospace Corporation; assesses five WIPP technical impact scenarios to achieve safe and regulatory legal compliance for plutonium storage at WIPP; and provides an economic cost analysis of the five WIPP Diluted Plutonium Storage scenarios compared to the MOX Fuel Irradiation alternative.
- Section 10 References – lists and describes over 40 publically available information references used by High Bridge as the basis for this assessment analysis and conclusions.

Criticality

The TRU waste slated to be dispositioned in WIPP has an extremely low concentration of fissile isotopes. The extremely low concentration led to the WIPP FEIS/Sandia conclusion that achieving a sustained nuclear chain reaction was very unlikely, based on:

- A total of 21 MTs of fissile isotopes were distributed uniformly in 6.2 million ft³ of waste
- 150 MTs of ²³⁸U was also uniformly distributed in the waste reducing the reactivity of the fissile isotopes
- The total mass of ²³⁹Pu was 12.8 MTs
- The fissile concentration of actinides was approximately 12% making the formation of a critical aqueous solution impossible since it must be assumed that water intrusion will occur.
- The non-fissile waste materials present made it impossible to compact the fissile materials sufficiently to form a critical mass
Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel Irradiation

However, the DOE/NNSA proposal to disposition surplus weapons plutonium in criticality control overpacks (CCOs) in WIPP violates all of the conditions that made criticality impossible in the design basis. At present, 52% of the legally allowed TRU waste has already been emplaced. As a result, the proposed disposition of surplus weapons plutonium at WIPP represents a significant increase in the concentration of actinide fissile isotopes because a far greater quantity will be placed in the remaining 48% of the allowable waste volume. Assuming that the original waste assessment was correct and the previous inventory remains proportional, the addition of 51.3 MTs of plutonium in the remaining space raises the average concentration of fissile isotopes (i.e. the enrichment) from 12% to 46%. This is shown diagrammatically in Exhibit 1-1.

Exhibit 1-1 – Change in Actinide Fissile Concentration if Surplus Weapons Plutonium is Dispositioned in WIPP

This increase in fissile concentration is significant and is far outside of the bounding analyses that support the NEPA documentation. None of the analyses supporting the NEPA documentation and the permit for WIPP’s operation have considered material with these fissile concentrations. Unlike the material from Rocky Flats, this material is more than twice the amount of fissile material that was analyzed in the supporting calculations for WIPP (21 MTs vs 51.3 MTs).

The SANDIA study (SAND99-2898) that supported the original conclusion that a criticality was impossible at WIPP were based on the assumption that it was impossible to compress the waste material enough to assemble a critical mass. The ANSI standard governing criticality assessments (ANSI/ANS-8.1-2014) is 7.3 kg/m³, the minimum concentration for criticality to be a concern. The SANDIA study suggested a lower concentration of 3 kg/m³ be used. Whereas the previous waste packaging for WIPP was comprised of difficult-to-compress materials, the CCO is essentially an empty 55-gallon drum with a criticality control container (CCC) secured in the center. Exhibit 1-2 shows the comparison of the Pipe Overpack Container (that is allowed by the WIPP WAC¹) and the CCO (that is not approved by the WIPP WAC). As can clearly be seen, it cannot be assumed that a CCO will not be crushed by the action of the salt overburden creeping into the waste storage rooms over an extended period of time.

¹ Waste Acceptance Criteria
At 380 grams per CCC, the density of fissile material inside the CCC is 29.2 kg/m³. The only reason a CCO is subcritical for shipping and handling purposes is that the distance between the CCCs is maintained by the intact drums. When the CCOs are crushed that separation is eliminated allowing the formation of a critical mass. Trace amounts of $^{239}$Pu in the surplus weapons plutonium provide free neutrons via spontaneous fissions and the presence of water in the repository set the minimum conditions necessary for an uncontrolled criticality to occur. A preliminary bounding analysis by Studsvik analysts has concluded that once these minimum conditions are achieved, the mass in a single stack (7x3) of CCOs stored in the repository is enough to go critical. The presence of over 50 MTs of surplus weapons plutonium emplaced in the repository in CCOs ensures that the criticality event would be wide-spread and significant in both output and duration.

In Sandia’s own study, they showed the likely impact of the crushing salt on their waste packages as shown in Exhibit 1-3 below.
Current WIPP operations call for the installation of either a 3,000 pound or a 4,200 pound supersack of magnesium oxide (MgO) on top of each waste stack before closure. This is done to absorb CO₂ produced by the decay of carbon-based materials in the waste forms, i.e., wood, paper, plastic, rubber, etc. Ironically, MgO is a weak nuclear moderator and a fairly efficient reflector of neutrons. This further enhances the physical conditions necessary for criticality.

In summary, the plan to place any amount of surplus weapons plutonium in WIPP in CCOs violates the WIPP WAC and constitutes an unacceptable risk of criticality. Given this risk and its potential consequences, High Bridge recommends that a detailed criticality and safety assessment be performed and made part of any NEPA documentation to inform decision-makers before this option is seriously considered or any surplus plutonium is shipped to WIPP.

Statutory and Regulatory

The DOE Waste Isolation Pilot Plant (WIPP) was created for disposition of transuranic (TRU) legacy wastes from U.S. nuclear weapons production. It has been developed as required by the United States Congress in the WIPP Land Withdrawal Act (Public Law 102-579, 1992).

DOE prepared a Supplemental Environmental Impact Statement (EIS) for approval in 1996 which was approved as the Final Supplemental EIS (FEIS DOE/EIS-0026 S-2) for the WIPP facility. Before significant changes can be made to the facility, its operation or its performance that could have a significant
environmental impact, a new FEIS or supplement to the FEIS for WIPP must be prepared by DOE to inform the decision-making process in accordance with the NEPA. In addition to providing updated information, including waste characterization and potential source terms, this new NEPA documentation needs to address whether WIPP itself could continue as the only facility available for TRU disposition. If the problems become insurmountable for the use of WIPP, a new facility would be required that will be designed to address the unique issues associated with the disposal of surplus weapons plutonium as TRU waste. A new facility could also be required if this material is disposed of in WIPP resulting in WIPP’s statutory limit being reached, in which case WIPP would need to be either expanded or a new facility authorized to continue serving programmatic needs.

DOE/NNSA has prepared a supplemental FEIS for Surplus Plutonium Disposition that concludes that 13.1 MTs of Surplus Weapons Plutonium can be dispositioned at WIPP. It appears to rely on the experience from Rocky Flats where 180 kg of weapons grade plutonium was permitted to be dispositioned at WIPP. If all surplus weapons plutonium were to be disposed of at WIPP, it would involve the total current inventory of 51.3 MT. This represents over 250 times the amount from the POC shipments from Rocky Flats. In an attempt to comply with the WIPP statutory limited storage volume, the Criticality Control Overpack (CCO) for this plutonium was developed. The CCO contains 380 grams within a Criticality Control Container. (See Exhibit 1-2 above.) However, this container has not been approved for use in WIPP and is not included in the WIPP Waste Acceptance Criteria (WAC).

In order to use the CCO, an amendment to the WIPP WAC will be necessary. A decision to amend the WIPP WAC to accommodate the use of the CCO would require NEPA documentation at the appropriate level to inform decision-making. In light of the potential effects on WIPP performance if the CCO is used for surplus weapons plutonium, it appears to High Bridge that a new or supplement to the FEIS would be the appropriate level.

In the journal *Nature*\(^2\), Stanford University researchers questioned whether, over time, storage containers at WIPP could be crushed by the salt, causing a nuclear accident or leak. Also, the researchers questioned the safety of disposal of diluted Plutonium in “inert” material. The authors pointed out that plutonium has many chemical states and that there are very few truly inert materials in geological time, especially in the WIPP environment. Due to the long timeframe of Plutonium wastes (half-life of 24,000 years), it is likely that the regulatory time-period will be increased\(^3\). This coupled with the large increase in the quantity of plutonium that is planned to be disposed, increases the probability of human intrusion. They also point out that the lack of a revised safety analysis of this action could likely result in future failures.

**Safety, Science and Technology**

WIPP operates based on the scientific and technical assumptions embodied in the NEPA documentation supporting the decisions to construct and operate WIPP including the Original EIS, Supplemental EIS and all of the Supplement Analyses that have been performed for decision-making concerning WIPP. The proposed action to dispose of significant quantities of surplus weapons plutonium at WIPP is well beyond the design basis for WIPP and if undertaken without appropriate analysis and formal process, could result in the immediate need to revise the permit for WIPP operation and be subject to prolonged litigation.

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\(^3\) A subtle point not made by the authors of that article is the fact that \(^{239}\)Pu decays to \(^{235}\)U that is just as hazardous albeit with a 704 million year half-life.
The major focus of the EPA regulations governing WIPP is the control of the releases of hazardous substances to the environment. Potential radiological releases are proportional to the inventory of radioactive isotopes available for release. WIPP was analyzed based on the presence of 21 MT of fissile isotopes uniformly distributed in the statutorily established limit of 175,564 m$^3$ (0.12 kg/m$^3$). Approximately 52% of the available legal volume limit of waste has been emplaced in WIPP. The disposal of 51.3 MTs of surplus weapons plutonium will increase this to 61.3 MT distributed in the remaining volume of 84,000 m$^3$ (0.73 kg/m$^3$). That is six times the concentration that was analyzed. Also, the crushing of the CCOs would result in a concentration of about 25 kg/m$^3$ or over 200 times the concentration analyzed. Therefore, disposing of CCOs loaded to the design basis limit (380 g) represents an unanalyzed condition that must preclude the disposal of a single CCO until these issues are resolved.

A specific limit imposed by the EPA on the WIPP repository is the thermal heat load naturally produced by radioactive decay. The EPA limit for the thermal load from the decay heat in the waste form is 10,000 watts/acre. Based on the original design, the projected heat load was estimated to be 4,270 watts/acre. However, the heat load above an entire panel filled with surplus weapons plutonium would be over 11,000 watts/acre. The area above an individual room filled with surplus weapons plutonium would be approximately 40,000 watts/acre.

While the entire repository may be within the EPA limited heat load, large areas of the repository will not. This would result in unanalyzed stresses in the geologic strata above the waste. This, too, is an unanalyzed condition and would preclude the disposal of surplus weapons plutonium at WIPP until it has been analyzed and demonstrated acceptable.

Safeguards

Without the termination of safeguards, the surplus weapons plutonium cannot be reasonably transported to or disposed of in WIPP. DOE/NNSA routinely cites the Rocky Flats experience as the basis for claiming that the surplus weapons plutonium safeguards can be terminated. If rigorous safeguards would be necessary for either the transportation of this material or for WIPP, there would be significant cost and programmatic consequences that have not been considered. For the following reasons, the Rocky Flats Environmental and Technology Site (REFTS) experience is largely inapplicable and the termination of safeguards for these quantities and attractiveness category would be unprecedented.

- The surplus weapons plutonium is of a higher attractiveness category than the REFTS Pu.
- The termination of safeguards for Rocky Flats material in WIPP was based partially on the small quantities involved - 180 kg out of 12,800 kgs.
- As shown in Exhibit 1-4, the permitted license basis for WIPP covers 12,800 kg of $^{239}$Pu at a concentration of 0.12 kg/m$^3$. The proposed increase in surplus weapons plutonium covers 51,300 kg of $^{239}$Pu at a concentration of 29.2 kg/m$^3$. This four-fold increase in quantity and 250 fold increase in concentration results in an approximate 1,000 fold increase in attractiveness for diversion.
- The termination was based on the perceived difficulty in separating plutonium from the inerting agent (stardust) added to the $^{239}$Pu in a POC. A CCO has 1.9 times the fissile plutonium permitted in a POC so this argument may not be applicable.
- At the time of this report, rigorous analysis to support termination safeguards of $^{239}$Pu in a CCO for either transportation or emplacement in WIPP has not been published.
High Bridge concludes that the DOE/NNSA plan to dispose of surplus weapons plutonium by diluting it and storing it in WIPP would violate the terms of the Plutonium Management and Disposition Agreement (PMDA) signed by the U.S. and Russia in 2000 and amended in 2010. The PMDA provides for the disposition of 34 metric tons of surplus weapons-grade plutonium by each side. This is enough material for approximately 17,000 nuclear weapons. Russia has long argued that disposing of weapons-grade plutonium in a geologic repository, such as Yucca Mountain or WIPP, is another form of long-term storage because it fails to degrade the isotopic composition of the plutonium thus continuing to allow it to be used for nuclear weapons purposes. As a result, the PMDA codifies the technical approaches for both countries to dispose of their surplus weapons-grade plutonium by irradiating it as mixed oxide (MOX) fuel in nuclear reactors to produce electricity. Once irradiated and converted to spent fuel, the plutonium can no longer be readily used in a nuclear weapon, thereby preventing it from falling into the hands of terrorists or rogue nations, i.e., “Spent Fuel Standard” as recommended by the U.S. National Academy of Sciences.

As set forth in the PMDA, Russia will dispose of its 34 MT of weapon-grade plutonium by fabricating it into MOX fuel to be burned in fast reactors operating under stringent nonproliferation conditions. The United States agreed with Russia’s use of fast reactors provided that Russia configured its reactors to burn more plutonium than they produce, operate under an extensive monitoring and inspection regime and agree to never reprocess spent fuel containing disposition (34 MT) plutonium. These very specific nonproliferation requirements (and others) are essential to provide the U.S. with confidence that Russia is disposing of its weapons-grade plutonium in accordance with the terms and conditions of the PMDA.

Thus far, the United States has not engaged Russia in detailed negotiations on changing the PMDA to permit weapons-grade plutonium disposition in WIPP. Historically, negotiations with Russia regarding the sensitive topic of weapons-grade plutonium disposition have been difficult and time-consuming.
Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel Irradiation

(frequently taking years). There is nothing to suggest that negotiating a change to the U.S. disposition approach would be any different given the current animus between the two sides as recently evidenced by Russian President Putin’s decision not to attend the 2016 Nuclear Security Summit in Washington.

Failure to reach agreement with Russia and amend the PMDA could result in Russia abandoning efforts to dispose of its surplus weapons plutonium. At a minimum, nonproliferation experts believe that if Russia were to abandon its long-standing position on the need to convert the plutonium to forms that can never again be used for weapons and accept the U.S. plan of diluting its weapons-grade plutonium and storing it in WIPP, Russia would demand relief from the stringent nonproliferation conditions contained in the amended PMDA that force Russia to operate its reactors in an inefficient and intrusive manner. Yet, these are the very requirements that are needed to provide the U.S. with confidence that Russia is disposing of its weapon-grade plutonium in accordance with the terms and conditions of the PMDA.

DOE/NNSA, the Plutonium Working Group (PWG), Aerospace, and the DOE Red Team all seem to discount the importance and the difficulty of amending the PMDA. Further, they all assert that the DOE could begin working on the Dilute and Dispose option almost immediately with little or no delay caused by amending the Plutonium Management and Disposition Agreement with Russia. DOE/NNSA and their consultants seem to view the PMDA as a minor issue that can be easily resolved once DOE officially abandons the MOX program in favor of the Dilute and Dispose option. This conclusion may be another costly and time consuming distraction from the critical mission of disposing of post-Cold War stocks of surplus weapons-grade plutonium.

Comparative Costs of Diluted Plutonium Storage at WIPP vs. MOX Fuel Irradiation

The DOE/NNSA has stated that cost is the major driving force for the plutonium disposition program. It has frequently cited the Aerospace 2015 Assessment of MOX estimated costs of about $1 billion per year (nearly $45.7 billion for about 50 years) as the reason it has decided to follow the plutonium dilution storage path at WIPP with estimated costs of about $400 million per year ($13.1 billion for about 30 years). High Bridge evaluated these Aerospace cost assessments and has concluded that the estimates are based on significantly flawed and incorrect analyses. The Aerospace approach was driven by very narrow parameters that maximized the MOX Fuel Irradiation costs while minimizing the WIPP Dilution Storage costs. Additionally, many significant WIPP cost and schedule elements required to deal with greatly increased plutonium quantities and concentrations (a 243 fold increase over the WIPP design basis) were not analyzed by Aerospace. Most importantly, Aerospace never analyzed the costs associated with these increased plutonium quantity and concentration levels from a nuclear criticality safety or FEIS regulatory compliance perspective.

As mentioned earlier, High Bridge performed a technical analysis that determined that the DOE/NNSA proposed plutonium disposal option will likely achieve a criticality during the period of regulatory concern. Therefore, five WIPP diluted plutonium storage scenarios were developed by High Bridge were evaluated based on reducing plutonium concentration levels to avoid criticality and ensure safety. The costs resulting from these scenarios were evaluated. High Bridge concludes that its scenario 5 is the most likely approach that will ensure safe and legal WIPP operations by avoiding nuclear criticality.

Based on these analyses, High Bridge concludes that the life cycle cost for the WIPP diluted storage option is $46.8 billion (not $13.1 billion as estimated by Aerospace) and that the life cycle cost for MOX Fuel Irradiation is $19.4 billion (not $47.5 billion as estimated by Aerospace). This High Bridge MOX estimate
represents a cost of about $500 million a year to complete construction and less than $400 million a year for operations. The life cycle costs for completing the MOX program never approaches $1 billion/year.

The WIPP dilution storage option estimated cost of $46.8 billion is more than double the MOX fuel irradiation estimated cost of $19.4 billion. The WIPP dilution storage option estimated duration to dispose of the 51.3 MT of surplus plutonium is 55.3 years and more than double the MOX fuel irradiation estimated duration of about 25 years. None of the High Bridge analysis leading to its estimates have been recognized or evaluated by Aerospace.

Moreover, the Aerospace cost estimate ignores the fact that if the MOX program is cancelled, all WIPP dilution storage NEPA regulatory and design bases need to be increased to cover the entire amount of surplus plutonium to be stored at WIPP. The High Bridge analysis in this report is based on 51.3 MTs of plutonium, while other sources place the surplus plutonium quantity at closer to 61.5 MTs. The NEPA and legal regulatory processes and approvals, along with the revised Land Withdrawal Act law, need to be completed before any surplus plutonium can be placed in WIPP.

Exhibit 1-5 summarizes the High Bridge estimated impacts on the WIPP repository for these five scenarios to store 51.3 MT of weapons plutonium. Scenario 1 considers the approach proposed by the Plutonium Working Group for disposing of this material in CCOs and endorsed by DOE/NNSA. Scenario 2 considers disposing of this material in POCs, given POCs are qualified for use at WIPP. Scenario 3 considers reducing the concentration of fissile material to the ANSI standard minimum for criticality of 7.3 kg/m$^3$ in CCOs. Scenario 4 considers the reduction of the concentration to meet the concentration used by Sandia when qualifying WIPP. Scenario 5 considers the plutonium being diluted to the average fissile content density of 0.12 kg/m$^3$ of WIPP as defined in the FEIS design basis using 55-gallon drums and an incompressible inert material.

**Exhibit 1-5 - Key Metrics for WIPP Plutonium Storage Cost Estimate Scenarios**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Plutonium Concentration kg/m$^3$</th>
<th>Drums</th>
<th>Duration Required Years to Emplace</th>
<th>Volume m$^3$</th>
<th>Storage Rooms</th>
<th>Will Go Critical</th>
<th>FEIS Compliant</th>
<th>Scenario Estimated Cost $Billions</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIPP Design &amp; FEIS Basis</td>
<td>0.12</td>
<td>N/A</td>
<td>25</td>
<td>175,564</td>
<td>56</td>
<td>No</td>
<td>Yes</td>
<td>N/A</td>
</tr>
<tr>
<td>Storage Storage Scenarios</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1 Using CCOs</td>
<td>29.2</td>
<td>171,000</td>
<td>4.6</td>
<td>35,568</td>
<td>21</td>
<td>Yes</td>
<td>No</td>
<td>$19.9</td>
</tr>
<tr>
<td>Scenario 2 Using POCs</td>
<td>16.7</td>
<td>301,765</td>
<td>8.2</td>
<td>62,767</td>
<td>35</td>
<td>Likely</td>
<td>No</td>
<td>$22.6</td>
</tr>
<tr>
<td>Scenario 3 Concentration Reduced to ANSI Standard</td>
<td>7.3</td>
<td>539,780</td>
<td>14.6</td>
<td>112,274</td>
<td>53</td>
<td>No</td>
<td>No</td>
<td>$26.6</td>
</tr>
<tr>
<td>Scenario 4 Concentration Reduced to Sandia Single Point Value</td>
<td>3.0</td>
<td>1,313,465</td>
<td>35.4</td>
<td>173,209</td>
<td>128</td>
<td>No</td>
<td>No</td>
<td>$37.0</td>
</tr>
<tr>
<td>Scenario 5 Concentration Reduced to WIPP Design Value</td>
<td>0.12</td>
<td>2,053,337</td>
<td>55.3</td>
<td>427,094</td>
<td>203</td>
<td>No</td>
<td>No</td>
<td>$46.8</td>
</tr>
</tbody>
</table>
It should be noted that only 23,600 cubic meters or 13 percent of the total WIPP repository volume of 175,564 cubic meters remains available for yet unidentified EM TRU waste.

All of the scenarios shown on Exhibit 1-5 address significant issues with DOE/NNSA plans to dispose of 51.3 MT of plutonium at WIPP. None of them will eliminate the need for a full and open NEPA process to provide the decision-maker information on the potential environmental consequences of adopting this proposal. In addition to this NEPA process addressing all reasonable alternatives, an amendment of the PMDA would be required along with a full legislative process to amend the LWA to permit this option to take place. Beyond the identified cost impacts associated with implementing the diluted plutonium storage option at WIPP, each dilution scenario significantly extends the operating period of WIPP well beyond the current planned lifetime, which represents a large part of the estimated cost for each scenario.

The current regulatory and statutory authorized size of WIPP involves a volume of 175,564 m³, 10 panels, and 70 rooms. Exhibit 1-5 shows the number of drums increasing 10 times, repository volume increasing 3 times, and repository panels/rooms increasing 3 times to achieve the FEIS design basis fissile concentration of 0.12 kg/m³ (Scenario 5). The estimated cost for each of these scenarios increases in proportion to the reducing plutonium concentrations and increasing plutonium quantities, repository volumes, and storage emplacement durations.

Team Member Qualifications

High Bridge is a nuclear industry consulting firm with recognized expertise in providing independent technical and economic assessments of complex facilities and programs. High Bridge assembled a team of subject matter experts to perform an assessment of the adequacy of the WIPP EM Repository to accept significant quantities of NNSA weapons plutonium in addition to the EM legacy TRU wastes destined for WIPP. Team members included:

- A Team Leader with over 40 years of experience in nuclear construction and independent assessments of complex industrial and DOE mega-projects
- A retired Professor of Nuclear Science and Engineering from MIT,
- A retired Professor of Engineering and Computer Science from the University of Tennessee and a former Division Director of Research and Development for the Tennessee Valley Authority,
- A former Chief Nuclear Engineer for Burns and Roe,
- An attorney recognized as an expert on the National Environmental Policy Act (NEPA) and formerly a top legal advisor for the Department of Energy (DOE) and the National Nuclear Security Administration (NNSA),
- Studsvik Scandpower, Inc., an international firm with recognized expertise in nuclear physics and criticality scientific analysis

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4 Original design called for 8 panels but was recently revised to permit a total of 10 panels.
2 Introduction

2.1 Plutonium Disposition Background and Recent Cost Estimate Studies

The MOX Program was a result of Arms Reduction Talks between the U.S. and the Russian Federation. A bi-lateral agreement signed in September 2000 committed both countries to follow parallel but independent paths to dispose of the surplus weapons plutonium no longer needed for their nuclear arsenals (Reference 1). The Plutonium Management and Disposition Agreement (PMDA) committed each country to dispose of 34 metric tons (MT) of surplus weapons plutonium by converting it into fuel for consumption in domestic commercial nuclear power plants. The MOX Fuel Irradiation Program came under scrutiny in 2012 after a re-baselining proposal was received by the DOE/NNSA to address a major scope change to the program. The Army Corps of Engineers was selected to perform an Independent Cost Estimate (ICE) of the proposal (Reference 2) and a Plutonium Working Group (PWG) was assembled to prepare a report that identified alternatives for the Surplus Plutonium Disposition (Reference 3). One of these alternatives was called Dilute and Dispose at WIPP (i.e. Downblend) and was pushed forward by DOE/NNSA management as a viable alternative to the MOX Program. DOE/NNSA selected the Aerospace Corporation to perform an economic assessment of the PWG alternatives. They issued their first report “Plutonium Disposition Study Options Independent Assessment” on the Dilute and Dispose option on April 13, 2015 (Reference 4).

On June 10, 2015, the MOX Services LLC Board of Governors (MOX Services) requested that High Bridge Associates, Inc. (High Bridge) perform an Independent Review of the Aerospace report. The purpose of this High Bridge review task was to provide an independent 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 surplus weapons plutonium. The High Bridge Phase 1 Executive Summary and Overview Report was delivered to MOX Services on June 29, 2015 (Reference 5). The High Bridge Phase 2 Detailed Report (Reference 6), which provided more comprehensive analyses and supporting information for the Phase 1 Report, was issued August 21, 2015. It confirmed High Bridge evaluations and conclusions presented in the Phase 1 Report that the Aerospace analysis was seriously flawed and incorrectly portrayed the MOX option as costing significantly more than the Dilution option.

In parallel during the summer of 2015, the Secretary of Energy commissioned a Red Team to review all of these reports associated with the MOX alternatives to try to resolve the apparent discrepancies among the report findings. The Red Team produced their report August 13, 2015 (Reference 7). Since the Red Team essentially validated the Aerospace report, the MOX Services Board of Governors requested High Bridge to perform a review of the Red Team Report that was produced September 21, 2015 (Reference 8).

A common theme in all of the reports issued by DOE/NNSA or their contractors was the implicit assumption that the surplus weapons plutonium was a relatively simple radwaste disposition problem and that WIPP could accept any quantity and any form of TRU Waste that the Department selected. The High Bridge team of reviewers disagreed with both of those assumptions. It pointed out that it was the acceptance of those two assumptions that led the DOE/NNSA to conclude that the Dilute and Dispose Option was cheaper and contained less programmatic risks than finishing the 68% completed MOX Fuel Fabrication Facility. The High Bridge Team concluded that Aerospace did not consider significant risks to the Plutonium Disposition Program with the Dilute and Dispose option. High Bridge concluded that these
actions also threatened the viability of WIPP and thereby jeopardized the completion of the Environmental Management Program.

At the request of the MOX Services LLC Board of Governors, High Bridge on November 16, 2015, issued a summary level report describing the potential impacts on WIPP in response to specific questions raised by congressional staff members. This report focused solely on WIPP and the potential impacts at a high level (Reference 9). It identified several potentially alarming issues that other reports ignored regarding nuclear safety, unanalyzed criticality parameters, radiological releases, and safeguards. This High Bridge report was sufficient to illuminate the issues, but was prepared quickly without enough time to evaluate these issues and their cost impacts in any detail.

As a result, the MOX Services Board of Governors requested in December 2015 for High Bridge to prepare a follow-up assessment and report that probed deeper into these issues discussed above. This March 2, 2016, report evaluates the potential impacts on WIPP of the WIPP Dilution Storage option now being followed as recently announced by DOE/NNSA. Additionally, this report provides a cost comparison of WIPP Diluted Plutonium Storage and MOX Fuel Irradiation. This report is an independent assessment of potential impacts on the design basis of WIPP and its future role as a waste repository.

2.2 High Bridge Assessment Methodology

High Bridge applied a standard systems engineering approach to reviewing safety and legal compliance parameters for storing diluted weapons plutonium at WIPP. First, the requirements for the disposal of TRU Waste at WIPP were identified. Then the impacts of the plan to dispose of surplus weapons plutonium at WIPP were developed and compared to the requirements. High Bridge reviewers concluded that the LWA and the high-level NEPA documents were not detailed enough to identify the design basis. High Bridge researched many relevant sources in the public domain to identify additional information and insight into the actual design basis for WIPP. As outlined in References Section 10 of this report, information from over 40 documents was used as the research basis for the High Bridge analysis and compilation of this report. Hundreds of other documents were consulted to verify references.

High Bridge became concerned when its analysis of the safety criticality limits assumed in the WIPP FEIS design basis and the plutonium quantity/concentration levels outlined in the DOE/NNSA proposals resulted in potentially dangerous conditions regarding nuclear criticality occurring at WIPP. High Bridge contracted with Studsvik Scandpower, Inc., an internationally recognized nuclear physics and criticality expert organization, to further evaluate these criticality issues.

The results of the Studsvik review of the technical details of the impact of the DOE/NNSA WIPP Dilution Storage plan are presented in Section 3.3 of this report and their independent report is included as Appendix F. Their analysis confirmed that plutonium in CCOs would go critical when exposed to the environmental conditions expected at WIPP and described in the design basis. High Bridge used the information in the design basis to develop five scenarios for WIPP diluted plutonium storage that could result in a non-critical nuclear environment and also be in compliance with the WIPP FEIS. High Bridge experts then performed a cost estimate of each WIPP Diluted Plutonium Storage scenarios and compared them to the current MOX Fuel Irradiation Program. Many of the critical failures in the logic of the DOE/NNSA can be overcome with the addition of adequate funding. However, the purpose of changing direction from the MOX Program to this Dilute and Dispose option was to save money. It is therefore significant that shifting to WIPP Diluted Plutonium Storage will not save money. The results of these evaluations are described in Sections 3 and 9.
High Bridge concluded that the disposition of any surplus plutonium in WIPP using CCOs and the approach proposed by DOE/NNSA is not viable due to the technical details and regulatory requirements. Once the DOE/NNSA terminates the MOX program, all of the NEPA documentation purporting to support this decision will become invalid. It is not legally permissible to place any surplus weapons plutonium in WIPP until and unless all NEPA documentation is complete using the combined total amount of plutonium that will eventually be placed into WIPP.

2.3 Importance of WIPP

The Waste Isolation Pilot Plant (WIPP) is a major national asset. It is essential to the cleanup of the Nation’s Weapons Complex from the legacy of the Cold War. It has been in operation since 1999 and is a key component of the DOE’s Environmental Management (EM) mission. In February 2014, accidents at WIPP resulted in a shutdown. A root-cause analysis and a remediation effort continues to the present. No official restart date has been announced.

Since 2012, the DOE/NNSA management has been assessing alternative disposal schemes for the nation’s surplus plutonium. Many of these approaches result in adding surplus weapons plutonium to WIPP as Transuranic (TRU) waste. It has been an intrinsic assumption of the studies that the packaged surplus weapons plutonium can be safely disposed of at WIPP.

WIPP was designed using certain assumptions about the composition and concentrations of the constituents in TRU waste. These wastes were typically byproducts and residues of the weapons manufacturing processes. The emplacement of these wastes resulted in low concentration transuranic elements that were widely dispersed within 6,200,000 ft³ of waste. Only the addition of relatively small amounts of pure plutonium from the Rocky Flats Plant were analyzed and found to be acceptable to the original design.

Again it should be noted that the WIPP facility is a geological repository designed and permitted primarily for disposal of low concentration manufacturing residues of transuranic (TRU) wastes from the weapons complex. It is not permitted to store large quantities of concentrated weapons grade plutonium in WIPP. Weapons plutonium is isotopically identical to that of the TRU waste plutonium currently stored in WIPP (both are $^{239}$Pu). However, the weapons plutonium if stored at WIPP will be significantly more concentrated and will create a much more hazardous condition relative to criticality and safety.

2.4 WIPP General Description

The design of WIPP takes advantage of the natural salt formation left over from the evaporation of an ancient sea during the Permian Period, approximately 250 million years ago. It is located in southeastern New Mexico in an area known as Los Medaños approximately 50 kilometers (30 miles) east of Carlsbad. The area is a relatively flat and sparsely inhabited plateau with little surface water. WIPP consists of the 41-square-kilometer (16-square-mile) area under the jurisdiction of DOE pursuant to the LWA. (See Appendix B for a detailed history of the development of WIPP.)

The WIPP site boundary was established to ensure that at least 1.6 kilometers (1 mile) of intact salt exists laterally between the waste disposal area and the accessible environment and to ensure that no permanent residences will be established in close proximity to the facility. The WIPP underground facilities

High Bridge Associates 17 March 2, 2016
are located at the repository horizon 655 meters (2,150 feet) beneath the surface (Exhibit 2-1). These facilities include the waste disposal area, an experimental region (deactivated in 1995 and 1996), access tunnels, and associated support facilities. The disposal area consists of eight panels mined into the salt deposit consisting of seven disposal rooms each.

The repository consists of four access tunnels running north-south with four waste storage panels arranged to the east and to the west of the access tunnels. Each waste storage panel consists of seven waste storage rooms that are 91 m long and 10 m wide. Each room is separated from the next by a pillar of salt 30 meters wide (Reference 10). Originally, panels 9 and 10 were intended to be the access tunnels running north-south and once filled, would seal off the entire repository. However, as can be seen in Exhibit 2-2 below, six of the eight planned panels were already filled and closed as of the February 2014 incidents after which all waste placement activities were terminated. Based on the packing efficiency actually achieved, it was clear that additional panels would need. So, DOE has been decided to construct two additional panels to the south of panels 4 and 5 to provide additional space to enable WIPP to accommodate its legally mandated limit of 175,564 m³. The shaded areas to the left (north) of the diagram are the experimental areas abandoned closed off in 1997.

Exhibit 2-1 - WIPP Surface and Underground Facilities
Exhibit 2-2 – WIPP Underground Status after the February Incidents

(Reference 12)

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 1,000 R/hr can be placed in WIPP. CH wastes can be safely handled more easily and are stacked directly on the floor of the panel rooms.

Salt is “plastic” and acts to close cavities 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. On February 5, 2014, a mining truck in the repository caught fire and forced a shutdown of operations. Subsequent to that event, on February 14th, 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.

The waste containers of interest for concentrated plutonium wastes are Criticality Control Overpacks (CCOs) (Exhibit 2-3). A CCO is essentially a 55-gallon drum with a Criticality Control Container (CCC) secured along the centerline of the drum. The CCC is a 6” diameter stainless steel pipe with blind flanges on either end. Waste material is placed in the CCC which is then secured within the CCO using plywood dunnage top and bottom and secured in place by the drum lid closure. The area surrounding the CCC is purposely kept empty to ensure adequate neutron leakage to ensure sub-criticality of the package.
Even so, the CCO can contain no more than 380 grams of $^{239}$Pu in the 13 liter volume of the CCC. Due to measurement errors and uncertainties, CCCs are routinely under-loaded with only about 300 grams of $^{239}$Pu per CCO (Reference 7). The CCCs are loaded with mixture of the plutonium and an inerting agent that makes recovery of the plutonium difficult. The CCC and the CCO are both vented to prevent the buildup of cases in the containers due to radiolytic or to biological decomposition of the materials in the package.

The Safety Analysis Report for the CCO is contained within revision 23 to the TRUPACT-II safety analysis report issued in December 2012 (Reference 13). It was prepared and submitted to the NRC by Washington TRU Solutions, LLC and Appendix 4.6 to the SAR is the Description of the Criticality Control Overpack. It is important to note that the SAR is for the TRUPACT-II shipping container; not WIPP. It is based on a stack of seven CCOs stacked two high in a TRUPACT-II shipment. It therefore considered 5,320 grams of plutonium; not 4.2 million grams as in the case of the current plan to dispose of 4.2 MTs of surplus weapons plutonium at WIPP. In spite of these limitations, the analysis resulted in a worst case criticality result of $K_{eff} = 0.9357$. A $K_{eff}$ of 0.9377 would have resulted in the rejection of the CCO as an approved container for shipping plutonium. In other words, using the most conservative assumptions possible for a shipment of CCOs, a criticality was not achievable but with a margin of only about 0.2%.

These drums are packaged on seven-drum pallets and shipped in TRUPACT-II overpacks two pallets each. Exhibit 2-4 shows how the drums are packaged in the TRUPACT-II. (Dimensions shown are in inches.) A typical shipment to WIPP consists of a truck loaded with three TRUPACT-II containers. That equals six pallets of seven CCOs each. These are placed into the repository and stacked three high. Therefore, each shipment results in two stacks of CCOs in the repository.

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5 See Appendix C for a discussion of Criticality and the meaning of $K_{eff}$. 

Exhibit 2-3 - Criticality Control Overpack
The once placed, the stacks of drums have a large bag of Magnesium Oxide stacked on top of the pallets. The MgO is added to the stack to control the pH of the repository after closure. The concern is that microbial activity will attack the carbon compounds (paper, plastic, rubber, etc.) in the waste releasing carbon dioxide. The concern is that the CO₂ will mix with the water in the repository over time resulting in the formation of carbonic acid (Reference 14).

The acidic nature of the potential aqueous environment would significantly increase the mobility of the actinides in the repository waste. To combat this, MgO backfill is added to each waste panel to ensure that the CO₂ will react with the MgO to form Magnesium Carbonate. This prevents the formation of carbonic acid and therefore reduces the mobility of the actinides in the repository over time. This serves as an Engineered Barrier to the movement of radionuclides after the closure of the repository.

The MgO is added to the waste panels in large “supersack” bags weighing either 3000 pounds or 4200 pounds depending on the carbon content of the waste. The 2014 Compliance Recertification Application summarized the work to reduce the quantities of supersacks used in each room (Reference 15). This was to be accomplished by placing the supersacks on every other row of waste packages rather than on every row which had been the practice up until the time of the change being approved by the EPA. They had been exceeding the ideal ratio of MgO to carbon by a factor of about 1.94 instead of the goal quantity of 1.2. In addition, there were more advanced estimates of the CO₂ generation rate from the decomposition of cellulose that were significantly lower than previous estimates. Criticallity is a condition in which a nuclear fission chain reaction can occur. Fission chain reactions occur because of interactions between neutrons and fissile isotopes (such as $^{235}\text{U}$ and $^{239}\text{Pu}$). The chain reaction requires both the release of neutrons from fissile isotopes undergoing nuclear fission and the subsequent absorption of some of these neutrons in fissile isotopes. When an atom undergoes nuclear fission, a few neutrons (the exact number depends on several factors) are ejected from the reaction. These free neutrons will then interact with the surrounding medium, and if more fissile isotopes are present, result in additional fissions. Thus, the cycle repeats to give a reaction that is self-sustaining.
3 Criticality Assessment

3.1 WIPP Design Basis

The history of WIPP was characterized by a series of starts and stops caused by the changing mission and regulatory requirements (See Appendix B). WIPP was begun in the 1970s before most of the regulations governing safe disposal of nuclear waste were finalized. Three separate sets of EISs were produced until the one that governs the design was approved in 1997. While EPA regulations do not require the consideration of nuclear criticality, the safety discussions in the 1997 FEIS and in subsequent documents cover it extensively (Reference 10). The result of these assessments was that the probability of criticality was so low that criticality did not need to be considered in the Performance Assessment. (See Appendix C for a description of criticality.) Subsequent reviews of this topic also indicated criticality was not likely to occur.

Revision 10 to the WIPP Consolidated Safety Analysis (Reference 16) issued in 2006 states that a criticality cannot occur at WIPP. However, the original 1997 analysis concluded that criticality was extremely unlikely under the conditions analyzed. Since no changes had occurred from the 1997 analysis, the statement in the 2006 Consolidated Safety Analysis was accurate as written. Additionally, it was written before the plan to develop the criticality control overpack and/or to dispose of large quantities of surplus weapons plutonium in WIPP. The probability of criticality occurring in WIPP has not been analyzed to address the significant increases in plutonium quantities and concentrations.

A 2000 Sandia report summarizes the basis for qualifying WIPP to meet the regulatory limits (Reference 17). The original design was based on the estimates of fissile material in the TRU wastes. WIPP was designed based on an estimate of 12.8 MTs of $^{239}$Pu and about 8 MTs of $^{235}$U. These were assumed to be uniformly mixed with 150 MTs of $^{238}$U and uniformly distributed in the 6.2 million cubic feet in the waste. This resulted in a concentration of fissile material in WIPP of approximately 0.12 kg/m$^3$.

The Sandia team concluded that in the WIPP repository predicted long-term environment:

For a mixture of $^{239}$PuO$_2$/Culebra dolomite (porosity $\phi$=16%) and brine,... the concentration limit for criticality is $\sim$3 kg/m$^3$ (1,250 ppm) ... and the mass limit is 2.2 kg ... (Reference 17 § 3.2)

In order to determine if a mechanism existed to increase the fissile concentration, Sandia examined two categories of events: compaction and solution/relocation. Sandia dispensed with compaction based on the following argument:

The radioactive waste to be emplaced at the WIPP contains very low concentrations of fissile material (primarily $^{239}$Pu); thus, the possibility of criticality is extremely remote prior to closure. Just as important, the possibility of criticality is also remote after closure because criticality requires that this emplaced fissile mass be substantially concentrated. To elaborate, the solid concentration below which an infinite volume of a homogeneous mixture of pure $^{239}$PuO$_2$, Culebra dolomite, and Culebra brine will not go critical is taken conservatively as 3 kg/m$^3$. This limit is 30 times larger than the average emplaced density of 0.12 kg/m$^3$ ($\rho_i$) with an initial porosity ($\phi_i$) of 0.848 based on a total Pu FGE mass scheduled to be placed in the WIPP of 21 Mg ... and a waste volume of 1.756 $\times$ $10^5$ m$^3$ (6.2
\( \times 10^6 \text{ ft}^3 \). This density could be increased somewhat through compaction; however, assuming compaction to an average porosity of 0.08... without any salt creep into the waste layer, the fissile mass bulk density \( (\rho_f) \) increases by only a factor of 6 to 0.72 kg/m\(^3\)...

Note that for final porosity values below 0.10 (greater than the mean and median of the final room porosities), the final room height is less than 0.45 m and the repository cannot go critical.... Furthermore, salt creeping or precipitating into pores within the waste as the MgO backfill is dissolved ... makes criticality even more difficult. Finally, if the transportation limit of 0.2 kg of FGE \(^{239}\text{Pu} \) per container is considered, the original 2.68 m height of the containers would have to be reduced to 0.18 m to reach the critical concentration—too thin to go critical... (Reference 17 § 3.5.1)

The other mechanism considered by Sandia was the movement of fissile materials out of the original waste locations and redistribution in geologic features of the WIPP repository site.

If movement of fissile material occurs from the repository into the disturbed halite or marker beds, a mechanism must exist for concentrating the solution. Furthermore, the mass and diameter of a sphere needed to produce criticality are both large and the concentration for plutonium must be about 53 kg/m\(^3\).... and at least as much for uranium. In general, the feasibility of concentrating the fissile material is not credible for two simple reasons: (1) the volume of disturbed halite and marker bed is very large (e.g., the volume of the disturbed rock zone is likely larger than the repository) and (2) no plausible mechanism exists for selective movement of fissile material into only a small portion of the disturbed rock zone or a marker bed.... The mass of plutonium FGEs required for criticality is 4 times greater than will be emplaced in any one room (~21 MT FGE of \(^{239}\text{Pu} \) will be emplaced in the repository, which has 118 equivalent rooms and thus ~178 kg FGE of plutonium per room). Also, spherical diameters that are the same or greater than the original height of the waste (2.76 m) are required for criticality in Salado salt... These arguments do not consider the \(^{238}\text{U} \) also present in the repository (149 Mg), which lowers the possibility of criticality because, when \(^{238}\text{U} \) is considered, the total fissile radioisotopes make up less than 14% of the total radioisotope inventory. (The average uranium enrichment is 5%...)(Reference 17 § 3.5.2)

The above are the main repository characteristics that Sandia evaluated and concluded would prevent criticality occurring at WIPP. As long as nothing is done to change those repository characteristics, criticality is a very low probability event. The Supplemental Analysis performed in 2002 justified the disposal of weapons grade plutonium from Rocky Flats Environmental Technology Site (RFETS). This 2002 analysis was issued only two years after the 2000 Sandia report and did not mention criticality as a concern. Reference 18 describes what was considered in the analysis as:

The potential environmental impacts of repackaging and transporting the proposed action materials for direct disposal at WIPP can be divided into three phases: (1) activities at RFETS to prepare the material for disposal, (2) transport of the material to WIPP, and (3) disposal activities at WIPP. In the first phase, the proposed action materials would be repackaged to meet the WIPP WAC and safeguards termination requirements. Once these repackaged materials meet the WIPP WAC and safeguards termination requirements, they would be ready for shipment to WIPP. (Reference 18 § Summary)
The previous analyses to dispose of weapons-grade plutonium at WIPP were based on the fact that the amount of plutonium being added was a small change to the WIPP design basis. It was concluded that the additional plutonium impacts were bounded by the previous analyses.

The Supplemental Analysis also contained the following statement.

DOE is now proposing to dispose of approximately 0.18 MT of the RFETS surplus plutonium (contained in approximately 0.97 MT of bulk materials) at WIPP instead of storing it in KAMS at SRS, pending possible disposition through other means. This SA examines whether the potential impacts of this action are adequately described in the WIPP SEIS-II. It should be noted that disposal at WIPP of the 50 MT of surplus plutonium from around the DOE complex that were the subject of the S&D PEIS was previously considered in scoping all alternatives for that PEIS. This option was eliminated from further consideration (i.e., determined to be unreasonable) because repackaging all 50 MT to a form that would make the material unattractive would have exceeded the capacity of WIPP. (Reference 18 § Summary)

In summary the Supplemental Analysis specifically excluded disposing of more than the additional 0.18 MT of plutonium from the cleanup of Rocky Flats at WIPP.

Even though the REFTS containers used POCs and were not specifically analyzed in the Supplemental Analysis, the POC (see Section 3.2 for a complete description of the POC) was developed to dispose of the approximately 0.18 MT of plutonium described above. The POC is a significant departure from the previous waste container in that it can contain up to 200 g of plutonium per container. In order for the POC to be certified by the NRC, verification was needed that the $^{239}$Pu contained in the POC would not become critical during preparation and shipment to WIPP.

Since the Rocky Flats weapons grade plutonium represented a very small mass compared to the WIPP design basis, it was judged not to represent a significant departure from previous design basis and was acceptable to be emplaced in WIPP. However, the Rocky Flats weapons grade plutonium was judged to be enough of a storage departure that the criticality analysis was again performed by Sandia (Reference 17) in 2000 to verify that criticality was virtually impossible. The same human intrusion events considered in the 1996 EIS were used by Sandia. The POC was judged by Sandia to be "incompressible" so compaction to a critical mass and concentration was judged not to be a credible event in the Sandia analysis. The result of the analysis was that the probability of criticality was so low that it did not need to be considered in the Performance Assessment. Despite the acceptance of the small amount of weapons grade plutonium packed in the POC from Rocky Flats, the current WIPP design basis does not consider the disposition of surplus weapons grade plutonium in WIPP.

DOE/NNSA is currently planning to emplace about 13.1 MTs of plutonium in WIPP that is in storage at SRS (Reference 40). The FEIS that describes this alternative does not address the impact on WIPP (Reference 19). If DOE cancels the MOX program, no disposition of plutonium at WIPP can take place until and unless formal analyses and a NEPA process informs all stakeholders and confirms that all surplus plutonium can be safely dispositioned at WIPP. The exact surplus plutonium inventory is at least the 51.3 MTs used in this report. See Appendix A for a discussion of public information regarding surplus weapons plutonium inventory.
3.2 Plutonium Overpacks

There are two NRC licensed containers for shipping plutonium bearing TRU wastes to WIPP: the Pipe Overpack Container (POC) and the Criticality Control Overpack (CCO). DOE/NNSA has approved the POC containers for dispositioning at WIPP. The CCO containers have not been approved for dispositioning at WIPP. Exhibit 3-1 shows the two containers in a side-by-side comparison.

![Exhibit 3-1 – Side-by-Side Comparison of TRU Containers](image)

The POC\textsuperscript{6} was first developed for packaging the concentrated plutonium wastes from the Rocky Flats Plant. It consists of a 6 inch diameter stainless steel pipe with a flange upper end. It is inserted into a 55-gallon drum and secured in place by protective dunnage over the entire length of the pipe. The waste is packaged inside the sealed pipe and then the POP is placed in the barrel with bottom and side dunnage in place. The upper dunnage is installed over the POP and the drum lid is secured with a metal locking band. The POP and the POC are vented to prevent over-pressurization.

The dunnage is plywood or particle board composites. The POC is licensed for transportation by the NRC under 10CFR71. It has a maximum licensed loading of plutonium of 200 grams. When disposing of relatively pure plutonium residues from Rocky Flats, the plutonium was blended with an inerting agent referred to as “Stardust.” This material was designed to make it difficult to recover the plutonium for illicit purposes. It was used by DOE/NNSA to lower the “attractiveness” of the waste to permit it to be disposed of without safeguards and security requirements that might otherwise have been imposed. WIPP is not designed to provide the security necessary to permit the disposal of weapons grade plutonium without first terminating the special nuclear material safeguards requirements.

The CCO has been recently proposed as a means of packaging surplus plutonium for disposal at WIPP because it purportedly can be used to dispose of nearly twice the fissile material per container. It is also based on the 55-gallon drum and it also has an inner storage container based on a 6” diameter stainless steel pipe. The major difference in the physical construction of the container is that the dunnage around

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\textsuperscript{6} This container is sometimes referred to by the name of the inner container as the Pipe OverPack or POP in the literature. In this report, POC will refer to the assemble package and POP will refer to the inner container only.
the inner Criticality Control Container (CCC) has been eliminated. The CCC is held in place by the upper and lower plywood dunnage only and it is slightly larger than the POP being 13 liters in nominal capacity vs 12 liters in the older design. There is also a difference in rated capacity of fissile material with the POC being limited to no more than 200 FGE whereas the CCO is rated at no more than 380 FGE. The POC was patented in 1999 (Reference 20) and the CCO was approved by the NRC for shipment of TRU Wastes June 2013 (Reference 21).

No TRU waste can be placed into WIPP unless it complies fully with the WIPP Waste Acceptance Criteria (WIPP WAC). At present, only the POC is listed in the WIPP WAC as an approved disposal container. In order to use the CCO, an amendment to the WIPP WAC will be necessary.

These drums are packaged on seven-drum pallets and shipped in TRUPACT-II overpacks two pallets each. Exhibit 2-4 shows how the drums are packaged in the TRUPACT-II. A typical shipment to WIPP consists of a truck loaded with three TRUPACT-II containers. These are placed into the repository and stacked three high. Therefore, each shipment results in two stacks of CCOs in the repository.

Once placed, the stacks of drums have a large bag of Magnesium Oxide (MgO) stacked on top of the pallets. This MgO is added to the stack to control the pH of the repository after closure. This is done to address the concern that microbial activity will attack the carbon compounds (paper, plastic, rubber, etc.) in the waste releasing carbon dioxide.

Carbon dioxide will mix with the water in the repository over time resulting in the formation of carbonic acid (Reference 38). The acidic nature of the potential aqueous environment would significantly increase the mobility of the actinides in the repository waste. To combat this, MgO backfill is added to each waste panel to ensure that the CO$_2$ will react with the MgO to form magnesium carbonate. This prevents the formation of carbonic acid and therefore reduces the mobility of the actinides in the repository over time. This serves as an engineered barrier to the movement of radionuclides after the closure of the repository.

The MgO is added to the waste panels in large “supersack” bags weighing either 3,000 pounds or 4,200 pounds depending on the carbon content of the waste. The 2014 Compliance Recertification Application summarized the work to reduce the quantities of supersacks used in each room (Reference 39). This was to be accomplished by placing the supersacks on every other row of waste packages rather than on every row which had been the practice until the time of the change being approved by the EPA. They had been exceeding the ideal ratio of MgO to carbon by a factor of about 1.94 instead of the goal quantity of 1.2. In addition, there were more advanced estimates of the CO$_2$ generation rate from the decomposition of cellulose that were significantly lower than previous estimates.

### 3.3 Impact of Surplus Plutonium Disposition on Criticality at WIPP

In order for the DOE/NNSA to approve the CCO for the disposition of surplus plutonium at WIPP, it will be necessary to demonstrate that the potential environmental impacts of the CCO are bounded by the existing analyses, or DOE/NNSA must undertake new analyses that demonstrate that the impacts are acceptable.
### 3.3.1 Concentration of Fissile Material

The original TRU waste slated to be dispositioned in WIPP had a low concentration of fissile isotopes. This resulted in the conclusion that achieving a sustained nuclear chain reaction was extremely unlikely. These characteristics were:

- A total of 21 MTs of fissile isotopes were distributed uniformly in 175,564 m³ (6.2 million ft³) of waste resulting in a concentration of 0.12 kg/m³
- 150 MTs of ²³⁸U was also uniformly distributed in the waste reducing the reactivity of the fissile isotopes
- The total mass of ²³⁹Pu was 12.8 MTs
- The fissile concentration of actinides was approximately 12% making the formation of a critical aqueous solution unlikely.
- The non-fissile waste materials present made it impossible to compact the fissile materials sufficiently to form a critical mass

At present, 52% of the legally allowed Contact Handled (CH) TRU waste has already been emplaced. As a result, the proposed disposition of surplus weapons plutonium at WIPP represents a significant increase in the concentration of actinide fissile isotopes because a significantly greater quantity will be placed in the remaining 48% of the allowable waste volume. Assuming that the original waste assessment was correct and the previous inventory remains proportional, the addition of 51.3 MTs of plutonium in the remaining space raises the average concentration of fissile isotopes (i.e. the enrichment) from 12% to 46%. This is shown diagrammatically in Exhibit 3-2.

**Exhibit 3-2 – Change in Actinide Fissile Concentration if Surplus Weapons Plutonium is Dispositioned in WIPP**

Specifically, the addition of surplus plutonium in CCOs to the waste form is not bounded by the conclusion that an aqueous solution from the waste form in WIPP cannot go critical. The impact is greater than shown in Exhibit 3-2 because there is no way to guarantee that the surplus plutonium can be mixed with the legacy waste form. The fissile concentration of actinides leached out of the surplus plutonium inventory will be approximately 100%. Therefore, all design analyses that assumed a relatively weak solution of fissile actinides being transported in WIPP after closure are not valid for the disposal of surplus weapons plutonium.
3.3.2 Compaction

A major consideration of the original design basis was the inability of the waste in the repository to be compacted enough to achieve a critical concentration. In order to understand this mechanism, it is necessary to realize that salt is a plastic medium. It will creep into voids to achieve a uniform density. The excavation of large hallways, rooms and tunnels in the salt dome will result in stresses that will result in the salt moving to fill the voids over time. Exhibit 3-3 is extracted from the Sandia report (Reference 17) and shows what the long-term condition of the repository is expected to be. It can be seen that the waste form will be compressed and flooded with salt water.

Exhibit 3-3 – Figure 13 from Sandia Report SAND99-2989 Showing the Long-Term Conditions in WIPP

The POC is filled with plywood or particle board dunnage and, assuming that the wood products do not appreciably decay over the next 10,000 years, the compression of the POC should not be significant. At least, that is the conclusion of the analyses done by Sandia for the Rocky Flats material.

The construction of the CCO is approximately 80% void. All of the fissile material contained in the CCC is in the middle of the otherwise empty CCO. A load of 380 g FGE in the CCC yields an average concentration of 29.2 kg/m³ in the CCC and an average concentration in the CCO of 1.73 kg/m³. The compression of the CCO void in an event such as salt creep or an earthquake will compress the CCO together. A fully compacted CCO yields an average local concentration of ~25 kg/m³. Exhibit 3-4 is an illustration the compression of the CCO from a non-compacted configuration to the fully compacted configuration yielding the ~25 kg/m³ concentration. Exhibit 3-5 graphically displays the change in average CCO ²³⁹Pu concentration with assumed compaction amounts with comparison to the ANSI standard and the Sandia WIPP limit.
The discussion in Appendix F illustrates the concern about compaction of the CCOs. If compaction events are credible, such systems cannot be bounded by the Sandia Report of 3 kg/m$^3$ single-parameter $^{239}$Pu limit. Under these compaction conditions, the criticality safety margins must be determined by means of a criticality safety evaluation. It should also be recognized that the SAR does not provide information on how much compression is considered in assessing criticality for shipping accidents. The SAR states “the hypothetical accident condition (HAC) is modelled as an infinite number of packages in the x and y directions with two packages in the z direction.” Such a model is very sensitive to the pitch between CCCs, or in other words on the degree of compaction of CCO. This makes the definition and justification of the accident geometry essential for the criticality safety evaluation of WIPP. (See Exhibit 3-5 for how compaction changes the pitch between neighboring CCCs.)
Characteristic Not Analyzed by Others

As described in Section 1 above, a bag of MgO is added to the stack to control the pH of the repository after closure. The MgO is added to the waste panels in large “supersack” bags weighing either 3000 pounds or 4200 pounds each depending on the carbon content of the waste. Exhibit 3-6 shows one of these supersacks being inserted onto the waste package.

Magnesium oxide is not usually considered to be a particularly effective moderator material in LWR nuclear reactor design. However, the total macroscopic cross section for magnesium between approximately 70 keV and 1 meV is significantly greater than that of graphite as is shown in Exhibit 3-7. Below that energy range, the total cross section for magnesium is only somewhat less than that of carbon or graphite while above the noted energy range, the cross sections for these materials are about equal.

The total cross section is a measure of the probability of an interaction between a neutron at a certain energy and the nucleus. The interaction can be to scatter the neutron or to absorb the neutron forming a new isotope. Magnesium’s cross section is almost entirely scattering. Each time a neutron scatters off of a magnesium atom, it loses energy. It loses energy until the neutron is the same energy as the bulk material in the system. This process is known as moderation and it is important because the probability of a nuclear absorption for most materials increases as the energy of the neutron decreases. The high energy neutrons released as a result of a fission are “moderated” to a lower energy thus increasing the probability that they will be absorbed by another fissile atom to carry on the chain reaction. This effect has been completely ignored in the analyses for WIPP criticality.
Studsvik Supporting Analysis

High Bridge contracted with Studsvik Scandpower, Inc. an internationally recognized expert on nuclear criticality to review this matter (See Appendix H to review their credentials). High Bridge engaged Studsvik to perform the following tasks:

- Task 1 - To review the Sandia report (Reference 17) for clarity and rigor.
- Task 2 - To review the SAR (Reference 31) for the CCO design.
- Task 3 - To conduct a preliminary study of placing the CCO containers in WIPP in accordance with the DOE/NNSA proposed concentration of weapons grade plutonium.

The results of these Studsvik tasks are reported in Appendix F and discussed in the remainder of this section.

Task 1

Studsvik found that the Sandia study did not completely conform to accepted rules found in “Guidelines for Preparing Criticality Safety Evaluation at Department of Energy Nonreactor Facilities” (Reference 22). Also, the ANSI standard governing criticality assessments (Reference 23) suggests a concentration of 7.3 kg/m³ be considered as the minimum concentration for criticality to be a concern. The Sandia study (Reference 17) used a more conservative limit of 3 kg/m³ for WIPP but cited no basis. The study asserted that as long as the $^{239}$Pu concentration remained below this limit conditions in WIPP would remain sub-critical. Instead of analyzing the criticality of various configurations, the Sandia study identified plausible concentrations of fissile isotopes for various scenarios within WIPP. For the conditions analyzed by Sandia the distributed concentration of fissile isotopes was 0.12 kg/m³, well below the 3 kg/m³. Moreover, Sandia determined that the waste form in WIPP could not be compressed or concentrated in any way to exceed the 3 kg/m³ concentration limit.

Studsvik concluded that, despite the lack of compliance with the DOE Standard for criticality safety evaluations or other accepted criticality standards, the conditions in WIPP as analyzed by Sandia would guarantee sub-criticality and safe operations in the repository.

Task 2

The safety analysis report issued by Washington TRU Solutions, LLC to obtain NRC approval of the use of CCOs in TRUPACT-II shipping containers (Reference 13) gave the physical description of CCO/CCC (See Exhibit 3-1). Studsvik reviewed all evaluations presented in the SAR. The SAR proposed an upper subcritical limit (USL) of $k_{eff} = 0.9377$ to assess whether the fissile material in the CCO would go critical under hypothetical shipping accident (HAC) scenarios.\(^7\)

Drop tests of actual CCOs and a series of NRC-required accident scenarios for transport were evaluated and a range of calculated $k_{eff}$ values were determined. While all were less than the upper sub-critical limit (USL) value, the worst case scenario resulted in a calculated value of $k_{eff} = 0.9357$. This is a margin against the USL value of only 0.2%. While the NRC accepted the application and issued a Certificate of Compliance

\(^7\) $k_{eff} = 1.0$ defines a sustained nuclear chain reaction is possible, but it is standard practice to establish a lower analytical limit to account for computational uncertainties.
for the CCO for shipping (Reference 21), Studsvik concluded that the lack of a large safety margin suggests that a more careful analysis of the impact on WIPP would be warranted.

**Task 3**

Using the physical and isotopic data contained in the SAR and the WIPP repository from the Sandia report, Studsvik built a simple model of the CCOs as stacked in the WIPP repository. Exhibit 3-8 shows a typical loading of 55-gallon drums at WIPP. The 7-pack pallets are removed from the TRUPACT-II in the aboveground facilities and moved to the underground disposal area. They are stacked three high and have a “supersack” of MgO loaded on top of alternate rows of CCOs. The Studsvik report presented in Appendix F describes in more detail the approach taken to develop this model.

Exhibit 3-8 – Typical Drum Stacking in WIPP

Studsvik performed criticality computations for four configurations of CCOs:

**Configuration 1:** Single CCOs (not stacked or arranged in a 7-pack CCO configuration) set in an infinite array with mirror conditions (no neutrons escaped the model) applied all around. Two configurations of the single CCO were modelled:

a. The void between the CCO and CCC contained water
b. The void between the CCO and CCC contained air.

**Configuration 2:** Three 7-pack CCOs, stacked three high, in an infinite array; 2 cases of non-compacted and compacted to 1/3 of the original CCO volume (shown in Exhibit 3-5) assuming the boundaries in the axial direction are black (i.e. neutrons that escape the packages are not reflected back).

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8 The drums in the photograph are simple 55-gallon drums of legacy waste; not CCOs.
**Configuration 3:** Two stacks of three 7-pack CCOs, compacted to 1/3 of the original CCO volume assuming all boundaries are black.

**Configuration 4:** Three stacks of the 7-pack CCOs, non-compacted, having MgO placed in various boundaries (black boundaries are applied on all outer surfaces with more than 30 cm of MgO):

a. no MgO,
b. 50 cm of MgO on top of stacks,
c. additional MgO between all CCOs, and
d. MgO surrounding the stacks excluding the bottom CCOs.

**Summary of Studsvik Results:**

Configuration 1 – Single CCO: This configuration was used by Studsvik to check their models to ensure consistency between Studsvik and Sandia analytical programs used. The configuration is not applicable to emplacing the CCOs in WIPP.

Configurations 2 and 3 - Three 7-pack CCOs, stacked three high and two stacks of three 7-pack CCOs: The resulting criticalities are shown in the table below:

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Non-compacted</th>
<th>Compacted</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (packed in an infinite array)</td>
<td>$K_{eff} = 0.8595$</td>
<td>$K_{eff} = 1.0944$</td>
</tr>
<tr>
<td>3 (packed in a finite array)</td>
<td>-</td>
<td>$K_{eff} = 0.9911$</td>
</tr>
</tbody>
</table>

Applying either an upper limit $K_{eff} = 0.95$ (generally accepted standard) or $K_{eff} = 0.9377$ as was used in the CCO SAR it is clear from the computations that criticality has a very high likelihood of being reached for these configurations of compaction. As pointed out in the Sandia analysis, salt creep is likely to compact the stored material packages in WIPP over time. While it is recognized in Appendix F that the infinite array configuration is probably not entirely applicable to the situation in the WIPP repository, the finite array configuration represents a realistic configuration and categorically implies the need to perform detail nuclear criticality computations for storing weapons grade plutonium in WIPP.

Configuration 4 - Three stacks of the 7-pack CCOs with MgO included: The resulting criticalities are shown in the table below:

<table>
<thead>
<tr>
<th>Configuration 4 Cases</th>
<th>Non-compacted</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. No MgO on any boundary</td>
<td>$K_{eff} = 0.6397$</td>
</tr>
<tr>
<td>b. Supersacks of MgO on top of each stack</td>
<td>$K_{eff} = 0.6650$</td>
</tr>
<tr>
<td>c. Additional MgO placed between drums</td>
<td>$K_{eff} = 0.8294$</td>
</tr>
<tr>
<td>d. All around MgO reflection (excluding drum bottom)</td>
<td>$K_{eff} = 0.9829$</td>
</tr>
</tbody>
</table>

The effect of having MgO included in the WIPP repository makes the likelihood of a nuclear criticality greater. That effect can clearly be seen from examining the data in the previous table. It is clear from the data in the last row of the table that the accepted upper limit $K_{eff}$ for sub-criticality is exceeded. Note that these results are for the non-compacted case. It would be expected that if the MgO was added to the models for the compacted cases that the results would have indicated a greater likelihood of nuclear
criticality than calculated. These analyses were not attempted because once the design fails, it fails. A single stack of CCOs in WIPP can go critical under the conditions expected to exist in the repository over time.

These results again emphasize the need to perform detail nuclear criticality computations for storing weapons grade plutonium in WIPP and in particular the need to realistically model the material properties in the geographical characteristics of WIPP.

Studsvik’s concluding remarks based on their analyses are:

The review of Reference 17 and Reference 13, relevant to a proposed disposal scheme of 7x3 CCOs loaded with 380g Pu-239 each, showed lack of concern for criticality or insufficient contingency considerations and lead to the following conclusions:

- The single parameter limit on $^{239}$Pu concentration established for WIPP by Reference 17, 3kg/m$^3$, is inapplicable for disposal of the suggested increased to 380g amount of $^{239}$Pu per CCO

- The criticality evaluation presented in Reference 13 for the transportation of CCO in TRUPACT-II is inapplicable for storing packages of 7x3 CCOs at WIPP since the analysis provided for the transportation safety are insufficient to cover the potential compaction in 10,000 years

- Criticality analysis of the CCC and CCO in the WIPP environment using similar assumptions as in the transportation analysis show the criticality is likely with only a ~30% crushing of a single stack of CCOs (7x3 array, 21 drums)

- The effect of MgO supersacks which are to be placed on top of the CCOs would enhance the likelihood of criticality.

Studsvik concludes that criticality safety evaluations for normal and all considered credible off-normal conditions are required for determination of the criticality safety margins of WIPP if 380g $^{239}$Pu is to be stored per CCO.

3.3.3 Physical Constraints

Unintended criticality accidents are usually self-limiting. That is, the energy released during the criticality is usually adequate to change the environment enough to achieve a non-critical state. The mechanism can be drying out the deposit, mechanical disassembly of the critical mass, or melting so that the material flows into a non-critical geometry. These effects tend to limit a criticality event to a relatively brief pulse rather than a continuous generation of energy.

However, these processes are made more difficult if the material involved is restrained as would be the case in WIPP. The action of the salt moving into the waste panels would cause the criticality by crushing the CCOs together would also make it difficult for the force of the energy release to push them apart. So, the criticality could be a long-term event, like the underground natural reactor formed in Gabon, West Africa two billion years ago (Reference 24). That event was caused when groundwater intruded into a
rich uranium deposit that was firmly fixed in solid rock. In that case, multiple criticality events persisted for a million years turning on and off occasionally over time.

While a criticality in WIPP would probably not be as persistent as the Gabon events due to the lack of structural strength of salt domes compared to hard rock sites. This example suggests that placing tons of pure plutonium in a geologic repository that permits both water intrusion and compression would be a long-term problem that would distort the shape of the repository and generate significant quantities of unanalyzed fission products.

In summary, the impacts of the results of a sustained criticality in the WIPP repository are unpredictable and have not been considered in any DOE/NNSA Performance Assessment for WIPP.

4 Legal and Regulatory Assessment

The construction of WIPP was authorized in section 213 of the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (Reference 25). It specifically stated:

The Secretary of Energy shall proceed with the Waste Isolation Pilot Plant construction project authorized to . . . demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission. (emphasis added) (Reference 25 § 213(a))

Surplus plutonium is not, by definition, waste. It is usable special nuclear material that has no current identifiable mission, but it is not waste per se. Therefore, it could be argued on that basis that disposal of surplus plutonium at WIPP is beyond the scope of the act that allowed its construction. Indeed, there are many other cases of DOE-owned TRU wastes that are prohibited from going to WIPP.

After the authorization to construct was enacted, WIPP has been developed as required by the WIPP Land Withdrawal Act (LWA) (Reference 13) that also sets a maximum size of WIPP in terms of the volume of TRU Waste that can be emplaced. The total TRU waste volume can be no more than 6.2 million cubic feet (175,564 m³). While the WIPP LWA sets specific curie limits for RH-TRU, it sets no specific limits for CH-TRU wastes can be sent to WIPP. Currently, the DOE-EM has set a maximum of 3,950 m³ of RH-TRU allowed at WIPP with 3,330 m³ currently identified and planned for disposal (Reference 27). This reference also identifies the total volume of waste already subscribed for disposition at WIPP as 152,000 m³; leaving only about 23,000 m³ available within the limits set forth in the Act.

DOE prepared a Supplemental Environmental Impact Statement (EIS) for approval in 1996 which was approved as the Final Supplemental EIS (Reference 10) for the WIPP facility. Before significant changes can be made to the facility, its operation or its performance that could have a significant environmental impact, a new FEIS or supplement to the FEIS for WIPP must be prepared by DOE to inform the decision-making process in accordance with the NEPA. In addition to providing updated information, including waste characterization and potential source terms, this new NEPA documentation needs to address whether WIPP itself could continue as the only facility available for TRU disposition. If the problems become insurmountable for the use of WIPP, a new facility would be required that will be designed to address the unique issues associated with the disposal of surplus weapons plutonium as TRU waste. A
new facility could also be required if this material is dispositioned in WIPP resulting in WIPP’s statutory limit being reached, in which case WIPP would need to be either expanded or a new facility authorized to continue serving programmatic needs.

DOE/NNSA has prepared a Supplemental EIS for Surplus Plutonium Disposition that concludes that 13.1 MTs of Surplus Plutonium can be dispositioned at WIPP (Reference 19). However, it devoted little effort to examining the impacts on WIPP and devoted its effort to the environmental impact of preparing the plutonium for disposal rather than to consider the impact of the material at WIPP itself. It appears to rely on the experience from Rocky Flats where 180 kg of weapons grade plutonium and approximately 3 MTs of $^{239}$Pu in total were dispositioned at WIPP. However, the details of the Rocky Flats experience are not accurately reproduced in the current DOE/NNSA planning and much of the work necessary to make this program possible is not in evidence.

At the same time, the DOE/NNSA is apparently considering whether to abandon the current strategy of disposing of approximately 34 MT of surplus weapons plutonium that had previously been identified for conversion into MOX fuel and irradiated in existing commercial reactors. Because this material had a special disposition path, none of the previously prepared NEPA documentation has considered, as a reasonable alternative, the disposal of these 34 MT of plutonium in WIPP or any other repository. Therefore, none of the EISs, Supplemental EISs or Supplement Analyses related to either operation of WIPP or the storage or disposition of surplus plutonium have ever considered the disposition of this large quantity of plutonium in WIPP. No NEPA documentation has been prepared for disposition of surplus weapons plutonium in CCOs, in WIPP or any other repository.

Moreover, the DOE is also considering the disposal of Greater-Than-Class-C (GTCC) wastes in WIPP as evidenced by the preparation of a Draft Environmental Impact Statement DOE/EIS-0375-D (Reference 34). If WIPP is selected as the disposal alternative for the GTCC low-level radioactive waste, it would potentially use all of WIPP’s unallocated capacity and would generate a whole spectrum of new operational problems. These documents are in fundamental conflict and cannot resolve the issues facing WIPP without a thorough, integrated approach.

The fundamental assumption in all of DOE/NNSA’s thinking on this issue appears to be that the disposal of this amount of surplus plutonium is bounded by previous Rocky Flats analyses and NEPA documentation. A recent article in the journal Nature has cast doubt on that assumption (Reference 28). Stanford University researchers questioned the safety of disposal of diluted Plutonium in “inert” material. The authors pointed out that plutonium has many chemical states and that there are very few truly inert materials in geological time, especially in the WIPP environment. Due to the long timeframe of Plutonium wastes (half-life of 24,000 years), it is likely that the regulatory time-period will be increased. This coupled with the large increase in the quantity of plutonium that is planned to be disposed, increases the probability of human intrusion. They also point out that the lack of a revised safety analysis of this action could likely result in future failures. This indicates the programmatic risks associated with reopening the NEPA process for WIPP; it could result in a Yucca Mountain like period of analysis that could force the closure of WIPP.

The National Environmental Policy Act (NEPA) and its associated implementing regulations issued by the Council on Environmental Quality (CEQ) (40 CFR Parts 1500-1508) and DOE (10 CFR Part 1021) require the preparation of an Environmental Impact Statement (EIS) for proposals for major federal action that may significantly affect the quality of the human environment. The NEPA process is to be integrated into the agency decision-making process so that the decision-maker can be informed of the potential
Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel Irradiation

environmental consequences of the decision and provide the public and other stakeholders an opportunity to be informed and participate in the decision-making process.

The applicable NEPA documentation on the operation of WIPP is the Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement finalized in 1997. (Reference 10) The analyses that formed the basis of technical support for the conclusions in that FEIS were based in part on the following relevant parameters:

- $^{239}$Pu inventory in repository is 12.8 MT
- Total fissile inventory in the repository is approximately 21 MT (primarily $^{235}$U and $^{239}$Pu)
- There is also 150 MT of $^{238}$U that has been used to downblend $^{235}$U
- The fissile inventory is assumed to be uniformly distributed in the 6.2 million cubic feet of waste for a concentration of 0.12 kg/m$^3$
- The current projection for the total TRU waste to be placed in WIPP is 152,000 m$^3$
- At the time of cessation of waste handling activities, approximately 91,250 m$^3$ of TRU Wastes had been emplaced in WIPP

While these parameters are not specifically mentioned in any of the NEPA documentation, they are the foundation upon which the conclusions and findings in the NEPA documentation are based. Any action that results in these values being exceeded or ignores the impact of changes to the WIPP design basis, need to be addressed in a Supplemental Analysis as a minimum and if found to be significant, a complete supplemental FEIS to adequately inform decision makers.

The decision by DOE/NNSA to use WIPP as the ultimate disposition pathway for the surplus plutonium disposition program results in the following violations of the WIPP design basis:

- The decision to dispose of any quantity of surplus plutonium at WIPP exceeds the 12.8 MT assumed in the design basis.
- The surplus plutonium is of weapons grade and cannot be mixed uniformly with the original volume of TRU waste at WIPP since 52% of that volume is already emplaced and sealed in waste panels at the original waste concentration.
- There is no depleted uranium in the surplus weapons plutonium to reduce the reactivity.
- The concentration of fissile material inside the criticality control container is 29.2 kg/m$^3$ which is 243 times greater than the 0.12 kg/m$^3$ analyzed for WIPP.
- The CCO is essentially a hollow drum that will be compacted by the repository introducing an uncontrolled criticality scenario into WIPP not previously analyzed.

These violations of the design basis should have generated the preparation of NEPA documentation to address the impacts of these new design basis conditions. However, no supplemental analyses addressing these items have been generated. Moreover, the fundamental FEIS has not been revised since its acceptance in 1997.

The applicable NEPA documentation on the disposition of surplus weapons plutonium is the Surplus Plutonium Disposition Final Environmental Impact Statement (SPD EIS) (DOE/EIS–0283). The SPD EIS addressed the disposition of 34 MTs of surplus weapons plutonium covered by the bi-lateral agreement between the United States and the Russian Federation. It was the culmination of a process started on May 22, 1997, when DOE published a Notice of Intent (NOI) in the Federal Register (62 FR 28009)
announcing its decision to prepare an EIS that would tier from the analysis and decisions reached in connection with the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic EIS (Storage and Disposition PEIS) (DOE/EIS–0229). A Record of Decision was issued 65 FR 1608, January 11, 2000, reflecting the decision to adopt the MOX alternative. This series of EISs and related NEPA documentation did not analyze, as a reasonable alternative for the disposition of the 34 MT of surplus weapons plutonium, the disposition in WIPP. We have not found any existing NEPA documentation that could be used to inform decision-making with regard to the disposition of these 34 MT of surplus weapons plutonium in WIPP or any other existing geologic repository.

In another tiered Environmental Impact Statement, DOE/EIS-0283-S2 (Reference 19), DOE/NNSA is considering the disposition of an additional 13.1 MT of surplus plutonium in WIPP, however, that EIS erroneously relies on inapplicable assumptions relating to the potential consequences of disposition of this material in CCOs in WIPP. Under CEQ and DOE implementing NEPA regulations, these connected actions must be analyzed as connected actions in an EIS and a thorough analysis needs to be conducted to determine what the cumulative potential environmental and other impacts would be. Further, it seems reasonably foreseeable that as a result of these two connected actions, as well as other proposed dispositions at WIPP, that WIPP would reach its statutory and regulatory capacity limit. Any proposals to dispose of surplus plutonium at WIPP will require a new NEPA analysis that necessarily needs to include potential alternatives to using WIPP as currently authorized, including seeking legislation to amend the WIPP Land Withdrawal Act as well as considering the authorization, construction and operation of a new geologic repository.

The most recent NEPA documentation on the Site-wide Operations at WIPP is a Supplement Analysis (DOE/EIS-0026-SA-07), issued in May 2009.9 Neither this document nor any other applicable NEPA documentation addresses the potential environmental consequences of disposal of this quantity of plutonium at WIPP. Further, there is no analysis of the potential environmental impacts that could result from the use of CCOs for disposition of this form of concentrated plutonium. WIPP is also currently not operating as the result of accidents occurring in 2014. In view of:

- The time that has passed since the site-wide EIS was prepared (DOE NEPA regulations provide for a review about every five years of the continued validity of Site-wide EISs),

- The changes to operations that may result from modifications in operation and design that may result from the ongoing restart activities,

- The potential for a criticality event arising from the proposed use of the CCOs,

- The increased cumulative environmental impacts that could result from using WIPP to dispose of these quantities of surplus weapons plutonium, in addition to those amounts already analyzed in the 1997 WIPP SEIS-0026-S-2

- The proposal to use WIPP as the repository for GTCC and GTCC-like wastes in addition to TRU Wastes in the 2011 Draft EIS (DOE/EIS-0475-D).

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9 Supplemental Analyses DOE/EIS-0026-SA-08 and 09 issued in Sep. 2010 and Mar. 2014 respectively did not address Site-Wide Operations.
High Bridge concluded that the NEPA documentation for the continued operation of WIPP needs to be updated to reflect all of these potential changes in order to make any significant decisions regarding its potential use. In view of the cumulative impacts of all of the proposals for the use of WIPP, that collectively far exceed its statutory capacity, the updated NEPA review should also include analyses of modifications to the facility and its operations that will be needed to increase capacity, approve new waste forms and obtain regulatory approvals. Additionally, an alternative for a new geologic repository needs to be considered.

The Land Withdrawal Act (Reference 31) sets the maximum size of WIPP in terms of the volume of TRU Waste that can be emplaced. The total TRU waste volume can be no more than 6.2 million cubic feet (175,564 m³). While the WIPP LWA sets specific curie limits for RH-TRU, it sets no specific limits for CH-TRU wastes can be sent to WIPP. Currently, the DOE-EM has identified 3,950 m³ of RH-TRU allowed with 3,330 m³ currently identified and planned for disposal at WIPP. (Reference 27) This reference also identifies the total volume of waste already subscribed for disposition at WIPP as 152,000 m³; leaving only about 23,000 m³ available within the limits set forth in the Act.

This report assumes a total of 51.3 MT of surplus plutonium is destined for WIPP. (See Appendix A for additional discussion.) It also outlines five scenarios to address the problem:

1. Dispose of surplus plutonium in CCOs as proposed by DOE/NNSA
2. Dispose of surplus plutonium in POCs which are accepted for use at WIPP in the WAC
3. Reduce the concentration of plutonium in the CCO to meet the ANSI/ANS standard of 7.3 kg/m³
4. Reduce the concentration of plutonium in the CCO to meet the Sandia report calculated criticality limit of 3 kg/m³
5. Reduce the concentration of plutonium in a 55-gallon drum to meet the overall site concentration of 0.12 kg/m³ of fissile isotopes.

Exhibit 4-1 demonstrates what the impact on WIPP would be for each of these scenarios.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Plutonium Concentration kg/m³</th>
<th>Drums</th>
<th>Duration Required Years to Emplace</th>
<th>Volume m³</th>
<th>Storage Rooms</th>
<th>Will Go Critical</th>
<th>FEIS Compliant</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIPP Design &amp; FEIS Basis</td>
<td>0.12</td>
<td>N/A</td>
<td>25</td>
<td>175,564</td>
<td>56</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Storage Storage Scenarios</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1 Using CCOs</td>
<td>29.2</td>
<td>171,000</td>
<td>4.6</td>
<td>35,568</td>
<td>21</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Scenario 2 Using POCs</td>
<td>16.7</td>
<td>301,765</td>
<td>8.2</td>
<td>62,767</td>
<td>35</td>
<td>Likely</td>
<td>No</td>
</tr>
<tr>
<td>Scenario 3 Concentration Reduced to ANSI Standard</td>
<td>7.3</td>
<td>539,780</td>
<td>14.6</td>
<td>112,274</td>
<td>53</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Scenario 4 Concentration Reduced to Sandia Single Point Value</td>
<td>3.0</td>
<td>1,313,465</td>
<td>35.4</td>
<td>273,200</td>
<td>128</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Scenario 5 Concentration Reduced to WIPP Design Value</td>
<td>0.12</td>
<td>2,053,337</td>
<td>55.3</td>
<td>427,094</td>
<td>203</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
High Bridge concludes from these comparisons that any action to dispose of surplus plutonium at WIPP in a manner that meets the mandates of safety for a radioactive waste repository will violate the volume limit imposed by the LWA. Moreover, the values shown in Exhibit 4-1 are the minimum values because they permit no margin for the continuing EM and other DOE programmatic missions. In addition, all of the proposed options require a new NEPA documentation to adequately inform the decision-makers of the impact of these decisions.

5 Radiological Release Limits

40CFR191 sets the standard for radiological releases for WIPP (Reference 15). Since the standard is based on future events that are unknowable, the regulation sets the standard that the repository “shall be designed to provide a reasonable expectation... that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal” are within certain probabilistic limits.

For WIPP’s original design basis of 12.8 MTs of $^{239}$Pu, that limit is less than a 10% chance of exceeding 1.28 Ci of $^{239}$Pu released and a less than a 0.1% chance of exceeding 12.8 Ci of $^{239}$Pu released in 10,000 years. In order to increase the scope of WIPP to include the surplus weapons plutonium disposition mission, it is obvious than a safety evaluation is necessary and a thorough reassessment of the assumptions and analyses used to permit WIPP for operation. The increase in the total inventory of $^{239}$Pu by a factor of five and its concentration, before compaction, by a factor of 19 is too significant to ignore. There is no published demonstration that this assessment has been made.

The performance of the WIPP disposal system is evaluated by means of the WIPP Performance Assessment (PA). The PA uses a probabilistic distribution of possible radionuclide releases from the WIPP repository over the next 10,000 years and characterizing the uncertainty in the distribution. The WIPP PA results are required to be expressed as Complementary Cumulative Distribution Functions (CCDFs). A CCDF represents the probability of exceeding cumulative releases for specific isotopes.

Every five years after the start of waste operations, the DOE must file a Compliance Recertification Application. The most recent of these submissions was in March of 2014 (Reference 16) made no mention of any plan to place surplus weapons plutonium in WIPP.

Compliance analyses performed on the undisturbed repository result in no releases from the repository to the accessible boundary. Therefore, all total normalized releases in the CRA-2014 PA correspond to the disturbed repository. Based on the assumptions used in generating the CRA-2014 compliance analysis, the overall mean releases have decreased since the CRA-2009. Exhibit 5-1 was taken from the CRA-2014 Executive Summary (Reference 35) and shows the mean CCDFs for total normalized release from WIPP. It suggests nearly two orders of magnitude compliance with the individual and groundwater protection standards in Part 191 Subparts B and C. This graph represents the results of a complex effort of analyzes but does indicate any increase in the expected source term. Indeed, the decreases came solely from assumptions about the nature and extend of the disturbances made to the repository over the 10,000 year period of regulatory concern.
The disposal of all of the surplus weapons plutonium at WIPP would involve the loading of 171,000 CCOs and the shipping of those containers to WIPP on approximately 4,100 truck shipments. The FEIS was based on the shipment of approximately 41,000 truck shipments of CH-TRU (Reference 10 § Table 5-24). The resulting accident rate and the radiological exposure associated with this 4,100 truck shipments of more highly concentrated weapons plutonium represent approximately a 10% increase over the values in the FEIS.

The radiological assessment for WIPP was based on the isotopic content shown in Exhibit 5-2. The isotopes of importance for the long-term exposure to the public are clearly the long-lived actinides $^{235}\text{U}$ and $^{239}\text{Pu}$. Of the two isotope inventories, plutonium was the more significant. While there was about 8 MTs of $^{235}\text{U}$, there were 12.8 MTs of $^{239}\text{Pu}$. If the surplus weapons plutonium is dispositioned at WIPP, the inventory of $^{239}\text{Pu}$ increases by a factor of five to 64.1 MTs.

As noted in Appendix A, there is substantially more plutonium than the 51.3 MTs considered in this report. Without the MOX alternative, all of this plutonium must eventually find its way into WIPP or a new repository. If it is all dispositioned at WIPP, it will have a significant, unanalyzed impact on the long-term dose rates at WIPP.
### Exhibit 5-2 - Anticipated Mass of Fissile Material in the WIPP Repository

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Mass (kg)</th>
<th>Proposed Change</th>
<th>New Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{232}\text{U}$</td>
<td>$1.21 \times 10^{-3}$</td>
<td></td>
<td>$1.21 \times 10^{-3}$</td>
</tr>
<tr>
<td>$^{233}\text{U}$</td>
<td>$2.01 \times 10^{2}$</td>
<td></td>
<td>$2.01 \times 10^{2}$</td>
</tr>
<tr>
<td>$^{234}\text{U}$</td>
<td>$8.13 \times 10^{1}$</td>
<td></td>
<td>$8.13 \times 10^{1}$</td>
</tr>
<tr>
<td>$^{235}\text{U}$</td>
<td>$8.07 \times 10^{3}$</td>
<td></td>
<td>$8.07 \times 10^{3}$</td>
</tr>
<tr>
<td>$^{236}\text{U}$</td>
<td>$6.64 \times 10^{6}$</td>
<td></td>
<td>$6.64 \times 10^{6}$</td>
</tr>
<tr>
<td>$^{237}\text{U}$</td>
<td>$7.36 \times 10^{-7}$</td>
<td></td>
<td>$7.36 \times 10^{-7}$</td>
</tr>
<tr>
<td>$^{238}\text{U}$</td>
<td>$1.49 \times 10^{5}$</td>
<td></td>
<td>$1.49 \times 10^{5}$</td>
</tr>
<tr>
<td>Plutonium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{236}\text{Pu}$</td>
<td>$1.96 \times 10^{8}$</td>
<td></td>
<td>$1.96 \times 10^{8}$</td>
</tr>
<tr>
<td>$^{238}\text{Pu}$</td>
<td>$1.53 \times 10^{2}$</td>
<td></td>
<td>$1.53 \times 10^{2}$</td>
</tr>
<tr>
<td>$^{239}\text{Pu}$</td>
<td>$1.28 \times 10^{4}$</td>
<td>$5.13 \times 10^{4}$</td>
<td>$6.41 \times 10^{4}$</td>
</tr>
<tr>
<td>$^{240}\text{Pu}$</td>
<td>$9.44 \times 10^{2}$</td>
<td></td>
<td>$9.44 \times 10^{2}$</td>
</tr>
<tr>
<td>$^{241}\text{Pu}$</td>
<td>$2.38 \times 10^{1}$</td>
<td></td>
<td>$2.38 \times 10^{1}$</td>
</tr>
<tr>
<td>$^{242}\text{Pu}$</td>
<td>$1.96 \times 10^{8}$</td>
<td></td>
<td>$1.96 \times 10^{8}$</td>
</tr>
<tr>
<td>$^{243}\text{Pu}$</td>
<td>$1.23 \times 10^{-18}$</td>
<td></td>
<td>$1.23 \times 10^{-18}$</td>
</tr>
<tr>
<td>$^{244}\text{Pu}$</td>
<td>$8.46 \times 10^{5}$</td>
<td></td>
<td>$8.46 \times 10^{5}$</td>
</tr>
<tr>
<td>$^{239}\text{Pu}$ fissile gram equivalent (FGE)</td>
<td>$2.11 \times 10^{4}$</td>
<td>$5.13 \times 10^{4}$</td>
<td>$7.24 \times 10^{4}$</td>
</tr>
<tr>
<td>Total (all radioisotopes)</td>
<td>$1.81 \times 10^{5}$</td>
<td>$5.13 \times 10^{4}$</td>
<td>$2.32 \times 10^{5}$</td>
</tr>
</tbody>
</table>

\(^a\) = Fissile isotope  
First three columns from Table 4 in Reference 17

The WIPP salt formation is an excellent barrier to the movement of radioactive material. The performance assessment done in support of the most recent RCA resulted in a lower CCDF than the 2009 CRA reported. (See Exhibit 5-1.) However, that value did not include the addition of significant quantities of additional plutonium. Also, the results are primarily due to intrusion into the repository by innocent stakeholders looking for something else, i.e., water, oil, natural gas, etc. The addition of extremely large quantities of surplus weapons plutonium to the repository adds additional unanalyzed intrusion scenarios. These scenarios have to do with people overtly seeking to divert the surplus weapons plutonium into nuclear devices for national or nefarious purposes. These intrusions would be into panels and rooms containing two orders of magnitude more concentrated fissile material than analyzed. These intrusion scenarios could eliminate the perceived safety margin for WIPP’s radiological performance assessment.

This impact would be exacerbated if this change to the waste being placed in WIPP can result in a critical mass being assembled. As discussed in Section 3.3.3, the criticality event resulting from placing CCOs with surplus plutonium in WIPP is likely to result in long-term criticality episodes. This will result in significant quantities of fission products. The curie loading of the reaction site will be many orders of magnitude greater than the source term used to determine the radiological impact of intrusion events. This would substantially alter the source term used in the pathways analyses and would have a significant impact on the performance assessment for WIPP.
6 Thermal Impacts

The TRU wastes planned for WIPP were the contaminated components, tools and residues used in the manufacture of nuclear weapons. They contain a large quantity of inert materials that are only radioactive by virtue of contamination. This tends to dilute the impact of the thermal energy resulting from nuclear decay. As a result, the thermal impact on WIPP was not great. The design thermal limit for WIPP is 10,000 watts-per-surface-area. (Reference 10 § 3.2.1)

The analysis in the Sandia report suggests that the anticipated decay heat loading for the repository would be 136 kW at the time of closure with 97.8% is from the radioactive decay of CH-TRU elements. Of that total, Sandia predicted that 18% of the decay heat would come from the decay of $^{239}$Pu which releases approximately 2.4 watts per kilogram. (Reference 17)

Sandia also estimated a maximum heat load for WIPP at 197 kW which is equivalent to a heat load of 4,380 w/acre over an individual panel.

The amount of heat produced by the radioactive decay of nuclear isotopes is a function of the decay rate and the energy released per event. Based on the Sandia study, the decay heat produced by $^{239}$Pu is 2.4 watts per kilogram. (Reference 17 §6.3.1) Depending on the amount of $^{239}$Pu placed in the repository, it is possible to calculate the resultant heat load.

Exhibit 6-1 is a summary of the volume of waste placed in WIPP extracted from Reference 29. Based on the performance to date, the average loading of a waste panel has been 15,040 m$^3$ with a maximum design loading of new panels being 18,750 m$^3$. Since each CCO occupies 0.208 m$^3$ of volume, this suggests that an average loading of a panel with CCOs would involve 72,308 CCOs. Since a CCO can store a maximum of 380 g of $^{239}$Pu, it means that an average loading of a waste panel contains 27,477 kg of $^{239}$Pu. That mass of $^{239}$Pu would produce 65.9 kW of heat that, if spread across the area of a waste panel, would represent a heat loading of 11,731 watts per acre; 17% in excess of the regulatory limit. Conversely, if the CCOs could be loaded into a waste panel at the maximum loading by design, this heat load would be increased to 14,642 watts per acre; 46% in excess of the regulatory limit. Therefore, if the surplus plutonium was loaded into WIPP as described by the DOE/NNSA, it would overheat the waste panels containing the plutonium. This is a new condition for WIPP because all previous loading scenarios were at a much lower concentration of heat producing radioactive elements. Thus uneven heating would need to be examined by analysis and adequate mitigation would need to be designed into the operations strategy if, indeed it was judged to be practicable.

The above discussion would only apply if CCOs loaded to the maximum value as planned by DOE/NNSA would be acceptable to the design of WIPP. High Bridge concludes that such a design would not be acceptable. This conclusion indicates that the $^{239}$Pu would need to be diluted down to meet one of the design bases for criticality; namely the maximum concentration would be 7.3 kg/m$^3$, 3.0 kg/m$^3$ or 0.12 kg/m$^3$ where the actual concentration would be determined by a thorough criticality analysis. These dilution levels would reduce the heat produced per panel to a potentially acceptable limit.
Safeguards and Security

Due to the proliferation concerns surrounding plutonium, special security protocols are required. These safeguards are described in detail in numerous DOE Orders, Standards, and Policy documents. Since these measures are intrusive and expensive, a graded approach is taken to special nuclear materials (SNM), including plutonium, based on the “attractiveness” of the material. Attractiveness refers to the ease of converting a given grade and mass of plutonium into a weapon. The Attractiveness is grade from “A” which is an operational weapon all the way down to “E” which is incidental or trace amounts of material. Exhibit 7-1 shows the definition of the graded attractiveness of plutonium and provides context for the material classes of interest.

Exhibit 6-1 – Summary of Waste Placed in WIPP

<table>
<thead>
<tr>
<th></th>
<th>CH-Permitted</th>
<th>Actual</th>
<th>% Used</th>
<th>RH-Permitted</th>
<th>Actual</th>
<th>% Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel 1</td>
<td>18,000</td>
<td>10,497</td>
<td>58.32%</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Panel 2</td>
<td>18,000</td>
<td>17,998</td>
<td>99.99%</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Panel 3</td>
<td>18,750</td>
<td>17,092</td>
<td>91.16%</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Panel 4</td>
<td>18,750</td>
<td>14,258</td>
<td>76.04%</td>
<td>356</td>
<td>176</td>
<td>49.44%</td>
</tr>
<tr>
<td>Panel 5</td>
<td>18,750</td>
<td>15,927</td>
<td>84.94%</td>
<td>445</td>
<td>235</td>
<td>52.81%</td>
</tr>
<tr>
<td>Panel 6</td>
<td>18,750</td>
<td>14,468</td>
<td>77.16%</td>
<td>534</td>
<td>214</td>
<td>40.07%</td>
</tr>
<tr>
<td>Panel 7</td>
<td>18,750</td>
<td>387</td>
<td></td>
<td>650</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Panel 8</td>
<td>18,750</td>
<td></td>
<td></td>
<td>650</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>148,500</td>
<td>90,627</td>
<td></td>
<td>2,635</td>
<td>641</td>
<td></td>
</tr>
<tr>
<td>Panels 1-6</td>
<td>111,000</td>
<td>90,240</td>
<td>81.30%</td>
<td>1,335</td>
<td>625</td>
<td>46.82%</td>
</tr>
<tr>
<td>Panels 1-8**</td>
<td>148,500</td>
<td>127,740</td>
<td>86.02%</td>
<td>2,635</td>
<td>1,925</td>
<td>73.06%</td>
</tr>
<tr>
<td>Legal Capacity</td>
<td>168,485</td>
<td></td>
<td></td>
<td>7,079</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panel 9*</td>
<td>18,750</td>
<td></td>
<td></td>
<td>650</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panel 10*</td>
<td>18,750</td>
<td></td>
<td></td>
<td>650</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panels 9-10***</td>
<td>186,000</td>
<td>165,240</td>
<td>98.07%</td>
<td>3,935</td>
<td>3,225</td>
<td>45.56%</td>
</tr>
</tbody>
</table>

Notes: *Panels 9 and 10 proposed capacities. ** If Panels 7-8 are filled to capacity.
***Total capacity if Panels 9 and 10 filled to proposed capacities.
"CH" is Contact-Handled waste; "RH" is Remote-Handled
"Permitted" refers to the capacity limits in the New Mexico WIPP permit
DOE Order 474.2 identified four conditions that must be met to terminate safeguards on nuclear material at the time of the Rocky Flats determination:

1. The nuclear material must be of no programmatic value to DOE.

2. If the nuclear material is in a form that meets the criteria for attractiveness level E, then no additional approval needs to be obtained if all other conditions are met. If the nuclear material is attractiveness level D or higher, approval to terminate safeguards must be received from the DOE departmental element after consultation with the Office of Health, Safety and Security (HSS). For NNSA facilities, approval to terminate is received from the Associate Administrator for Defense Nuclear Security after consultation with HSS.

3. The nuclear material being written off the accounting record system will be transferred to decontamination and decommissioning (D&D) or a waste management reporting identification symbol (RIS).

4. The nuclear material for which safeguards have been terminated will not be collocated with nuclear materials which are still in the accountability system for safeguarded materials.

(Reference 31)

DOE/NNSA has used two equally successful strategies for terminating safeguards of nuclear materials that were attractiveness level D. Both approaches need approval as described in condition 2 above. The first strategy is simply to process the attractiveness level D material into a form that meets the criteria for

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**Exhibit 7-1 – Annotated Graded Attractiveness Table**

<table>
<thead>
<tr>
<th>Attractiveness Level</th>
<th>Pu Category (kg)</th>
<th>Relavent Examples of Pu Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEAPONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembled weapons and test devices</td>
<td>A</td>
<td>All</td>
</tr>
<tr>
<td>HIGH-GRAD MATERIALS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbides, oxides, nitrites, solutions (≥25 g/L) etc.; fuel elements and assemblies; alloys and mixtures; UF4 or UF6 (≥50% enrichment)</td>
<td>B</td>
<td>&gt;2</td>
</tr>
<tr>
<td>LOW-GRAD MATERIALS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solutions (1 to 25 g/L) process residues requiring extensive reprocessing; Pu-238 (except waste); UF4 or UF6 (≥20% &lt;50% enriched)</td>
<td>D</td>
<td>N/A</td>
</tr>
<tr>
<td>ALL OTHER MATERIALS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highly irradiated forms, solutions (&lt;1 g/L), compounds; uranium containing (&lt;20% U-235 or &lt;10% U-233 (any form, any quantity)</td>
<td>E</td>
<td>N/A</td>
</tr>
</tbody>
</table>
attractiveness level E. This option has not often been used because the costs can be prohibitive since it increases the final waste form volume significantly and/or might involve technically challenging processing protocols; such as vitrification or cementation. The second and more common approach has been to perform a security analysis to show that when the attractiveness level D nuclear material is declared waste and transferred to waste management, the addition of this nuclear material in the waste management storage area does not significantly increase the risk of adversarial actions by either an insider or outsider threat (Reference 30).

The Rocky Flats materials were Attractiveness Level D because the material inside the POC was no more than 200 grams in the 12 liter POP. That represented a “solution” of about 16 g/l which falls within the 1-25 g/l defining Attractiveness Level D in Exhibit 7-1. However, the CCO has a maximum of 380 g in a 13 liter CCC which exceeds the limits for Attractiveness Level D. It is also a pure product further complicating the effort to terminate safeguards for this material.

WIPP is a “property protection area” with security standards even below those required for sites possessing a Category IV quantity of SNM. The systems and procedures in place at WIPP are wholly insufficient to meet the Nuclear Material Control and Accountability requirements outlined in Reference 30 and the other DOE Orders concerning SNM. Without the termination of safeguards, the surplus weapons plutonium cannot be transported to or disposed of in WIPP. If rigorous safeguards would be necessary for either the transportation of this material or for disposition at WIPP, there would be significant cost and programmatic consequences that have not been considered.

The Rocky Flats decision was based on an early version of DOE Order 474.2. The current revision of that Order identifies the following eight requirements for the termination of safeguards:

1. Determine that the nuclear material is of no programmatic value to DOE.
2. Require that designated facilities and nuclear materials for safeguards termination are assigned the proper categorization and attractiveness levels according to Attachment 2, Table C, Graded Safeguards Table and Attachment 2, page 4, Using the Graded Safeguards Table. (This is the same as Exhibit 7-1.)
3. Meet the criteria for attractiveness level E. When termination of safeguards for attractiveness level D or higher SNM is requested, approval is received from the departmental element after consultation with the Office of Health, Safety and Security (HSS). For 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.
5. Ensure that the nuclear material being written off the accounting record system will be written off as a transfer to decontamination and decommissioning (D&D) or a waste management reporting identification symbol (RIS).
(6) Ensure that the nuclear material for which safeguards have been terminated is not co-located with accountable nuclear materials.

(7) Ensure the requirements associated with the level of security specified by DOE line management as a condition of termination of safeguards are implemented effectively.

(8) When the site/facility operator requests termination of safeguards for a nuclear material facility, the following must be done:

(a) DOE line management conducts a termination survey to ensure that no accountable nuclear material remains.

(b) Ensure that the only remaining material is waste or residual holdup that meets the definition of attractiveness level E.

(c) Ensure that nuclear material has been written off the accounting record system as a transfer to a waste management RIS or D&D organization RIS. (Reference 30 § 4(g))

This is a significant increase in the requirements over those in effect in 2000. Therefore, the successful termination of Rocky Flats material may not be relevant any longer. Item (3) above suggests a jurisdictional issue could arise since the surplus plutonium would need to be transferred from NNSA control and management to an Environmental Management facility operated by the Carlsbad Operations Office. They have no experience or official expertise in Safeguards and Security so a simple NNSA termination would not be credible. This would force the decision to the Office of Health, Safety and Security (HSS) that would no doubt insist on proof that this action would not result in the potential diversion of SNM.

Item (4) above also poses a problem in that the proposed amount is far in excess of Category II so a detailed security assessment is required to ensure that the material is not diverted during shipping or final disposition. WIPP only has a physical protection security system with no systems or procedures in place to be able to guarantee that the material is not being diverted. Moreover, the shipments of TRU wastes to WIPP have minimal security provisions that, once again, are inadequate to make a positive judgement that this statement would be true.

In order to comply, significant, and at this point unknown, security precautions would be required. They would therefore be applied to all shipments to WIPP and to all materials received for disposal at WIPP. This represents a huge increase in the security costs at WIPP and would adversely impact WIPP operations.

In a paper presented in 2012, DOE suggested that the same approach be utilized for the entire surplus weapons plutonium inventory (Reference 31). While on the surface it is a reasonable argument, it lacks perspective. First, the RFETS material met the original intent of WIPP in that it was residue resulting from the cleanup of an abandoned asset left over from the weapons program. It was of a higher attractiveness level than expected during the original permitting work and therefore required special consideration. It also represented a relatively small fraction of the total inventory of Plutonium 239 placed in the repository. Secondly, the RFETS material was packaged in POCs with a maximum load of 200 gm of 239Pu whereas the proposed package for the surplus weapons plutonium is CCOs. CCOs contain a maximum of 380 gm of 239Pu or nearly twice as much. So, for the same effort, a potential diverter could obtain twice
as much weapons material. Finally, the amount of $^{239}$Pu from RFETS that was weapons compatible was 180 kg. The total amount of surplus weapons material being proposed to be placed in WIPP is 51,300 kg; 285 times as much.

Exhibit 7-2 demonstrates the significance of this graphically. The column on the left was the result of adding weapons-capable plutonium from Rocky Flats to WIPP. The column on the right would be the result of adding the surplus weapons plutonium to WIPP.

Exhibit 7-2 – Relative Weapons Material Attractiveness with Plutonium Storage at WIPP

It stretches credulity to argue that the two cases are equivalent. The Safeguards Termination used for RFETS was concerned with the disposal of 180 kg weapons-grade plutonium in WIPP. Based on the projected inventory of $^{239}$Pu at the time, it was judged to be a negligible risk. The premise that the same approach can be used for the proposed action to dispose of 51.3 MTs of surplus weapons plutonium is not correct. The quantity of surplus weapons plutonium is adequate to make thousands of nuclear weapons, regardless of how difficult it would be to recover. DOE/NNSA has concluded that any planned amount of surplus weapons plutonium (e.g. 4.2 MTs) is no more attractive to potential diversion than the RFETS experience. High Bridge concludes this assumption is incorrect.

Finally, the DOE/NNSA has stated that they prefer to cancel the MOX program and dispose of the 34 MTs of surplus weapons plutonium currently planned for MOX at WIPP. However, assuming that the Russian

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10 The numerical values shown in Exhibit 4.7-1 are in Metric Tons.
Federation eventually agrees to this proposed action, the 34 MTs would be subject to IAEA oversight and inspection. The current design of WIPP does not provide features that would make that required oversight and inspection possible. The cost of security for that option is unknown. The impact on other WIPP operations is also unknown. Neither are expected to be insignificant.

8 U.S.-Russian Plutonium Management and Disposition Agreement

U.S. efforts to dispose of surplus weapons-grade plutonium stemmed from a September 1993 Presidential directive committing the United States to “seek to eliminate, where possible, accumulations of stockpiles of high enriched uranium and plutonium.” In January 1994, the United States and Russia establish working groups and tasks their experts to develop options 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 a bilateral Plutonium Management and Disposition Agreement (PMDA) that commits each country to dispose of 34 MT of surplus weapons grade plutonium – enough for approximately 17,000 nuclear weapons.

Disposition methods allow under the 2000 PMDA included irradiation and reactors, immobilization, or other methods that may be agreed to by the Parties in writing. Russia has long argued 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 (Reference 32). While the Russians accepted the U.S. immobilizing 9 MT of oxides and impure metal that had never been in a nuclear weapon (approximately one quarter of the 34 MT surplus US inventory) they were adamant remaining 25 MT of U.S. weapons grade plutonium from nuclear weapons fits 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 rather than disposal. The immobilized 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, United States insisted Russia use light water reactors for plutonium disposition because the U.S. was relying on existing and widely available light water reactors in the United States works plutonium disposition program. Fast reactors were not the preferred approach for plutonium disposition for two reasons: (1) while weapons grade plutonium fuel irradiated and fast reactors is reduced to reactor-grade, its overall plutonium 240/plutonium 239 ratio is much closer to weapons-grade than plutonium irradiated in light water reactors,11 and (2) fast reactors also contain blanket assemblies, which when processed, could result in the separation of additional weapons-grade plutonium.

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11 This is because $^{240}\text{Pu}$ is fissioned in the neutron spectrum in a fast reactor whereas it is not fissioned by the neutron spectrum in a LWR. So, the ratio of $^{240}\text{Pu}$ to $^{239}\text{Pu}$ in used MOX fuel from a LWR is significantly increased over that ratio in used fuel from a fast reactor.
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 US and its international partners contributed the entire $2 billion costs of Russians disposition program. When it became clear that the required funding could not be raised, Russia proposed to fund the majority of the cost of their disposition program if they could use fast reactors that are consistent with Russia’s national energy strategy. The US ultimately agreed with Russia’s use of fast reactors providing that: (1) Russia committed to never reprocess spent fuel containing disposition plutonium; and (2) any reprocessing of other spent fuel will never result in the separation of additional weapons-grade plutonium. Russia agreed to these stringent nonproliferation conditions as well as other stipulations including:

- The plutonium breeding blanket from the BN 600 fast reactor would be removed before that reactor could be used for disposition
- BN 800 fast reactors 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 could be reprocessed as long as it did not result in the accumulation of new separated weapons-grade plutonium
- Russia agreed to forgo reprocessing the blanket assemblies from the BN-800 fast reactor
- Up to 30% of the assemblies irradiated in the BN-800 could be reprocessed for testing fuel cycle technology as long as it did not result in the separation of any plutonium.

The fast reactor approach offers several major advantages:

1. Russia would pay for the majority of the capital and operational costs associated with implementation
2. Russia is politically committed to timely implementation of its energy strategy
3. Fast reactors can be configured to burn plutonium more efficiently than other
4. Fast reactors will be subject to extensive monitoring and inspection regime consistent with the 2000 agreement.

In order to account for these changes, United States began a series of detailed negotiations in 2007 that resulted in the two sides signing a protocol in April 2010 amending the 2000 PMDA. According to the amended PMDA, 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. The NNSA and its Russian counterpart, Rosatom, would also jointly seek international contribution for Russia’s program.

To implement the US plutonium disposition, DOE’s NNSA is overseeing the construction of two major facilities at the Savannah River site: the MOX Fuel Fabrication Facility and a Waste Solidification Building. At the same time, Russia is making significant investments in its MOX fuel fabrication capabilities and construction of the BN-800 fast reactor. The PMDA requires both countries are to begin disposition in 2018.

High Bridge concludes that the DOE/NNSA plan to terminate the MOX program and to dispose of surplus weapons plutonium by diluting it and storing it in WIPP would violate the terms of the Plutonium Management and Disposition Agreement (PMDA) signed by the U.S. and Russia in 2000 and amended in 2010. Moreover, the agreement would be violated with the decision to terminate MOX and without negotiations with the Russian Federation could lead to the following undesirable outcomes:
1. Article III of the amended PMDA clearly states that the disposition of weapons grade plutonium shall be by irradiation of plutonium as fuel in civil nuclear reactors. Disposition of weapons-grade plutonium via dilution and placement in the DOE’s Waste Isolation Pilot Plant (WIPP) with New Mexico when clearly require a change to the PMDA.
2. Russia has long argued that immobilization (and by inference dilution and placement in a geologic repository such as WIPP) is another form of long-term storage because it fails to change the isotopic composition of the plutonium thus making it less usable for nuclear weapons.
3. If Russia were to now abandon its long-standing position on the need to irradiate the plutonium as MOX fuel and civil nuclear reactors and except the U.S. plan of mixing the plutonium with a non-fissile inerting agent and storing it in WIPP, Russia would, almost certainly the man really from the stringent nonproliferation conditions contained in the amended PMDA, e.g., limits on blanket removal, IAEA monitoring, spent fuel reprocessing prohibitions and loosening the definition of “weapons-grade plutonium” to include civil plutonium stored at Mayak. These are the very activities that were included to provide the US with confidence that Russia was disposing of its weapon grade plutonium in accordance with the terms and conditions of the Agreement.
4. Historically, negotiations with Russia regarding the sensitive topic of weapons-grade plutonium disposition have been difficult and time-consuming; frequently taking years. There is nothing to suggest that negotiating a change to the US disposition approach to allow for the dilution and storage in WIPP would be any different given the current address between the two nations.
5. If the US were to unilaterally dispose of the stockpiles of weapons-grade plutonium in advance of Russia, the concept of “parallelism” called for the PMDA would be abandoned and it is likely that Russia would have no incentive to dispose of its stocks of weapons-grade plutonium in a transparent and verifiable manner.

DOE/NNSA, the Plutonium Working Group (PWG), Aerospace, and the DOE Red Team all seem to discount the importance and the difficulty of amending the PMDA. Further, they all assert that the DOE could begin working on the Dilute and Dispose option almost immediately with little or no delay caused by amending the Plutonium Management and Disposition Agreement with Russia. DOE/NNSA and their consultants seem to view the PMDA as a minor issue that can be easily resolved once DOE officially abandons the MOX program in favor of the Dilute and Dispose option. This conclusion may be another costly and time consuming distraction from the critical mission of disposing of post-Cold War stocks of surplus weapons-grade plutonium.

9 Economic Assessment

9.1 Prior Economic Analyses of WIPP and MOX

9.1.1 Prior WIPP Diluted Plutonium Storage and MOX Fuel Irradiation Comparisons

Introduction - The January 2000 DOE Record of Decision identified the Savannah River Site as the location for all three projects comprising the US surplus weapons plutonium disposition program. This included the MOX Fuel Facility, the Immobilization Facility, and the Pit Disassembly Facility. The Immobilization and Pit Disassembly Facilities were canceled by DOE during the 2000’s due to budget pressures. This resulted in significant scope/design/construction challenges and estimated cost increases for the MOX fuel facility to address multiple design/construction/operating parameters not originally planned for. Various cost estimate studies have been developed since 2014 regarding the MOX Fuel Irradiation and WIPP Dilution Storage Options for surplus weapons plutonium disposition. The Aerospace Corporation issued its April

9.1.2 High Bridge and Aerospace Comparisons

High Bridge concluded in its August 2015 independent assessment of the Aerospace April 2015 report that Aerospace developed estimated costs for the MOX Fuel Irradiation and WIPP Dilution Storage options based on a significantly flawed and incorrect analysis process. The Aerospace approach was driven by very narrow parameters that maximized the MOX Fuel Irradiation estimated costs and minimized WIPP Dilution Storage estimated costs. Flawed/incorrect analysis processes that resulted in skewed Aerospace estimated costs for MOX and WIPP include:

1. As stated by Aerospace in their report, it 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 dilution 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 Dilution Options. High Bridge found this to be evidence of a lack of basis for developing estimated cost values for the MOX Irradiation or WIPP Dilution options.

2. 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 (un-escalated) dollars analysis as a decision making basis for evaluating the estimated costs for the MOX Fuel or WIPP Dilution options. Aerospace did not follow GAO, DOE, or industry guidelines in providing economic analyses with constant present day dollar values excluding escalation.

3. Aerospace ignored the cost impact on WIPP of the DOE/NNSA plan to dispose of surplus weapons plutonium in CCO containers. No increased costs for WIPP operations, consumables, transportation, or capital improvements were identified in the Aerospace Report for dealing with this significant increase in plutonium containers to be emplaced at WIPP.

4. Aerospace included no costs for WIPP for a revised NEPA FEIS (supplement or new) process, revised Land Withdrawal Act (LWA), or the design and analysis efforts required for such a large change to the design basis of WIPP.

5. Aerospace used two reduced annual funding scenarios (approximately 20% and 40%) to analyze estimated costs for MOX that extended the construction schedule and increased costs. It never considered an optimum annual funding case for completing construction that reflected the 2012 MOX revised baseline.

6. Aerospace reduced the MOX 2012 re-baseline annual funding for completing construction by 20% from $625 million to $500 million, but defined a 400% increase in schedule duration from 6 years to 25 years. This was a major flaw in their estimating process that incorrectly added over $5 billion in escalation to complete MOX construction.
High Bridge attended a meeting to review these above issues with Aerospace and DOE/NNSA. It was held on August 5, 2015 at a Senate Office Building meeting room arranged by Senator Graham’s office. When questioned by High Bridge, the Aerospace representatives answered that:

1. DOE/NNSA had directed them to not examine the technical or scientific parameters of the MOX Irradiation or WIPP Dilution options;
2. DOE/NNSA had directed them to not analyze WIPP impacts of receiving and storing surplus weapons plutonium as they were negligible;
3. DOE/NNSA had directed them to only use reduced annual funding scenarios for MOX due to budget constraints; and
4. DOE/NNSA had directed them to provide escalated real dollar estimate values to support forecasting requirements without escalating the available annual funding.

High Bridge concluded that the results of this meeting with Aerospace and DOE/NNSA confirmed that the Aerospace estimated costs were biased and skewed to maximize MOX Fuel Irradiation estimated costs and minimize WIPP Dilution Storage estimated costs. It also found Aerospace and DOE/NNSA to be less than forthcoming in their meeting conduct and comments. While DOE/NNSA cited MOX contractor management issues and project cost increases, they did not acknowledge the plutonium disposition program scope changes (i.e., DOE cancelation of the Immobilization and Pit Disassembly Facilities) that caused a significant part of the resulting MOX Facility cost increases.

As a result, High Bridge developed and presented a cost estimate in its August 2015 Assessment Report for WIPP Dilution Storage and MOX Fuel Irradiation (Reference 6). The estimate was based on the assumption that the DOE/NNSA plan would be acceptable technically and would not create any nuclear criticality safety concerns. The estimate also assumed it would be possible to get regulatory approval to place 51.3 MTs of surplus weapons plutonium in CCOs at WIPP. The estimate included costs for engineering, design, regulatory, and statutory activities in the WIPP cost estimate that had not been addressed by DOE/NNSA and their contractors. Exhibit 9-1 below provides a summary of this August 2015 High Bridge estimate analysis:

**Exhibit 9-1 – Summary Comparison of Life Cycle Cost Estimates**

<table>
<thead>
<tr>
<th>Summary Comparison of Life Cycle Cost Estimates (B-FY14$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Element</strong></td>
</tr>
<tr>
<td><strong>High Bridge</strong></td>
</tr>
<tr>
<td><strong>Base Costs</strong></td>
</tr>
<tr>
<td><strong>Contingency/Risk</strong></td>
</tr>
<tr>
<td><strong>Changes</strong></td>
</tr>
<tr>
<td><strong>Unescalated Total</strong></td>
</tr>
<tr>
<td><strong>Escalation $</strong></td>
</tr>
<tr>
<td><strong>Escalation %</strong></td>
</tr>
<tr>
<td><strong>Escalated Total</strong></td>
</tr>
</tbody>
</table>
Exhibit 9-1 identifies the impact of including omitted WIPP costs for the WIPP Dilution option and corrects the biases in the Aerospace Report caused by the direction given to them by DOE/NNSA. When presented in constant fiscal year dollars (FY$) and corrected for inaccuracies, the costs of the two programs were evaluated as comparable. These evaluated cost estimates have an accuracy range within the maturity level of the data. Furthermore, High Bridge conducted a formal Monte Carlo analysis of risks for each option that provided an 85% confidence value for the contingency.

Exhibit 9-1 also reflects how the Aerospace 20% reduced annual funding level for MOX skewed escalation and overall assessed costs by Aerospace. MOX Fuel escalation of $20.3 billion reflects 75% of the MOX Fuel un-escalated costs while WIPP Dilution escalation of $4.1 billion represents 30% of WIPP Dilution un-escalated costs. High Bridge experience and industry benchmarks for large programs like MOX Fuel Irradiation and WIPP Dilution Storage confirm that the MOX escalation value as a percentage of the un-escalated cost total is exceptionally high and unreasonable. The High Bridge MOX estimate represents a cost of about $500 million a year to complete construction and less than $400 million a year for operations. Contrary to the often cited DOE estimate, the life cycle costs for completing the MOX program never approaches $1 billion/year.

This March 2, 2016 High Bridge report reflects a more detailed and thorough evaluation of the proposed WIPP Dilution disposition approach. The impact of the DOE planned approach on the estimated costs for the WIPP Dilution Option is far worse than predicted in Exhibit 9.1. Details of the impact are presented in Section 9.2.

9.1.3 MOX Fuel Sales and Clean Energy

Introduction - The August 2015 Aerospace Report identified no net income credit for the MOX Fuel option, 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 a troubling and revealing omission.

MOX Fuel Sales - The goal of the MOX project is to alter the isotopic makeup of the surplus weapons plutonium into a form that makes it less usable 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 fuel assemblies.

AREVA is a major fuel supplier to the American nuclear fleet of commercial power reactors and they produce fuel for all types of reactors in operation today. They began MOX fuel marketing activities in the 2009 timeframe and were successfully building a list of interested nuclear operating company potential customers. By 2013, AREVA had several letters of intent and several more being developed to strengthen their negotiating position for future MOX fuel sales discussions. Negotiations were curtailed when DOE reduced the program funding in 2013 due to budget constraints. However, 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 MOX facility would convert the uranium and plutonium oxides into fuel pellets for the specific reactor and fabricated the fuel assemblies.
The core of a nuclear reactor is “reloaded” every 18 or 24 months and about a third of the total core is replaced with fresh fuel assemblies. Overall, the 34 MT of surplus weapons plutonium would produce approximately 30 core reloads for a 1,200 megawatt (electric output) 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.

The nuclear operating companies are currently not negotiating this deal. They lack confidence in DOE/NNSA and 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/NNSA 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.

Even though the MOX project fuel sales could net approximately $1B dollars to defray operational costs, revenue to the US government was never the driver for selecting the MOX fuel approach. Permanently altering the isotopic structure of plutonium to prevent use as a weapon was the priority for the US and Russia to serve as the foundation for the PMDA. 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.

**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 consumes 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 (GNP) of the electricity sales ($35B) from the MOX fuel is greater than the MOX Fuel Irradiation option 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 the WIPP Dilution Storage option that produces no trickle-down revenue or GNP contribution and represents a net loss to the taxpayers, the MOX Fuel Irradiation option represents a net improvement in the GNP wealth of the U.S.. 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.

**Exhibit 9-2** provides a summary comparison of revenue, cost impact items, and value considerations for key elements of the MOX Fuel Sales and WIPP Dilution Storage 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 9-2**, it is estimated that >10,000 jobs will result from the consumption of clean electricity over 20 years. The picture presented by **Exhibit 9-2** clearly shows the value add economic and
clean air contribution that the MOX Fuel Irradiation option provides to the US, while also illustrating the lack of value for the WIPP Dilution Storage option.

### Exhibit 9-2 – Comparison of Plutonium Disposition Program Alternatives

<table>
<thead>
<tr>
<th>#</th>
<th>MOX Irradiated Fuel Option</th>
<th>WIPP Diluted Plutonium Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Metric Tonnes of Plutonium Pu 239</td>
<td>34</td>
</tr>
<tr>
<td>2</td>
<td>Pounds of Plutonium Pu 239</td>
<td>74,956</td>
</tr>
<tr>
<td>3</td>
<td>Compliance with US-Russia Plutonium Management Disposition Agreement and Isotopic Change Achieved</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>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</td>
<td>2,000</td>
</tr>
<tr>
<td>5</td>
<td>Approximate Net Revenue to U.S. Treasury for MOX Fuel Sales</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>6</td>
<td>Approximate Number of Shipments in Casks with 2 Fuel Assemblies/Cask, 4 Casks/Truck, and 3 Trucks/Shipments</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>Approximate WIPP Storage Capacity Volume Consumed</td>
<td>~0</td>
</tr>
<tr>
<td>8</td>
<td>Approximate Megawatt Hours of Clean Electricity Produced</td>
<td>285 Million</td>
</tr>
<tr>
<td>9</td>
<td>Approximate Value of Clean Electricity Produced</td>
<td>$35 Billion</td>
</tr>
<tr>
<td>10</td>
<td>Approximate State/Local Tax Revenues Generated</td>
<td>&gt;$5 Billion</td>
</tr>
<tr>
<td>11</td>
<td>Approximate Life Cycle Cost of MOX Program</td>
<td>$19.4 Billion</td>
</tr>
<tr>
<td>12</td>
<td>Approximate US Jobs Created for 20 Years</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>13</td>
<td>Avoided Carbon Emissions</td>
<td>335 Million Tons</td>
</tr>
<tr>
<td>14</td>
<td>Avoided NOx Gas Emissions</td>
<td>420,000 Tons</td>
</tr>
<tr>
<td>15</td>
<td>Avoided SO2 Gas Emissions</td>
<td>675,000 Tons</td>
</tr>
</tbody>
</table>

**NOTE:** The values identified in this Exhibit are approximate based on the analysis performed during the High Bridge Phase 2 Report Review.

### 9.2 Economic Analysis of WIPP Plutonium Storage Concentration Scenarios

High Bridge’s August 2015 independent assessment of the cost of the Dilute and Dispose option determined that the DOE/NNSA and its contractors had ignored the cost impact on WIPP of their plan. No costs for WIPP operations, consumables, transportation or capital improvements were identified in the Aerospace Report. Moreover, there were no costs for a revised NEPA process or the design and analysis efforts certain to be required for such a large change to the design basis of WIPP. While High Bridge recognized that the statutory limit on waste volume would be exceeded, it was not able to investigate the technical implications of this large increase in weapons plutonium inventory. The High Bridge August 2015 report assumed that the technical requirements could be met with the technology proposed by the DOE/NNSA, i.e., disposal as TRU waste in CCOs.
In order to assess the full cost impact that the planned DOE/NNSA action would have on the life cycle cost of WIPP, High Bridge assumed that the plan to dispose of surplus plutonium at WIPP in CCOs would be acceptable. High Bridge made an estimate of the costs omitted by Aerospace. These omitted costs were assumed associated with the costs for engineering; design, permitting, and contingency would need to be addressed in the cost estimate. Exhibit 9-3 displays the results of the WIPP cost estimate reported in High Bridges’ August 2015 assessment (also displayed in Exhibit 9-1 as the WIPP Dilution Storage; High Bridge estimate) (Reference 6).

### Exhibit 9-3 – Downblend WIPP Cost Estimate

<table>
<thead>
<tr>
<th>Cost Element</th>
<th>Base - FY14$</th>
<th>Adder - FY14$</th>
<th>Estimate - FY14$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFFF Termination</td>
<td>$1.49</td>
<td>$0</td>
<td>$1.49</td>
</tr>
<tr>
<td>NEPA/NMED Activities (invariant with Scenario)</td>
<td>$0</td>
<td>$0.35</td>
<td>$0.35</td>
</tr>
<tr>
<td>PMDA Activities (invariant with Scenario)</td>
<td>$0</td>
<td>$0.08</td>
<td>$0.08</td>
</tr>
<tr>
<td>LWA Activities (invariant with Scenario)</td>
<td>$0</td>
<td>$0.01</td>
<td>$0.01</td>
</tr>
<tr>
<td>CCO Packaging/Transportation (Scenario Sensitive)</td>
<td>$4.44</td>
<td>$1.15</td>
<td>$5.59</td>
</tr>
<tr>
<td>SC Fines (Scenario Sensitive)</td>
<td>$0</td>
<td>$1.10</td>
<td>$1.10</td>
</tr>
<tr>
<td>PWG Changes Cited in Aerospace Report</td>
<td>$1.87</td>
<td>$0</td>
<td>$1.87</td>
</tr>
<tr>
<td>Total ETC w/o Contingency</td>
<td>$10.1</td>
<td>$4.8</td>
<td>$14.9</td>
</tr>
</tbody>
</table>

Contingency: $5.0

| Total ETC with Contingency                        | $15.2        | $4.8          | $19.9           |

High Bridge Aug. 2015 Report Contingency Analysis 34%
This evaluated cost estimate has an accuracy range consistent with the maturity level of the data. Furthermore, the contingency value from the structured risk assessment and independent Monte Carlo analyses performed by High Bridge was $5.0B reflecting an 85% confidence level.

High Bridge performed a technical analysis that determined that the proposed disposal option will likely achieve a criticality during the period of regulatory concern. Therefore, five diluted plutonium storage scenarios (described below) for WIPP were evaluated based on reducing plutonium concentration levels to avoid criticality and ensure safety.

In order to perform an economic assessment of the five scenarios High Bridge required a common basis for WIPP estimated costs. High Bridge used the estimated costs that appear in the July 2002 National TRU Waste Management Plan (Reference 33). The plan provides cost estimates for various components of the TRU waste management plan including those for WIPP, reported as the Carlsbad Field Operation estimates.

To fully investigate the proposed plan to emplace up to 51.3 MT of weapons grade plutonium in WIPP, High Bridge has estimated the physical impact that each scenario would have on WIPP repository. The implications of these physical impacts on the WIPP life cycle costs are evaluated by using data shown in Exhibit 9-3 and high level metrics developed from the data reported in Table 4.3-1 – Baseline Cost Data of the July 2002 National TRU Waste Management Plan (Reference 33) for each scenario.

The estimates were made using the following cost elements:

- MFFF Termination
- NEPA/NMED Activities (invariant with Scenario)
- PMDA Activities (invariant with Scenario)
- LWA Activities (invariant with Scenario)
- CCO Packaging/Transportation – “MIFT” (Scenario Sensitive)
- WIPP Operations (Scenario Sensitive)
- WIPP Expansion Capital (Scenario Sensitive)
- South Carolina Fines (Scenario Sensitive)
- PWG Changes Cited in Aerospace Report (invariant with scenario)
- Contingency (Scenario Sensitive)

These above cost elements align with those in Exhibit 9-3. It is noted in the description of each element whether High Bridge assumed each cost element would be expected to change or not change with increases in WIPP storage volume and/or the life of the WIPP project, i.e. invariant or sensitive with changing scenarios.

- Scenario 1 considers the approach proposed by the Plutonium Working Group, assessed by Aerospace, and endorsed by DOE/NNSA for disposing of this material in CCOs with a concentration of 29.2 kg/m³. The assumption is that CCOs are stored in WIPP but needed repository volume increases. Certain regulatory and capital improvement activities will be needed.

- Scenario 2 considers disposing of this material in POCs (as used for 180 kg from Rocky Flats) at a concentration of 16.7 kg/m³. The assumption is that POCs are certified for storage in WIPP, but
the number of containers and amount of repository volume increase. Again certain regulatory and capital improvement activities will be needed.

- Scenario 3 considers reducing the concentration of fissile material to the ANSI standard maximum amount to avoid criticality of 7.3 kg/m$^3$ in CCOs. The assumption is that CCOs are certified for storage in WIPP, but the number of containers and amount of repository volume needed to meet the ANSI standard increase. Again certain regulatory and capital improvement activities will be needed.

- Scenario 4 considers the reduction of the concentration to meet the concentration used by Sandia when qualifying WIPP, i.e. 3.0 kg/m$^3$. The assumption is that CCOs are certified for storage in WIPP, but the number of containers and amount of repository volume needed to reach the Sandia single point plutonium density of 3.0 kg/m$^3$ increases. Again certain regulatory and capital improvement activities will be needed.

- Scenario 5 considers the plutonium being diluted to the average TRU-waste fissile content density of 0.12 kg/m$^3$ of WIPP as defined in the FEIS design basis using 55-gallon drums and an incompressible inerting material. The assumption is that drums are already certified for storage in WIPP, but the number of containers and amount of repository volume needed to meet the WIPP design plutonium density of 0.12 kg/m$^3$ will increase significantly. Again certain regulatory and capital improvement activities will be needed.

The data displayed in Exhibit 9-4 shows the estimated physical impacts on the WIPP repository for each of the five scenarios to store 51.3 MT of weapons plutonium. It summarizes the scenario plutonium concentration decreases and incremental increases for repository drums, volume, panels and rooms required to achieve compliance with the WIPP FEIS design basis.

All of the scenarios shown on Exhibit 9-4 address significant issues with DOE/NNSA plans to dispose of 51.3 MT of plutonium at WIPP. None of them will eliminate the need for a full and open NEPA process to provide the decision-maker information on the potential environmental consequences of adopting this proposal. In addition to this NEPA process addressing all reasonable alternatives, an amendment of the PMDA would be required along with a full legislative process to amend the LWA to permit this option to take place. Beyond the identified cost impacts associated with implementing the diluted plutonium storage option at WIPP, each dilution scenario significantly extends the operating period of WIPP well beyond the current planned lifetime, which represents a large part of the estimated cost for each scenario.

The current regulatory and statutory authorized size of WIPP involves a volume of 175,564 m$^3$, 10 panels, and 70 rooms. Exhibit 9-4 shows the number of drums increasing 10 times, repository volume increasing 3 times, and repository panels/rooms increasing 3 times to achieve the FEIS design basis fissile concentration of 0.12 kg/m$^3$ (Scenario 5). The estimated cost for each of these scenarios increases in proportion to the reducing plutonium concentrations and increasing plutonium quantities, repository volumes, and storage emplacement durations.
It should be noted that only 23,600 cubic meters or 13% of the total WIPP repository volume of 175,564 cubic meters remains available for EM TRU-waste. Also a recent change has been approved to increase the number of panels from 8 to 10. Six panels are filled and sealed. Panel 7 is completed and was being loaded at the time of the WIPP shutdown.

Using data from the previous estimate (Exhibit 9-3 and August 2015), and the estimated impacts of the assumptions made for each scenario, High Bridge has developed estimates for each scenario using scenario 1 as the baseline. High Bridge used metrics derived from the data for the DOE Carlsbad Field Office (WIPP costs) reported in Table 4.3-1 – Baseline Cost Data of the July 2002 National TRU Waste Management Plan (Reference 33). Specific steps followed by High Bridge in performing the cost estimates for each of the above scenarios include the following:

1. Cost data given in Table 4.3-1 for the out years 2011 to 2034 are given in five year increments (CY2031-2034 is a four increment). These groups were divided into equal values for each CY increment.
2. Cost data given in Table 4.3-1 is reported for four high level cost activities, Transportation, Disposal, and Remaining Mission-Critical Activities.
3. Cost data from the National TRU Waste Management Plan were further divided into fixed and variable costs for each cost activities. Variable cost percentages used for each cost activities are:
   a. Transportation – 41% variable to total cost,
   b. Disposal – 59% variable to total cost,
   c. Other Mission-Critical – 13% variable to total cost
4. Cost data given in Table 4.3-1 is reported in real year dollars (RY$) using a 2.1 percent per year escalation factor from CY2002. These data were de-escalated by the same factor to CY2002 dollars (FY02$) for each cost activities for both variable and fixed costs.
5. The total of for FY02$ of each cost activity’s fixed and variable costs were then escalated to FY14$ by the 2.1% escalation factor. The data in High Bridge’s August 2015 and Aerospace’s 2015 reports were presented in FY$14s, see Exhibit 9-3.

6. Two metrics for each activity (fixed - $/year and variable - $/m³) were used to estimate WIPP costs for each scenario.

7. DOE penalties payable to South Carolina were based on two parameters. First, penalties would be assessed until plutonium shipments began leaving South Carolina. Second, penalties would be assessed unless shipments totaled at least 1 MT per year. High Bridge developed its estimates based on these requirements.

8. Program changes estimated by PWG from FY2012 to FY2014 and reported in the 2015 Aerospace report were assumed constant for each scenario.

9. Regulatory activities that High Bridge believes to be necessary for each scenario were also held constant from previous 2015 estimates; see Exhibit 9-3.

10. High Bridge computed the contingency shown in Exhibit 9-3 using the risk elements from the Aerospace report and the High Bridge August 2015 Monte Carlo risk analysis. High Bridge did not perform any similar analysis for scenarios 2 through 5 but has simply increased the contingency by 34% from one scenario to the next based on its August 2015 Monte Carlo analysis.

11. The cost estimated by PWG and reported by Aerospace for the termination of MFFF was held constant for each scenario.

12. Additional capital costs for WIPP were estimated as ~$426 million in scenario 1, zero for scenarios 2 and 3, ~$600 million in scenario 4 and ~$1,000 million in scenario 5.

The resulting cost estimates for WIPP under the assumptions made for each of the scenarios are summarized in Exhibit 9-5. Details of the cost estimates performed are presented in Appendix E.

As can be seen by the data displayed in Exhibit 9-5 the assumed scenarios 2 to 5 increases the programmatic costs in excess of the WIPP Dilute and Disposal option (Exhibit 9-1) described in High Bridge’s August 2015 report (Scenario 1). For example the increase in programmatic cost are in large part driven by shipping, unloading, and emplacing over 2,000,000 CCO drums over a period of more than 50 years and the cost to increase the volume size of WIPP three-fold. In the case of Scenario 5, that assumes approval is given to dispose weapons grade plutonium consistent with WIPP repository design (0.12 kg/m³), the programmatic costs are more than double of that given in Exhibit 9-1. High Bridge concludes that the overall programmatic costs for Scenario 5 could be more than twice the cost of a fully funded MOX Program.

Under the assumptions used High Bridge concludes that WIPP Dilution Plutonium Storage Scenario 5 has the greatest likelihood of success. Storage Scenario 5 is estimated to be a LCCE of $46.8 billion or $26.8 billion more than Storage Scenario 1 at $19.9 billion using CCO containers. The cost elements for packaging/transportation, WIPP operations, and South Carolina fines represent the largest share of the cost increase and are driven by the additional required 55.3 years for WIPP operation to cover shipping, unloading, and emplacing over 2,000,000 drums.
Overall the High Bridge analysis of WIPP Dilution Storage versus MOX Fuel Irradiation indicates that:

- Storage Scenario 1 (CCOs) and Storage Scenario 2 (POCs) are not technically viable due to the nuclear criticality issues involved with their plutonium concentration levels.
- WIPP plutonium storage Scenario 3 to meet ANSI Standard requirements will require a Life Cycle Cost of $26.6 billion or $7.2 billion more than the MOX Fuel Irradiation option Life Cycle Cost of $19.4 billion ($FY14).
- WIPP plutonium storage Scenario 4 to meet the Sandia criticality and concentration level will require a Life Cycle Cost of $37.0 billion or $17.6 billion more than the MOX Fuel Irradiation option Life Cycle Cost of $19.4 billion ($FY14).
- WIPP plutonium storage Scenario 5 to meet the current WIPP FEIS concentration level allowed will require a Life Cycle Cost of $46.8 billion or $27.4 billion more than the MOX Fuel Irradiation option Life Cycle Cost of $19.4 billion ($FY14).

Moreover, the Aerospace cost estimate does not acknowledge the fact that if the MOX program is cancelled, all WIPP dilution storage NEPA regulatory and design bases need to be increased to cover the entire amount of surplus plutonium to be stored at WIPP. The High Bridge analysis in this report is based on 51.3 MTs of plutonium, while other sources place the surplus plutonium quantity at closer to 61.5 MTs. The NEPA and legal regulatory processes and approvals, along with the revised Land Withdrawal Act law, need to be completed before any surplus plutonium can be placed in WIPP.
10 References


29) Southwest Research and Information Center, SRS Presentation. “Challenges at the Waste Isolation Pilot Plant (WIPP) & Impacts on DOE Sites.” 24 Mar. 2015


APPENDIX A

Surplus Weapons Plutonium Inventory
Appendix A – Surplus Weapons Plutonium Inventory

High Bridge Associates has been unable to obtain a clear understanding of the actual surplus weapons plutonium inventory from the literature. The surplus weapons plutonium program is an outgrowth of the end of the Cold War. After the SALT-II agreement, both the Russian Federation and the United States were burdened with surplus plutonium that had no mission. In addition to weapons components and residue from the fabrication processes, there was a large inventory of non-weapons grade plutonium around the complex that had no mission. However, it is perfectly reasonable for a degree of secrecy to still be in place regarding the specifics.

In January 1994, President Clinton and Russia’s President Yeltsin issued a Joint Statement between the United States and Russia on Nonproliferation of Weapons of Mass Destruction and the Means of Their Delivery. In accordance with these policies, the focus of the U.S. nonproliferation efforts in this regard is five-fold: (i) To secure nuclear materials in the former Soviet Union; (ii) to assure safe, secure, long-term storage and disposition of surplus weapons-usable fissile materials; (iii) to establish transparent and irreversible nuclear arms reductions; (iv) to strengthen the nuclear nonproliferation regime; and (v) to control nuclear exports. The policy also states that the United States will not encourage the civil use of plutonium and that the United States does not engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes.

However, identifying the actual inventory of surplus weapons plutonium from the public record is a difficult challenge. President Clinton announced on March 1, 1995, that approximately 200 metric tons of U.S.-origin weapons-usable fissile materials, of which 165 metric tons were HEU and 38 metric tons were weapons-grade plutonium, had been declared surplus to the United States’ defense needs.

Later, the Secretary of Energy’s Openness Initiative announcement of February 6, 1996, announced that the United States had about 38.2 metric tons of weapons-grade plutonium. Additional quantities of plutonium were to be declared surplus in the future; therefore, the S&D Final PEIS analyzes the disposition of a nominal 50 metric tons of plutonium, as well as the storage of 89 metric tons of plutonium.

A GAO report\(^1\) issued in April 1997 identified 52.7 MTs of surplus plutonium but noted that the actual inventory amounts allocated among the national security subcategories were classified. It generally described the split as 38.2 MTs of weapons-grade plutonium and 14.5 MTs of non-weapons-grade plutonium.\(^2\)

The SPD FEIS\(^3\) analyzed a nominal 50 MT (55 tons) of surplus weapons-usable plutonium, primarily in the form of pits (the core element of a nuclear weapon’s fission component), metals, and oxides. In addition to 38.2 MT (42 tons) of weapons-grade plutonium already declared by the President as excess to national security needs, the material analyzed included weapons-grade plutonium that may be declared surplus in the future, as well as weapons usable, reactor-grade plutonium that was surplus to the programmatic and national defense needs of DOE. Some materials were already in a final disposition form (i.e., irradiated...
fuel) and would not require further action before disposal. These materials, therefore, were not included in the 50 MT (55 tons) analyzed in the SPD EIS.

In 2015, a SPD Supplemental EIS was issued in which DOE identified the need to disposition 13.1 metric tons (14.4 tons) of surplus plutonium for which a disposition path is not assigned, including 7.1 metric tons (7.8 tons) of plutonium from pits that were declared excess to national defense needs after publication of the 2007 NOI, and 6 metric tons (6.6 tons) of surplus non-pit plutonium. In addition, the 38.2 MTs formerly declared to be surplus weapons grade as part of the PMDA had been reduced to 34 MTs by mutual agreement of the two countries.

Exhibit A-1 is an approximate break out of the surplus plutonium inventory obtained by piecing together fragments of information. It does not provide any consistent accounting of the inventories described in the literature.

Exhibit A-1 – Summary of U.S. Surplus Plutonium Inventory

Exhibit A-2 is a figure from a 2012 reference that shows a different picture. While internally inconsistent, this reference is the newest of the references found in the literature. It shows the 34 MTs of plutonium covered by the PMDA as well as the 13.1 MTs covered by the Surplus Plutonium Disposition FEIS (albeit summing to only 12.7 MT). It describes the 1994 total of surplus plutonium as

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Exhibit A-2 – U.S. Surplus Plutonium Disposition Inventories

Exhibit A-2 – U.S. Surplus Plutonium Disposition Inventories

being 52.5 MTs (comparing well to the HBA assumption of 51.3 MTs and the GAO assessment of 52.7 MTs and identifies an additional declaration of 9 MTs that brings the total surplus plutonium to 61.5 MTs. The reference also makes note of “up to approximately 4 MT of surplus, non-pit plutonium could be evaluated for disposal...” at WIPP. At the time of the writing of this reference, the Pipe Overpack Container (POC) was the recognized packaging medium for surplus plutonium being dispositioned at WIPP. When the DOE Red Team questioned the SRS technicians in 2015, they were packaging the plutonium in Criticality Control Overpacks.

In the absence of any authoritative source, High Bridge Associates developed its assumptions on the following basis. The announced and agreed to amount of weapons-grade plutonium in the PMDA negotiations was 38.2 MTs. DOE has recently identified a plan for disposing of 13.1 MTs of surplus plutonium at WIPP in their Supplemental FEIS. High Bridge has assumed that they are additive for a total of 51.3 MTs. This may be wrong, in that the 4.2 MTs that were deleted from the total may constitute some portion of the 13.1 MTs, but we could find no reference that confirmed that. In any case, 51.3 MTs is less than the 54.5 MTs in Exhibit A-1 and the 52.7 MTs mentioned in the GAO report, so we believe that it is representative of the true size of the problem facing the DOE.
APPENDIX B

WIPP History
Appendix B – Chronological History of WIPP

WIPP has had a long and contentious history. It is worth recounting a bit of that history because it seems to have been discounted. Many of the assumptions regarding the future use of WIPP seem to be based on the assumption that New Mexico is a willing host for WIPP. While there was wide-spread support for WIPP before the February 2014 incidents, it was by no means universal. The brief summary of the history presented here is intended to illuminate the reality of New Mexico’s participation in the WIPP design and permitting process and to offer a sobering vision about the likely reaction to DOE violating the design basis and the permit to save money.

In 1957, the National Academy of Scientists recommended bedded salt formations as the best type of formation for underground disposal of radioactive waste. The weapons complex had long deferred the decision for the ultimate disposition of the wastes accumulating from the weapons program. However, in 1969-1970 a series of fires at the DOE Rocky Flats facility near Denver, CO forced the decision to stop storing plutonium wastes at Rocky Flats and to begin shipping transuranic wastes (TRU-wastes) to Idaho National Laboratory (INEEL at the time). Idaho was promised that the waste would only be stored for ten years at INL and the search began for a site to permanently dispose nuclear wastes from the weapons programs. After 1970, the weapons complex began to store TRU-waste retrievably at all their facilities in anticipation of the opening of a permanent disposal facility.

In June of 1970, the AEC selected an abandoned salt mine near Lyons, Kansas but by 1972 it was discovered that the combination of numerous poorly plugged boreholes and large volumes of water "lost" in fractures in the salt rendered the site unsuitable for a waste repository. They considered several New Mexican sites and eventually settled on the site near Carlsbad. The encouragement of local politicians and businessmen was an important factor in bringing WIPP to this area. In 1974, the Energy Reorganization Act split up the Atomic Energy Commission into a regulatory body (NRC) and a nuclear weapons and research organization (Energy Research and Development Agency – ERDA).

Throughout the period from 1974 through 1978, ERDA conducted site characterization of the salt deposit near Carlsbad, NM. In 1978, ERDA was consolidated into the new Department of Energy that took over the development of the site. Early plans for the repository showed two levels—the lower level for hotter defense wastes and a upper level for spent fuel rods. In 1979, the annual DOE authorization bill was amended authorizing WIPP. High Level Waste (HLW)—fuel rods and waste from reprocessing—was excluded from permanent disposal at the site, but was allowed for "experiments." The DOE prepared the Draft Environmental Impact Statement in April 1979 and the Final EIS was issued October 1980.¹

At this point the State of New Mexico filed suit to stop WIPP from proceeding as planned. The suit was settled out of Court with a Stipulated Agreement between the State and the DOE. In this agreement the state agreed to allow permanent facility construction and underground excavation. DOE agreed to do

certain tests as well as to allow independent state monitoring. DOE also agreed that the TRU waste would be subject to a period of retrievability before the repository was closed. In addition, a Consultation and Cooperation (C & C) Agreement was signed between the DOE and the state of New Mexico.

In January of 1981, DOE issues a Record of Decision to construct WIPP, but a previously drilled test well was deepened to 2,900 feet where it struck a pressurized body of brine. This discovery forced the relocation of the repository 6,000 feet to the south to avoid this large body of water. Smaller bodies of brine were identified beneath this new location, but were judged to be acceptably stable. Underground excavation began in October 1982 and construction of the aboveground facilities began in July of 1983. When construction began at the site several hundred people demonstrated at WIPP. Twenty-one people were arrested after crossing the WIPP site boundary line.

In 1984 the C & C agreement was partially modified (First Modification). DOE agreed to do more geological studies and agreed to comply with all applicable federal and state laws including Environmental Protection Agency (EPA) standards for permanent disposal of radioactive waste. The WIPP mission still included an amount of HLW for experiments, but the amount of RH-TRU waste that could be disposed was limited and described in this agreement. In 1987 a federal court threw out the existing EPA standards for being too weak. EPA began to research and rewrite the standards.

It was known that the salt at the site had water in it and that there were numerous other problems with the site and the waste. At this point DOE declared that WIPP would be opened for a "Test Phase" and that 15% of the wastes would be "stored" at WIPP for tests. Since the wastes were only stored and not permanently disposed, they would not be regulated under the more stringent EPA standards for permanent disposal. If, after 15% of the waste was emplaced, DOE decided to dispose of the waste, only then would they have to show compliance with disposal standards. Again, New Mexicans protested by camping on the sidewalk in front of Senator Bingaman's and Senator Domenici's offices for a week.

In this same year DOE tried to get a variance from the Department of Transportation to permit the temporary use of the TRUPACT-I shipping container. When this failed they agreed in the Second Modification to the C & C agreement to get NRC certification for future shipping containers. They also agreed again to comply with EPA, DOT and NRC regulations relating to WIPP and that they would try to get $190 million for road improvements and bypasses. Other agreements included not allowing mining and drilling into the WIPP site and that both natural and engineered barriers would be used to confine the waste. Governor Carruthers declared that this Second Modification had resolved state concerns.

In April of 1985, President Reagan decides that there is no reason to develop a defense high level waste repository and that spent fuel and reprocessing wastes from the nuclear weapons program will be stored in the Commercial HLW repository. This eliminated the pressure to store high level wastes at WIPP and cleared the way for a TRU only waste repository.

DOE began the process to withdraw the land around WIPP from general use and put it under exclusive DOE use. This was the first step toward actually opening the repository to receive waste and DOE announced that WIPP would open in 1988.

However, the process of bringing the Land Withdrawal Act before Congress brought WIPP under the jurisdiction of committees other than the Armed Services Committees. When these committees held hearings, numerous problems with the site and the facility were revealed. Passage of the Land Withdrawal Act was stopped and in fact it took five years before the Act finally became law.
Meanwhile, the Governor of Idaho refused to accept any more waste from the Rocky Flats facility near Denver. He later allowed a few shipments to continue but in 1989 DOE tried to come up with interim storage plans for the waste. Much had changed since the original 1980 EIS and after being threatened with a suit by several environmental groups and the state of Texas, DOE agreed to supplement the 1980 EIS and hold hearings. They also announced in the Draft Test Phase Plan that they would only bring 3-8% of the waste to WIPP for tests. Eight hundred people testified in the New Mexico SEIS hearings; most strongly criticized the project and the so-called Test Phase.

In January 1990, the DOE issued the Final SEIS. In it DOE stated that it was "...committed to full compliance with RCRA requirements..." The RCRA requirements include regulation of the hazardous materials in the mixed waste. At the same time that DOE was promising full compliance, it applied for and received a variance from those requirements for the Test Phase. That same year DOE tried and failed to get the NRC to approve 24 defective TRUPACT-II shipping containers.

The New Mexico Environmental Improvement Board (EIB) held route designation hearings beginning in 1990. The next year the routes to WIPP were designated by the state of New Mexico which chose to send the waste south on highway 285 for much of its journey. Throughout 1991 there was a struggle back and forth over withdrawing the land for WIPP. The DOE and Department of the Interior (DOI) made several attempts to withdraw the land administratively when various versions of the Land Withdrawal Act failed to pass. Administrative withdrawals were blocked by Representative Bill Richardson and by a lawsuit filed by the Attorney General and several environmental groups which resulted in a preliminary injunction against the opening of WIPP.

The Land Withdrawal Act (LWA) was passed in 1992. It included provisions for a Test Phase but also that WIPP must comply with the EPA’s Resource Conservation and Recovery Act (RCRA) regulations as well as with the Solid Waste Disposal Act. DOE was required to help the State get money for highway upgrades and emergency-preparedness training and equipment. Retrievability plans as well as plans for decommissioning WIPP and surveys and plans for disposal of all TRU waste (including the large amount that is not retrievably stored) were required. HLW was specifically prohibited at WIPP—even for experiments. EPA certification requirements were key to the compromise that resulted in passage of the Act. DOE would no longer be able to self-certify the facility. Instead, EPA would decide if WIPP could safely contain the waste.

The next year DOE decided that it could not justify doing experiments in the repository with WIPP waste since it would be, in effect, placing TRU Wastes before approval to do so. It substituted a series of laboratory experiments. DOE found that they couldn't seal the alcove rooms excavated in salt that were required for gas generation experiments underground. So in 1993 the Test Phase was canceled and the next year DOE began concentrating its efforts to open WIPP as a permanent disposal facility. In 1994 and 1995 they began tests to understand the hydrology and geology of the area. These tests are crucial to showing compliance with permanent disposal standards, but since they were started so late DOE wanted to start operations before completing the tests. This turned out to be more optimistic than real.

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In 1996, the DOE submitted the first Compliance Certification Application (CCA) for WIPP. It was the DOE’s attempt to demonstrate compliance with 40 CFR 191 prepared before the EPA’s guidance regulation 40 CFR 194 was promulgated in 1998. In 1997, DOE issued the Final Supplemental Environmental Impact Statement that demonstrated the acceptability of the WIPP. The EPA accepted the CCA in May of 1998 and certified WIPP for operation.


Exhibit 2-2 – Relevant WIPP Timeline

Key Timeline Takeaways:

1. There were three Final Environmental Impact Statements spanning nearly 20-years of debate and negotiations.
2. WIPP was designed and permitted without consideration of the disposal of the surplus weapons plutonium.
3. Contentious arguments were present throughout the WIPP development process which shaped the final form of the facility.
4. Major revisions to the agreed to parameters of the design invalidate the FEIS.
5. No analysis of CCOs for use in WIPP exists.
6. The decisions made for plutonium disposition program after 2012 have taken place with the assumption that WIPP exists and that nothing will impact WIPP.
The WIPP received its first shipment of waste in March 1999. This enabled the beginning of the cleanup of the legacy wastes from the weapons complex by providing a repository for TRU wastes. However, one of the most daunting challenges facing the EM Program was the concentrated plutonium wastes being characterized from the cleanup of the Rocky Flats Plant. This was addressed by a new waste container called the Pipe Overpack Container (POC). This design permitted high concentrations of Plutonium per package than other packages. This was not judged to be a major revision to the FEIS so it was addressed in a supplemental analysis released in November of 2002\(^8\). This SA described the acceptability of the use of POCs to dispose of Rocky Flats TRU wastes that contained a more concentrated form of $^{239}\text{Pu}$.

**WIPP Design**

An inherent assumption of the DOE/NNSA management and their contractors regarding the disposition of surplus plutonium at WIPP has been that changes to the character and makeup of the waste being sent to the repository can be accomplished quickly and without undue interference from intervenors. In the history of the Waste Isolation Pilot Plant program there are almost no examples of things going rapidly. This Appendix provides a historical summary of some of the key events in the history of WIPP that amplify the point that changes to WIPP require a great deal of effort to implement.

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<th>Year</th>
<th>Event</th>
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<tr>
<td>1957</td>
<td>The AEC sponsors several years of research (1957-1961) at the Oak Ridge National Laboratory (ORNL) in Tennessee on phenomena associated with the disposal of radioactive waste in salt.</td>
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<td>1962</td>
<td>The U.S. Geological Survey (USGS) reports on the distribution of domestic salt deposits that may be suitable for radioactive waste disposal. The Permian Basin, which includes the Delaware Basin in southeastern New Mexico and large areas in Kansas, west Texas, and Oklahoma, is one of the areas identified in the USGS report.</td>
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<td>1963</td>
<td>The research at ORNL is expanded to include a large-scale field program in which simulated waste (irradiated fuel elements), supplemented by electric heaters, is placed in an existing salt mine at Lyons, Kansas. The field program, known as Project Salt Vault, continues until 1967.</td>
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<td>1969</td>
<td>May 11: First Major Fire in Glovebox 776/777 at Rocky Flats Plant that triggers the move to end the storage of Pu at Rocky Flats plant.</td>
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<td>1970</td>
<td>Jan: AEC changes policy and requires all TRU Wastes to be stored in retrievable forms In June, the Lyons site is selected by the AEC as a potential location for a radioactive waste repository.</td>
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<td>1972</td>
<td>The Lyons site is judged unacceptable due to the area's uncertain geology/hydrology and previously undiscovered drill holes which could lead to extensive dissolution of salt.</td>
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<td>1973</td>
<td>A nation-wide search for a suitable salt site is resumed, resulting in the selection by the AEC, USGS, and ORNL of a portion of the Permian Basin in southeastern New Mexico as best meeting their site selection criteria.</td>
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<td>1974</td>
<td>A location 30 miles east of Carlsbad is chosen for exploratory work and extensive field investigations.</td>
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Year | Event
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1975 | On October 11, the U.S. Congress passes the *Energy Reorganization Act of 1974* (Public Law 93-438). Section 202 of the Act stipulates that the federal Nuclear Regulatory Commission (NRC) shall have "...licensing and related regulatory authority as to facilities used primarily for the receipt and storage of high-level radioactive wastes...".

| 1975 | A 3,000-foot-deep exploratory borehole, ERDA-6, is drilled at the northwest corner of the originally selected site. The borehole encounters pressurized brine upon intersecting a highly deformed structure at the 2,710-foot level. Consequently, the site is abandoned.

| 1975 | An area approximately 7 miles southwest of the abandoned site is recommended by the USGS for further examination.

| 1975 | New Mexico Governor Apodaca establishes a "Governor’s Advisory Committee on WIPP," consisting of 10 individuals from New Mexico’s scientific/academic community.

1976 | On December 3, the federal Energy Research and Development Administration (ERDA), the U.S. Department of Energy’s predecessor agency, files an application with the U.S. Interior Department’s Bureau of Land Management (BLM) for the withdrawal of 17,200 acres of land in Eddy County for the WIPP Project. The application effectively segregates the identified lands from public entry for a period of two years from the date of its noticing. [Federal Register, Vol. 41, No. 243, p. 54994, December 16, 1976]

| 1976 | Detailed site characterization and engineering design programs are initiated and continue for several years. Results of these studies through late 1978 are reported in the *Geological Characterization Report* (Powers et al., 1978).

1977 | In November, ERDA notifies the NRC of its intention to request a license to construct and operate a radioactive waste repository in New Mexico.

1978 | On October 13, the U.S. Department of Energy (DOE) files an application with the BLM for the withdrawal of 17,200 acres of land in Eddy County, New Mexico, for the WIPP Project. The application effectively continues an earlier segregation of the same identified lands from public entry for a period of two years from the date of its noticing. [Federal Register, Vol. 43, No. 221, p. 53063, November 15, 1978]

| 1978 | The Environmental Evaluation Group (EEG) is established late in this year to provide a full-time, independent technical assessment of the WIPP Project. Although funded entirely by the DOE through Cooperative Agreement No. DE-AC04-79AL10752, the EEG is made a part of the Environmental Improvement Division of the N.M. Health and Environment Department.

1979 | During the First Session of the 34th New Mexico State Legislature, a new law is enacted establishing the interim legislative Radioactive and Hazardous Materials Committee and the Radioactive Waste Consultation Task Force, an executive-branch group of three Cabinet secretaries. [Laws of 1979, Chapter 380; Section 74-4A-2 New Mexico Statutes Annotated 1978]

| 1979 | In April, DOE issues its Draft Environmental Impact Statement (DEIS) on WIPP, which clearly defines the project as a combination military/commercial nuclear waste repository. The following month, however, the House Armed Services Committee of the U.S. Congress moves to cut off funding for the WIPP, citing as the reason DOE’s expansion of the project to a fully licensed (by the U.S. Nuclear Regulatory Commission), commercial facility.

| 1979 | As a consequence of the House Armed Services Committee threat to cut off funding for WIPP, the DOE withdraws its plans for a combined commercial/defense repository and retreats to its original proposal to limit the project to an unlicensed, research and development facility for the storage of defense transuranic (TRU) wastes and some limited, high-level waste experiments.
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<td><strong>1979</strong></td>
<td>On December 29, 1979 the U.S. Congress approves the <em>Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980</em> (Public Law 96-164). Section 213(a) of the Act authorizes WIPP &quot;...for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission.&quot; The Act also directs the DOE Secretary to enter into a written &quot;consultation and cooperation agreement&quot; with the State of New Mexico by September 30, 1980.</td>
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<td><strong>1980</strong></td>
<td>On January 17-18, the EEG convenes a group of 35 scientists and other interested parties to address unresolved geotechnical issues on WIPP. A complementary geological field trip to the WIPP site, hosted by the EEG, occurs in June. Negotiations on a consultation and cooperation agreement are initiated in early spring and continue through August, when New Mexico Attorney General Jeff Bingaman declares the draft agreement legally deficient in protecting the State's rights. On July 14, DOE initiates drilling of a 12-foot-diameter exploratory shaft at the WIPP site. This first WIPP shaft reaches a total depth of 2,305 feet on October 24, 1981. In October, the DOE issues its Final Environmental Impact Statement (FEIS) on WIPP, anticipating that revision of the document will resolve deficiencies cited by New Mexico Governor King in the State's response to the draft EIS. [U.S. Department of Energy, <em>Final Environmental Impact Statement, Waste Isolation Pilot Plant</em>, DOE/EIS-0026, October 1980] On November 7, the DOE files an application with the BLM for the withdrawal of 8,960 acres of federal land for the purpose of conducting a Site and Preliminary Design Validation (SPDV) program at the WIPP. [Federal Register, Vol. 45, No. 196, p. 75768, November 17, 1980]</td>
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<td><strong>1981</strong></td>
<td>Although State concerns regarding the FEIS are given only cursory attention, the DOE issues in late January its &quot;Record of Decision&quot; to proceed with WIPP construction. [Federal Register, Vol. 46, No. 18, p. 9162, January 28, 1981] On May 14, New Mexico Attorney General Bingaman files suit in U.S. District Court (Albuquerque) against the DOE and the Interior Department, alleging violations of federal and State law in connection with the continuing development of WIPP. [Civil Action No. 81-0363 JB] On July 1, U.S. District Judge Juan G. Burciaga issues a federal court Order, which provides New Mexico a meaningful role in the decision-making process for the WIPP Project. The Order stays all proceedings in the State lawsuit in accordance with a Stipulated Agreement, signed by Attorney General Bingaman, DOE, and the U.S. Interior Department. The Stipulated Agreement requires the DOE perform additional geotechnical studies at the WIPP site and then provide the results to the State for review. It also requires DOE and the State to reach a negotiated settlement on certain State &quot;off-site concerns&quot; (e.g., emergency response, highway upgrading, transportation monitoring, accident liability). Attached as an appendix to the Stipulated Agreement is a fully executed Consultation and Cooperation Agreement, signed by Governor Bruce King and DOE Secretary James Edwards on the same day (July 1, 1981). The &quot;C &amp; C Agreement,&quot; as it has become known, provides for the timely and open exchange of information about WIPP. Significantly, the Agreement also provides New Mexico a mechanism for conflict resolution on matters &quot;...relating to the public health, safety or welfare of the citizens of the State.&quot; At EEG's urging, the DOE starts deepening a previously drilled borehole (WIPP-12) into the Castile Formation. Located north of the site, WIPP-12 had been drilled to a depth of 2,737 feet in 1978.</td>
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*Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel*

*High Bridge Associates*

*B-9*

*March 2, 2016*
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<td>1982</td>
<td>On November 22, the DOE strikes a large, highly pressurized brine reservoir in WIPP-12 at a depth of 2,900 feet, producing 350 gallons per minute of brine at the surface. Following an extensive hydrological and geological evaluation, and an EEG recommendation to relocate the TRU waste storage area away from WIPP-12, the DOE redesigns the proposed repository with the TRU waste area relocated approximately 6,000 feet south of its original location. On December 22, the DOE initiates drilling of a 6-foot-diameter ventilation shaft at the site. This second WIPP shaft reaches a total depth of 2,203 feet on February 22, 1982.</td>
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<td>1982</td>
<td>On March 30, 1982, the BLM issues Public Land Order 6232, withdrawing 8,960 acres of federal land (and 1,280 acres of State trust land, if acquired by the federal government) for the purpose of conducting the SPDV program at WIPP. This administrative withdrawal is effective for an 8-year period, March 30, 1982-1990. [Federal Register, Vol. 47, No. 61, p. 13340, March 30, 1982] In October, underground excavation of the repository begins. Salt is transported to the surface via the exploratory shaft (i.e., the Construction and Salt Handling shaft). On December 28, the DOE and New Mexico enter into the Supplemental Stipulated Agreement Resolving Certain State Off-site Concerns over WIPP, as required by the July 1, 1981 Stipulated Agreement. Among other provisions, the 1982 Agreement commits DOE to seeking a special Congressional appropriation for upgrading selected non-Interstate WIPP routes in New Mexico. It also clarifies that DOE is liable for any WIPP-related accidents at or en route to the site. The Agreement is signed by Governor Bruce King, Attorney General Bingaman, N.M. Radioactive Waste Task Force Chairman George Goldstein, and Joseph Canepa, Special Assistant Attorney General and primary negotiator of the Agreement.</td>
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<td>1983</td>
<td>On January 7, President Reagan signs into law the Nuclear Waste Policy Act of 1982 (Public Law 97-425). This Act establishes for the first time a national policy for the safe storage and permanent disposal of spent fuel and high-level radioactive wastes. On January 17, the DOE files an application with the BLM for the withdrawal of 8,960 of federal land (and 1,280 acres of State land, if acquired by the federal government) for the purpose of constructing WIPP. [Federal Register, Vol. 48, No. 19, p. 3878, January 27, 1983] In late March, the DOE completes its SPDV program and issues a report entitled &quot;Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program&quot; (WIPP-DOE-161). The State is given 60 days to review and comment. On May 31, the State delivers its comments on the WIPP-DOE-161 report, citing various unresolved issues (e.g., uncertainties about federal liability under the Price-Anderson Act, compensation for the loss of mineral revenues, etc.). The EEG concludes in its comments that based on existing evidence &quot;...the Los Medanos site for the WIPP project has been characterized in sufficient detail to warrant confidence in the validation of the site for the permanent emplacement of approximately 6 million cubic feet of defense transuranic waste.&quot; The EEG also recommends that several additional studies be conducted to resolve outstanding geotechnical issues. [EEG, &quot;Evaluation of the Suitability of the WIPP Site,&quot; Report EEG-23, May 1983] On June 29, the BLM issues Public Land Order 6403, withdrawing 8,960 acres of federal land (and 1,280 acres of State trust land, if acquired by the federal government) for the construction of full facilities at the WIPP site. This administrative withdrawal is effective for an 8-year period, June 29, 1983-1991. However, the withdrawal order prohibits &quot;...use or occupancy of the lands hereby withdrawn for the transportation, storage, or burial of any radioactive materials...&quot;. [Federal Register, Vol. 48, No. 130, p. 31038, July 6, 1983] On July 1, the DOE announces its decision to proceed with full facility construction of the WIPP. [Federal Register, Vol. 48, No. 128, p. 30427, July 1, 1983]</td>
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<td><strong>1983</strong></td>
<td>In August, the EEG reports on the potential for hydrogen gas explosions during transportation of high-curie content contact-handled transuranic (CH-TRU) wastes. [EEG, &quot;Potential Problems from Shipment of High-Curie Content CH-TRU Wastes to WIPP,&quot; Report EEG-24, August 1983] On September 23, the DOE initiates drilling of a 14-foot-diameter exhaust shaft. This third WIPP shaft reaches a total depth of approximately 2,200 feet on November 22, 1983.</td>
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<td><strong>1984</strong></td>
<td>In November, the State and DOE execute the &quot;First Modification to the 1981 Consultation and Cooperation Agreement.&quot; Among other provisions, it requires the DOE to comply with &quot;...all applicable state, federal and local standards, regulations and laws, including any applicable regulations or standards promulgated by the Environmental Protection Agency (EPA).&quot; The modification is signed by Joseph Goldberg, Chairman, N.M. Radioactive Waste Consultation Task Force, and Raymond G. Romatowski, Manager of DOE's Albuquerque Operations Office (DOE-AL), on November 30.</td>
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<td><strong>1985</strong></td>
<td>On April 30, President Reagan advises DOE Secretary John S. Herrington he finds no basis to conclude a defense-only repository is required for the disposal of defense high-level wastes (DHLW). The DOE is therefore directed to proceed with arrangements for disposal of DHLW in civilian repositories in conformance with the presumption of the Nuclear Waste Policy Act of 1982. On July 29, the EEG notifies DOE that the single-contained, vented rectangular TRUPACT-I, the transportation packaging container intended for shipping contact-handled transuranic wastes to WIPP, is unacceptable for use in New Mexico.</td>
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<td><strong>1986</strong></td>
<td>In mid-May, the DOE informs the State of New Mexico that the TRUPACT-I is being redesigned to meet the applicable NRC regulations by incorporating double containment and eliminating the venting feature. On May 28, President Reagan approves DOE’s recommendation of three sites for detailed characterization as this nation's first defense/commercial high-level waste repository. These sites include: 1) Deaf Smith County, Texas (bedded salt); 2) Hanford, Washington (basalt); and 3) Yucca Mountain, Nevada (tuff). In July, the EPA clarifies that the hazardous constituents of radioactive mixed wastes are subject to regulation under Subtitle C of the Resource Conservation and Recovery Act of 1976 (RCRA). [Federal Register, Vol. 51, No. 128, p. 24504, July 3, 1986] This EPA interpretive notice impacts the WIPP Project in that a majority of the wastes destined for WIPP are radioactive mixed wastes and therefore subject to applicable RCRA regulations.</td>
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<td><strong>1987</strong></td>
<td>In early May, the DOE confirms and further clarifies EPA's July 3, 1986, interpretive notice, stating &quot;...all DOE radioactive waste which is hazardous under RCRA will be subject to regulation under both RCRA and the AEA (Atomic Energy Act of 1954).&quot; [Federal Register, Vol. 52, No. 84, p. 15937, May 1, 1987] In June, the DOE announces that a request for a competitive procurement will shortly be issued for the design and fabrication of a transportation packaging container for use in shipping CH-TRU wastes to WIPP. Later in the year, the DOE selects a new right-circular-cylinder design with unvented double containment. On July 17, the U.S. Court of Appeals for the First District (Boston) vacates and remands to the EPA for reconsideration Subpart B of its &quot;Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Waste,&quot; 40 CFR Part 191. This action, deciding a legal challenge to the EPA standards by the Natural Resources Defense Council and others, impacts WIPP in that there are now no repository standards applicable to the project.</td>
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<td>In early August, the State and DOE execute the &quot;Second Modification to the Consultation and Cooperation Agreement.&quot; It requires the DOE to comply with &quot;...all applicable regulations of the U.S. Department of Transportation and any applicable corresponding regulations of the U.S. Nuclear Regulatory Commission (NRC).&quot; The agreement also states: &quot;All waste shipped to WIPP will be shipped in packages which the NRC has certified for use.&quot; Another key provision requires DOE to continue its performance assessment planning &quot;...as though EPA's 1985 repository disposal standards) remain applicable.&quot; The modification is signed by New Mexico Governor Garrey Carruthers and Attorney General Hal Stratton and by Raymond G. Romatowski, DOE-AL Manager, and DOE-AL Chief Counsel James Stout on August 4, 1987.</td>
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<td>A separate agreement, which amends the 1982 Supplemental Stipulated Agreement and relates to funding for WIPP by-passes and relief routes in New Mexico, is also executed on August 4.</td>
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<td>On December 22, President Reagan signs into law the Nuclear Waste Policy Amendments Act of 1987 (Public Law 100-203). This Act provides the defense/commercial high-level waste program dramatic new directions, prohibiting further study of the Washington and Texas candidate repository sites while focusing all efforts on the Yucca Mountain site. The elimination of the bedded salt site in Deaf Smith County, Texas, impacts the mission of the WIPP Project in that the proposed defense high-level waste experiments at the New Mexico repository now have no purpose.</td>
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<td>1988</td>
<td>On May 1, the DOE initiates drilling of a second ventilation shaft after reevaluating a 1981 decision to eliminate it as a cost-saving measure. This shaft (the 4th and final WIPP shaft) is completed on April 17, 1989.</td>
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<td>On May 3, the BLM issues to the State of New Mexico a land exchange conveyance document. The document conveys to New Mexico 2,519.43 acres of federal land in Eddy County (both surface and mineral estate) in exchange for 1,280 acres of State trust lands (both surface and mineral estate) located within the WIPP withdrawal area. All acreage (i.e., ~10,240 acres) at the WIPP site is now under federal control and administered by BLM. [Federal Register, Vol. 53, No. 115, p. 22391, June 15, 1988]</td>
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<td>In June, DOE and New Mexico execute a Cooperative Agreement, No. DE-FC04-88AL53813, entitled &quot;WIPP Enhancement of the State of New Mexico’s Emergency Response Capability.&quot; The Agreement is the funding mechanism by which DOE will meet its commitments as specified in the 1982 Supplemental Stipulated Agreement between the two parties.</td>
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<td>On September 13, the DOE announces WIPP will not open as scheduled in early October. Shortly thereafter, the New Mexico Congressional delegation declares all WIPP land withdrawal legislation &quot;dead&quot; for the current session.</td>
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<td>On September 29, President Reagan signs into law the National Defense Authorization Act for Fiscal Year 1989 (Public Law 100-456). Section 1433 of the Act assigns the Environmental Evaluation Group (EEG) to the New Mexico Institute of Mining and Technology and provides for continued funding from DOE through Cooperative Agreement No. DE-AC04-89AL58309.</td>
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<td>By October 1, the construction activities at WIPP are essentially complete.</td>
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<td>On October 19, Idaho Governor Andrus imposes a ban on all out-of-state shipments of radioactive wastes to the Idaho National Engineering Laboratory (INEL) due to delays in the scheduled opening of WIPP. Two ATMX railcars of wastes are sent back to the Rocky Flats Plant near Denver, Colorado.</td>
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<td>On December 16, Governors Andrus, Carruthers, and Romer (Colorado) meet with DOE Deputy Secretary Joseph Salgado in Salt Lake City to discuss the WIPP Project and options to avert a shutdown of the Rocky Flats Plant, which is rapidly approaching its mixed waste storage capacity limit imposed by the State of Colorado. The DOE agrees to pursue two parallel paths regarding WIPP land withdrawal: administrative and legislative; it also agrees to look at &quot;interim storage&quot; options for Rocky Flats wastes.</td>
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<td>1989</td>
<td>On January 19, DOE files an application with BLM for the withdrawal of 10,240 acres of federal land. The application is noticed in the <em>Federal Register</em> of April 19, 1989.</td>
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<td>On February 23, Governor Andrus lifts his ban on radioactive waste shipments from Rocky Flats, allowing two ATMX railcars of waste per month to move to INEL for a six-month period. If WIPP is not open by September 1, Andrus states he will reimpose his ban.</td>
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<td>In early March, the DOE submits to the U.S. Environmental Protection Agency (EPA) a &quot;No-Migration Variance Petition.&quot; If granted, this petition would provide the DOE a variance (or waiver) from the land disposal restrictions contained in the <em>Resource Conservation and Recovery Act (RCRA)</em> and corresponding regulations.</td>
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<td>In mid-April, the DOE issues its Draft Supplement Environmental Impact Statement (DSEIS) on WIPP. [{<em>Federal Register</em>, Vol. 54, No. 76, p. 16350, April 21, 1989}]</td>
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<td>On April 26, the DOE issues its 5-year Test Plan, entitled &quot;Draft Plan for the WIPP Test Phase: Performance Assessment and Operations Demonstration,&quot; DOE/WIPP-89-011, April 1989. An amendment to the Plan is issued on June 16; and a &quot;Draft Final&quot; version of the Plan is issued in December 1989.</td>
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<td>On June 27, DOE Secretary Watkins announces an indefinite delay in the opening of the WIPP. He emphatically states &quot;...WIPP will only open when I deem it safe and other key non-DOE reviewers are satisfied.&quot;</td>
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<td>In an August 21 letter to DOE Secretary Watkins, Governor Andrus announces his intention to immediately halt all further shipments of radioactive wastes to INEL.</td>
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<td>On August 29, the U.S. Nuclear Regulatory Commission (NRC) issues a &quot;Certificate of Compliance&quot; for the TRUPACT-II, the transportation packaging container to be used for shipping contact-handled transuranic (CH-TRU) wastes to the repository.</td>
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<td>In July, Secretary James Watkins formed the Office of Environmental Restoration and Waste Management, later renamed the Office of Environmental Management, that takes over the responsibilities for TRU Wastes.</td>
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<td>In October, the DOE issues its &quot;Draft Decision Plan on WIPP.&quot; This Plan outlines the process for reaching the DOE Secretary’s decision point on WIPP’s readiness for initial receipt of waste. It also identifies key prerequisites and activities to be completed prior to the Secretary’s decision.</td>
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<td>Revision 1 to the Draft Decision Plan, issued in November, identifies July 1, 1990, as the &quot;earliest possible opening date for WIPP&quot; due to the various prerequisites and activities that must be completed—many of which are beyond DOE’s control (e.g., land withdrawal, EPA’s decision on &quot;No-Migration Variance Petition&quot;).</td>
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<td>In April, EPA issues its proposed regulation granting a conditional no-migration variance for WIPP mixed wastes, as allowed under <em>Resource Conservation and Recovery Act (RCRA)</em> regulations. [{<em>Federal Register</em>, Vol. 55, No. 67, p. 13068, April 6, 1990}]</td>
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<td>In mid-April, the DOE issues its &quot;WIPP Test Phase Plan: Performance Assessment,&quot; DOE/WIPP 89-011, Revision 0. This document provides DOE’s plans for conducting a number of studies and experiments with TRU wastes during a five-year Test Phase at the WIPP facility. Approximately 4,500 drums of wastes, or about 0.5% of WIPP’s design capacity, are proposed to be brought to the repository for conducting gas generation experiments.</td>
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<td>1990</td>
<td>On June 14, the DOE approves the Final Safety Analysis Report (FSAR), a document which identifies and analyzes the risks of potential hazards associated with WIPP operations (fires, radiation releases) as well as naturally occurring hazards that may affect the facility (tornadoes, earthquakes). The FSAR also outlines measures to reduce risks and control or mitigate the hazards. Not addressed in the present-scope FSAR are activities proposed for the WIPP five-year Test Phase; these activities are to be analyzed and documented in Addenda to the FSAR.</td>
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<td>Also in mid-June, the DOE announces Secretary Watkins' approval of a &quot;Record of Decision&quot; (ROD) on the WIPP Final Supplement Environmental Impact Statement. The ROD states DOE's intention to proceed with a phased approach to the development of WIPP. Full operation of the WIPP is to be preceded by a Test Phase of approximately five years during which time certain experiments with limited waste volumes would be carried out. However, the ROD notes that &quot;...a decision on whether to proceed with an Operations Demonstration as part of the Test Phase should not be made until a high level of confidence in complying with the EPA disposal standards has been achieved and a determination is made that additional operational experience with waste is required.&quot; Also noted is the fact that a second WIPP Supplemental Environmental Impact Statement (SEIS) will be prepared prior to a decision on whether to proceed from the Test Phase to the Disposal Phase. [Federal Register, Vol. 55, No. 121, p. 25689, June 22, 1990]</td>
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<td>Concurrent with the issuance of the Record of Decision, DOE Secretary Watkins announces that January 1991 is the earliest possible date for the initial receipt of wastes at WIPP.</td>
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<td>On June 30, the DOE reaches agreement with a New Mexico subsidiary of International Minerals and Chemical Corporation (IMC Fertilizer, Inc.) regarding the purchase of its leasehold interests in a federal potash lease. The purchase agreement, totalling $25.8 million, settles the last of the existing mineral leases within the WIPP withdrawal area.</td>
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<td>Effective July 25, the New Mexico Environment Department (NMED) is authorized by EPA to regulate radioactive mixed wastes in New Mexico in accordance with its approved program. This State regulatory authority extends to TRU mixed wastes destined for WIPP. [Federal Register, Vol. 55, No. 133, p. 28397, July 11, 1990]</td>
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<td>As a cooperating agency on the WIPP Supplemental Environmental Impact Statement (SEIS), BLM issues in mid-September a &quot;Record of Decision&quot; to implement the Proposed Action in the SEIS by recommending that the Secretary of the Interior approve DOE's request for an amended administrative withdrawal for the WIPP. [Federal Register, Vol. 55, No. 182, p. 38586, September 19, 1990; Vol. 55, No. 222, p. 47926, November 16, 1990]</td>
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<td>On October 12, the N.M. Environmental Improvement Board (EIB) designates a &quot;preferred route,&quot; as that term is defined in 49 CFR 397.101, from the State's northern border to the WIPP repository. The EIB designation also requires the use of by-passes and beltways around communities, when they are available.</td>
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<td>In late October, the EPA issues a conditional no-migration determination for the WIPP facility. As a result of this determination, the DOE may place a limited amount (i.e., up to 8,500 drums or 1% of the repository's total design capacity) of untreated hazardous waste subject to the land disposal restrictions of the federal Resource Conservation and Recovery Act (RCRA) in the WIPP for the purposes of testing and experimentation. [Federal Register, p. 47700, November 14, 1990]</td>
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<td>1991</td>
<td>In late January, the BLM issues another WIPP &quot;Record of Decision&quot; (ROD) to adopt the Final SEIS and implement the Proposed Action by approving the public land order modifying the administrative withdrawal for the WIPP Project. [Federal Register, Vol. 56, No. 18, p. 3114, January 28, 1991]</td>
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<td>Concurrent with the preceding BLM action, the U.S. Interior Department issues Public Land Order No. 6826, which modifies an earlier WIPP administrative land withdrawal order (Public Land Order No. 6403) as follows: (1) Expansion of the Order’s purpose to include the conduct of a Test Phase at WIPP using retrievable, transuranic radioactive waste; (2) Extension of the term of the withdrawal for six years, through June 29, 1997; and (3) Expansion of the DOE’s exclusive use area, where WIPP surface facilities are located, from 640 acres to 1,453.90 acres. [Federal Register, Vol. 56, No. 18, p. 3038, January 28, 1991; and Vol. 56, No. 29, p. 5731, February 12, 1991]</td>
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<td>On March 6, the Interior and Insular Affairs Committee of the U.S. House of Representatives approved a resolution by Congressman Bill Richardson (D-NM) that is aimed at nullifying the federal Interior Department’s Public Land Order No. 6826. The resolution invokes a provision found in Section 204(e) of the Federal Land Policy and Management Act of 1976 and corresponding regulations.</td>
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<td>In early April, the U.S. Interior Department proposes to modify WIPP Public Land Order 6826 for the purposes of prohibiting until June 30, 1991, the transportation or emplacement of any radioactive waste within the WIPP. The action is proposed to accommodate concerns raised in the above-referenced House resolution about environment, safety, and public health matters. [Federal Register, Vol. 56, No. 62, p. 13335, April 1, 1991]</td>
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<td>Effective April 4, the New Mexico State Legislature transfers responsibility for the designation of highway routes for the transport of radioactive materials from the N.M. Environmental Improvement Board (EIB) to the N.M. State Highway Commission. [Laws of 1991, Chapter 204, Section 1; 74-4A-1 NMSA 1978] This action also nullifies and voids EIB’s 1990 WIPP route designation.</td>
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<td>On June 26, the Interior and Insular Affairs Committee of the U.S. House of Representatives passes a WIPP land withdrawal bill, H.R. 2637. Two other committees in the House (Energy and Commerce, Armed Services) and one in the Senate (Energy and Natural Resources) also have jurisdiction over the legislation.</td>
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<td>On July 1, the New Mexico Environment Department (NMED) notifies DOE of its preliminary determination that WIPP may not qualify for &quot;interim status&quot; under the State's Hazardous Waste Act (HWA). The HWA is the state analog to RCRA, and NMED enforces the HWA and its corresponding regulations in New Mexico.</td>
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<td>In August, the N.M. State Highway Commission designates new WIPP routes in New Mexico after a comprehensive comparative analysis of alternative routes and a series of public hearings. The N.M. State Highway and Transportation Department (SHTD) incorporates the WIPP route designation in its SHTD Rule No. 91-3 and provides subsequent notice of the designation to the U.S. Department of Transportation pursuant to 49 CFR Part 397.101.</td>
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<td>In late September, the Ninth Circuit Court of Appeals rules that the ban on out-of-state radioactive waste shipments imposed by Idaho Governor Andrus is illegal. The Court's decision may have implications on other states' attempts to stop such shipments. On October 5, a shipment of high-level nuclear waste from the inactive Fort St. Vrain reactor in Colorado crosses the state's border en route to the Idaho National Engineering Laboratory.</td>
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<td>On October 3, DOE Secretary Watkins notifies U.S. Interior Secretary Manuel Lujan, Jr., that WIPP is ready to begin the Test Phase. Similarly, the State of New Mexico is notified that the first shipment of waste may reach the WIPP site by October 10. The Watkins letter to Secretary Lujan certifies that &quot;...all environmental permitting requirements have been met by DOE for WIPP.&quot; This certification is required under Public Land Order (PLO) 6403, as modified by PLO 6826, before the Interior Department may issue a &quot;Notice to Proceed&quot; to the DOE. This same day, Mr. David O'Neal, Assistant Secretary of the Interior, issues the preceding notice, which provides DOE authorization to transport and emplace wastes at the WIPP site under the above-referenced Public Land Orders (i.e., the so-called &quot;administrative&quot; withdrawal). [Federal Register, Vol. 56, No. 196, p. 50923, October 9, 1991]</td>
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<tr>
<td>1991</td>
<td>On October 9, New Mexico Attorney General Tom Udall files a lawsuit against DOE and the U.S. Department of the Interior (DOI) to stop the threatened shipment of wastes to WIPP under the administrative withdrawal. [Civil Action No. 91-2527] The lawsuit, filed in the U.S. District Court for the District of Columbia, alleges violations of the National Environmental Policy Act, the Federal Land Policy and Management Act, and the Administrative Procedure Act. The State of Texas, three Congressmen, and four environmental groups sign on as plaintiff-intervenors in the case. The 1,000-page filing by the Attorney General provides documentation in support of a motion for both a Temporary Restraining Order and a Preliminary Injunction. A hearing date is set for November 15.</td>
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<td>1992</td>
<td>On October 16, the Energy and Natural Resources Committee of the U.S. Senate substantively amends and reports out its version of WIPP land withdrawal legislation, S. 1671. This bill is unanimously passed by the full Senate on November 5.</td>
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<td>1992</td>
<td>In early November, the same four environmental groups participating as plaintiff-intervenors in the State of New Mexico’s Civil Action No. 91-2527 file a separate WIPP lawsuit in U.S. District Court for the District of Columbia. [Civil Action No. 91-2929] This lawsuit, which alleges that WIPP lacks &quot;interim status&quot; under RCRA, is consolidated with the State's suit in December.</td>
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<td>1992</td>
<td>On November 20, the Energy and Commerce Committee of the U.S. House of Representatives passes its version of WIPP land withdrawal legislation (H.R. 2637). The following day, the House Armed Services Committee passes a separate version of the same bill. All three House committees with jurisdiction over the WIPP legislation have now acted and must reconcile their differences.</td>
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<td>1992</td>
<td>On November 26, U.S. District Court Judge John Garrett Penn issues an Order, along with a corresponding explanatory memorandum, granting the State’s motion for a preliminary injunction. [Civil Action 91-2527] The Order directs DOE to cease all activities relating to the WIPP Test Phase insofar as they involve the introduction or transportation of TRU waste into New Mexico.</td>
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<td>1992</td>
<td>On January 31, Judge Penn issues an Order that imposes a permanent injunction prohibiting the transport or disposal of any TRU waste at WIPP; it also grants two separate motions for summary judgment in the consolidated WIPP lawsuits.</td>
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<td>1992</td>
<td>In the first of the consolidated suits, State of New Mexico v. Watkins (Civil Action No. 91-2527), the issue was whether the U.S. Interior Department had violated the Federal Land Policy and Management Act (FLPMA) by issuing a WIPP administrative withdrawal order. Judge Penn granted the plaintiff-intervenor’s motion for summary judgment on the basis that &quot;...the Secretary of Interior cannot extend a withdrawal of WIPP for a new purpose not required by the purpose of the original withdrawal.&quot; Interior’s original Public Land Order No. 6403 withdrew federal lands at the WIPP site for &quot;construction&quot; of the facility and prohibited the transport or emplacement of any radioactive waste at WIPP. However, the DOE's proposed modification to the original withdrawal was for conduct of a Test Phase requiring the use of radioactive waste—clearly a &quot;new&quot; purpose.</td>
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<td>1992</td>
<td>In Environmental Defense Fund v. Watkins (Civil Action No. 91-2929), the Court had to decide whether WIPP has &quot;interim status&quot; under the Resource Conservation and Recovery Act (RCRA) so that DO may proceed with its Test Phase. On this issue, Judge Penn granted EDF’s motion for summary judgment on the basis that &quot;...the WIPP facility could never gain interim status because it was built after the wastes it will manage became regulated by RCRA.” Judge Penn identified the operative RCRA &quot;trigger&quot; date as November 19, 1980 — the date when the federal EPA's initial hazardous waste management program regulations became effective. DOE had conceded in its filings that WIPP was not in existence on or before that date.</td>
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<td>1992</td>
<td>On June 18, the House Rules Committee of the U.S. Congress agrees to bring to the House floor the Energy and Commerce version of the WIPP legislation. However, two major changes are made to that version: (1) the land withdrawal would be permanent; and (2) radioactive wastes cannot be emplaced at WIPP for Test Phase experiments until EPA issues final repository disposal standards (40 CFR Part 191).</td>
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<td>1992</td>
<td>On July 10, the federal Appeals Court (D.C. Circuit) issues its decision on DOE's appeal of the U.S. District Court's ruling in the WIPP consolidated lawsuits. [Civil Action Nos. 91-5387 and 92-5044] The decision reversed the earlier ruling that WIPP was not eligible for interim status under RCRA. Hence, WIPP may qualify for interim status, but the Appeals Court deferred that decision to the U.S. District Court. On the second issue, the U.S. Court of Appeals upheld the District Court’s decision that Interior Secretary Lujan exceeded his authority under FLPMA in approving WIPP Public Land Order 6826, issued January 22, 1991. Consequently, the permanent injunction prohibiting any transportation or disposal of waste at WIPP is left in place.</td>
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<td>1992</td>
<td>On July 21, H.R. 2637 (WIPP land withdrawal legislation) is debated on the U.S. House floor, amended, and passed by the full House on a vote of 382-10. An amendment by Congressman Bill Richardson (D-New Mexico) to prohibit the receipt of wastes until DOE demonstrates compliance with final EPA repository disposal standards fails. The provisions of the Senate and House WIPP bills must now be reconciled through a conference committee. Consequently, seven (7) conferees are appointed by the Senate and twenty-four (24) by the House.</td>
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<td>1992</td>
<td>On August 5, the 31-member Conference Committee appointed to reconcile differences between the competing versions of WIPP land withdrawal legislation meets to go over the ground rules and identify key issues for resolution.</td>
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<td>1992</td>
<td>On October 6, U.S. Senate and House conferees agree on a Conference Report regarding WIPP land withdrawal legislation. The report is subsequently adopted by voice vote in both the House (on October 6) and the Senate (on October 8). The bill is sent to the President for signature.</td>
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<td>1992</td>
<td>On October 30, President Bush signs the WIPP legislation into law. Among its key provisions, the WIPP Land Withdrawal Act (Public Law 102-579) establishes prerequisites for initial receipt and permanent disposal of TRU wastes at WIPP. The Act also specifies the statutory, regulatory and other requirements and restrictions applicable to the WIPP facility and its operations. Significantly, the EPA is designated as a primary independent regulator at WIPP with authority to determine whether the repository is suitable as a long-term disposal facility.</td>
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<td>1992</td>
<td>At year-end, DOE issues a key document entitled &quot;Gas Generation and Source-Term Programs: Technical Needs Assessment for the WIPP Test Phase.&quot; [DOE/WPIO/001-92, Revision 0, December 1992]</td>
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<td>1993</td>
<td>On March 25, DOE issues two key WIPP documents: 1) a &quot;Test Phase Plan&quot; [DOE/WIPP 89-011, Revision 1, March 1993]; and 2) a &quot;Waste Retrieval Plan&quot; [DOE/WIPP 89-022, Revision 1, March 1993]. Submission of these plans to EPA for review, along with public notice of their availability, are required under the WIPP Land Withdrawal Act. [Federal Register, Vol. 58, No. 55, p. 15845, March 24, 1993]</td>
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<td>1994</td>
<td>On October 21, DOE announces that tests using radioactive waste will be conducted in laboratories rather than underground at the WIPP site. Various organizations had criticized the previously planned bin and alcove tests in that they would not provide information directly relevant to a certification of compliance with the applicable disposal standards.</td>
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<td>1994</td>
<td>On December 9, DOE creates a new area office in Carlsbad, New Mexico (i.e., Carlsbad Area Office), which combines all functions of the WIPP Project Integration Office in Albuquerque and the WIPP Project Site Office in Carlsbad. Mr. George Dials is selected as the first DOE-CAO Manager.</td>
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<td>1994</td>
<td>In a letter to Judith Espinosa (Cabinet Secretary, New Mexico Environment Department) dated February 14, 1994, George Dials (WIPP Project Manager, DOE-CAO) states that &quot;...DOE has no plans or intentions of disposing of any wastes (neither hazardous, radioactive, nor mixed) in the WIPP prior to receipt of a RCRA Part B Disposal Phase permit.&quot; DOE later reverses its above-stated position regarding the receipt of non-mixed waste at WIPP prior to issuance of a RCRA Part B Disposal Phase permit from the New Mexico Environment Department (NMED).</td>
</tr>
<tr>
<td>1995</td>
<td>In a letter to Judith Espinosa (Cabinet Secretary, New Mexico Environment Department) dated February 14, 1994, George Dials (WIPP Project Manager, DOE-CAO) states that &quot;...DOE has no plans or intentions of disposing of any wastes (neither hazardous, radioactive, nor mixed) in the WIPP prior to receipt of a RCRA Part B Disposal Phase permit.&quot; DOE later reverses its above-stated position regarding the receipt of non-mixed waste at WIPP prior to issuance of a RCRA Part B Disposal Phase permit from the New Mexico Environment Department (NMED).</td>
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<td>1995</td>
<td>On May 17, H.R. 1663 is introduced in the U.S. House of Representatives by Congressman Joe Skeen (R-New Mexico), with co-sponsorship by Dan Schaefer (R-Colorado) and Mike Crapo (R-Idaho). If enacted, this legislation would amend the 1992 WIPP Land Withdrawal Act (Public Law 102-579).</td>
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<td>1995</td>
<td>On July 25, NMED determines DOE’s RCRA Part B application for WIPP is &quot;administratively&quot; complete. Over the next year, DOE provides additional documentation to NMED in response to its ongoing review and comments on the application.</td>
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<td>1995</td>
<td>On November 8, S. 1402 is introduced in the U.S. Senate by Senator Larry Craig (R-Idaho), with co-sponsorship by J. Bennett Johnston (D-Louisiana) and Dirk Kempthorne (R-Idaho). It is a companion bill to H.R. 1663.</td>
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<td>1996</td>
<td>On April 8, the New Mexico Attorney General files a petition in the U.S. Court of Appeals for the D.C. Circuit for review of EPA’s final WIPP Compliance Criteria, 40 CFR Part 194. [Civil Action No. 96-1107] This petition is ultimately consolidated with two other similar petitions filed by: two environmental groups and two individuals [Civil Action No. 96-1108]; and the Texas Attorney General [Civil Action No. 96-1109]. The petitions allege violations by EPA of the WIPP Land Withdrawal Act and the Administrative Procedure Act in promulgating the WIPP criteria.</td>
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<td>1996</td>
<td>On June 20, legislation (H.R. 1663, S. 1402) amending the 1992 WIPP Land Withdrawal Act is attached as a &quot;rider&quot; (Amendment #4085) to S. 1745, the National Defense Authorization Act for Fiscal Year 1997. It passes the full U.S. Senate on a voice vote.</td>
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<td>1997</td>
<td>On January 25 a TRUPACT-II transporter struck a cow approximately 40 miles north of Carlsbad, NM. The truck was NOT carrying any waste. There were no injuries to the drivers. The drivers contacted the State Police, who investigated the incident. No citations were issued. However, the State of New Mexico was not notified of the incident until the following morning. Therefore, in the days following the incident, both the State and DOE put in place directives that all incidents from this point forward would follow established notification procedures, regardless of whether or not the vehicle was transporting waste.</td>
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<td>In early February, spent nuclear fuel shipments from Los Alamos National Laboratory followed vehicle inspection procedures established for transuranic waste shipments to WIPP. The New Mexico Motor Transportation Division (MTD) inspected all 3 shipments to ensure compliance with CVSA Level VI inspection criteria.</td>
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<td>On June 6, the U.S. Court of Appeals for the D.C. Circuit denies petitions filed by the New Mexico Attorney General and others for review of EPA’s final WIPP Compliance Criteria. In denying the petitions, the Appeals Court judges state: &quot;We have addressed petitioners’ strongest arguments, and find no merit in the others.&quot; The final criteria stand as promulgated.</td>
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<td>In September, DOE issues its WIPP Disposal Phase Final Supplemental Environmental Impact Statement (DOE/EIS-0026-FS2, September 1997). The document’s Proposed Action, which is also DOE’s Preferred Alternative, is to continue with the phased development of WIPP by disposing of TRU waste at the repository.</td>
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<td>On September 26, NMED rescinds its “technical” completeness determination on the RCRA Part B permit application for WIPP after receiving substantial new material (~10,000+ pages) from DOE.</td>
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1997

On June 26, NMED determines that DOE’s RCRA Part B permit application is "technically" complete.

On July 10, the full U.S. Senate passes S. 1745 by a vote of 68-31. The Senate incorporates the measure as an amendment to H.R. 3230, the U.S. House of Representatives’ version of the National Defense Authorization Act for Fiscal Year 1997 and requests a conference with the House.

On July 15, DOE-CAO submits a final No-Migration Variance Petition to the EPA. The petition seeks a variance from the Land Disposal Restrictions of the Resource Conservation and Recovery Act (RCRA), as codified in 40 CFR Part 268, in order to dispose of TRU "mixed" waste at WIPP.

On July 30, the House/Senate conferees for H.R. 3230 produce a Conference Report. The report, which includes the WIPP Land Withdrawal Act amendments, is filed in the U.S. House of Representatives. [H. Report 104-724, Title XXXI, Subtitle F, Sections 3181-3191]

On August 1, the full U.S. House of Representatives approves the H.R. 3230 Conference Report on a vote of 285-132.

On September 10, the full U.S. Senate approves the H.R. 3230 Conference Report on a vote of 73-26 and sends it on to the President for signature.

On September 23, President Clinton signs into law the National Defense Authorization Act for Fiscal Year 1997 (Public Law 104-201). This law contains amendments to the 1992 WIPP Land Withdrawal Act, most notably a provision exempting WIPP mixed waste from the land disposal restrictions under the federal Resource Conservation and Recovery Act (RCRA). This RCRA exemption obviates the need for DOE to receive EPA approval under 40 CFR Part 268 of the pending WIPP No-Migration Variance Petition. |
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>In mid-January, the New Mexico Environment Department (NMED) determines that DOE’s RCRA Part B permit application is “technically” complete.</td>
</tr>
<tr>
<td></td>
<td>Also in January, DOE issues a &quot;Record of Decision&quot; (ROD) to dispose of TRU waste at WIPP. [Federal Register, Vol. 63, No. 15, p. 3624, January 23, 1998] This ROD documents DOE’s decision to implement the Preferred Alternative, as analyzed in the WIPP Disposal Phase Final Supplemental Environmental Impact Statement. Simultaneously, DOE issues a related ROD on where (i.e., at which DOE sites) the Department will prepare and store its TRU waste prior to disposal at WIPP. [Federal Register, Vol. 63, No. 15, p. 3629, January 23, 1998] This ROD is based on analyses in the Final Waste Management Programmatic Environmental Impact Statement (DOE/EIS-0200-F, May 1997).</td>
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<td>On May 13, EPA announces it is certifying that WIPP will comply with the applicable disposal regulations set forth at Subparts B and C of 40 CFR Part 191. [Federal Register, Vol. 63, No. 95, p. 27354, May 18, 1998] Immediately following the EPA announcement, DOE Secretary Federico Pena notifies Congress that WIPP is ready to begin disposal operations. Also on this same date, DOE petitions the U.S. District Court for the District of Columbia to lift its 1992 permanent injunction barring the transport or introduction of any TRU waste at WIPP. Subsequently, oral arguments in the case are scheduled for March 12, 1999.</td>
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<td>On May 15, the New Mexico Environment Department (NMED) issues a draft RCRA Part B permit for the storage and disposal of TRU mixed waste at WIPP. Issuance of the draft permit starts a 90-day public comment period.</td>
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<td>On May 21, DOE Secretary Federico Pena notifies the State of New Mexico that it intends to use WIPP to dispose of selected non-mixed TRU waste from Los Alamos National Laboratory (LANL) prior to the receipt of a RCRA Part B permit from NMED. This reverses DOE’s earlier position that it would not dispose of any TRU waste at WIPP before issuance of a RCRA permit.</td>
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<td>On June 11, NMED determines that DOE has failed to adequately characterize the selected LANL waste stream (TA-55-43, Lot 1) to demonstrate it is non-mixed TRU waste. Shortly thereafter, DOE and NMED reach agreement on a schedule and process for making a determination on the LANL waste in question.</td>
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<td>On July 16, the New Mexico Attorney General, three environmental groups, and a private citizen file petitions in the U.S. Court of Appeals (D.C.), alleging violations of notice and comment rulemaking and substantive technical errors in EPA’s certification of WIPP. [Civil Action Nos. 98-1322, -1323, -1324] Subsequently, oral arguments in the consolidated cases are scheduled for May 6, 1999.</td>
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<td>On July 27, DOE submits a &quot;Confirmatory Sampling and Analysis Plan&quot; to NMED. This plan goes through several revisions and is ultimately approved by NMED on September 24. DOE proceeds to sample and analyze the selected LANL waste stream in accordance with the approved plan.</td>
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<td>October 1, DOE Issues Final EIS for WIPP. DOE/EIS-0026</td>
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<td>On November 13, NMED issues a revised draft permit for the storage and disposal of TRU mixed waste at WIPP. Issuance of the revised draft permit starts a 60-day public comment period; a series of public hearings, commencing February 22, 1999, in Santa Fe, are also scheduled.</td>
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<td>Year</td>
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<tr>
<td>1998</td>
<td>On November 16, DOE provides the results of its confirmatory sampling and analysis on the selected LANL waste stream to NMED. [U.S. Department of Energy/Los Alamos National Laboratory, Sampling and Analysis Project Validates Acceptable Knowledge on TA-55-43, Lot No. 1, Rev. 0, November 16, 1998]</td>
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<tr>
<td>1998</td>
<td>On December 2, NMED makes a determination that the selected LANL waste stream (TA-55-43, Lot 1) is non-mixed waste.</td>
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<td>1999</td>
<td>March 26: The first TRU waste delivered to WIPP</td>
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<td>1999</td>
<td>January 1: NNSA was formed and took over some responsibilities for the Weapons Complex</td>
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<td>1999</td>
<td>July 12: First TRU Waste Shipment from Hanford to WIPP</td>
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<td>2000</td>
<td>November 1: Supplement Analysis 3 FEIS issued that made the argument for POCs from RFETS</td>
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<td>2000</td>
<td>All Pu De-Inventoried from Rocky Flats Plant</td>
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<tr>
<td>2000</td>
<td>March 26: DOE Issues Compliance Recertification Application for WIPP</td>
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<tr>
<td>2000</td>
<td>October 1: Rocky Flats Plant Closure completed</td>
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<tr>
<td>2000</td>
<td>March 29: EPA accepts CRA and recertifies WIPP for operation</td>
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<tr>
<td>2002</td>
<td>November 1: First Remote Handled TRU Waste packages received at WIPP</td>
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<tr>
<td>2002</td>
<td>March 26: DOE Issues Compliance Recertification Application for WIPP</td>
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<td>2002</td>
<td>July 9: Last shipment of TRU Leaves Nevada Test Site for WIPP</td>
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<td>2005</td>
<td>November 25: NMED agrees to extend WIPP’s RCRA permit until the renewal application can be reviewed and approved</td>
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<td>2006</td>
<td>November 18: EPA accepts CRA and recertifies WIPP for operation</td>
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<td>2006</td>
<td>August 25: WIPP receives first TRUPACT-III waste shipment</td>
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<td>2006</td>
<td>September 24: WIPP Receives 10,000th shipment of TRU Waste</td>
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<td>2007</td>
<td>Washington TRU Solutions submits Rev. 23 of the TRUPACT-II and HalfPACT Rev. 6 to the NRC to certify the Criticality Control Overpack</td>
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<td>2007</td>
<td>May 31: EM Completes TRU Cleanup of 22 legacy sites</td>
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<td>2007</td>
<td>June 30: LANL completes 1,000th shipment of TRU to WIPP</td>
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<td>2007</td>
<td>November 1: WIPP receives 11,000th shipment of TRU wastes</td>
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<td>2007</td>
<td>November: DOE-EM announces the plan to rename the waste in the Hanford Tanks from HLW to TRU waste so that it can be disposed of at WIPP</td>
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<td>2010</td>
<td>April 8: WIPP submits a Class 2 permit modification request NMED to allow the Tank Waste from Hanford to be dispositioned at WIPP</td>
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<td>2010</td>
<td>June 19: NRC provides COC for TRUPACT-II and HalfPACT designs to incorporate the CCO and higher Pu content per shipment.</td>
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<tr>
<td>2010</td>
<td>September 9: Received the first shielded shipment from Argonne National Laboratory</td>
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<td>2010</td>
<td>October 1: EM Begins an aggressive campaign to place TRU wastes at WIPP</td>
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<td>2010</td>
<td>December 3: EPA agrees to review DOE’s request to change the approach to panel closure.</td>
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<td>2014</td>
<td>February 5: Salt haul truck catches fire in the underground forcing the shutdown and evacuation of the underground</td>
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<td>2014</td>
<td>February 14: A waste drum packaged in LANL overheats and ruptures setting off radiation alarms and initiating an investigation to identify the root cause.</td>
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<td>Event</td>
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<td></td>
<td>March 9: Underground Recovery begins</td>
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<td>March 26: DOE Issues Compliance Recertification Application for WIPP</td>
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<tr>
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<td>September 30: EPA approves the redesign of Run-of-Mine Salt Panel Closure System for panel closure</td>
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<tr>
<td>2015</td>
<td>January 15: WIPP Hosts Stakeholder Workshop to describe progress on recovery.</td>
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<td></td>
<td>February 11: Underground Salt Haul Truck Fire Event Report released</td>
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<td></td>
<td>March 13: WIPP begins underground decontamination activities</td>
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<td></td>
<td>March 17: Waste Isolation Pilot Plant Technical Assessment Team Report Issued</td>
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<td></td>
<td>April 16: DOE Issues WIPP Radiological Release Phase II Investigation Report</td>
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<td>May 14: Panel 6 closures</td>
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<td>2016</td>
<td>January 29: Respiratory Protection requirements reduced in parts of WIPP underground</td>
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APPENDIX C

Criticality
Appendix C – Criticality

Criticality is a condition in which a nuclear fission chain reaction can occur. Fission chain reactions occur because of interactions between neutrons and fissile isotopes (such as $^{235}$U and $^{239}$Pu). The chain reaction requires both the release of neutrons from fissile isotopes undergoing nuclear fission and the subsequent absorption of some of these neutrons in fissile isotopes. When an atom undergoes nuclear fission, a few neutrons (the exact number depends on several factors) are ejected from the reaction. These free neutrons will then interact with the surrounding medium, and if more fissile fuel is present, some may be absorbed and cause more fissions. Thus, the cycle repeats to give a reaction that is self-sustaining.

The effective neutron multiplication factor, $k_{\text{eff}}$, is the average number of neutrons from one generation of fissions to the next. If $k_{\text{eff}}$ is calculated to be less than 1.0, the system is said to be subcritical and the chain reaction will cease. If $k_{\text{eff}}$ is calculated to be greater than 1.0, the system is said to be supercritical and the chain reaction will increase in magnitude. Exhibit C-1 is an example of $k_{\text{eff}} = 1.0$ or a steady state criticality in which exactly one neutron released from each fission interacts with another fissile nucleus to cause another fission. This is the situation that exists in a nuclear reactor under steady state operation. The sustained chain reaction will persist until one or more of the conditions necessary for the criticality to exist changes in a way to end the chain reaction.

Exhibit C-1 – Diagram of Nuclear Chain Reaction

Each fission event fissions the target nucleus into two fission fragments and releases 2.4 neutrons on average from a $^{235}$U atom or 2.9 neutrons on average from a $^{239}$Pu atom. These particles recoil from the fission location with the force of about 200 MeV. If a gram of $^{239}$Pu fissions, it will release approximately 22 Megawatt-hours of energy. By comparison a single stack of 21 CCOs contains a maximum of 7,980 grams of $^{239}$Pu. In addition, the fission fragments are generally unstable nuclei that undergo a series of radioactive decay events that also release energy adding to both the heat generation rate and to the radiological hazard.

A key to controlling criticality is to avoid moderating the neutrons. Nuclear moderation refers to the loss of energy of the neutrons by undergoing multiple elastic scattering events with light weight nuclei. The reason that this needs to be avoided is shown on Exhibit C-2. The cross section of an isotope represents the probability of interaction between a neutron and the nucleus. As can be seen in Exhibit C-2, the probability of fission increases as the energy of the neutron decreases. In other words, the probability that a neutron will interact with a fissile isotope and cause fission increases with moderation. Any light weight atom that has a larger probability of scattering the neutron than of absorbing the neutron will
result in neutron moderation. Reactor designers routinely use water (i.e., hydrogen or deuterium) or graphite (i.e., carbon). However, a wide range of atoms will accomplish the same thing without being useful in reactor design due to heat transfer or durability characteristics.

**Exhibit C-2 – Neutron Cross-Sections for Fission of Uranium and Plutonium**

The factors that impact whether or not an assembly of materials containing fissile isotopes can become critical are:

- The mass of fissile material present, i.e., a critical mass
- The concentration of fissile material
- The presence of a moderator to reduce the energy of the neutrons in the assembled mass
- The geometry of the mass in the assembled mass, and
- The presence of a “reflector” to return neutrons to the system that would have otherwise left.

The calculations that predict the likelihood of a material going into a critical state are complex. Civil and military installations that handle fissile materials employ specially procedures to minimize the probability of criticality. These procedures usually seek to minimize the mass of the material that is neutronically coupled, i.e., close enough that a large fractions of the neutrons released from spontaneous fissions shine directly on the adjoining stored mass. Materials that moderate neutrons, i.e., low atomic mass atoms, are either banned from the storage area or, if necessary, “poisoned” with neutron absorbers that prevent criticality by reducing the availability of neutrons to sustain the chain reaction. With perfect moderation, a critical mass of $^{239}$Pu is approximately half of kilogram. Without moderation, a critical mass of $^{239}$Pu is as large as 11 kilograms.

The American National Standards Institute (ANSI) and the American Nuclear Society (ANS) jointly published guidelines to assure subcriticality for fissile materials out of a reactor. ANSI/ANS-8.1-2014 was published to provide guidelines and standards that, if followed, would prevent a criticality. This standard specifies the need to have low concentrations of fissile material in the “system” being considered, to avoid trained personnel to monitor operations and prevent criticality accidents. The calculations that predict the excursion characteristics can also be complex, as this requires knowledge of the likely process upset conditions.
Criticality in an unconstrained environment is unpredictable. The results release large amounts of energy in a relatively small volume that can lead to a wide range of physical responses. Some of these would act to disassemble the critical geometry; other would tend to make the problem worse. For this reason, nuclear waste repositories cannot tolerate any condition that could lead to criticality.
APPENDIX D

Plutonium Disposition Program
Appendix D - Pu Disposition Program

The MOX Fuel Program has spanned 25 years of program definition and evolution. It began in the mid 1990’s and consisted of three new facilities and several repurposed existing facilities at several national laboratories. The new facilities were the Pit Disassembly and Conversion Facility (PDCF), the Immobilization Facility and the MOX Fuel Fabrication Facility (MFFF). These facilities were intended to address the material flows shown in Exhibit D-1. The PDCF was intended to break apart the pits from weapons, to declassify the material composition of the pit and to convert the material to an oxide safe for transportation. The IF was intended to immobilize the surplus plutonium that was considered to be uneconomical to convert into MOX fuel. The MFFF was originally designed to take pure plutonium oxide and to use it to fabricate fuel for light water reactors. Finally, facilities at national laboratories, especially LANL and SRS were repurposed to fabricate Lead Test Assemblies for qualifying the MOX fuel and to store and convert plutonium scraps to oxides.

Over the years, budget cuts and other externalities have impacted the program. Exhibit D-2 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.

As a result of each of these perturbations, the scope of the facilities remaining in the Surplus Plutonium Disposition (SPD) Program necessarily changed. When the Immobilization Facility was canceled due to practical and economic considerations, it forced a redesign of the MFFF consisting of the addition of an aqueous processing system to cleanup plutonium to make it pure enough for MOX fuel.

Likewise, when the PDCF was cancelled for economic reasons, the MFFF needed plutonium oxide production facilities added to supplement the capabilities of the SRS legacy facilities to produce pure plutonium oxide for MOX fuel.

These design changes reduced the overall cost of the SPD Program but did so at the cost of increasing the scope, cost and complexity of the MFFF. The cost increases to MFFF enabled net cost reductions to the SPD Program but enabled the enemies of the MOX program and nuclear power in general to recast the discussion about MOX as an attack on an out of control, poorly managed government program.
Exhibit D-2 – Summary of Plutonium Disposition Changing Requirements and Scope Evolution Impacts on MFFF Project


- **1991**: Nunn-Lugar Act
- **1997**: Hybrid MOX, Irradiation, and Immobilization Technologies Selected
- **1999**: PDCF Contractors Selected & SRS Site Selected
- **2000**: Immobilization Facility Canceled & Added to MFFF
- **2001**: 10-month Delay in MOX Facility Contract
- **2002**: NRC Construct. Authorization Issued for MFFF
- **2003**: MFFF Construct. Begins; MOX Program NET Costs Reduced Approx. $3B while MFFF Project Costs NET Increase Approx. $3B
- **2004**: PDCF Construct & Added to LANL, KAMS, & MFFF
- **2005**: US-RF PMDA Amended, Signed
- **2006**: H-Canyon & HB Line Author. Feed-Stock
- **2007**: US-RF PMDA Re-Base line
- **2008**: MFFF Annual Funding Reduced $625M to $350M
- **2009**: Immobilization Facility Cancelled & Added to LANL, KAMS, & MFFF
- **2010**: US-RF PMDA Amended & LANL
- **2011**: MFFF Annual Funding Reduced $625M to $350M
- **2012**: MFFF Annual Funding Reduced $625M to $350M
- **2013**: MFFF Annual Funding Reduced $625M to $350M
- **2014**: MFFF Annual Funding Reduced $625M to $350M
- **2015**: MFFF Annual Funding Reduced $625M to $350M

Several Hundred Milestones, Decisions, and Events Impacting Cost Program Evolution, Technical/Regulatory/Geo-Political Requirements, Scope & Design, & Annual Funding MOX Program NET Costs Reduced Approx. $3B while MFFF Project Costs NET Increase Approx. $3B

(See Appendix D for Detailed Compilation of Event Cost Drivers)
## WIPP Cost Elements and Concentration Scenarios Addressed in High Bridge Estimate

### Elements are Noted that Changed or Did Not Change with Scenario

<table>
<thead>
<tr>
<th>Cost Elements Estimated</th>
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<tbody>
<tr>
<td>MFFF Termination</td>
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<tr>
<td>NEPA/NMED Activities (invariant with Scenario)</td>
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<tr>
<td>PMDA Activities (invariant with Scenario)</td>
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<tr>
<td>LWA Activities (invariant with Scenario)</td>
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<tr>
<td>CCO Packaging/Transportation – “MIFT” (Scenario Sensitive)</td>
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<tr>
<td>WIPP Operations (Scenario Sensitive)</td>
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<tr>
<td>WIPP Expansion Capital (Scenario Sensitive)</td>
</tr>
<tr>
<td>South Carolina Fines (Scenario Sensitive)</td>
</tr>
<tr>
<td>PWG Changes Cited in Aerospace Report (invariant with scenario)</td>
</tr>
<tr>
<td>Contingency (Scenario Sensitive)</td>
</tr>
</tbody>
</table>

### Scenarios Estimated

High Bridge assessed five scenarios for diluted plutonium storage at WIPP developed to analyze criticality safety and NEPA compliance parameters. These scenarios were defined around incrementally lower plutonium concentration levels in the storage containers based on container type, ANSI standards, Sandia analysis basis, and WIPP FEIS design basis.

**Scenario 1** - is the approach proposed by the Plutonium Working Group, assessed by Aerospace, and endorsed by DOE/NNSA for disposing of this material in CCOs with a concentration of 29.2 kg/m³. The assumption is that CCOs are stored in WIPP but certain regulatory and capital improvement activities will be required. (Estimated in High Bridge’s August 2015 Phase 2 Report)

**Scenario 2** - is disposing of this material in POCs (as used for 180 kg from Rocky Flats) at a concentration of 16.7 kg/m³. The assumption is that POCs are certified for storage in WIPP, but the number of containers and amount of volume increase. Again certain regulatory and capital improvement activities will be required.

**Scenario 3** - is reducing the concentration of fissile material to the ANSI standard minimum for criticality of 7.3 kg/m³ in CCOs. The assumption is that CCOs are certified for storage in WIPP, but the number of containers needed to meet the ANSI standard increases. Again certain regulatory and capital improvement activities will be required.

**Scenario 4** - assumes the reduction of the concentration to meet the concentration used by Sandia when qualifying WIPP, i.e. 3.0 kg/m³. The assumption is that CCOs are certified for storage in WIPP, but the number of containers needed to meet the reach the Sandia single point plutonium density of 3.0 kg/m³ increases. Again certain regulatory and capital improvement activities will be required.

**Scenario 5** - reflects the plutonium being diluted to the average fissile content density of 0.12 kg/m³ of WIPP as defined in the FEIS design basis using 55-gallon drums and an incompressible inverting material. The assumption is that drums are already certified for storage in WIPP, but the number of containers needed to meet the Sandia single point plutonium density of 0.12 kg/m³ increases significantly. Again certain regulatory and capital improvement activities will be required.
1. Cost data given in Table 4.3-1 for the out years 2011 to 2034 are given in five year increments (CY2031-2034 is a four increment). These groups were divided into equal values for each CY increment.

2. Cost data given in Table 4.3-1 is reported for four high level cost activities, Transportation, Disposal, and Remaining Mission-Critical Activities.

3. Cost data from the National TRU Waste Management Plan were further divided into fixed and variable costs for each cost activities. Variable cost percentages used for each cost activities are:
   a. Transportation – 41% variable to total cost,
   b. Disposal – 59% variable to total cost,
   c. Other Mission-Critical – 13% variable to total cost

4. Cost data given in Table 4.3-1 is reported in real year dollars (RY$s) using a 2.1 percent per year escalation factor from CY2002. These data were de-escalated by the same factor to CY2002 dollars (FY02$s) for each cost activities for both variable and fixed costs.

5. The total of for FY02$ of each cost activity’s fixed and variable costs were then escalated to FY14$ by the 2.1% escalation factor. The data in High Bridge’s August 2015 and Aerospace’s 2015 reports were presented in FY$14s, see Exhibit 9-3.

6. Two metrics for each activity (fixed - $/year and variable - $/m^3) were used to estimate WIPP costs for each scenario.

7. DOE penalties payable to South Carolina were based on two parameters. First, penalties would be assessed until until plutonium shipments began leaving South Carolina. Second, penalties would be assessed unless shipments totaled at least 1 MT per year. High Bridge developed its estimates based on these requirements.

8. Program changes estimated by PWG from FY2012 to FY2014 and reported in the 2015 Aerospace report were assumed constant for each scenario.

9. Regulatory activities that High Bridge believes to be necessary for each scenario were also held constant from previous 2015 estimates; see Exhibit 9-3.

10. High Bridge computed the contingency shown in Exhibit 9-3 using the risk elements from the Aerospace report and the High Bridge August 2015 Monte Carlo risk analysis. High Bridge did not perform any similar analysis for scenarios 2 through 5 but has simply increased the contingency by 34% from one scenario to the next based on its August 2015 Monte Carlo analysis.

11. The cost estimated by PWG and reported by Aerospace for the termination of MFFF was held constant for each scenario.

12. Additional capital costs for WIPP were estimated as ~$426 million in scenario 1, zero for scenarios 2 and 3, ~$600 million in scenario 4 and ~$1,000 million in scenario 5.
### Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel

#### Table: Transportation Cost Estimating Metrics

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#### Basis for High Bridge Life Cycle Cost Estimate Summary - SFY14

Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel
### High Bridge August 2015 WIPP Dilution Storage Cost Estimate

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<th>Cost Element</th>
<th>2014 Base - FY14$</th>
<th>2015 Adder - FY14$</th>
<th>HBA August 2015 Estimate - FY14$</th>
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*Base Cost of $8.2B from PWG has $0.8B contingency in FY14$; High Bridge did not distribute.*

**High Bridge August 2015 Report**

- **Using CCOs; Add’l 35,568 cubic meter & 4.6 years**
- **Reported by the Plutonium Working Group - 2015**

- **High Bridge August 2015 Report Contingency Analysis**
  
  34%

- **High Bridge Asscoiates**

- **E-5**

- **March 2, 2016**

- **Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel**
### Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel

#### Scenario Comparison

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<th>Scenario</th>
<th>Fissile Concentration kg/m³</th>
<th>Drums</th>
<th>Duration Required Years</th>
<th>Volume m³</th>
<th>New Panels</th>
<th>New Rooms</th>
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## WIPP Life Cycle Cost Estimate Summary
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### Operations and Transportation Costs

- **Fixed Cost Estimated**: $175,564
- **Variable Cost Estimated**:
  - Transportation: $427,094
  - Disposal: $1,854,723,921
  - Mission Control Activities: $1,854,723,921

### Summary

- **Total Estimated Cost**: $2,074,303,117
- **Transportation**: $34,116,780
- **Disposal**: $19,948,826
- **Mission Control Activities**: $88,009,950

---

*High Bridge Associates*

**E-7**

*March 2, 2016*
### Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel

#### High Bridge Life Cycle Cost Estimate Summary - FY14

**Evaluating WIPP Plutonium Storage Concentration Level Scenarios**

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**High Bridge Aug. 2015 Report Contingency Analysis**

- Increasing in Total ETC from Scenario 1: $37,038,134,503
- Total ETC with Contingency: $26,637,830,012
- Contingency: $19,891,601,816

**Indicative Evaluation of WIPP Plutonium Storage Concentration Level Scenarios**

- Scenario 2: FY14 $5,043,000,000
- Scenario 3: FY14 $6,935,753,074
- Scenario 4: FY14 $11,590,778,244
- Scenario 5: FY14 $17,125,588,878

**High Bridge Aug. 2015 Report**

- Estimate for resources required for 30 years of WIPP operations: $8.2B from PWG
- PWG Contingency: $0.8B from PWG
- SC fines (scenario sensitive): $0
- WIPP expansion capital (scenario sensitive): $0
- WIPP operations (scenario sensitive): $0
- CCO packaging/transportation (scenario sensitive): $0
- DOE staff, legislative staff to revise the Land Withdrawal Act: $0
- LWA activities (invariant with scenario): $10M
- CE activities/costs (invariant with scenario): $15M
- MFFF termination: $1.5B
- NEPA/NMED activities (invariant with scenario): $5B
- DOE estimated cost to complete and retire WIPP: $6.9B

**Estimated WIPP LC Cost Increase**

- Scenario 1: $0
- Scenario 2: $5,043,000,000
- Scenario 3: $6,935,753,074
- Scenario 4: $11,590,778,244
- Scenario 5: $17,125,588,878

**March 2, 2016**
Comparison of Plutonium Disposition Alternatives: WIPP Diluted Plutonium Storage and MOX Fuel
APPENDIX F

Studsvik Scandpower Criticality Assessment
Studsvik

Memorandum

To: Charles Hess, HBA
Copies: SSP internal
From: Teo Simeonov
Date: 2016.01.24
Project: WIPP-HBA
Doc. No.: SSP-16 / 401-M
Title: WIPP: review of criticality evaluation
Subject: Effect of increasing the amount of Pu-239 per CCC to 380g

Summary

Studsvik has been approached by HBA for an overall review concerning criticality at WIPP and a general assessment of the impact on the criticality margins caused by an increase in the amount of Pu-239 per Criticality Control Container.


Reference 1 postulates Pu-239 concentration of 3kg/m³ to be the critical concentration below which safe operations including storage can be performed with any volumes of fissile materials at WIPP without criticality concerns.

Reference 2 suggests a substantial increase of the amount of Pu-239 to 380g per Criticality Control Container (CCC) which would correspond to a homogeneous concentration of Pu-239 per CCC of 29.2kg/m³.

A hypothetical event, e.g. creep of the salt over the time, may compress a number of Criticality Control Overpacks (CCO) together resulting in an average local concentration as high as ~25kg/m³. If found credible, such configurations cannot be bounded by the single-parameter limit of 3kg/m³ and the criticality safety margins should be determined by means of a criticality safety evaluation.
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1 Introduction

Studsvik has been approached by HBA for an overall review concerning criticality at WIPP and a general assessment of the impact on the criticality margins caused by an increase in the amount of Pu-239 per Criticality Control Container, CCC.


This document also presents an illustrative example of general safety and criticality considerations under the proposed disposal scheme in support of the conclusion that the limit established in Reference 1 is insufficient to cover the suggested increase of 380g Pu-239 per CCC/CCO in the considered storage configuration.

2 Review of SAND99-2898

2.1 General comments and observations

The usual review plan for criticality assessments, Reference 3 “Standard Review Plan for Spent Fuel Dry Storage Facilities.” NUREG-1517, March 2000, was found inapplicable for this review, because the format and the contents of SAND99-2898 is not in-line with what would be expected from a criticality safety evaluation (CSE). An evaluation of criticality margins shall strictly follow certain rules concerning: the required documentation and references, description of applied methodology, discussion of contingency, definition and discussion of acceptance criteria with associated uncertainty analyses. An example of such rules can be found in Reference 4, “Guidelines For Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities.”, DOE, STD-3007-93, November 1993.

For the most part SAND99-2898 works with the general approach of low probability and low consequences which is outside the scope of this review. The notes and comments in this Section are primarily based on information provided in Section 3, “Low Probability Based on Physical Constraints on Critical Concentration”, and Section 7 “Summary and Conclusions”.

2.2 Contents, purpose, approach

The prescriptions given in DOE-STD-3007-93, Chapter III, “Format and Contents of Criticality Safety Evaluation” are not applicable to SAND99-2898.

The purpose of the report is clearly defined in its “Introduction” as “…to present arguments that support the omission of the criticality event from the performance assessment for the WIPP…”

The approach is well justified in Chapter 1.3 "Overall approach", “…the overall approach of this report is to use arguments of both low probability and low consequence to demonstrate that the criticality could be appropriately eliminated from inclusion in the compliance performance assessment for the WIPP.”

2.3 Criticality and critical limits

Section 3.5.1, Reference 1, postulates a criticality safety limit defined as “critical concentration” and applied as a limiting parameter throughout the report.
The report determines the maximum concentration of Pu-239 to be 3kg/m$^3$. The way this number is determined/computed is unclear. The report only provides the following explanation in Section 3.5.1: “To elaborate, solid concentration below which an infinite volume of a homogeneous mixture of pure $^{239}$PuO$_2$, Culebra dolomite, and Culebra brine will not go critical is taken conservatively as 3kg/m$^3$.”

Although not stated anywhere, by doing this the report applies the so called “single parameter limit” approach. This is in general the most restrictive approach and basically postulates that in all credible conditions that may affect basic parameters such as: material compositions, densities and geometries, the system will remain sub-critical as long as, the Pu-239 concentration remains below the defined maximum value.

It should be pointed out that the as defined critical limit is ~60% smaller than the single-parameter limit of 7.3 kg/m$^3$ established by ANSI/ANS-8.1-1998, (Reference 5) Table 1.

According to Table 4, SAND99-2898, the total amount of fissile gram equivalent (FGE) Pu-239 to be disposed in WIPP on design basis is $21.1 \times 10^4$. If distributed uniformly throughout the WIPP’s volume of 175,564m$^3$ it will result in 0.12kg/m$^3$ Pu-239 which is significantly below the “critical limit” of 3kg/m$^3$.

It can be concluded, that despite the lack of compliance with the practice of a criticality safety evaluation, SAND99-2898 postulates Pu-239 “critical concentration” which would guarantee the sub-criticality and safe operations at WIPP.

3 Review of “TRUPACT-II Safety Analysis Report.” Rev.23. Appendix 4.6, 380g Pu/CCC

3.1 General comments and observations

Reference 2 provides general description of CCO, shown in Figure 1, structural evaluation in normal and accident conditions, thermal evaluation and criticality evaluation for transport packages TRUPACT-II and HalfPACT considering that the amount of Pu-239 placed in the Criticality Controlled Container (CCC) will be 380g. Each package is made of 7 CCO and two such packages are stacked together for transporting. It should be noted that the TRUPACT report only addresses transportation safety not disposal.
3.2 Contents, purpose and approach

The criticality evaluation includes normal condition and hypothetical accident condition scenarios analyzed with respect to the upper subcritical limit (USL) defined as 0.9377. In both scenarios 380g Pu-239 contained in the CCC is assumed homogeneously mixed with a moderator consisting of 74% water, 25% polyethylene and 1% Beryllium. In normal condition the CCO inside the spacing is preserved and filled with water. In accident condition the CCOs are assumed compressed and voided (filled with air).

The way an USL is defined, the conservative approach to the moderator and the consideration of a hypothetical accident are in-line with the common practice of criticality safety evaluation. Yet the format and contents are more like of a summary than of a criticality safety evaluation.

3.3 Criticality and criticality limits

A load of 380g FGE Pu-239 per CCO will result, if uniformly distributed in the CCO volume, in Pu-239 average concentration of \(1.73 \text{ kg/m}^3\), which presents a considerable margin to the single parameter limit of 3kg/m\(^3\). The CCO dimensions used in the calculation are 24”x29.5”.

3.4 Applicability to WIPP

The construction of the CCO presumes that the fissile material is contained in the CCC, a tube with dimensions 6.065”x27.5”, placed in the middle of otherwise empty CCO. Given a concentration inside the CCC of 29.2kg/m\(^3\), a hypothetical event, such as the creep of salt over the time or an earthquake, may compress a number of CCO together resulting in an average local concentration of up to \(\sim 25\text{kg/m}^3\). The structure of CCC is assumed intact.

If found credible, such configurations cannot be bounded by the single-parameter limit of 3kg/m\(^3\) Pu-239 concentration established by Reference 1 and the criticality safety margins should be determined by means of a criticality safety evaluation.

Further, it must be pointed out that Reference 2 does not provide information of how much compression is considered other than: “In HAC models, reduced drum dimensions consistent with accident geometry are modelled, which results in a highly compressed array within the package.” If the computational model assumes the following: “The HAC array is modelled with an infinite number of packages in the x and y directions and two packages in the z direction.” such a model is expected to be very sensitive on the pitch between the CCC, or in other words on the level of compression of CCO. This makes the definition and justification of the “accident geometry” critical for the criticality safety evaluation of WIPP.

4 Illustration of general safety and criticality considerations.

4.1 Introduction.

The purpose of this section is to illustrate why a criticality safety evaluation should be considered when 380g Pu-239 per CCO is to be stored in WIPP. The computational models presented here are purposely built to underline the importance of various factors for the criticality margins. We shall use the same material descriptions and assumptions as found in the TRUPACT-II report Reference 2 for this analysis.

4.2 Description

Packages of 7 CCO are stacked by three and stored in rows by six at WIPP. A “supersack” filled with MgO is placed on top of each stack.
4.3 Programs and nuclear data

4.3.1 Programs

HELIOS2 v2.1.2(Studsvik) and KENOVI (SCALE, ORNL/TM-2005/39 Version 6.1) are used in this illustration.

- The lattice code HELIOS is a neutron and gamma transport code, for lattice burnup, in general two dimensional geometry.
- KENOVI is a 3D Monte Carlo code.

4.3.2 XSs

HELIOS: 177-group neutron library, ENDF/B-VII.R0
KENOVI: CE, ENDF/B-VII.R0

4.4 Methodology

The main factors affecting the criticality margin are the moderation inside and the reflective properties outside the assumed volume of fissile material. Because the exact composition inside the CCC is unknown and secondly because the conditions during the considered 10,000 year period may change significantly, the recommended conservative approach is to consider aqueous solution fully reflected in water with the remark that the assumed conservatism shall be justified. This was also the assumption in the transportation safety analysis.

Following Reference 2, two cases: a normal condition transport (NCT) and a hypothetical accident case (HAC) are defined. In both cases the CCC is assumed intact and the material composition inside is assumed 380g Pu dissolved in 74% water, 25% polyethylene and 1% Beryllium. The main difference between NCT and HAC is that in NCT the space between CCC and CCO outer dimension is assumed filled with water while in HAC it is filled with dry air. No other materials, steel or other structural components are taken into account for conservative reasons.

The HAC case is analysed assuming that the CCO might be pressed simultaneously together by external force which will change uniformly the pitch between the CCC/CCO within the package and in addition the entire array of packages will be compressed accordingly. Reference 2 defines the dimensions in HAC by “In the HAC model, reduced drum dimensions consistent with accident geometry are modelled, which results in a highly compressed array within the package.” Because the exact HAC dimensions are unknown the calculations in this work are performed at two compaction levels: 1/3 and 2/3 of the initial volume.

The models, shown in Figure 2, include: a single CCO, stacked bundle of 7x3 CCOs and as well as multi 7x3 stacked configurations. The single unit in an infinite array is the most conservative approach. The infinite mesh is modelled by mirror boundary conditions on both radial and axial surfaces. In a more realistic cases, the CCOs are assumed radially packed by 7 and stacked axially by 3. The compression scenario assumes that the pitch inside the 7-pack and the pitch between the packs will change uniformly. The effect of the reflector is investigated by adding 50 cm MgO on top of the stack. The effect of MgO placed in between the stacks and on the radial boundaries is investigated as well.
Figure 2 Single CCO, 7-pack CCOs and 7x3 pack CCOs models

4.5 Inputs

4.5.1 Material compositions

Material composition inside CCC (H₂O/CH₂/Be, 74%/25%/1% + Pu 380g)

Densities:
- H₂O 1.0 g/cm³
- CH₂ 0.96 g/cm³
- Be 1.85 g/cm³
- Pu-239 19.8 g/cm³

Homogeneous mixture:
- Density 1.0262 g/cm³
- Pu-239 2.84 wt%
- Be 1.80 wt%
- H 11.42 wt%
- C 19.99 wt%
- O 63.95 wt%

Material compositions between CCC and CCO:
- NCT H₂O (Density 1.000 g/cm³)
- HAC Dry Air (Density 0.001 g/cm³), N₂ 75.5%, O₂-24.5%

Reflector: MgO supersacks
- Density 3.58 g/cm³
- Mg 60 wt%
- O 40 wt%
- Thickness 50 cm

4.5.2 Dimensions

- CCC diameter 6.065” (15.24 cm)
- CCC height 27.5” (63.5 cm)

55-gallon drum:
- CCO diameter 24” (60.96 cm)
- CCO height 29.5” (74.93 cm)

4.5.3 Temperature

All dimensions, densities and cross sections are assumed at room temperature 20°C.
4.6 **Conservatism and uncertainty**

4.6.1 **Moderation**

- The assumption of moderator mixture of water-polyethylene-beryllium is a very strong conservative approximation.
- The assumption that the space between the CCC and CCO is left empty in HAC is not investigated, but it is considered conservative compared to NCT due to elimination of “absorbing” material.
- It is difficult to predict the most favourable (optimal) moderation as a combination of the two separated volumes in-CCC and the interspace CCC-CCO and it is out of scope for this illustration.

4.6.2 **Structural materials**

The structural materials of CCO and CCC are neglected. This is a conservative approximation, because absorbing material (steel) is removed from the system. The effect is not evaluated.

4.6.3 **Reflector**

The effect of various reflective conditions, except for MgO, is not investigated. The properties of the surrounding media are not modelled assuming either black or mirror boundary.

Homogeneous regions of MgO are added on the top axial and on all radial surfaces. The assumption made in the computational system of 3x3 uncompressed CCOs, is that there is enough MgO to cover 50 cm on the top, and in addition to fill the space between the stacks and at least 30 cm all around in x and y direction.

4.6.4 **Geometry and dimensions**

- In all condition the integrity of the CCC is assumed intact. Conservative effect preserving the moderation.
- In compressed conditions when the distance between CCC is changed, it is changed for all units included in the model. It is difficult to predict a more favourable configuration in the compressed scenarios. An ordered system is in general more conservative.
- The uncertainty associated with the dimensions is not investigated.

4.7 **Acceptance criteria**

A generally acceptable as Upper Subcritical Limit is USL=0.95

4.8 **Evaluation and results**

4.8.1 **Single CCO**

The NCT and HAC are applied to a single CCO in an infinite array. Because HELIOS is a 2D code, the real CCO is approximated by a 2D model assuming equal heights for CCC and CCO. The models are shown in Figure 3.

---

*Figure 3 2D KENOVI (left) and HELIOS (right), models.*
The size of the water reflector inside the CCO is large enough (~23cm) to assume fully reflected system independent from the external boundary condition. Nevertheless, for the sake of consistency a mirror boundary is applied all around. HELIOS and KENOVI are in very good agreement, which shows the consistency in the models:

<table>
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<th>HELIOS</th>
<th>0.81248</th>
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<tr>
<td>KENOVI</td>
<td>0.8147 ± 0.0010</td>
</tr>
</tbody>
</table>

In the second case the CCO is filled with air instead of water. The water is a very efficient neutron moderator and in the same time a neutron absorber. In this particular case, because of the moderation in the CCC and the all-mirror boundary condition, the absorption is by far the dominating effect. In other words, without water between CCC and CCO any neutron born in the system has a better chance to reach and react with the material in the neighboring elements, which improves significantly the neutron economy and results in much higher infinite multiplication factors. Note that the distance between the CCC is irrelevant because of the all-mirror boundary condition and the lack of material between the CCCs.

<table>
<thead>
<tr>
<th>HELIOS</th>
<th>1.58328</th>
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</thead>
<tbody>
<tr>
<td>KENOVI</td>
<td>1.58538 ± 0.00052</td>
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</table>

The computed infinite multiplication factors, show a critical system by over 50% which is unacceptable criticality safety situation. The “single CCO” approach to criticality is apparently too conservative and inapplicable as part of a criticality evaluation for WIPP. It is necessary to adopt more realistic conditions such as: a more realistic or exact geometry; more realistic external boundary conditions or an explicit reflector model; a more realistic or exact material composition for the structural and reflector regions.

4.8.2 **A stack of 7x3 CCOs**

A package of 7x3 CCO, as shown in Figure 2c, is modelled and calculated by KENOVI in HAC configuration. The axial boundary is assumed black in all cases in this Section.

The $K_{eff}$ of an infinite in x and y direction array without compaction is:

$$0.8595 ± 0.0011.$$ 

Sandia analyses of the WIPP repository for Environmental Management of legacy wastes assumes eventual compaction of the overpacks. Shown on Figure 4 below is their visualization of what would likely occur over time.
Figure 4 Figure 13 from SAND99-2898, Reference 1,

Thus, given the voided condition of the CCO barrels, it is reasonable to assume some compaction will occur. If 1/3 compaction is applied, the $K_{\text{eff}}$ becomes:

$$1.0944 \pm 0.0011$$

With Upper Subcritical Limit of 0.95, this supercritical configuration is in excess of that limit by 14.4%. The assumption of infinite array in x and y direction, Reference 2, is inapplicable to the criticality safety at WIPP in this configuration and this material composition.

Opposite to the infinite array is a system of with all black boundary conditions. It can be shown that such a system cannot be considered subcritical in all situations. For example if two 7x3 packs, Figure 5, are compressed to 1/3 of their original volume (CCO pitch=20cm from the initial 61cm), even with black boundary applied all around, the $K_{\text{eff}}$ will give an unacceptable margin to criticality:

$$0.9911 \pm 0.0011$$

Figure 5. Two packs of 7x3 CCOs compressed to 1/3 of original volume

4.8.3 The reflector and MgO effect on the reflective properties

For the proposed disposal scheme, it is understood to have super sacks of MgO emplaced on top of the CCOs as in other panels as shown in Figure 6a.
In the previous sections the reflector has been effectively “ignored” and accounted for by the two bounding cases: no reflection and perfect reflection. In this section the media surrounding the drums and stacks of drums, is partially modeled by assuming certain material properties. The purpose is to illustrate the effect of MgO, stored in significant quantities at WIPP, Reference 6, on the reactivity at WIPP in three configurations:

0. Case0 – no MgO
1. Case1 – “supersacks” of MgO are placed on top of each stack - Figure 6a
2. Case2 – MgO is also placed between the drums- Figure 6b
3. Case3 – all around reflection in MgO - Figure 6c

No CCO compaction is assumed in the computational system presented in Figure 6. Black boundary condition is applied on all outer surfaces after at least 30cm MgO when and where applicable. The $K_{eff}$ is presented in Table 1.

<table>
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<tr>
<th>Case</th>
<th>$K_{eff}$ ± $\sigma$</th>
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<tbody>
<tr>
<td>0</td>
<td>0.6397 ± 0.0012</td>
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<tr>
<td>1</td>
<td>0.6650 ± 0.0011</td>
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<tr>
<td>2</td>
<td>0.8294 ± 0.0013</td>
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<tr>
<td>3</td>
<td>0.9829 ± 0.0015</td>
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</table>

Table 1 Effect of MgO on reactivity of 7x3x3 CCOs

The axial effect, the difference between Case 0 and Case 1, is expectedly relatively small. However the MgO between the drums, Case 2, adds moderation to the system and the effect is about 16% relative to Case 1. Finally applied as a reflector on all the radial and the top axial surfaces, Case 3, MgO considerably limits the leakage of neutrons and creates a reactivity effect of about 31%, relative to Case 1.

As it can be seen here, the effect of reflector can be significant and it is going to be even stronger if certain level of compaction is applied over the stacks of CCOs. It should be pointed out that the material properties shall not be limited to MgO and the geological characteristics of WIPP, Reference 1, shall be considered in the criticality assessment.
5 Summary and Conclusions

The review of reference documents 1 and 2, relevant to a proposed disposal scheme of 7x3 CCOs loaded with 380g Pu-239 each, showed lack of concern for criticality or insufficient contingency considerations and lead to the following conclusions:

- The single parameter limit on Pu-239 concentration established for WIPP by Reference 1, 3kg/m\(^3\), is inapplicable for disposal of the suggested increased to 380g amount of Pu-239 per CCO

- The criticality evaluation presented in Reference 2 for the transportation of CCO in TRUPACT-II is inapplicable for storing packages of 7x3 CCOs at WIPP since the analysis provided for the transportation safety are insufficient to cover the potential compaction in 10,000 years

- Criticality analysis of the CCC and CCO in the WIPP environment using similar assumptions as in the transportation analysis show the criticality is likely with only a ~30% crushing of a single stack of CCOs (7x3 array, 21 drums)

- The effect of MgO supersacks which are to be placed on top of the CCOs would enhance the likelihood of criticality.

A criticality safety evaluation in normal and all considered credible off-normal conditions is considered necessary for determination of the criticality safety margins of WIPP if 380g Pu-239 is to be stored per CCO.
6 References


4. “Guidelines For Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities.”, DOE, STD-3007-93, November 1993


Acronyms

CCC  Criticality Control Container
CCO  Criticality Control Overpack
HBA  High Bridge Associates
MgO  Magnesium Oxide
MT   Metric Tons
WIPP  Waste Isolation Pilot Plant
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

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
High Bridge Associates, Inc. (HBA)
Industries, Capabilities, and Customer Overview

New Facility Design/Construction & Operating Plant Outage/Modification Support Services

Selected Owner & Agency Customers

Selected EPC Customers
Alberici, Altran Mediterranean, Bechtel, Burns and Roe, CH2MHIll, Fluor, Graycor, Jacobs, Kiewit, Parsons, Sachs Electric, SAIC, Sargent & Lundy, Shaw Environmental, Shaw Nuclear, Tetra Tech, URS/Washington Group, Worley Parsons

Selected OEM Customers
Alstom, Areva, Babcox & Wilcox, Cogema, Framatome, Foster Wheeler, GE Power, Mitsubishi, NuScale, SPX Technologies, Toshiba, Voith Power, Westinghouse
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<td>Spallation Neutron Source (SNS) Project - ORNL</td>
<td>International Atomic Energy Agency (IAEA)</td>
<td>Entergy Grand Gulf #2</td>
<td>Dominion Energy, North Anna #3</td>
<td>24 Units &amp; 17 Sites - Dominion, Entergy, &amp; NextEra/FP&amp;L</td>
<td>&gt;20 Utilities and &gt;50 Nuclear Units</td>
<td>Sellafied UK Nuclear Management Partners/NMP</td>
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<td></td>
<td>Project Mgt. &amp; Controls Support to Owner/Operator Team</td>
<td>Senior Consulting &amp; Subject Matter Expert</td>
<td>Owner's Team Project Controls Support to Evaluate LLWR Supplier Options; Evaluated Price, Technical, &amp; Risk Parameters for OEM/EPC Consortiums</td>
<td>Owner's Team to Support Open Competition for LLWR OEM/EPC Supplier &amp; Services; Developed Financial Submittal Templates &amp; Evaluated Proposals</td>
<td>US Operating Nuclear Fleet, Post-Fukushima Support for NRC Orders &amp; Initiatives</td>
<td>US Operating Nuclear Fleet Outage/Mod Support for EPU/Major/Minor Projects</td>
<td>Site cleanup, risk &amp; hazards reduction</td>
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<td>Tennessee Valley Authority Watts Bar #2 Construction Completion &amp; Startup Owner's Team</td>
<td>Westinghouse &amp; CB&amp;I/Shaw AP1000 New Nuclear Corporate and Project Support</td>
<td>Duke Power Crystal River #3 Owner's Team, Reactor Building Modification Support</td>
<td>Urenco USA Uranium Enrichment Project, Owner's Construction Management &amp; Integration Team</td>
<td>Stone &amp; Webster Mixed Oxide Fuel Processing Facility (MOX) Duke Cogema Stone &amp; Webster and Shaw Areva</td>
<td>UniStar Constellation Calvert Cliffs #3, New Nuclear Project Areva EPR, Owner's Team</td>
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## Commercial Nuclear Plant Description

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**Total 17 Sites & 25 Units**

### New Nuclear Power Facilities, Advanced Reactor Designs, and Uranium Enrichment

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<th>Facility Description</th>
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**Total 20 Sites & 32 Units**

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**Total 64 Sites and 112 Units**

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*High Bridge Associates*  
*March 2, 2016*
## High Bridge Associates/Work Management Experience Summary

**US DOE/NNSA, DOD, Advanced Technology, & Science Projects**

### Facility/Program Location/Description

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<th>Facility/Program Location/Description</th>
<th>Facilities/Projects</th>
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<td><strong>ITER International Fusion Research &amp; Demonstration Facility, Cadarache France</strong>&lt;br&gt;a. Project Management, Planning, Integration, Scheduling, Estimating, Project Controls, &amp; Risk Management</td>
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<td>2</td>
<td><strong>SMART Park Alternative Energy Project (Sustainable Manufacturing and Recycling Technology)</strong>&lt;br&gt;a. Develop, Integrate, Design, Construct, Own, &amp; Operate a Municipal Solid Waste to Ethanol Renewable Fuel facility</td>
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<td>3</td>
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<td><strong>DOE National Nuclear Security Administration (NNSA):</strong>&lt;br&gt;a. Supporting planning, project controls, &amp; program integration for weapons systems development in Albuquerque</td>
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<td>5</td>
<td><strong>DOE Los Alamos National Laboratory (LANL):</strong>&lt;br&gt;a. Weapons Experimental Program: Project Controls, Planning, Scheduling, EVM Reporting, Procedures, &amp; Risk Management&lt;br&gt;b. Accelerator Production of Tritium (APT) Project: Cost Estimating, Planning, &amp; Scheduling</td>
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<td><strong>DOE Fermi National Accelerator Laboratory (FNAL):</strong>&lt;br&gt;a. Long Baseline Neutrino Project: Executive Consulting for Integrated Planning, Project and Program Performance&lt;br&gt;b. Accelerator Production of Tritium (APT) Project: Cost Estimating, Planning, &amp; Scheduling</td>
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<td>Facility/Program Location/Description</td>
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<td>d. High Level Nuclear Waste Tank Farm: Operations Review</td>
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<td>g. K-Reactor Upgrade Modifications &amp; Restart: Project Management</td>
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**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

---

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
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

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
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

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, Desalination, 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
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

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)
**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)

**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
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

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
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

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
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.

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
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

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
APPENDIX H

Studsvik Scandpower Corporate Qualifications
Studsvik

Fuel and materials performance
Commercial reactor fuel and irradiated components

Studsvik has 60 years’ experience in testing and investigating commercial nuclear reactor fuel and materials. Hundreds of fuel pins from Europe, the USA and Japan have provided a broad basis for the development of equipment and techniques which have been applied in our hot cells.

The expertise and database gained form the basis from which we carry out each new investigation in the field. We perform a large number of tests and examinations on fuel pellets, cladding, fuel and core components, such as guide tubes, spacer grids, control rods, and other highly irradiated and activated materials.

**Fuel Rods**

Fuel rods are normally investigated visually, and this includes video recordings of the inspection to provide a detailed record. Gamma-scans provide high resolution information of the local burn-up and any redistribution of volatile nuclides, including fission gases and pellet-pellet gaps. Rod damage and penetration is investigated by eddy current (EC) techniques and leak tests.

**Pellets**

Pellets are investigated through ceramography for porosity, cracks, grain growth, restructuring (rim zone), nuclide distribution, and other features. We use light and scanning electron microscopes (SEM) equipped with WDS and chemical element mapping (EPMA) capabilities. FEGSIM and other microscopes giving nano-scale details are also available.

**Cladding and Components**

The oxide thickness is determined by an eddy current technique or metallography in SEM or light microscope (LOM) while the hydrogen concentration can be assessed by vacuum extraction techniques. Local hydrogen distribution is quantitatively determined by SEM with a backscatter electron detector. Local studies down to nano-scale are possible and are feasible for SPP (Second Phase Particle) studies. Local hardness determination is carried out by a nanoindentor and mechanical properties are investigated using a wide range of techniques – axial (ATT) and ring (RTT) tensile tests, burst tests, and fatigue and creep tests in various conditions. PCI (pellet cladding interaction) sensitivity can be screened with our new mandrel testing equipment.

**Spent Fuel and Back-end**

The long term creep and hydrogen redistribution that can arise in an interim dry-storage environment is simulated in laboratories by accelerated methods allowing a wide range of temperature and internal pressure variations.
We also simulate repository conditions by investigating pellet corrosion, fuel leaching, the impact of canister material on these processes, radiolysis effects and other associated phenomena.

**In the Future**

Fuel power ramp testing is performed in the Halden HBWR with the jointly developed ramp rig. The Norwegian JEEP-II reactor is used to perform neutron radiography, and to non-destructively scan whole fuel rods for chipped pellets, local hydrogen spots and other small fuel cladding and stack features. The demands of our customers and market trends mean that we are continuously developing new equipment, techniques and methods. Examples of recently developed equipment and techniques include creep hardening relaxation testing, cladding RIA testing using the EDC technique, DHC (delayed hydride cracking) testing using the PLT technique to mention a few. Studsvik has recently renewed its equipment for density measurements. Measurements can now be conducted on small fuel fragments or parts of the pellet – such as the rim zone. Pellet density versus radial position can also be determined. Recently acquired equipment includes a new gas mass spectrometer for fission gas nuclide analysis. This has been joined by a new ICP-MS offering fuel pellet burn-up analysis; almost full fuel pellet isotope analysis, fuel corrosion analysis and fuel crud deposit analysis. Advanced microscopy is routinely used to characterize irradiated fuel pellets, cladding, CRUD and structure materials.

**Our Scope of Services**

- Post Irradiation Examination and Testing
- Lead Test Fuel Assembly Characterization and Testing
- Mechanical Testings
- Failed Fuel Cause Analysis
- Failed Structure Material Root Cause Analysis
- Control Rod Characterization
- Fuel Storage Studies
- Activated Materials Analysis

- We handle the transport.
- We execute all necessary
  - Examinations
  - Tests
  - Analyses
  - Assessments
to characterize the material and the phenomena.
- We report the findings.
- We deliver on time.
Specialists in Nuclear Fuel

Studsvik is a world leading provider of services related to studies, experiments and characterization of nuclear fuel, materials behavior, corrosion and water chemistry. With 60 years of experience we handle everything from transport, using our own designated transport group.

Studsvik operates a number of state of the art facilities used for characterization of fuel and materials as well as various phenomena related to fuel and material behavior. Thanks to our lengthy, global experience of commercial materials, we can understand intact as well as failed fuel behavior under all possible operation conditions, determine the root cause of failures, mechanically characterize and test both cladding and structure materials, exhaustively examine and test fuel. Furthermore, we can also understand, efficiently study and simulate and analyze environmental effects on corrosion and crud build-up taking also mechanical and material parameters into account. Studsvik performs work on behalf of clients worldwide, complying with demanding test and time schedule conditions.

Root cause analysis of failed fuel and components is performed on a wide variety of materials using our extensive experience as platform for the highly qualified conclusions, supporting the industries striving for trouble-free fuel and materials.

LTA (Lead Test Assembly) evaluation and verification of existing fuel and material behavior is another important field in which Studsvik’s large experience and expertise supports the nuclear industry in becoming a more and more reliable electricity producer.

Studsvik has established a co-operation with the well-known irradiation facility Halden Reactor Project (HRP) located only 6 hours drive from the Studsvik site. Studsvik and HRP complement each other in terms of expertise. HRP offers expertise in instrumented irradiations, while Studsvik provides expertise within PIE and other tests, such as corrosion assessments and mechanical testing. Together, we provide added value to our customers.

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E-mail: nuclear@studsvik.se
Studsvik is the global leader in the development and support of fuel vendor-independent reactor analysis. We offer a full suite of software and engineering services to support operating utilities, fuel vendors, safety authorities, and research organizations.

**Put Our Experience to Work**
Studsvik offers a wide range of services to support nuclear fuel analysis efforts, such as independent core reload design, cycle length economic studies, multi-cycle optimization and verification services.

With over 30 years and 1000+ operating cycles of experience in nuclear fuel analysis, Studsvik software remains the industry standard for light water reactor analysis.

We have provided cycle design reviews, alternate core loading strategies, fuel bid evaluations and cask loading optimization for customers around the world.

Examples of our service capabilities include:
- Reactivity insertion analysis
- Uncertainty analysis methods for assessing criticality of spent fuel
- Criticality Safety Evaluations
- Independent startup analysis
- Independent fuel bid evaluation
- Cycle length and multi-cycle core design optimization
- S3K/System code linkage (RELAP, TRACE, etc.)
- CMS model development
- AP1000 and EPR reactor studies
- Secondary Source evaluation
- Fuel failure analysis
- Refueling optimization
- Safety and transient analysis
- Licensing activities
- Hosted Software

**Independent Fuel Bid Evaluation**
With significant fuel costs and changing cycle strategies, it is important for you to know that your fuel investment will yield the most energy possible.

Our fuel vendor-independence allows us to perform fuel bid reviews that consistently compare each proposal using the same industry-leading methods.

**Next-Generation Analysis**
For organizations exploring new, advanced plant designs for future construction, Studsvik can provide engineering services and consultation at every phase of analysis.

We can build or review a fuel vendor-independent core model of the proposed core design, perform transient calculations to assess reactor dynamics, and even assist in design certification.

**Unparalleled Training**
Studsvik has extensive experience in helping our customers implement our products and get up and running quickly. Introductory, refresher and advanced training courses are offered throughout the year. Studsvik International User Group Meetings give our customers the opportunity to build relationships with Studsvik product developers and engineers while learning about new techniques and products.
In-Core Fuel Management
Studsvik sets the industry standard for in-core fuel management software with unparalleled accuracy, production-level run times, and easy-to-use input.

CASMO5
State-of-the-Art Lattice Physics

SIMULATE
3D, Steady-State Nodal Simulator

SIMULATE3-K
3D Transient and Safety Analysis

ENIGMA
Thermo-mechanical Fuel Performance Analysis

XIMAGE
Automated Loading Pattern Design

Training Simulator Core Models
Modern training simulators require high fidelity to the plant and real-time response. Studsvik simulator solutions help organizations meet these requirements by providing cycle-specific core models that can be added to most existing plant simulator installations.

S3R
Cycle-Specific Simulator Core Model

Spent Fuel Analysis
Managing spent nuclear fuel demands an increasing amount of engineering resources. We offer advanced, integrated solutions to analyze fuel pools / racks and optimize the loading of fuel storage casks.

SNF
3D Spent Nuclear Fuel Analysis

CASKLOAD
Cask Loading Optimization

Engineering Services
With hundreds of years of combined experience in reactor analysis, Studsvik’s engineers can help organizations with a wide range of core analysis engineering services, including:

• Core Reload Design and Verification
• Independent Fuel Bid Evaluation
• Refueling Shuffle Optimization
• Safety Analysis
• Design Certification

Operations Support
Studsvik’s integrated product line allows a single cycle-specific core model to simplify many aspects of plant operations, from online core monitoring to refueling optimization.

GARDEL
Advanced Core Monitoring and Automated Reactivity Management

MARLA
BWR Refueling Optimization
APPENDIX I

High Bridge Biographies

Review Team

Ken Aupperle (Task Lead)
Henry Garson, J.D.
Dr. Mike High
Charlie Hess
Dr. Andy Kadak
Steve Maehr
Teodosi Simeonov
## High Bridge Independent Review of Plutonium Disposition Program

### WIPP Dilution Storage and MOX Fuel Irradiation Options

#### High Bridge Review Team Expert Experience

<table>
<thead>
<tr>
<th>Name</th>
<th>Years Nuclear/DOE Experience</th>
<th>Past Experience Working Together</th>
<th>Nuclear Criticality Analysis Experience</th>
<th>NEPA FEIS Legal Experience</th>
<th>MOX Project Experience</th>
<th>Plutonium Disposition Program Experience</th>
<th>First of a Kind (FOAK) Project Experience</th>
<th>Specific Unique/Relevant Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henry Garson</td>
<td>&gt;40</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Is a nationally recognized expert in Environmental Law including the National Environmental Policy Act (NEPA) as well as being a former top level senior legal advisor for the Department of Energy (DOE) and the National Nuclear Security Administration (NNSA). He has routinely dealt with the most difficult legal questions facing the DOE and NNSA.</td>
</tr>
<tr>
<td>Charlie Hess</td>
<td>&gt;35</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Was DOE team member in the 1990’s that negotiated the Plutonium Disposition Agreement between Russia &amp; the USA. He was responsible for developing/integrating the schedule of activities for the Russian MOX facilities &amp; coordinating with the US MOX program.</td>
</tr>
<tr>
<td>Dr. Mike High</td>
<td>&gt;50</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Past Director of TVA Technology Research and Development activities; He chaired the Electric Power Research Institute’s (EPRI) Environmental Research Division Advisory Committee.</td>
</tr>
<tr>
<td>Dr. Andy Kadak</td>
<td>&gt;40</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>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.</td>
</tr>
<tr>
<td>Steve Maehr</td>
<td>&gt;35</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>Teodosi Simeonov (Studsvik)</td>
<td>&gt;25</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>International nuclear fuels engineer for Studsvik. Responsible for developing analytical codes used to model nuclear fuels systems and has developed specific models for nuclear power plants in Europe and in the USA. Developed the online core supervision system GARDEL and the CPRCHECK code used to determine critical power ratio analyses. Developed the HELIOS 2D analytical program used for this report.</td>
</tr>
</tbody>
</table>

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*High Bridge Associates*

1-2

*March 1, 2016*
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 database, 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. Some recent areas of responsibility include:

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.

HENRY K. GARSON, J.D.

Mr. Garson is a nationally recognized expert in Environmental Law including the National Environmental Policy Act (NEPA) as well as being a former top level senior legal advisor for the Department of Energy (DOE) and the National Nuclear Security Administration (NNSA). He has over 40 years of experience as a government and private practice lawyer who has routinely dealt with the most sensitive and difficult legal questions facing the DOE and NNSA. His expertise includes interpretation of all aspects of the Atomic Energy
Act of 1954, the Department of Energy Organization Act, The National Nuclear Security Administration Act, and applying these and other organic statutes to the civilian and military scientific and nuclear programs. Mr. Garson has a unique understanding of the nuclear weapons complex and the laws under which it must operate. His expertise on state regulation of these facilities under Federal statutes such as the Clean Water Act (CWA), Safe Drinking Water Act (SDWA), and the Resource Conservation and Recovery Act (RCRA) is nationally recognized. He is an expert on the applicability of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) at NNSA Sites.

Before joining the NNSA Office of General Counsel, Mr. Garson was the Director of the Environmental Support Division for NNSA. In this position Mr. Garson was the National Environmental Policy Act (NEPA) Compliance Officer for NNSA. His responsibilities in this position involved planning and execution of NNSA’s environmental compliance efforts including compliance with the National Environmental Policy Act, RCRA, CWA, CAA, CERCLA, SDWA as well as all applicable State and local laws. Mr. Garson also directed the integration of Environmental Management Systems (required by Presidential Executive Order) into the NNSA Integrated Safety Management System. The waste management and pollution prevention efforts of NNSA were considered exemplary under Mr. Garson’s direction.

Mr. Garson has been involved in legal, technical and environmental matters for over 30 years for the nuclear weapons complex. He has an excellent understanding of the facilities, activities and materials used in the nuclear weapons business. He was also responsible for providing counsel to the Office of Civilian Radioactive Waste Management and for the development of the Waste Isolation Pilot Plant for defense waste. He has served on many diverse projects including an assessment of possible external regulation of DOE nuclear activities and facilities, site evaluation teams evaluating locations for significant nuclear facilities and many reorganization and planning teams. He was the public spokesperson for the Office of New Production Reactors while he was the Director of Program Plans and Environment for that Office. He has drafted legislation that became law.

**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.

**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 Daiichi 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
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.

TEODOSI SIMEONOVA

Mr. Simeonov is a Senior Consultant at Studsvik with over 25 years of nuclear industry experience. He is responsible for criticality safety evaluations, spent nuclear fuel methods, and the development and maintenance of spent nuclear fuel analyses code (SNF) for application in light water nuclear reactors where he is responsible for customer support and training. He is responsible for developing analytical codes used to model nuclear fuels systems and has developed specific models for nuclear power plants in Europe and in the USA. He developed the online core supervision system GARDEL and the CPRCHECK code used to determine critical power ratio analyses. He is responsible for the Studsvik lattice physics code system HELIOS 2D analytical program used for the criticality analysis developed for this report. He also manages maintenance, upgrading, customer support and training of HELIOS for various projects and customers.
APPENDIX J

Subject Matter Expert Résumés
High Bridge Associates, Inc.

KENNETH J. AUSSPERLE

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/modified of commercial nuclear/fossil power, industrial, environmental, and U.S. Department of Energy (DOE) projects. He has managed/perform 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.
KENNETH J. AUPTERLE

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)


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)


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)


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)
**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)
KENNETH J. AUPPERLE

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:


* **Nuclear Materials Production Division (NMPD), Savannah River Site** – Assessment of Engineering Organization Functions, Processes, and Staffing (1995)


* **Solvent Refined Coal Project (SRC 1), Alternative Fuel Demonstration Facility, Department of Energy** – Schedule and Cost Estimate Development and Integration (1983)

KENNETH J. AUERPLE

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.
Mr. Garson is a nationally recognized expert in Environmental Law including the National Environmental Policy Act (NEPA) as well as being a former top level senior legal advisor for the Department of Energy (DOE) and the National Nuclear Security Administration (NNSA). He has over 40 years experience as a government and private practice lawyer who has routinely dealt with the most sensitive and difficult legal questions facing the DOE and NNSA. His expertise includes interpretation of all aspects of the Atomic Energy Act of 1954, the Department of Energy Organization Act, The National Nuclear Security Administration Act, and applying these and other organic statutes to the civilian and military scientific and nuclear programs. Mr. Garson has a unique understanding of the nuclear weapons complex and the laws under which it must operate and his expertise on state regulation of these facilities under Federal statutes such as the Clean Water Act (CWA), Safe Drinking Water Act (SDWA), and the Resource Conservation and Recovery Act (RCRA) is also nationally recognized. He is also an expert on the applicability of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) at the NNSA Sites.

Since his retirement from Federal service in January, 2005, he has been a consultant employed by government contractors, and hopeful government contractors, on various matters including business development, preparation of environmental analyses, safeguards and security, procurement law, and assisting in determinations on the final disposition of special waste streams. Clients have included Tetra Tech, Inc., Booz Allen Hamilton, Battelle Energy Alliance, Systematic Management Services, Inc., and DOE (NNSA and NE).

At NNSA, Mr. Garson most recently was the Associate General Counsel for the NNSA. In this capacity he has led the legal efforts to “stand up” the NNSA and negotiated agreements with the rest of the Department of Energy which recognized the “separately organized” nature of the NNSA. He also was instrumental in resolving legal questions, including those arising under the National Environmental Policy Act and Department of Transportation regulations allowing the urgent relocation of Nuclear Materials from abroad including Libya, Iraq, and other locations some of which remain classified. Mr. Garson’s expertise was recognized by other agencies including the Departments of State and Defense and the President’s Council on Environmental Quality in that he provided both the legal advice for these missions as well as the execution planning for these
missions. In this position he also provided high level management with advice on a broad range of issues including fee reduction at Government Owned – Contractor Operated facilities for failing to meet safety and security requirements, international Mutual Defense Agreements, procurement matters, fiscal law, personnel law, proposed legislation, safeguards and security matters, and a host of other varied and novel legal matters. Mr. Garson was also responsible for the review of all Price Anderson enforcement matters at all NNSA facilities as well as the transition planning for NNSA’s potential assumption of Environmental Management activities at NNSA Sites.

Before joining the NNSA Office of General Counsel, Mr. Garson was the Director of the Environmental Support Division for NNSA. In this position Mr. Garson was the National Environmental Policy Act (NEPA) Compliance Officer for NNSA. His responsibilities in this position involved planning and execution of NNSA’s environmental compliance efforts including compliance with the National Environmental Policy Act, RCRA, CWA, CAA, CERCLA, SDWA as well as all applicable State and local laws. Mr. Garson also directed the integration of Environmental Management Systems (required by Presidential Executive Order) into the NNSA Integrated Safety Management System. The waste management and pollution prevention efforts of NNSA were considered exemplary under Mr. Garson’s direction.

Prior to the creation of the NNSA, Mr. Garson was the Associate Deputy Assistant Secretary for Core Technical Support and Facility Transition for the Office of Defense Programs. Mr. Garson was responsible for a professional staff of approximately 70 persons engaged in the conduct of various safety reviews including: Operational Readiness Reviews, providing expert review of Operational Safety Basis and review of the Engineering Design and Analysis for the Department’s nuclear weapons facilities and activities. This organization, in addition to providing these services, provided technical experts to both Headquarters and field elements to assist them in planning and implementing their programs. Also, this Office provided the technical support for the Principal Deputy Secretary of Defense Programs For Safety and Quality. He has also been responsible for the coordination of Defense Programs responses to letters and Recommendations received from the Defense Nuclear Facilities Safety Board. Mr. Garson also supervised the staff engaged in safeguards and security for the Office of Defense Programs as well as that staff engaged in Environmental matters including Five Year Environmental Plans, Pollution Prevention, and NEPA Compliance.

Mr. Garson has been involved in legal, technical and environmental matters for over 30 years for the nuclear weapons complex. He has an excellent understanding of the facilities, activities and materials used in the nuclear weapons business. He was also responsible for providing counsel to the Office of Civilian Radioactive Waste Management and for the development of the Waste Isolation Pilot Plant for defense waste. He has served on many diverse projects including an assessment of possible external regulation of DOE nuclear activities and facilities, site evaluation teams evaluating locations for significant nuclear facilities and many reorganization and planning teams. He was the public spokesperson for the Office of New Production Reactors while he was the Director of Program Plans and Environment for that Office. He has drafted legislation that became law.
PROFESSIONAL HISTORY

- Associate General Counsel, NNSA

- Director, Office of Environment, NNSA, DOE (Defense Programs)

- Associate Deputy Assistant Secretary of Defense Programs for Core Technical Support and Facility Transition, DOE

- Director, Office of Program Plans and Environment, Office of New Production Reactors, DOE

- Acting Deputy General Counsel for Procurement and Technology Transfer

- Assistant General Counsel for Environment, DOE

- Assistant General Counsel for Coal Regulation, DOE

- Special Assistant to the Principal Deputy General Counsel and Acting General Counsel, DOE

- Deputy Assistant General Counsel, ERDA, a predecessor of DOE

- Attorney, Office of General Counsel, Environmental Protection Agency

- Associate Attorney, Surrey, Karasik and Morse

- Attorney, Securities and Exchange Commission

EDUCATION / PROFESSIONAL CERTIFICATIONS

- Juris Doctor, State University of New York at Buffalo, School of Law, 1967 (Member, Buffalo Law Review)

- Bachelor of Science, Finance, State University of New York at Buffalo, 1964

- Member: New York Bar, District of Columbia Bar

- Clearance: DOE “Q” (Active), SCI (Inactive)
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)
• 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


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 multinational (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.
• 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
Michael D. High

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) help 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).

(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...
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 Parcells 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.
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:


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).
• Atmospheric Fluidized-Bed Combustion, invited paper, Second Mid-Western Acid Rain Conference, Chicago, IL (1986).

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:**

- Turbulent Boundary Layers with Electron Thermal Nonequilibrium and Finite Rate Ionization, Eleventh Symposium on Engineering Aspects of Magneto hydrodynamics.
- 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 Propulsion Conference, San Diego, C.
- Transition Prediction Technique

Also, author or co-author of seven AEDC technical reports on fluid mechanics and ground testing.
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.
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
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
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 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


OTHER MAJOR PUBLICATIONS
27. T.A. Galen, D.G. Wilson, and A.C. Kadak, Comparison Between Air and Hydrogen for Use as Working Fluids in the Energy-Conversion Cycle of the MPBR (February 2001

SELECTED INVITED LECTURES
- American Physical Society Conference - Nuclear Renaissance, October 31, 2006
- Bettis Atomic Power Laboratory, “MIT Fuel and Safety Research”, May 11, 2001
- University of Rhode Island, “China’s Nuclear Energy Program”, December 2013
- World Nuclear Fuel Market Conference, New York City, “Nuclear Power Construction Programs – Can We Do It Again?” June 2014
- Japan Atomic Industrial Forum, “The Environmental Imperative of Nuclear Energy – Despite the Challenges”, Tokyo, Japan, April 2014


SELECTED MANAGEMENT PRESENTATIONS


SELECTED OTHER LECTURES AND PRESENTATIONS


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.

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

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
CURRICULUM VITAE

Teodosi Simeonov
Principal Nuclear Engineer

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309 Waverley Oaks Road, Suite 406
Waltham, MA-02452-8443, USA

Tel. +1-617-607-7241
teodosi.simeonov@studsvik.com

EDUCATION

Engineering degree in Nuclear Physics (MSc equivalent), Sofia University, Bulgaria 1987 – 1992

Languages: Bulgarian, English, Russian, German, Norwegian, French

PROFESSIONAL EXPERIENCE

Studsvik Scandpower Inc, USA 2013- present

Principal nuclear engineer 2013- present

Responsible for spent nuclear fuel methods. Development and maintenance of spent nuclear fuel analyses code SNF for application in light water nuclear reactors. Customer support and training.

Responsible for lattice physics code system HELIOS. Maintenance, upgrading, customer support and training of the general two dimensional code system HELIOS.

Responsible for methods and code development for WWER reactors.

Responsible for criticality safety evaluations.
Curriculum vitae: Teo Simeonov

Responsible for Software Control Management (SCM) system maintenance and licensing administration.

**Studsvik Scandpower GmbH, Germany** 2007-2013

**Principal consultant** 2010-2013

Several small and medium projects in cooperation with WWER operating companies was carried out: HELIOS licensing (Czech Republic); XS library generation for WWER-440 (VUJE, Slovakia; PAKS, Hungary) and WWER-1000 NPP Temelin (Czech Republic); nuclear data library extension- NPP Kozloduy (Bulgaria).

Criticality safety evaluations for the hot cell laboratory at Studsvik AB, Sweden, related to maintenance and design activities.

Fuel Management System (FMS) administration. Customer support, deliveries, installation and reporting, This includes code systems: HELIOS, PRESTO-2, SNF, RAMONA5, REFUSIM and CASKLOAD.

**Senior consultant** 2007-2010

Development of methods and tools for online spent fuel analyses. Based on SNF code, a decay heat module DHM was developed and implemented in the online core supervision system GARDEL. This project was financed by Vattenfall GmbH. The module was implemented at NPP Brunsbüttel and NPP Krümmel, Germany. (2009-20010)

Reactor model development, methods and procedure for application of CMS code system CASMO5/SIMULATE-3 for Konvoi type of reactors. The project for modeling Grafenrheinfeld NPP was carried out in cooperation with E.ON GmbH Germany (2009).

Methods and application of HELIOS system for Criticality safety analyses for AGR fuel storage in the frame of a joined project between BNFL, Studsvik Nuclear AB and Studsvik Scandpower GmbH. (2008)

Development of procedures and tools for in-core measurement system management of Ringhals NPP, Sweden. The tools were implemented in the online core supervision system GARDEL. (2007)

**Studsvik Scandpower AS, Norway** 2000-2007

**Senior consultant** 2000-2007

Online core supervision system GARDEL:
Curriculum vitæ: Teo Simeonov

- Development of various modules in GARDEL system: plant data acquisition modules, process control modules and documentation modules.
- Responsible for model development and installation of several reactors: Forsmark Unit-1 (2005), Ringhals Units: 2, 3, 4 (2004-2008) in Sweden; TVO 1 and 2, Finland (2005); SONGS, Units 2 and 3, USA. (2005)
- Responsible for maintenance, upgrades and customer support for Ringhals NPP. (2004-2008)

Development of CPRCHECK code, applied for critical power ratio analyses. The project was financed by German utility HEW. (2005)

Implementation of customer specific CPR correlations, CUSPEC module, in the 3D core simulator PRESTO-2. (2005)

Development and implementation of cross section models for 3D core simulator PRESTO-2 based on HELIOS lattice physics system: reconstituted fuel (2003); unified data bank (2004); wet pool model and analyses (2004); burnable absorbers rods-shim rods (2004).

Initial development of spent fuel analyses code SNF. The project was sponsored by four utilities: HEW, EnBW and E.ON in Germany; AXPO (former NOK) in Switzerland. (2002-2004, First release- 2004)

Development of HELIOS Input Library for application and generation of cross section (XS) libraries for PRESTO-2 for PWR, BWR and WWER type of reactors. The HIL was applied in for XS libraries and reactor models in 11 reactors in Germany and Switzerland. (2001-2005)

Rewriting ORION code, an auxiliary tool for HELIOS input processing and validation, adding an extensive set of functionalities. (2001)

Responsible for QA system maintenance, deliveries and licensing.

Kozloduy NPP, WWER-440, Bulgaria

1992-2000

Head of reactor data and core analyses section

1997-2000

WWER-440 operational support, safety analyses, work coordination and administration:
  - Loading pattern design and safety justification analyses.
  - Thermal-hydraulic analyses
  - Installation and maintenance of 3D reactor core simulators: BIPR7 (Kurchatov Institute, Russia) and SPPS (INRNE, Sofia, Bulgaria).
Curriculum vitae: Teo Simeonov

- Cross section model and XS data banks generation for SPPS code by HELIOS code.
- Reactor data acquisition.

**Training at Forschungszentrum Rossendorf, Germany** 1998-1999

WWER-440 reactor dynamics analyses at Kozloduy NPP (1998-1999). This project was funded by the IAEA and included six months training on the application of a 3D kinetic code DYN3D for transient analyses. The training was conducted at Institute for Safety Research at FZ Rossendorf (today HZDR), Dresden, Germany. (September 1998-February 1999). The work included analyses of recorded and simulated transients such as: a control assembly drop at Hot Full Power (HFP); Main Circulation Pump (MCP) trip and startup at HFP with inadvertent boron dilution.

**Reactor engineer** 1992-1997

**Training at Idaho National Laboratory.** July 1995

Participation in Safety Review Team. Preparation of reactor neutronic data for accident analyses with RELAP-3D. The project was sponsored by DOE (USA) and included 30 days training at Idaho National Lab. (INL, Idaho Falls, USA)

Implementation of sub-channel thermo-hydraulic analyses with help of a modified (WWER DNB correlation) version of code COBRA-3I. The project was in cooperation with Institute for Nuclear Research and Nuclear Energy, (INRNE) Sofia. (1995)

Kozloduy NPP Unit 2, WWER-440 type of reactor, responsible engineer. 1993-2000

- Responsible for cycle safety reports, startup tests analyses and operational support.
- Design and software development for reactor data acquisition system with a pilot implementation on Unit 2 (1995) , followed by Unit 1, 3, and 4 (1997).

Implementation and validation of 3D reactor core simulators BIPR7, SPPSB7 and SPPS on a PC. This project included code and data porting from IBM mini-computer to PC and was part of the initial training received at NPP Kozloduy. It was the starting point for the MSc theses (1992).